An Economic and Social Evaluation of the UK Subsea Cables Industry

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Executive Summary

This research report seeks to estimate the value of the UK subsea cables industry, considering its value to

1) the digital economy;

2) the electricity industry.

A preliminary estimate of the economic value of the UK telecommunications subsea cables industry to the digital economy values it at £62.8 billion per annum. The impact of the UK electricity subsea cables industry is smaller but still significant at £2.8 billion per annum.

The economic value of the UK subsea cables industry both for the telecommunications and energy sectors is then measured in more detail using the Computable General Equilibrium (CGE) modelling approach that has increasingly overtaken the more traditional Cost Benefit Analysis approach to computing economic values. This analysis also provides estimates of the impact of changes in the industry on various sectors of the economy, as well as on the macro economy. Yet first a qualitative research methodology, namely a Comprehensive Impact Evaluation Framework is applied to identify benefits of the UK subsea cables industry to multiple stakeholders in the telecommunications and energy sectors. By identifying the relevant direct and indirect stakeholders, this ensures that the CGE models developed are as accurate as possible.

The stakeholder analysis also allows us to going beyond a monetary analysis of the potential benefits of the subsea cables industry, by identifying the range of stakeholders positively impacted by the presence of the UK subsea cables industry. In the telecommunications sector there are benefits to businesses and households from better quality and speed of digital communication, as well as improved reliability of Internet connectivity. These benefits translate into improved business efficiency, improved ability to manage people and processes, as well as improved opportunities for the international communication of product and process innovations. In the electricity sector, the use of subsea cables is vital for the import and export of electricity, as well as to connect offshore electricity production to the mainland electricity grid system. Hence, subsea cables ensure improved reliability and security

of electricity supplies, as well as access to international markets. Given that offshore electricity production is a vital part of renewables electricity production in the UK, this production has environmental benefits and contributes to reduced pollution and the UK's better ability to meet pollution reduction targets.

The qualitative and quantitative analyses combine to highlight the positive value of the UK subsea cables industry both on the telecommunications and electricity market sectors. The impact on the telecommunications sector is larger as was to be expected given the importance of this sector on the UK economy as a whole, while subsea cables are of importance in the electricity market predominantly in terms of electricity imports and exports, and the production of electricity from off-shore wind farms.

Not only is the UK subsea cables market important in terms of its impact on the telecommunications and electricity sectors, but the quantitative analysis highlights the benefits of future growth in the UK subsea cables industry on UK macroeconomic variables including GDP; consumer income; capital formation; exports and imports and government revenues. Growth in the UK telecommunications subsea cables industry is likely positively to impact the UK financial and insurance sector the most, while growth in the UK electricity subsea cables industry is expected to have its greatest positive impact on the UK manufacturing industry.

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Abbreviations Used

Asian-Pacific Economic Cooperation	APEC
Boston Consulting Group	BCG
Cobb-Douglas	C-D
Comprehensive Impact Evaluation Framework	CIEF
Computable General Equilibrium	CGE
Computer Programming and Consultancy	CPA
Constant Elasticity of Substitution	CES
Constant Elasticity of Transformation	CET
Cost Benefit Analysis	CBA
Distribution Network Operators	DNO
Electric Power Generation, Transmission and Distribution	EPGTD
European Subsea Cables Association	ESCA
Great British Pounds	GBP
Gross Domestic Product	GDP
Gross Value Added	GVA
Industry Associated Activity	A
Industry Associated Commodity	C
Information Service Activities	ISA
Manufacture and Distribution of Gas and other fuels, Steam and other Air Conditioning	MDG
McKinsey Global Institute	MGI
National Grid Electricity Transmission	NGET
Next Generation Broadband	NGB
Office for National Statistics	OSN

Office of Communications	OFCOM
Office of Gas and Electricity Markets	OFGEM
Per Annum	pa
Programming and Broadcasting Activities	PBA
Publishing Activities	PA
Rest of World	ROW
Scottish Hydro-Electric Transmission Limited	SHET
Scottish Power Transmission Limited	SPT
Small and Medium Sized Enterprises	SME
Subsea distribution networks	SDNO
Subsea Energy and Telecommunications Cable Industry	SETCI
Telecommunications	T

1. Introduction

The subsea cables industry is of vital importance to economies across the world, including that of the UK. [2] However, unlike other industries that are so key, this is an industry that remains unfamiliar to many. Yet, the UK's international Internet traffic relies almost exclusively on this industry. It is also important for electricity imports and exports, as well as for the transmission of electricity generated from offshore wind farms.

This research project aimed to measure the value of the UK subsea cables industry, considering both its social impact and crucially its economic impact, with explicit consideration given both to its contributions to ensuring reliable and non-exhausted international Internet and electricity supplies.

Patterns in international economic transactions have significantly changed in the 21st century. The McKinsey Global Institute (MGI) reported that by the end of 2014 traditional international in and out flows of goods and services had flattened. Globalisation patterns are now being dictated by digitalised international activities. A report by MGI highlighted that the world is becoming more deeply connected by international data flows with less developed countries and smaller businesses finding it easier to engage in data exchange. Accessibility to the Internet allows small and medium sized businesses to contribute to global economic growth by trading, exchange of ideas, innovation collaboration and technology development in multiple economic sectors around the world. Even a small enterprise nowadays has a chance to operate globally. MGI also identified a significant, positive, linear relationship between the connectedness of countries and their Gross Domestic Product (GDP) per capita levels.

Meanwhile, demand for energy including electricity continues to grow across the world. Yet, with depleting supplies of some natural fuels such as coal, and environmental concerns regarding the production of electricity for example via coal and nuclear processes, there has been increased interest in and use of relatively

[2] See http://www.submarinecablemap.com/ for a map indicating all current subsea cables worldwide.

new and more environmentally friendly forms of electricity generation such as via wind and off shore wind farms. It must also be noted that many countries continue to rely at least partially on imports of electricity.

How information and transactions are carried internationally via the Internet is of vital importance to the global economy. It is imperative to ensure that international Internet connections are reliable, rapid and not close to capacity as demand for the Internet continues to grow. Simultaneously, reliable electricity supplies are essential for the smooth running of economies, for quality of life and to ensure continued economic growth in many countries.

This research report seeks to estimate the value of the UK subsea cables industry, considering its value to 1) the international, internet economy, and 2) the electricity industry. The economic value of the UK subsea cables industry is measured using the Computable General Equilibrium (CGE) modelling approach that has increasingly overtaken the more traditional Cost Benefit Analysis (CBA) approach to computing economic values. But first a qualitative research methodology, namely a Comprehensive Impact Evaluation Framework (CIEF) is applied to identify benefits of the UK subsea cables industry to multiple stakeholders, going beyond a monetary analysis of the potential value of this industry and identifying the range of stakeholders positively impacted by the presence of the UK subsea cables industry. By identifying the relevant direct and indirect stakeholders, this also ensures that the CGE model developed are as accurate as possible.

1.1Telecommunications and the Subsea Cables Industry

Telecommunications cables have been present on the seabed since the instalment of the first transatlantic telegraph cable in the mid-19th century (Clark, 2016). However, since 1988 these cables have been fibre optic rather than copper wire, ensuring much greater efficiency and the bandwidth required to carry international Internet traffic (Clark, 2016). There are now two potential technologies to transfer data across oceans and to drive the digital globalisation process, namely satellites and submarine cables. The Asian-Pacific Economic Cooperation (APEC) states that subsea cables carried about 97% of all international data traffic in 2012, with comparable results confirmed by ESCA (2016). Internet connections are now shared among the continents through the submarine cables which connect all the continents and countries within (Manyika & Roxburgh, 2011). APEC explains that dominance of the use of subsea cables reflects both technological and economic features of subsea cable technology. Modern fibre optic technology now ensures that subsea cables are faster, more reliable and cost effective to the only alternative of satellite technology. *S*ubmarine cables on average transfer IP packages long distances 5 times faster than satellites, and the costs of subsea cables carrying international data traffic are vastly lower, making satellites a non-economic option. Further, submarine cables are generally more reliable. Specifically, if a satellite operation gets disrupted it is not economically rational to send a maintenance team to bring it back into operation and typically there will be no alternative satellite to take over the traffic carriage from the broken satellite. Moreover, the effective operational lifetime of subsea cables is twice as long as that of an average satellite. Hence, unsurprisingly, governments' policies related to innovation in the field of technology are also promoting wide spread of cable networks (Choudrie & Papazafeiropoulou, 2007).

Nevertheless, submarine cables operations may be affected by either an environmental or marine human operations hazard. Therefore, the APEC highlights the importance of maintaining alternative submarine cables routes. Substitute cables routes can maintain international communication while the main route is under maintenance. The APEC suggests that satellites may form an emergency replacement technology in the unlikely case that all alternative subsea cables are out of operation.

The Boston Consulting Group (BCG) expects digital globalisation to connect more than 3 billion active users worldwide by the end of 2016. Moreover, the G-20 Internet economy is expected to reach 4.2 trillion US$ by the end of the same year. BCG notes that the global Internet economy is evolving from a fixed access stage to a more flexible interactive phase. The evolution of the Internet economy involves more mobile and innovative devices. It creates its own ecosystem with a new generation of economic agents. SERI Research and Innovation highlights that Next Generation Broadband (NGB) introduction in Cornwall, UK and its rural areas led to significant performance improvements of local businesses. NGB allows employees to work remotely and more efficiently, enables businesses to work in new and different ways, allows local businesses to grow faster, develop new goods and services, and helps generate new sales as well as letting business access new markets. For businesses connected to NGB average turnover increased by £91,000 in 2013-2014 while for non-connected businesses average turnover rose by only £21,000. By June 2015 NGB connected businesses created 4,666 jobs on a FTE equivalent basis (117% of the target), while Gross Value Added (GVA) to the regional economy was £162 million (115% of the target).

The Internet is a significant input into the UK's economy and has rapidly become essential (Robinson, 2010; Kalapesi et al., 2010). The UK is the largest per capita e-commerce market and second largest online advertising market globally (Robinson, 2010). The success of the Internet in the private sector encouraged the public sector to join the Internet revolution to provide their services as effectively and efficiently as possible (Choudrie, Weerakkody, & Jones, 2005). The UK Internet economy sector's contribution to the country's GDP is the highest among G-20 economies, with a 12.4% GDP contribution share forecast by the end of 2016 (BSG, 2015). The BCG expects the UK Internet economic sector to contribute about £180 billion in 2015, an 80% increase from 2010. Similarly, in 2011, Frontier Economics estimated that the Internet's contribution to the UK economy was estimated to rise to £221 billion by 2016. It is also forecasted that by 2016 more than 23% of all purchases in the UK will be done online through the Internet (ESCA, 2016). Yet, the BCG highlights that standard GDP measures do not capture all consumer and business economic impacts of the Internet sector. The BCG estimates that a 10% increase in e-procurement activities also results in a 2.6% increase in productivity for the manufacturing sector. E-procurement lowers transaction costs, facilitates information exchange across supply chains, and automates purchases. Moreover, UK small and medium sized enterprises (SMEs), a key economic growth driver globally, use modern communication technology to expand geographically without actual physical presence, ensuring greater collaboration with customers, suppliers, and partners worldwide. The BCG states that three years sales growth rates for 2010-2012 are higher for high and medium level Internet integrated SMEs, 12% and 7% respectively, than for low or non-Internet integrated SMEs, 4%. Higher Internet integrated SMEs also create more new jobs on average than low integrated SMEs. The BCG reports that, for 2010-2012, in high integrated SMEs staff increased by 85% on average while in low integrated SMEs staff numbers grew only by 51%.

Consequently, a preliminary estimate of the economic value of the UK telecommunications subsea cables industry to the digital economy in 2015 values is £62.8 billion per annum (pa)

This is calculated as:

The UK Internet economy in 2015 was valued at £180 billion pa[3]

36% of UK Internet traffic is international, resulting in a value of it of £64.8 billion pa[4]

97% of this international traffic is routed through subsea cables[5], resulting in a value of £62.8 billion pa

For comparison purposes, see Appendix 1 for the magnitudes of other UK industries.

1.2 The Electricity Industry and the Subsea Cables Industry

The subsea cables industry also offers new opportunities for a more globalised energy sector. Seabed power interconnector systems transmit electricity between countries. Subsea power cables systems allow consumers to consume cheaper

[3] BCG (2015) as reported in https://www.techuk.org/insights/news/item/4075-uk-s-digital-economy-is-world-leading-in-terms-of-proportion-of-gdp

[4] https://oecdinsights.org/2014/02/18/beyond-the-first-mile-where-your-internet-comes-from/

[5] APEC (2012)

energy from sources outside of the country. Simultaneously, domestic energy producers can export to countries with higher energy prices. Currently Great Britain has 5 interconnectors with Ireland, Northern Ireland, France, Norway, and Netherlands. A new electricity interconnector that will link Great Britain and Belgium is currently under development and scheduled to start its operations in 2018.

Demand for more interconnected UK and European energy is driven by the new European energy production environmental standards and diminishing production of the UK oil and gas sector. Moreover, by 2020 UK nuclear plants are to produce 7.5GW less energy as some reactors will reach the expected end of their service lives. Nuclear power production takes on average 15 years to launch new energy generating facilities. Coal plants are also experiencing more binding legislative and environmental constraints and are expected to decrease production by 12GW by the end of 2016 to meet environmental standards. UK total energy demand in 2013 equalled 310TW and is expected to grow on the basis of changing lifestyles and growing populations. While combined capacity of the UK's various energy plants will remain higher than expected peak demand levels it is essential for the country's energy sector to keep plant margins high to ensure demand fluctuations are met.

Energy subsea cables also connect the UK with its offshore renewable wind and wave energy plants. The European Union integrated energy/climate change proposal (EU 20/20/20 vision) aims at a 20% share of renewable energy plants in the total energy production of the EU by the end of 2020. Given the UK's 15% share in European energy production it is estimated that to meet the objectives of the EU 20/20/20 vision energy production from renewable sources in the UK will have to contribute 30% of the total energy production. Moreover, the Climate Change Act 2008 (CCA 2008) objectives are to significantly reduce greenhouse gas emissions by 2050. To achieve its 2020 goals renewable energy production share should account for 34% of total energy production. To achieve goals specified in the agreements highlighted above the UK government plans to increase the country's energy production capacities of new nuclear, offshore wind, and low emissions gas power plants. However, offshore wind plant energy supplies are intermittent.

Therefore, a developed interconnector network will play an important role in keeping safe levels of plant margin and maintaining energy market efficiency.

Doorman and Froystad (2013) evaluated societal costs and benefits of the recent GB-Norway interconnector. A CBA conducted by Doorman and Froystad (2013) indicated that the Scotland-Norway electricity interconnector achieves the highest benefits for Scotland, under the assumption of less thermal energy production, amounting to 322 million Euros annually. Its benefits for Scotland are lower an assumption of high natural gas prices and are about 15 million Euros annually. Southern regions of Great Britain have significantly less societal benefits from electricity interconnection with Norway. Under a high gas price scenario, the south of Great Britain bears costs of 25 million Euros annually. A south Great Britain – Norway interconnector has societal benefits only under the base case scenario, UK energy production capacities are fixed on 2010 levels, and are 35 million Euros annually. To contrast, under the same scenario Scotland is projected to benefit by about 46 million Euros annually from the interconnection with Norway.

A preliminary estimate of the economic value of the UK electricity subsea cables industry to the UK energy sector values it as £2.8 billion pa:

This reflects a UK energy economy valued at £28 billion pa in 2010[6]

Offshore wind is expected to contribute 5%, namely £1.4 billion pa[7]

Electricity imports are expected to contribute 5%, namely £1.4 billion pa[8]

6 http://www.ey.com/Publication/vwLUAssets/Powering_the_UK/$FILE/Powering_the_UK.pdf

7 https://www.thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy/

8 http://www.energy-uk.org.uk/energy-industry/electricity-generation.html

2. Unpacking the Ecosystem of the UK Subsea Energy and Telecommunications Cable Industry: A Stakeholder Perspective using a Comprehensive Impact Evaluation Framework

2.1 Introduction

This section of the report identifies the various stakeholders involved in the UK Subsea Energy and Telecommunications Cable Industry (SETCI). In particular, we provide a framework that integrates these diverse stakeholders into clusters, which is necessary to understand the impact created by this industry. Consistent with the research project objectives, the stakeholder clusters are framed in accordance with their ability to contribute to the economic value created by the UK SETCI operations. This exercise is not only important in its own right but crucial for the CGE modelling to follow. Only if the interrelationships between the numerous stakeholders are understood can an accurate CGE model be developed.

However, incorporating all stakeholders is a complex activity and can result in inaccurate outcomes: it can result in a conclusion that 'everything is influencing everything'. Therefore, the stakeholders we consider are the groups/organisations whose involvement is practical, necessary, and prudent (Bryson, 2004). In this report, accordingly, key is the SETCI contributions to the UK economy so that identified stakeholders are included in accordance with their expected impact / value-added in the SETCI.

2.2 Methodology

For this part of the research project, a qualitative methodology for data collection and analysis was adopted to understand the ecosystem of the UK SETCI and to map its complex stakeholder system. In particular, an integrative stakeholder analysis based on both primary and secondary data was conducted to explore and understand the

UK SETCI operating framework as well as to generate and to justify hypotheses and assumptions made regarding the nature of the industry for the quantitative phase of the study discussed in Section 3 below.

Qualitative research approaches often serve as an exploratory tool (Stadtler, 2016). They are useful in instigating investigations of complex industries that have not been studied in detail before and thus can shift the focus of or restructure primary data collection methods during the exploratory part of a study. Moreover, the use of a Comprehensive Impact Evaluation Framework (CIEF) gives rise to benefits that include data collection from the insider's viewpoint, a rich description of the industry structure, and identification of the fundamental businesses for the industries' operations and growth from the multiple viewpoints of the participating stakeholders. However, qualitative approaches can be criticised on the grounds of the difficulty producing generalisable and quantifiable results as well as potential difficulties testing hypotheses formulated. Therefore, the aim of this part of the report is not to produce confirmatory results. Rather, it aims to complement and provide information for the second part of the study that involves Computable General Equilibrium (CGE) economic modelling to evaluate the SETCI impact on the UK economy and economic agents.

Overall, two main data sources are used: secondary and primary. For the secondary data, a document analysis technique (Miles & Huberman, 2008) has been implemented to begin the UK SETCI stakeholder identification, formulate a preliminary industry operations framework and stakeholder ecosystem, and formulate interview questions and main themes for the primary data collection method. Documents utilised are listed in Table 2.1 below. Further, to establish better understanding of the UK SETCI operations and stakeholder framework, information available on the official websites of the identified stakeholders and economic agents (for example BPP Cables; European Subsea Cables Association; Global Marine; OFCOM; OFGEM; Offshore Renewable and Cable Awareness; Renewables UK; TATA Communications; Virgin Media, etc.) were investigated to formulate interview questions and themes.

No	Report / Academic Publication Title	Author (s) / Publishing Organisation
1	Economic Impact of Submarine Cable Disruptions	Asia-Pacific Economic Cooperation
2	The Internet Economy in G-20	Boston Consulting Group
3	Undersea Cables and the Future of Submarine Competition	Bryan Clark (Bulletin of the Economic Scientists)
4	Social Cost-Benefit Analysis of Electricity Interconnector Investment: A Critical Appraisal	Michiel de Nooij (Energy Policy)
5	Contribution of the Digital Communications Sector to the Economic Growth and Productivity in the UK	Frontier Economics
6	Development of an Interconnector between the United Kingdom and Belgium	NemoLink
7	Regional Differences in Network Charges	Office of Gas and Electricity Markets (OFGEM)
8	Submarine Electricity Cables: Cost Benefit Analysis Methodology Statement	Scotish and Southern Energy Power Distribution (SSE PD)
9	Welfare and Competition Effects of Electricity Interconnection between Ireland and Great Britain	Laura Malaguzzi Valeri (Energy Policy)
10	UK Renewable Energy Roadmap	Department of Energy and Climate Change

Table 2.1: List of secondary data materials and sources

A flexible semi-structured interview design was then selected to incorporate emerging themes and to maximise richness of the data during the primary data collection process. Two main blocks of interview topics were designed. The first block included themes associated with the industry specific stakeholder framework; major and minor stakeholders; structure of the economic relationship among various groups of the stakeholders. The second thematic block incorporated participants' perceptions of different types of potential and actual impact of the industry on the UK economy; society; groups of businesses; various organisations; and individuals.

For the primary data collection, we approached the European Subsea Cables Association (ESCA) to obtain the contact details of potential interviewees representing the identified stakeholders during the primary data analysis phase. ECSA provided a contact list of their members, 55 in total, who were approached via email and asked to take part in the research project. We received 16 positive responses, representing a 29% initial response rate. However, during the primary data collection phase 4 respondents dropped out (due to personal reasons), reducing the response rate into 22%. Participants' information as well as interview details are summarised in Table 2.2 below.

A thematic analyses strategy (Braun and Clarke 2006) was implemented to process and analyse the primary data collected. First, two primary data collection sessions (interviews) were transcribed and analysed immediately after the conclusion of the interviews to identify key emerging themes not covered by the secondary data analysis and to update the initially designed thematic blocks. The remaining ten interviews were transcribed and analysed after the primary data collection phase had been finished. The analysis was conducted as follows: first interview data was transcribed to familiarise the researchers with the content; then transcriptions were continuously re-read to identify common emerging themes in all interviews; third thematic extracts were made and analysed; the final extracts were then selected and the final report combining both primary and secondary data produced.

#	Title	Organisation	Interview Duration	Interview Date	Interview Type
1	Owner of the company / CEO	Consultancy company	45 minutes	22/07/2016	phone
2	Senior Optical Specialist / Program Manager	Telecommunication company	50 minutes	22/08/2016	phone
3	Submarine Infrastructure Managers	Telecommunication company	40 minutes	25/08/2016	phone
4	Technical Concept Development Manager	Energy company	60 minutes	20/08/2016	Skype
5	Chief Technology Officer & Project Director	Telecommunication company	55 minutes	15/08/2016	Skype
6	Consultant Director	Consultancy company	30 minutes	15/08/2016	phone
7	Cable Engineer	Energy company	20 minutes	11/08/2016	phone
8	Director of Field Operations(Customers Service and Operations Manager)	Telecommunication company	90 minutes	10/08/2016	face-to-face
9	Principle Engineer and Core Network Support Manager	Telecommunication company	60 minutes	01/08/2016	phone
10	Maintenance Liaison Officer	Telecommunication company	55 minutes	28/07/2016	phone
11	Engineering and Business Development Manager	Telecommunication company	55 minutes	22/07/2016	phone
12	Senior Asset Manager	Cable operating company	35 minutes	30/08/2016	phone

Table 2.2: Interviews and interviewee details

2.3 Analysing the Stakeholder Impact

Stakeholder identification and analysis have gained popularity for evaluation and investigation of different matters. Bryson (2004) indicates that as long as investigated phenomenon, for example an industry or sector of the economy, encompasses many people, groups and organisations, evaluations should incorporate all participants as no single participant is fully in charge of the investigated matter and economic value of the industry is not created by a single company. Stakeholder analysis begins with a clear stakeholder definition. Following Freeman (1984), we define stakeholders broadly as any group or individual who can affect or is affected by the UK SETCI operation activities. Careful consideration of a stakeholder is a key issue when seeking to understand organisational performance and impact (Bryson et al. 2011). Typically, several misleading evaluation conclusions may be avoided if interests, views, influences, involvement, needs and roles of the stakeholders are taken systematically into account in the analysis.

As a starting point for understanding the impact of various stakeholders, we draw on the conceptualisation of the UK telecommunication sector framed by Frontier Economics (2011) to distinguish between the direct and indirect impacts. We then adapt this conceptualisation to the SETCI conditions so that it can incorporate both telecommunications and energy seabed cables' potential impact.

Informed by our analysis of both secondary and primary data, Figure 2.1 summarises how UK SETCI stakeholders (as one integrated system) contribute to UK economic and social development through direct and indirect channels. While direct channels are identical for both telecoms and power cables, indirect channels differ for each sub-sector. The direct channels describe the means by which this industry creates value in the UK economy, including:

- capital investment;
- production of goods and services;
- employment;
- exports to foreign markets;

- investments in research and development.

Indirect channels, on the other hand, capture UK SETCI impacts on other industries not involved in UK SETCI operations. For telecommunication cables indirect effects include:

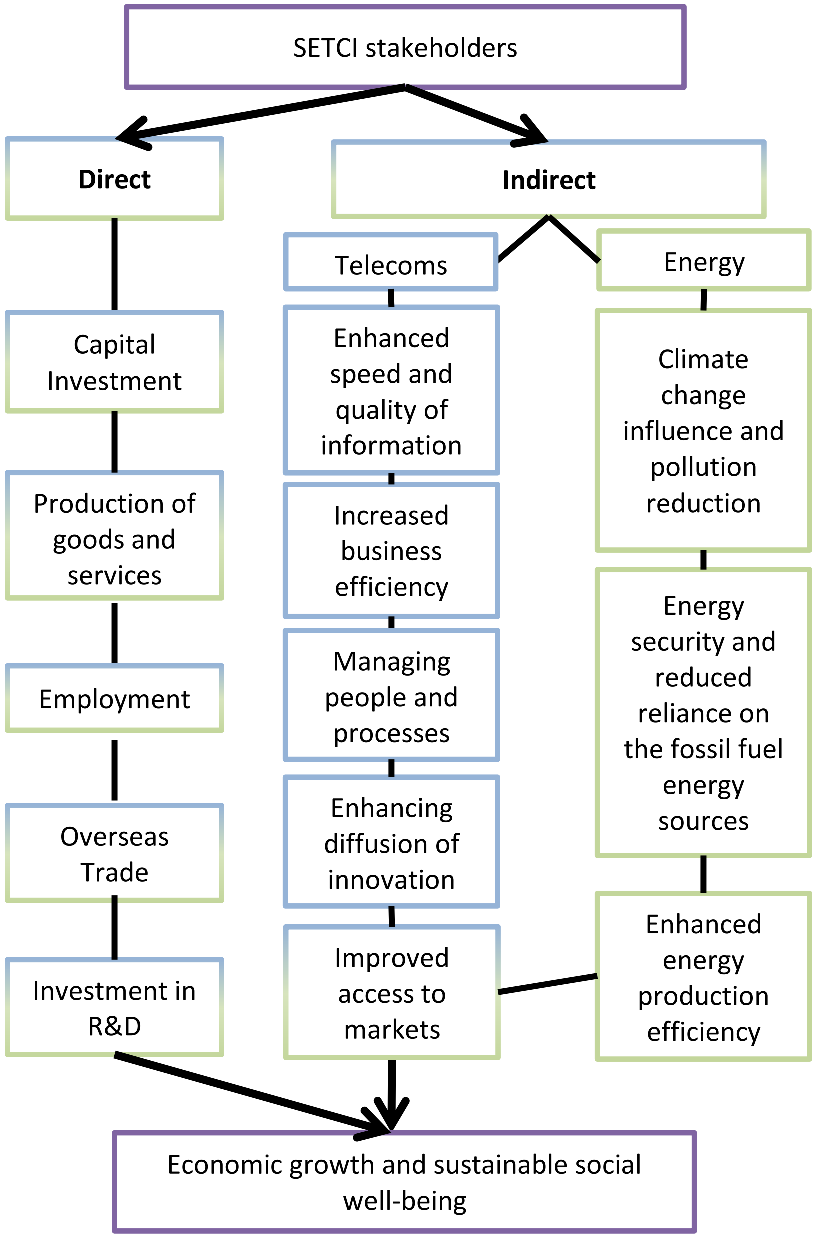
- better speed and quality of information;
- better business efficiency;
- enhanced management of people and processes;
- easier communication of innovations.

For energy cables indirect channels include:

- effects on climate change and reduced pollution;
- improved energy security;
- enhanced energy production efficiency.

Improved access to markets is the common indirect effect of both sub-sectors of the UK SETCI.

Ultimately, subsea energy cables transmitting energy from the off-shore renewable energy power plants indirectly influence pollution levels and thus the health of the nation. From the telecommunication cables indirect impacts, better managing people and processes may give rise to opportunities to work more effectively and comfortably from home for various categories of people. At the same time, it should be noted that the indirect impacts are typically more difficult to assess accurately due to the uncertain nature of their long-term effect and the difficulty in completely controlling for the effect of other factors. Understanding the structure of the stakeholder groups constituting the UK subsea cables industry is vital to the development of an accurate CGE model in Section 3.



Note. Green boxes denote the power subsea cable sector, blue boxes denote telecommunication subsea cable sector and bicolour boxes denote channels associated with both sectors of the Subsea Energy and Telecommunications Cable Industry (SETCI).

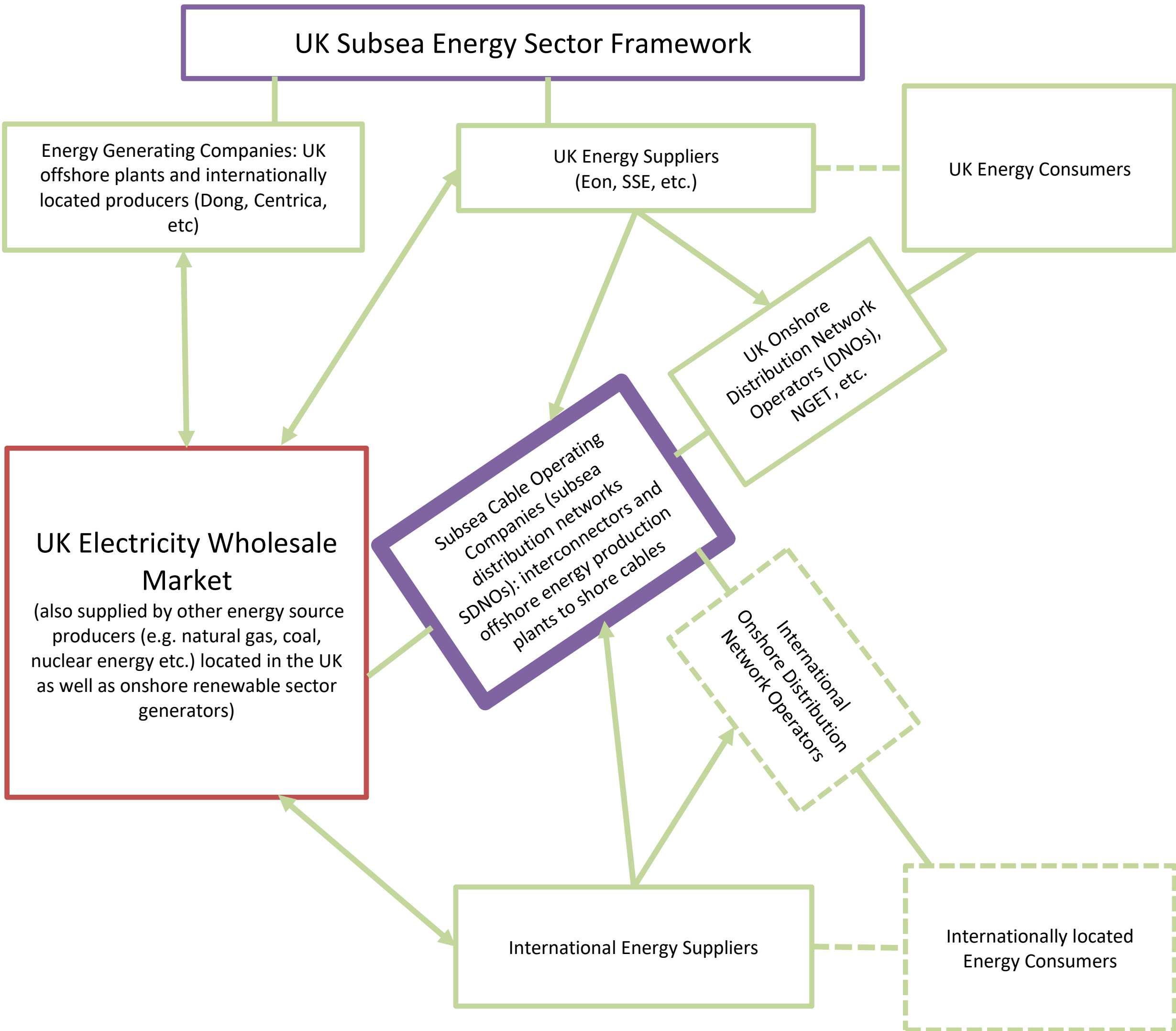
Figure 2.1: Channels through which the SETCI contributes to the UK economy
Adapted from De Nooij (2011), Frontier Economics (2011), Nemo Link (2013), Valeri (2009) & SSE PD (2015)

2.4 The Energy Sector of the UK SETCI

Starting with the UK energy sector of the SETCI, we introduce Figure 2.2 below that highlights how the energy subsea cables sector contributes to the comprehensive energy sector of the UK economy.

The UK energy sector's heart is the wholesale electricity market. Its competitive economic environment incorporates electricity producers from various energy sources (for example gas; offshore and onshore wind; coal etc.); electricity suppliers; final consumers (for example corporations; households etc.) with electricity delivered through the distribution network operators (DNOs). DNOs are electricity transmission monopolies in designated geographical areas of the United Kingdom. They deliver electricity from power stations to the end customers (for example UK Power Network in Eastern England and London; Northern Powergrid in the Yorkshire region etc.). Power stations are connected to the high voltage network owned by NGET (National Grid Electricity Transmission) in England & Wales, SPT (Scottish Power Transmission Limited) in southern and central Scotland, and SHET (Scottish Hydro-Electric Transmission Limited) in the northern part of Scotland. Electricity suppliers are indirectly linked with consumers as the transmission and distribution networks are not operated by them. OFGEM (2015) highlights that electricity suppliers pay charges for usage of the transmission networks across the UK. Charges for distribution network usage may be included to the final consumer's electricity bills. However, consumers do not pay these charges directly due to the regulatory framework of the UK energy sector.

In Figure 2.2 below we demonstrate that the subsea energy cables are part of the UK electricity distribution networks, where they bring together onshore electricity networks with offshore energy generation plants (for example windfarms) and onshore electricity generated in the UK or internationally with the international or UK electricity markets respectively. To clarify, after energy is produced offshore and sold into the wholesale market to an energy supplier it first travels from the subsea cables grid to shore. Modern market conditions allow offshore produced energy to be purchased by an internationally located energy supplier. In this case, first energy is transmitted to shore, then through onshore networks linked to an interconnector. Further it travels through the interconnector to the internationally based supplier's consumer through foreign onshore distribution networks. Such a scenario demonstrates maximum utility of the UK subsea electricity cables and creates maximum value for the economy. Alternatively, international located power generating companies may offer electricity to the UK suppliers which will in their turn utilise the subsea cables in the opposite direction.



Notes:
Red box denotes UK electricity wholesale market participants, purple box highlights the subsea cables division, and green boxes indicate other energy sector stakeholders. Dashed green boxes indicate international participants which are not considered in the analysis. Dashed green lines denote energy suppliers' links to consumers through a straight green link of distribution network operators. Green arrows indicate the relationship structure of the stakeholders.

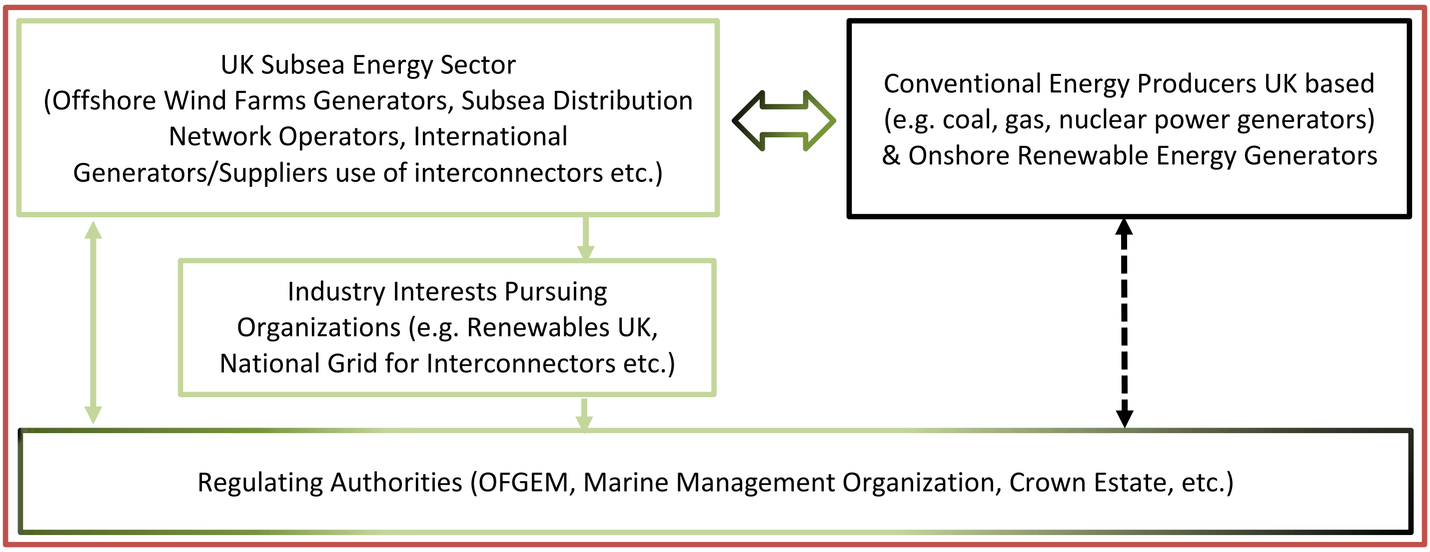
Figure 2.2: UK Subsea Distribution Networks positioned in the UK Energy Sector as part of the overall UK Electricity Market

Adapted from OFGEM (2015), Nemo Link (2013), and refined by primary data

Drawing on the above discussion, we may now summarise the first part of the electricity subsea cable associated stakeholder analysis. Stakeholders include offshore energy plants generators (for example E.ON; DONG Energy; Centrica Energy etc.); subsea DNOs (for example Frontier Power for windfarms to shore networks or BritNed and EirGgrid for interconnectors operators); energy suppliers to consumers (for example E.ON, Npower, EDF Energy, etc.); NGET; and onshore DNOs. They also may include international companies importing (suppliers) or exporting (generators) electricity from or to the UK electricity market.

The above specified stakeholder groups are all associated with the UK electricity market. As energy in general is one of the most fundamental aspects of the modern society's economic development, electricity and energy markets are closely monitored by the regulating authorities (for example OFGEM) to ensure their effective and stable long-term performance ensuring future economic growth and societal prosperity. Regulating authorities set up conditions for electricity markets operations. To illustrate, under the UK Electricity Act 1989 any distribution network operator and/or its subsidiaries cannot hold a generation or supply licence. Hence, companies like Frontier Power participate in tender bidding for operating constructed subsea transmission networks. On the other hand, interconnectors are a special case. Under the UK legal framework an interconnector operator cannot hold a licence for generation, supply, and other transmission licences. Thus, even though the National Grid may develop project proposals for interconnectors, interconnector projects are operated and owned by international companies like BritNed which then closely cooperates with TenneT in Netherlands and the National Grid in the UK respectively

In addition to the above UK subsea cable industry stakeholders (i.e., distribution-related as in Figure 2.2), this industry has another strand of important stakeholders that affect the socio-economic value creation, as demonstrated in Figure 2.3 below. In essence, these involve other power generators (i.e. coal; nuclear; and gas-sourced energy generating companies also contributing to the UK electricity market and thus influencing the economic environment) and other regulatory bodies that enact and control the overall behaviour of the sector.



Notes:
Red frame denotes UK energy market framework of the stakeholders, green boxes denote UK subsea sector stakeholders, black box demonstrates onshore energy market participants, and bicolour box highlights regulating authorities. Arrows denote relationship structure of the market participants, green lines for the subsea sector and dashed black coloured line for the onshore respectively. Dashed line indicates simplified relationship structure. Bicoloured both directional arrow denotes two types of market participants' competitive relationship structure.

Figure 2.3: Other Key Stakeholders in the UK Energy Market and their Relationship within the Subsea Cables Industry
Adapted from OFGEM (2015), Nemo Link (2013) and refined by primary data collected by the research team

Key electricity subsea cable stakeholders' operations affect and are affected by other electricity market participants as well as regulating authorities. Today the UK energy sector operates under environmental constraints. For instance, it has become harder for coal-fired power generating plants to meet required environmental standards, with gradually diminishing production of the hydrocarbons sector (for example oil and gas production in the UK halved in the last 15 years) and time demanding renovation of the energy production plants (for example of nuclear power plants concluding their operational life). Importantly, the above conditions advocate for the higher economic significance of the subsea distribution networks. Moreover, due to the intermittence of the energy flow from the renewable offshore energy sources and the importance of maintaining acceptable levels of the energy production margin, the role of the UK interconnector operators and expansion of the their transferring capacities is likely to increase.

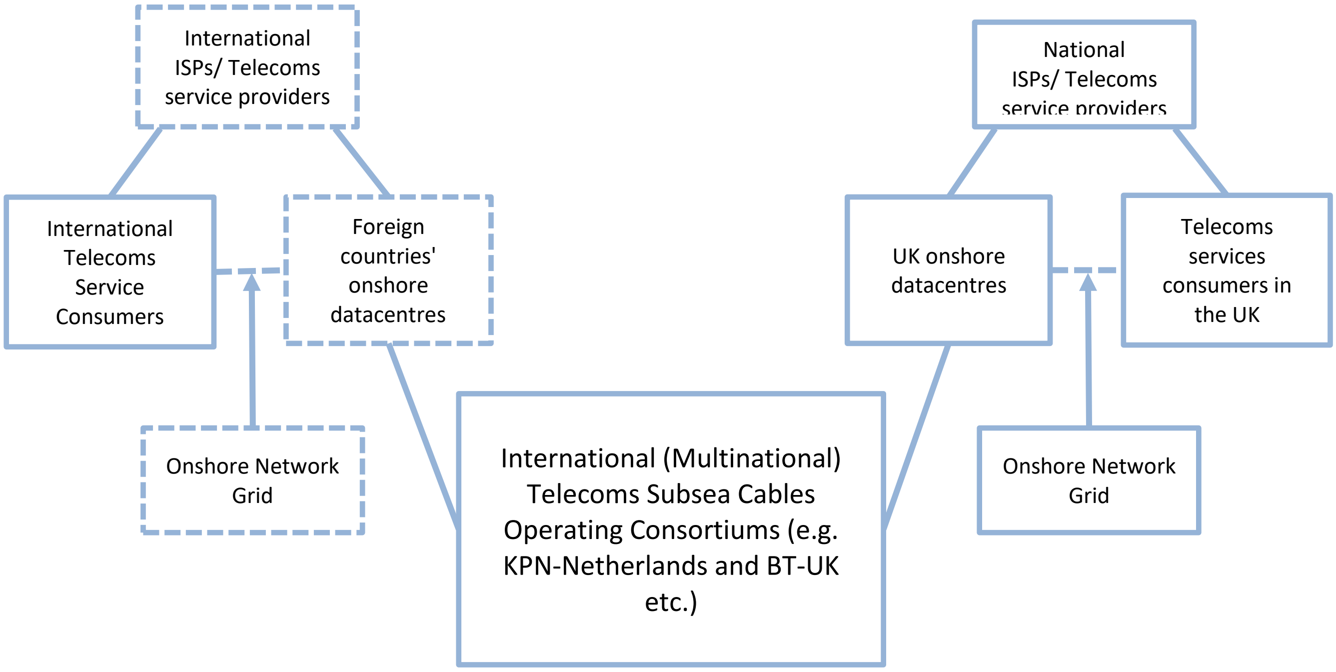
It is worth emphasising that similar trends in energy production shifts are observable in other European markets. Shifts in European energy production imply not only increases of the overall interconnector capacity, higher capital investments, but also more diversified grid connections to other European markets to ensure sustainable energy production and reliable supply in the UK and across Europe. Energy production shifts in Europe also give rise to export prospects for the UK offshore sustainable energy producers under the scenario of production disruptions in the overseas markets. On the other hand such market conditions as falling hydrocarbons prices internationally may negatively affect economic prospects of the subsea electricity cables stakeholders. Therefore, there is a place for associations advocating sustainable energy production (for example Renewables UK) and the National Grid's emphasis on the necessity of interconnector projects to keep UK energy systems secured, diversified and less dependent on one particular energy source or country of electricity production. For example, one of the interviewees explained:

> *"I can only speak to the energy sector, the telecom sector is much more established. The energy sector, primarily at the moment, is built by the*

developers of the wind farms and they ... build the export sub stations and cables as part of that development. Then because of the unbundling as a European requirement, it [i.e., the requirement] applies to sell off that section of the assets [i.e., subsea cables]... They sell that off, to the highest bidders, but obviously there is the "preferred bidder" from OFGEM. They obviously have a criteria for selecting the "preferred bidder", which involves acquiring a licence and finances of course " [12]

2.5 The Telecommunications Sector of the UK SETCI

We begin the telecoms subsea cable stakeholder analysis with Figure 2.4 below.



Notes:
Dashed blue coloured boxes represent assumed foreign onshore telecommunication network structures. Dashed blue lines indicate onshore network grids which may include other onshore datacentres omitted for the simplicity of the figure.

Figure 2.4: Subsea Telecommunications / Internet Sector Stakeholder Map

Overall, it can be argued that the structure of the relevant stakeholders in the telecommunications subsea cables industry is simpler than that in the energy part of the industry. To be specific, a single stakeholder is often involved in the subsea cables network, the land network and data centres operations as well as service provision to the final consumer. Subsea cable networks are operated by international consortiums (i.e., KPN and BT jointly operate a cable linking Netherlands and UK) where each company is responsible for its part of the cable network. Each subsea cable is then linked to the data centre onshore connecting it with onshore telecommunications cable systems carrying information packages to the final consumer. Onshore cable grids are operated by the various companies both providing Internet (ISPs) and telecommunications services to customers (for example BT; Virgin Media etc.) and companies involved solely in networks operations for ISPs operations (for example Tata Communications; Level 3 etc.). It is common for companies like BT; Virgin Media; and Tata Communications or Level 3 to operate and own both subsea & onshore cable systems as well as data centres necessary for modern telecommunication service provision. Nevertheless, there are also more specialised companies, including companies providing data centres service (for example Equinix; Iomar; Redcentric etc.) and Internet or telecommunications services to customers (for example ASK4 broadband service targeting student customers specifically etc.) with smaller network assets possession than BT; Virgin Media or Tata communications.

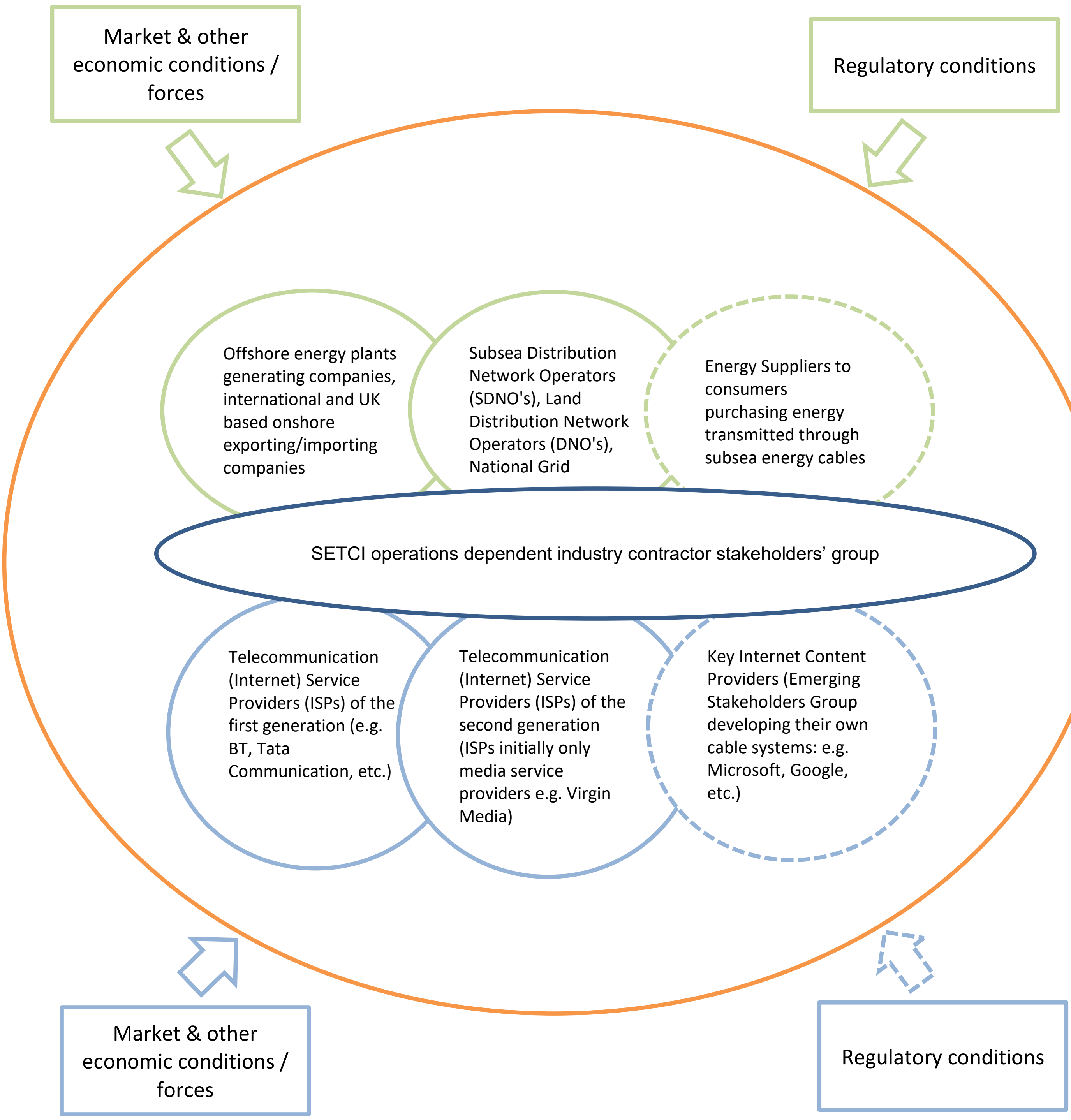
The telecommunications subsea cable ecosystem is best described by a time trend development of the modern comprehensive telecommunication sector and the Internet in particular. With growing reliance of the telecommunication sector on Internet operations (for example IP package transfer from data centres located across the globe) companies initially operating subsea cable networks like BT (1st generation of subsea cables owners) were joined by companies like Virgin Media building their own networks (2nd generation of the subsea cables owners) previously participating only in media service provision to consumers and relying on the seabed networks of the 1st generation of cable owners when necessary. Today, we observe the emergence of a new group of telecommunications subsea cable owners and stakeholders (3rd generation of the subsea cables owners), previously only content providers to customers (for example Google; Microsoft, etc.), see Clark (2016). The 3rd generation group of seabed cable owners' emergence is possible due to actual development of the Internet, its further integration, popularity and significance for everyday business operations and for peoples' lifestyle. Interestingly, an interviewee provided a new perspective to this point as follows:

> *"To be quite honest, there is actually no subsea industry as such. ... We actually do not see the subsea industry as a kind of standalone business, it is rather a part of our infrastructure and we always treated it as a part of our global infrastructure." [Submarine Infrastructure Managers-3]*

2.6 The Ecosystem of the UK Subsea Cables Industry: An Integrative Framework

We are now in a position to produce an integrative stakeholder framework that describes the ecosystem of the UK SETCI encompassing both the energy and telecommunications sectors. As demonstrated in Figure 2.5 below, this framework can have several benefits. For example, it can help us acknowledge and understand the manifold intended and unintended outcomes of the operation of this industry. Further, it can help us to visualise the value creation process as it reveals the connections between the various organisations and entities constituting this industry. These can then be modelled quantitatively in Section 3 below.

Of central importance are previously introduced stakeholders in the energy and telecommunications sectors, due to their ability to impact UK economic and social systems both through direct and indirect channels. To illustrate, being part of the energy sector offshore energy plants operators invest in new project development, produce electricity, and employ people. They also produce environmental friendly energy, through competitive participation in the electricity market, influence energy production efficiency, and enhance UK energy security diversifying the country's energy generating portfolio. Subsea distribution networks (SDNOs) participate in electricity delivery and contribute to the generators' impact. They also employ people, participate in tenders for subsea distribution networks and spend on the maintenance of the existing networks. Interconnectors' operators provide access to foreign markets to UK electricity generators or connect country scale energy markets. Similarly for their operations they employ people and spend resources on maintenance of the intercountry transmission systems. Electricity suppliers in their turn emerge from the market structure (note, however, that some companies like E.ON operate Blyth, Robin Rigg, Scroby Sands offshore generation facilities as well as sell electricity to consumers) to link the sector with its final consumers in the UK and make financial transfers from consumer groups to all DNOs and generating companies. The sector may also include participating international companies belonging to either group. Finally, the presence of all electricity stakeholder groups and company categories in the centre of Figure 2.5 is necessary to the functioning of the sector under the regulatory framework.



Notes:
Green ellipses and boxes denote energy subsea cables sector, blue ellipses and boxes denote telecommunication subsea cables sector, and big orange ellipse describes the "workhorse" industry of the submarine cables projects contractors and sub-contractors dependent on the primary both sectors stakeholders. Dashed ellipses denote "emerging" stakeholder either due to regulatory conditions for the energy sector or by modern telecommunications sector wide scope and economic success for the telecommunication sector.

Figure 2.5: SETCI Integrative Stakeholder Framework / Ecosystem

Telecommunications sector key stakeholders in the centre of Figure 2.5 are ISPs or telecommunication network solutions providers of the three generations discussed previously. They all invest in subsea cable projects, maintain and upgrade them to enhance transferring capacity, employ people and provide services to consumers. Participating in the telecommunications service provision they all enhance speed and quality of information, increase business efficiency, help manage people and businesses, spread innovation, and provide access to markets without actual physical presence both for consumers and producers of goods and services. This point is elaborated upon by one of the interviewees:

> *"I think you have to have typical Porter's five forces there. So you have suppliers [implies contractors], this is then from our perspective, primarily the large suppliers like Siena and Alcatel. Then you have the competition within, so they [i.e., the suppliers or subcontractors] have the competitors within them. Then you have the formal incumbent, or normal telecom operator, like us, who normally organise themselves in consortia, and you have competing with them private systems, and they build the cables for themselves and trying to live from selling the capacity to carry [implies provide internet service] us. So, then you have buyers which probably not big enough for having own capacity or having changing demands, big banks, for example, that have requirements for some transport capacity and therefore...so what we observed in the last time is that the customers, what used to be our customers, are becoming competitors and building their systems themselves. For example, Googles, Microsofts, and Apple are becoming more and more from a customer of the incumbency to a competitor, and sometimes what we see is that they have even more infrastructure in the submarine area in place than the old incumbents"* [Submarine Infrastructure Managers-3]

Next, telecommunications and energy subsea cables key stakeholders' economic activities create a foundation to the industry of contractors supporting their operations and growth. The contractors group consists of companies producing and developing subsea telecommunications (for example Alcatel-Lucent etc.) and electricity (for example BPP cables) cables as well as cable laying and maintenance equipment (for example ETA Subsea Cable Specialists; SMD etc.). Contractors are also companies operating vessels necessary for the implementation of the new subsea cable projects and maintenance of the existing cable systems (for example Global Marine; Briggs Marine etc.). Obviously contractors are dependent on the cable operators' capital investment, successful service provision, etc. However, their economic impact and potential to add value cannot be left unspecified. For example, designers and producers of cables as well as cable laying and maintenance equipment directly affect UK economic performance by investment in new production facilities, actual production of cables and equipment, exporting cables and equipment to foreign projects, employment of personnel and spending on the research and development for advanced cables and equipment production in the future. Here we would like to highlight that some of the above companies and other companies in this group do not limit their portfolio of products and services to equipment and cables design and production. They also provide 'turnkey' solutions for subsea cables projects (for example those provided by Alcatel-Lucent for telecommunications projects). The contractors group include companies providing engineering and other consultancy services necessary for subsea cables projects operations and expansion. New subsea cable projects have to be designed, consulted to meet environmental and legislative standards as well as financed and insured. Examples of companies participating and specialising in the development and design of the subsea cables projects are Pelagian and Marine Management Offshore. For environmental, legal and insurance consultancy participating companies examples are Fugro Emu and Red Penguin Associates. Two of the interviewees explained:

> *'In the telecom sector of course they have been around for so long. There are lots of established companies; there are one or two relatively new starts of some things [e.g., Facebook and Google]. However, you have a lot of "turnkey" solutions being requested form the big telecoms ... like Vodafone and Virgin, and have AT&Ts and the global crossings.... They would tend to go up for a complete "turnkey" installation to cable and equipment manufacturer like*

Alcatel, who would design the whole system for them, from the terminal stations through the subsea cables and basically handover to them. There are various suppliers that will come in part way through. For instance, there are independent ship operators that can install cables and give them various support and shore and landings and that sort of stuff. And of course the route engineering, survey and alike' [CEO - Solar energy company-1]

'The submarine systems were always closed networks. They were designed and operated by an actual business and traffic, as in bandwidth [i.e., final product of internet provided to houses], which is actually sold on the submarine cables. So, if we go back to the [subcontractors], for instance, there is a set of companies who are involved in the designing of submarine systems and usually what happens is, it might have an actual in house designer in the actual company but recently consultancy comes from the outside. The consultants could be associated with the company that is going to lay the submarine cable, for example Tyco or Global Marine. They will assist in in the designing of the submarine cable, do the survey work and the route you want to take and do measurement of the sea depth' [Senior Optical Specialist - 2]

The contractors' group of stakeholders have a wide range of economic activities influencing the UK economy mostly through direct channels. Also the majority of the contractors do not limit their involvement to either marine telecommunications or energy cables related economic activities and thus are generalisable to a unified stakeholders group. However, clear division is also present. To be specific, Alcatel-Lucent provides "turnkey" solutions for telecommunications projects. For completion of the project they may also subcontract any specific company from the above discussed groups to perform a particular activity on the project. Similarly, companies like SIEMENS producing turbines for power generation may subcontract companies to perform works necessary for electricity cable projects. In general contractors invest, employ, produce and develop to implement new or maintain current projects of the both telecommunications and energy subsea cables operators. Contractors may export their services, technology and products to overseas clients as well. This group may be roughly summarised as the “wheel horse”of the SETCI and its contributions to the UK economy. Reflecting on the energy-related contractors:

> *“SIEMENs actually doesn't produce transmission cables. For transmission cables you have got Nexans [a cable manufacturer company] and a few others....my knowledge of the construction is that you will have a main contractor...you may have the cable manufacturer with its own vessel, laying the cable as part of the sub contract to the main developer [e.g., DONG energy]. Also, you may have cable laying company buying the cable and laying it themselves, and likewise it could be the other way around. Because the costs of cable in installation broadly not dissimilar, it can go either way. They are by far the biggest cost, I mean, you are looking at multi-million pound cost of laying cables, so it is, it happened lots of different ways”* [Senior Asset Manager – power company-12]

Figure 2.5 demonstrates that both groups of stakeholders (i.e., telecommunications and energy related) are influenced by market forces and UK economic performance. It also demonstrates that regulatory conditions (for example from OFCOM) for the telecommunications sector are not found to be as important as for the electricity sector. However, some requirements for certain environmental standards for telecommunications cable laying are present (for example MMO). For instance, a submarine infrastructure manager has explained:

> *“There is a little pressure from the regulators, it is actually markets. Markets with their influence, totally from who wants capacity, it is from the operators itself. It is from companies like Microsoft and Facebook and Amazon who are in in the situation that they want to get from point A to point B, who see that there is none enough cable systems and probably in the near future they won’t be a submarine cable built to actually meet their needs. Therefore, they have to go and ... build the submarine cable for themselves and offer it to anyone else. However, it (implies new generation of the subsea cables e.g. Facebook, Microsoft etc.) will not care about the market, because they know that the*

usage of their content, usage of their committal to the society, that's so big, people will always contact them for information" [2]

2.7 Conclusions

The stakeholder analysis undertaken is crucial for understanding the complex set of relationships between multiple stakeholders in the UK telecommunications and electricity industries. This analysis also highlights a large number of benefits of the subsea cables industry that are difficult to quantify.

In the telecommunications sector the subsea cables industry provides benefits to businesses and households from:

- better quality and speed of digital communication;
- improved reliability of Internet connectivity.

These benefits translate into:

- improved business efficiency;
- improved ability to manage people and processes;
- improved opportunities for the international communication of product and process innovations.

In the electricity sector, the use of subsea cables is vital for the import and export of electricity, as well as to connect offshore electricity production to the mainland electricity grid system. Subsea cables ensure improved reliability and security of electricity supplies, as well as access to international markets Given that offshore electricity production is a vital part of renewables electricity production in the UK, this production has environmental benefits and contributes to reduced pollution and the UK's better ability to meet pollution reduction targets.

Finally, the stakeholder analysis described in this section is essential for identifying interrelationships between stakeholders that in Section 3 below will be modelled using a Computable General Equilibrium (CGE) model. This in turn allows us to go beyond estimating the value of the UK subsea cables industry to forecasting the impact of changes in the magnitude of the industry on sectors of the UK economy as well as on the UK macro economy. Hence, it is important to highlight that the CGE model does not emerge from abstract economic theory nor *a priori* assumptions about how the industry operates, but rather from a concrete, practical understanding of the structure of the industry developed through the stakeholder analysis.

3. An Economic Evaluation of the UK Subsea Cables Industry using Computable General Equilibrium Modelling

3.1 Introduction

In this section of the report a CGE (Computable General Equilibrium) model for the UK economy is developed to analyse the likely socio-economic impact of the SETCI using the stakeholder analysis of Section 2 above to depict the interrelationships between the multiple stakeholders in both the telecommunications and electricity sector. Three possible scenarios are considered for each sector. The CGE model is numerically calibrated to the UK Social Accounting Matrix (SAM). See Appendix 2 for an explanation of a SAM.

Reflecting the aims of the research project and the stakeholder analysis conducted in the qualitative part of the study above activities and commodities accounts were split into more specialised subaccounts. Specifically, activities and commodities were disaggregated into 25 industry specific subaccounts in accordance with the Eurostat (2008) economic sectors classification. Table 3.1 below demonstrates each industry of the UK economy used in the analysis. Note that in further account notation capital letter A is added to an account code to denote industry associated activity, while capital letter C denotes an industry associated commodity.

Having identified the stakeholder structure of the UK SETCI during the qualitative phase of the research, energy and telecommunications accounts were further disaggregated to reflect industry specific impacts on the UK economy. To be specific, the Electricity, Gas, Steam and Air Conditioning Supply account, as reported by The Office for National Statistics (ONS) has been split into two subaccounts of Electric Power Generation, Transmission and Distribution (EPGTD) and Manufacture and Distribution of Gas and other fuels, Steam and other Air Conditioning (MDG) accounts. The telecommunications and information account (as reported by the ONS) has been split into five subaccounts of Publishing Activities (PA), Programming and Broadcasting Activities (PBA), Telecommunications (T), Computer Programming and Consultancy (CPA), and Information Service Activities (ISA).

The EPDTG subaccount includes: production of electricity; transmission of electricity and electricity trade for both onshore and offshore electricity network distribution networks and generators. However, from the stakeholder ecosystem developed the UK SETCI energy segment is mainly associated with offshore wind production, its delivery to shore, and transfer of electricity between countries through interconnectors. Therefore, the UK SETCI energy sector portion in the EPDTG account can be easily identified. Renewables UK (2012, 2014) reports renewable energy share in the total electricity demand at 5.3% level in 2012 and 6% level in 2014. To correspond to the specific year of the SAM developed, 5.06% share of the renewable electricity demand in 2010 was obtained through linear interpolation. Next, knowing the generation capacity of the UK offshore and onshore plants the UK SETCI energy segment share can be obtained. To illustrate, the Department of Energy and Climate Change (2011) reports UK total renewable energy capacity of 5.3 GW with 4 GW produced by onshore generation plants and remaining capacity by the offshore plants. Hence, 1.2397% share of the EPDTG account corresponds to the SETCI energy segment.

The telecommunications subaccounts disaggregation rationale is more straightforward. The subaccount includes all wired and wireless telecommunication associated economic activities. The ISA subaccount contains telecommunications content associated economic activities. For a more detailed description see Eurostat (2008). Thus, for the telecommunications segment of the UK SETCI evaluation a clear emphasis is placed on the T and ISA subaccount economic activities. For example, the PA account includes publication activities such as of periodicals; books; software and computer games both off and online and thus its economic impact is more indirect.

#	Account Code	Account Name
1	AAF	Agriculture, Forestry and Fishing
2	MQ	Mining and Quarrying
3	M	Manufacturing
4	EPGTD	Electric power generation, transmission and distribution
5	MDG	Manufacture and distribution of gas other fuels, steam and air conditioning
6	WSS	Water Supply, Sewerage, Waste Management and Remediation Activities
7	C	Construction
8	WRT	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles
9	TS	Transportation and Storage
10	AFS	Accommodation and Food Service Activities
11	PA	Publishing Activities (Telecommunications)
12	PBA	Programming And Broadcasting Activities (Telecommunications)
13	T	Telecommunications (Telecommunications)
14	CPC	Computer Programming and Consultancy (Telecommunications)
15	ISA	Information Service Activities (Telecommunications)
16	FIA	Financial and Insurance Activities
17	REA	Real Estate Activities
18	PST	Professional, Scientific and Technical Services
19	ASS	Administrative and Support Services
20	PAD	Public Administration and Defence, Compulsory Social Security Services
21	E	Education
22	HHS	Human Health and Social Work Services
23	AER	Arts, Entertainment and Recreation
24	O	Other Services
25	AHE	Activities of Households as Employers

Table 3.1: System of National Industry Accounts - Energy and Telecommunications split in accordance with Eurostat (2008) and the 2010 UK SAM: Micro View

Simplified for demonstration purposes and modified to incorporate this project's research objectives the SAM for the UK economy in 2010 obtained from the Fraser and Allander Institute Macroeconomic Modelling Database is presented in Table 3.2 below. It demonstrates (in million GBP) income/expenditure flows of the investigated sectors, other industries (summed in activities (A) and commodities accounts(C)), institutions and the ROW. Further, Tables 3.3 and 3.4 demonstrate sector EPGTD T and ISA accounts have the highest levels of association. To illustrate, EPGTD accounts are highly associated with internal goods and services consumption (36.71% spending share). They are also heavily linked to the manufacturing sector (6.69% share) as well as to mining and quarrying (17.23% share). A significant portion of the industry spending is allocated to labour (7.1% share) and capital (12.56% share). EPGTD 2.43% share of total spending is tax expenses while importing expenditures are 13.81%. The telecommunications segment is also dependent on the manufacturing sector of the economy (7.34% share in T account spending) while the biggest expenditure flows are directed to the financial and insurance (2.70% share for T 2.16% share for ISA) as well as professional, scientific and technical services (2.74% share for T and 10. 04 for ISA).

	A	A. EPGTD	A. PA	A. PBA	A. T	A. CPC	A. ISA	C	C. EPGTD	C. PA	C. PBA	C. T	C. CPC	C. ISA	L	K	STAX	YTAX	HH	CORP	GOV	S-I	DSTK	ROW	**Totals**
A								2145183																	**2145183**
A. EPGTD									57267																**57267**
A. PA										19631															**19631**
A. PBA											21750														**21750**
A. T												36092													**36092**
A. CPC													47697												**47697**
A. ISA														6491											**6491**
C	850753	24103	6558	6346	10298	12291	1743												696720		332364	157308	1382	390290	**2490156**
C. EPGTD	23401	21024	120	117	412	378	50												20471		476	818	1	1106	**68374**
C. PA	5331	260	1657	80	85	116	18												6926		658	2150	31	3825	**21137**
C. PBA	5309	59	107	1143	141	222	34												8568		2006	2483	-18	4166	**24220**
C. T	19991	104	120	1325	1155	420	62												17087		73	1001		5163	**46501**
C. CPC	24961	402	180	398	1185	1407	254												6067		853	13415	54	4435	**53611**
C. ISA	3304	55	25	106	104	79	24												2030		105	182	-1	1171	**7184**
L	746780	4065	6849	5268	11893	23894	3047																		**801796**
K	465353	7195	4015	6967	10819	8890	1259																		**504498**
STAX								74967	1663	228	289	836	564	74											**78621**
YTAX																			75920	69907					**145827**
HH															801796	176761			1542	73485	254173			4099	**1311856**
CORP																312237			102926		4366			2	**419531**
GOV																15500	78621	145827	218789	45786	168			3897	**508588**
S-I																			41232	230353	-98224			5445	**178806**
DSTK																						1449			**1449**
ROW								270006	9444	1278	2181	9573	5350	619					113578		11570				**423599**

Totals	2145183	57267	19631	21750	36092	47697	6491	2490156	68374	21137	24220	46501	53611	7184	801796	504498	78621	145827	1311856	419531	508588	178806	1449	423599	

Table 3.2: UK Social Accounting Matrix, 2010 (million GBP). Original data source: Fraser and Allander Institute Macroeconomic Modelling Database, University of Strathclyde.

Expenditure, %			
Account	EPGTD	T	ISA
Mining and Quarrying	17.23	0.04	0.03
Manufacturing	6.69	7.34	2.19
Electric power generation, transmission and distribution	36.71	1.14	0.77
Manufacture and distribution of gas other fuels, steam and air conditioning	7.96	0.07	0.02
Construction	1.01	2.96	0.52
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	1.48	3.31	2.14
Telecommunications (Telecoms)	0.18	3.20	0.96
Computer Programming and Consultancy (Telecoms)	0.70	3.28	3.91
Financial and Insurance Activities	2.29	2.70	2.16
Real Estate Activities	0.24	1.13	0.55
Professional, Scientific and Technical Services	1.96	2.74	10.04
Administrative and Support Services	1.11	2.10	5.98
Education	0.26	1.16	0.32
Labour	7.10	32.95	46.94
Capital	12.56	29.98	19.40
Before TAX and ROW	*83.76*	*77.62*	*90.35*
Taxes	2.43	1.80	1.03
ROW	13.81	20.58	8.62

Table 3.3: Sectors' Interconnections within the UK economy, Expenditure Viewpoint. Electricity Generation and Distribution; Telecommunications and Information Service Provision Accounts Key Spending Share Contributions to the UK Economy.

Note: Sectors with below 1% participation of EPGTD, T and ISA accounts are omitted.

The sector mostly spends on labour (32.95% for T and 46.94% for ISA) and capital (29.98% for T and 19.40% for ISA). Both telecommunications accounts pay taxes (1.8% for T and 1.03% for ISA) as well as heavily rely on imports (20.53% for T and 8.62% for ISA).

Financial inflows to the EPGTD are mainly internal (30.75% share) and from households (29.94% share). Other key contributing sectors to the EPGTD revenues are manufacturing (9.54% share), wholesale and retail trade; repair of motor vehicles and motorcycles (5.03% share) and manufacture and distribution of gas and other fuels, steam and air conditioning (3.80% share). Similar for T and ISA accounts main sources of income are households (36.75% and 28.26% share respectively). Other key contributing sectors include financial and insurance (11.68% for T and 8.60% for ISA) and professional, scientific and technical services (5.17% for T and 5.15% for ISA). Unlike in EPGTD, the T and ISA sector is very export oriented (11.1% and 16.3% share respectively).

Income, %			
Account	EPGTD	T	ISA
Manufacturing	9.54	1.97	4.12
Electric power generation, transmission and distribution	30.75	0.22	0.77
Manufacture and distribution of gas other fuels, steam and air conditioning	3.80	0.06	0.25
Construction	1.31	0.82	1.46
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	5.03	6.92	6.47
Transportation and Storage	1.64	3.16	4.61
Accommodation and Food Service Activities	0.84	1.54	1.50
Programming And Broadcasting Activities (Telecoms)	0.17	2.85	1.48
Telecommunications (Telecoms)	0.60	2.48	1.45
Financial and Insurance Activities	2.14	11.68	8.60
Real Estate Activities	1.46	1.21	0.58
Professional, Scientific and Technical Services	1.04	5.17	5.15
Administrative and Support Services	0.86	1.87	2.56
Public Administration and Defence, Compulsory Social Security Services	1.59	4.08	0.61
Human Health and Social Work Services	1.63	1.75	1.21
Arts, Entertainment and Recreation	0.50	0.93	6.31
Other Services	0.19	0.54	1.59
Households	29.94	36.75	28.26
Government	0.70	0.16	1.46
Investment	1.20	2.15	2.53
ROW	1.62	11.10	16.30

Table 3.4: Sectors' Interconnections within UK economy, Income Viewpoint. UK economy Sectors' Key Contributions to the Electricity Generation and Distribution, Telecommunications and Information Service Provision Accounts.

Note: Sectors with below 1% participation in EPGTD, T and ISA accounts are omitted.

3.2 Theoretical Structure of the Computable General Equilibrium Model

A CGE model may be defined as a system of equations describing the behaviour of the stakeholders identified in the model and the technological and institutional constraints facing them. In other words, it investigates the coordination of mutually influencing yet separately decided activities of millions of agents by means of price signals. The model developed here is neo-classical in structure. Its main features involve profit maximisation by producers, utility maximisation by households, and competitive markets. The model follows the SAM disaggregation of factors, activities, commodities and institutions described above. It can identify changes in the sectoral composition of output, changes in relative prices and their consequences. The model draws upon the contributions to recursive dynamic CGE models by Dervis et al. (1982) and Lofgren et al. (2002).

CGE modelling of economic impacts have several strengths that are worthy of emphasising. CGE models have a solid microeconomic foundation and are capable of capturing the direct and indirect effects of a wide range of possible policy change without excessive simplification or aggregation. The second strength refers to the fact that CGE models recognise the complexity of interactions in the behaviour of the economic agents as they act in their own interests. By explicitly recognising resource constraints and incorporating mechanisms for potential crowding out of one activity by another as well as all input-output mechanisms, CGE models can provide substantial input into policy making. The resulting CGE models can be tested for robustness and the assumptions can be varied, providing researchers and policy makers with an analytical tool for identifying the economic impacts of particular types of economic shocks. CGE modelling can be used to quantify the effects of changes in taxation; technology; population growth; subsidies; domestic and foreign investments; as well as predicting the effects of a range of alternative policies or exogenous expenditure shocks.

Yet CGE modelling has a number of drawbacks. One of the general criticisms of CGE modelling is that it relies on the elasticity parameter values that are included in models developed by researchers. To address this concern, CGE modellers now perform sensitivity analysis for exogenously provided values or estimate the elasticity parameters econometrically where appropriate data are available. In the analysis below a sensitivity analysis is provided.

3.2.1 Specification of Model Equations

The model involves specification of a CGE model in terms of non-linear algebraic equations and solving them directly with numerical solution techniques. The equations define the behaviour of the different actors and are presented in the following order: price equations, production and factor demand, foreign trade, demand for goods and services, income and savings of institutions and system constraint equations. The basic structure of the production of the domestic and composite commodities, domestic supply and demand is laid out in Figure 3.1 below.

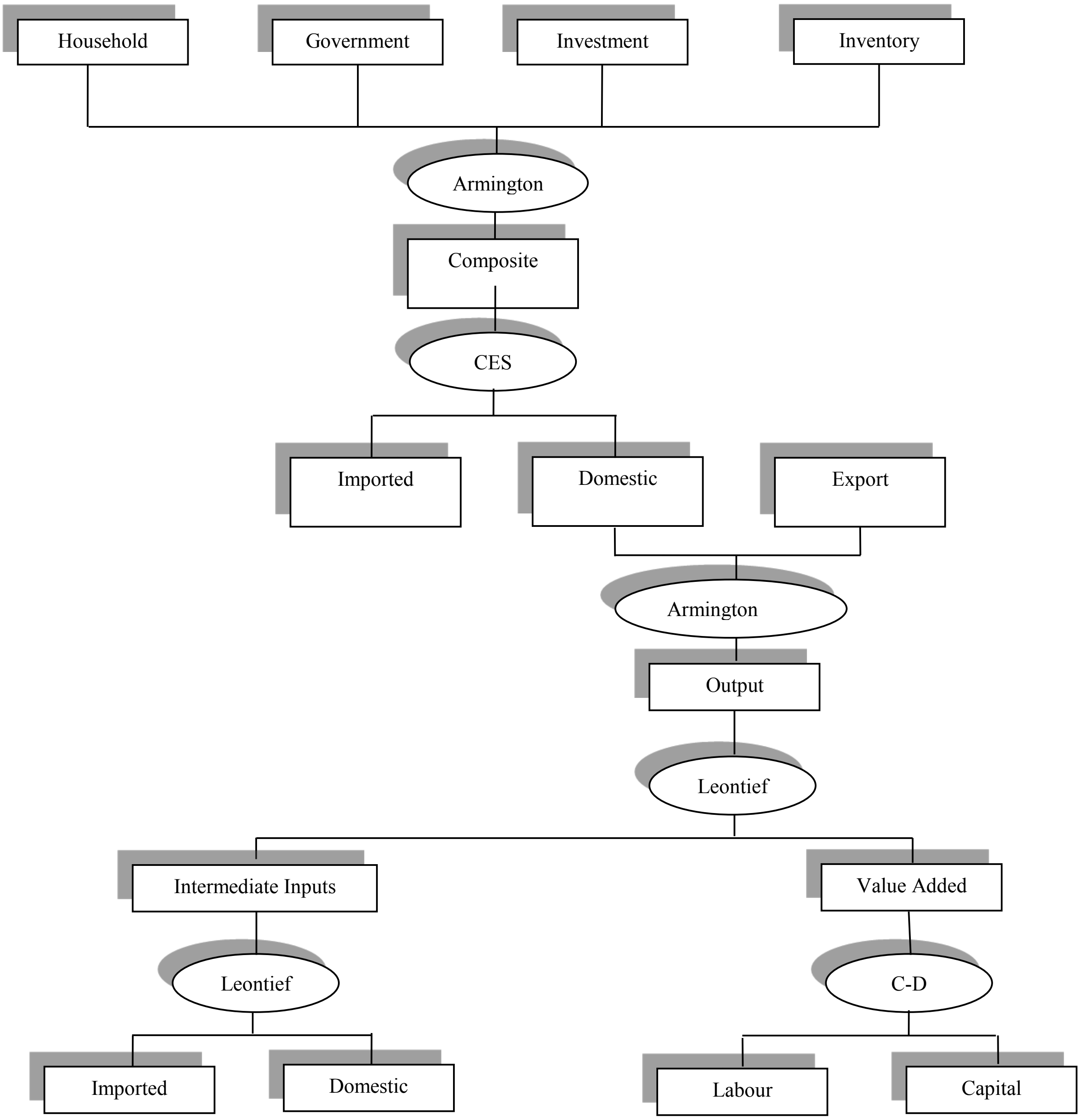


Figure 3.1: Production of the Domestic and Composite Commodities, Domestic Supply and Demand

Figure 3.1 above should be read from the bottom to the top. At the bottom, labour and capital are combined to produce the value added using a Cob-Douglas (C-D) substitution function. Another component of this stage consists of the combination of intermediate inputs of different sectors to produce aggregate intermediates using a Leontief substitution function. The value added is then combined with intermediate inputs to produce the output which is either exported or sold domestically using a constant elasticity of transformation (CET) function. The Armington aggregate refers to the substitution between imported and domestically produced commodities which is assumed to follow a constant elasticity of substitution (CES) function.

Details of the algebraic specification of the model are necessarily technically complex. Hence, they are described in detail in Appendix 3.

3.2.2 Simulation Design

The CGE model is used to investigate empirically the impact of supply and demand shocks in the subsea cables or related industries on GDP; labour demand; household and government income. This was carried out by considering three alternative scenarios.

Scenario 1: An increase in household expenditure impacts on T and ISA by 5 per cent (the UK SETCI telecommunications sector)

Scenario 1a: An increase in investment demand for T and ISA by 5 per cent (the UK SETCI telecommunications sector)

Scenario 1b: A 5 per cent decrease in sales tax on T and ISA (the UK SETCI telecommunications sector)

Scenario 2: An increase in household expenditure shares on PA, PBA, T, EPC, ISA (UK telecommunications industry account) by 5 per cent

Scenario 2a: An increase in investment demand for PA, PBA, T, EPC, ISA (UK telecommunications industry account) by 5 per cent

Scenario 2b: A 5 per cent decrease in sales tax on PA, PBA, T, EPC, ISA (UK telecommunications industry account)

Note that an assumption of 5% growth in the telecommunications industry is likely to be conservative as Moores Law indicates that demand for the Internet doubles every two years.

Scenario 3: An increase in household expenditure impacts on EPGTD (UK electricity generation and distribution account) by 5 per cent

Scenario 3a: An increase in investment demand for EPGTD (UK electricity generation and distribution account) by 5 per cent

Scenario 3b: A 5 per cent decrease in sales tax on EPGTD (UK electricity generation and distribution account)

3.3 Simulation Results

The simulation results are reported separately in terms of macro-economic and sectoral impacts and in terms of employment; income and consumption impacts.

3.3.1 Macroeconomic Results

Macro-economic impact results for the industry are presented in Tables 3.5, 3.6, and 3.7. Compared to the baseline scenario, macro-economic results indicate that the proposed changes in the telecommunications and energy sectors lead to an increase in GDP in almost all scenarios. The highest increase is recorded under Scenario 1 with an increase in GDP by 0.6% followed by Scenario 2 (0.25%) and the lowest change is registered under Scenario 3b (closest to 0% marginal economic growth). Furthermore, the expansion of the industry causes income increases, enabling consumers to enjoy a small increase in private consumption, which increases by almost 2% under Scenario 2 (Table 3.6) and 1.6% under the Scenario 1 (Table 3.5).

Effects of additional growth in the telecommunications segment of the UK SETCI (percentage deviations change from CGE-baseline results)			
	Scenario 1	Scenario 1a	Scenario 1b
GDP	**+ 0.5964**	**+ 0.0012**	**+ 0.0058**
Household consumption	**+ 1.6367**	+0.1850	+ 0.0022
Total investment	+ 0.6557	**+10.0914**	0.0000
Government income	+ 0.2685	- 0.0001	+ 0.0088
Household income	**+ 0.7636**	**+ 0.0005**	**+ 0.0044**
Total export	+ 1.1378	+0.03800	+ 0.0021
Total import	+ 1.2248	+ 0.0505	+ 0.0017
Domestic demand	**+ 1.1756**	+0.0298	+ 0.0021
Labour demand	**+1.2449**	+ 0.0106	+ 0.0039

Table 3.5: Macroeconomic Simulation Results for the UK SETCI Telecommunications Sector I

Effects of additional growth in the UK telecommunications sector (percentage deviations change from CGE-baseline results)			
	Scenario 2	Scenario 2a	Scenario 2b
GDP	+ 0.2595	+ 0.0053	+ 0.0012
Household consumption	**+ 1.9868**	+ 0.2299	+ 0.0005
Total investment	+ 0.1457	**+ 19.50**	- 0.0020
Government income	+ 0.1076	+ 0.0128	+ 0.0041
Household income	**+ 0.3580**	**+ 0.0035**	**+ 0.0058**
Total export	+ 0.4877	**+ 2.0220**	+ 0.0006
Total import	+ 0.6318	+ 1.7383	+ 0.0013
Domestic demand	+ 0.5344	**+ 1.9541**	+ 0.0009
Labour demand	**+ 1.1567**	**+ 3.0810**	+ 0.0024

Table 3.6: Macroeconomic Simulation Results for the UK Telecommunications Sector II

Effects of additional growth in the UK SETCI share of EPGTD account (percentage deviations change from CGE-baseline results)			
	Scenario 3	Scenario 3a	Scenario 3b
GDP	**+ 0.0010**	0.0000	0.0000
Household consumption	+ 0.0508	0.0000	+ 0.0010
Total investment	+ 0.0290	**+ 0.0595**	+ 0.0010
Government income	+ 0.0003	0.0000	+ 0.0020
Household income	+ 0.0006	0.0000	0.0000
Total export	+ 0.0456	+ 0.0011	0.0000
Total import	+ 0.0651	+ 0.0018	0.0000
Domestic demand	+ 0.0512	+ 0.0013	0.0000
Labour demand	**+ 0.0337**	+ 0.0016	0.0000

Table 3.7: Macroeconomic Simulation Results for the UK SETCI Energy Sector

On the expenditure side, the industry expansion stimulates capital formation and generates changes in the growth rate of aggregate investments, which with the exception of Scenario 2, increase under all scenarios. With respect to trade, the simulated percentage changes for exports and imports are positive. Total imports (~3.71% growth for all scenarios) is marginally outweighed by the increase in total exports (~3.73% for all scenarios) indicating an overall positive impact from the international markets to the UK economy from the industry growth. However, the difference in exports and imports growth rates may be attributed to the initial shares of imported and exported commodities in the different sectors of the economy.

On the income side, the growth of the industry affects the fiscal position of the government favourably by increasing government revenue. Tables 3.5 to 3.7 further show the effects that the expansion of the industry has on labour demand. The results indicate that the effects of changes in household demand for the industry's product, as well as changes in investment and sales tax will generate significant labour demand effects. In the simulation results, the largest effects are recorded under Scenario 2a (3.08%) followed by Scenario 1 (1.24%) and Scenario 2 (1.16%). Additional findings of this study are the projected increases in domestic demand, which grows by almost 2% for all commodities under Scenario 2a and 1.18% under Scenarios 1. For the UK SETCI electricity sector domestic demand grows the highest under scenario 3 (0.05%). Overall, the third scenario records the lowest changes in macroeconomic variables. It may be attributed by the relatively small share of the UK SETCI energy sector portion in the EPGTD account and UK economy consequently.

3.3.2 Sectoral Results

Sectoral results for the industry are presented in the Tables 3.8, 3.9, and 3.10 below. Three sectors were selected for investigation for each set of scenarios for illustrative purposes. The first sector in each scenario set represents the sector with highest income contribution to the investigated sector (for example from Table 3.4 for the UK SETCI telecommunications accounts it is financial and insurance services). The second sector represents medium income contribution to the investigated sector (for example from Table 3.4 for the SETCI telecommunications sector accounts it is professional; scientific and technical consultancy services). The third sector represents lesser income contribution to the investigated sector but with higher than a 1% contribution share (for example for electricity generation and distribution it is transportation and storage services).

	Percentage change in variables from the benchmark UK economy model											
	Scenario 1				Scenario 1a				Scenario 1b			
Sectors	Import	Domestic supplies	Export	Quantity demanded	Import	Domestic supplies	Export	Quantity demanded	Import	Domestic supplies	Export	Quantity demanded
Financial and Insurance	+1.4085	+1.6085	+1.7311	+1.6318	+0.0006	+0.0004	+0.0003	+0.0004	+0.0076	+0.0026	-0.0004	+0.0020
Professional, Scientific and Technical	+1.2709	+1.2538	+1.2440	+1.2523	-0.0022	-0.0017	-0.0014	-0.0017	+0.0052	+0.0041	+0.0035	+0.0040
Administrative and Support	+1.1471	+1.3132	+1.4176	+1.3343	-0.0011	-0.0009	-0.0008	-0.0009	+0.0069	+0.0050	+0.0039	+0.0048

Table 3.8: Illustrative Sectoral Simulation Results for the UK SETCI Telecommunications Sector I

	Percentage change in variables from benchmark											
	Scenario 2				Scenario 2a				Scenario 2b			
Sectors	Import	Domestic supplies	Export	Quantity demanded	Import	Domestic supplies	Export	Quantity demanded	Import	Domestic supplies	Export	Quantity demanded
Financial and Insurance	+0.4158	+0.7488	+0.9534	+0.7877	+0.0211	+0.1498	+0.0112	+0.0142	+0.0049	+0.0017	-0.0003	+0.0013
Professional, Scientific and Technical	+0.5053	+0.3485	+0.5899	+0.5639	+0.0017	-0.0003	-0.0014	-0.0005	+0.0039	+0.0030	+0.0025	+0.0029
Administrative and Support	+0.3757	+0.5655	+0.6848	+0.5896	+0.0028	-0.0009	-0.0032	-0.0014	+0.0049	+0.0035	+0.0027	+0.0034

Table 3.9: Illustrative Sectoral Simulation Results for the UK Telecommunications Sector II

	Percentage change in variables from benchmark											
	Scenario 3				Scenario 3a				Scenario 3b			
Sectors	Import	Domestic supplies	Export	Quantity demanded	Import	Domestic supplies	Export	Quantity demanded	Import	Domestic supplies	Export	Quantity demanded
Manufacturing	+ 0.0234	+ 0.0060	+ 0.0011	+ 0.0012	0.0000	+0.0002	0.0000	+ 0.0004	0.0000	0.0000	-0.0001	0.0000
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	- 0.0001	+ 0.0010	+ 0.0015	+ 0.0009	0.0000	0.0000	0.0000	0.0000	+ 0.0001	+ 0.0001	+ 0.0001	+ 0.0001
Transportation and Storage	+ 0.0004	+ 0.0005	+ 0.0006	+ 0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	+ 0.0001	+ 0.0001	+ 0.0001

Table 3.10: Illustrative Sectoral Simulation Results for the UK Energy Sector

In response to the UK SETCI telecommunications segment simulated growth, all selected industries experience an increase in the demand for their services except under Scenario 1a. Consequently as demand for the services increases this stimulates increases in imports, domestic supplies and exports. The best performing sector under the UK SETCI telecommunications growth scenarios is the financial and insurance sector. It performs best from an increase in demand of 1.63% under Scenario 1. It increases both domestic supplies (1.61%) and exports (1.73%). Under Scenario 1 financial sector export growth outperforms import growth by 0.32%. When a comprehensive UK telecommunications sector growth performance is tested, identical effects on the selected sectors are observed. Similarly, the financial sector outperforms professional; scientific; technical; administrative; and support services. However, the growth of the financial sector is smaller under Scenario 2. Specifically, under Scenario 2, demand for the financial and insurance services market increases only by 0.79%. On the other hand, financial exports outperform imports growth rates by 0.54%. Scenarios 2a and 2b demonstrate better performance of the selected sectors than under Scenarios 1a and 1b respectively. For the selected sectors influenced by the UK SETCI energy segment set of growth scenarios impacts of a smaller scale are observed as expected. The highest growth in demand is observed under Scenario 3. The best performing sector under Scenario 3 is manufacturing. Demand for manufacturing goods increases by 0.0012%. Exports increase by 0.0011% while imports increase by 0.0234%. In general, under all scenarios set for the UK STECI energy segment a small positive impact on the selected sectors is observed. However, similar to the macroeconomic indicators reported in Table 3.7 above, the impacts on the sectors are marginal and relatively small when compared to the telecommunications accounts growth.

3.4 Conclusions and Recommendations from the CGE Modelling Analysis

From the simulations results on the UK SETCI subsectors, the significance of the subsea cables industry for the UK economy has been determined. Positive effects from UK SETCI economic activities have been identified for the:

- UK labour market;
- Government revenues;
- Other sectors of the economy;
- UK GDP;
- Households.

To illustrate the interrelationship between the subsea cables industry and households, if households increase their consumption of the UK SETCI telecommunications sector stakeholders' services (for example switching to a faster broadband option) the impacts on the economy are positive and significantly so. Households' Internet connections and going online in fact stimulates UK economy the most. Efficient access to information stimulates administrative, supporting, scientific and professional services sectors of the economy. Yet, the financial sector benefits the most. It experiences a rise in exports over imports and increased domestic demand. Comparing outcomes for the UK SETCI specific telecommunications stakeholders' accounts with the UK comprehensive telecommunication sector simulations indicates that stimulating households' interests in the UK SETCI specific services positively influences the labour market ensuring higher business efficiency and improved management of people and processes.

The UK SETCI energy sector effects on the economy are also positive. However, they are less significant than those for the UK SECTI telecommunications stakeholders. Specifically, the energy subsector positively influences the labour market, other sectors (for example manufacturing etc.), and UK GDP but these effects are rather marginal. This is explained by its relatively small share in the UK GDP when compared to other sectors (for example financial services; construction etc.). Stimulating the sector through additional investment to enhance its production capacity and share in the UK electricity portfolio benefits the economy (Table 3.7, Scenario 3a) as well as increasing the sector's future impact.

3.5 Sensitivity Analysis of Key Model Parameters

Given that the elasticities used in this CGE model were not estimated econometrically, a sensitivity analysis is used to demonstrate the robustness of simulation results by varying parameters that may significantly affect the results. By increasing or decreasing the values of key parameters in the model, we examine the stability of equilibrium values of variables such as GDP and demand for labour. The elasticities for wich we performed a sensitivity analysis are price elasticities of import (CES) and export (CET).

We define a higher-elasticity case with 20 per cent higher values and a lower-elasticity case with 20 per cent lower value for those parameters. To evaluate the robustness of the simulation results, we check whether the signs of the changes in quantity variables remain unchanged in all cases. The results of the sensitivity analysis shown in Table 3.11 below indicate that the simulation results show that all quantity variables will always be affected in the same direction with the different assumed elasticity values. Moreover, the results indicate that the volume of exports and import are smaller when goods have only relatively poor substitutes and larger when the goods are assumed to be readily substitutable. In general, the sensitivity analysis shows the robustness of the results, which are consistent with theoretical predictions; that is, higher export demand elasticities will produce larger impacts on the quantity variables, for any given policy changes.

Output of:	Elasticity of substitution/transformation		
	Baseline case	Higher-elasticity case	Lower-elasticity case
GDP	+ 0.5964	+0.4795	+0.5590
Household consumption	+ 1.6367	+1.5468	+1.7141
Total investment	+ 0.6557	+0.3457	+0.7405
Government income	+ 0.2685	+0.1076	+0.1121
Household income	+ 0.7636	+0.3580	+0.3580
Total export	+ 1.1378	+1.2077	+0.8177
Total import	+ 1.2248	+1.6418	+0.6318
Domestic demand	+ 1.1756	+0.8344	+1.5024
Labour demand	+1.2449	+1.0267	+1.3567

Table 3.11: Impact of different elasticity values on sectoral output under Scenario 1

All quantity variables will always be affected in the same direction regardless of the different assumed elasticity values. Ultimately the sensitivity analysis shows the robustness of the results, which are always also reassuringly consistent with theoretical predictions.

4. Conclusions

The qualitative and quantitative analyses above combine to highlight the positive value of the UK subsea cables industry both on the telecommunications and energy market sectors. The impact on the telecommunications sector is larger as was to be expected given the importance of this sector on the UK economy as a whole, while subsea cables are of importance in the electricity market predominantly in terms of electricity imports and exports, and the production of electricity from off-shore wind farms.

Not only is the UK subsea cables market important in terms of its impact on the telecommunications and electricity sectors, but the quantitative analysis has highlighted the benefits of future growth in the UK subsea cables industry on UK macroeconomic variables including GDP; consumer income; capital formation; exports and imports and government revenues. Growth in the UK telecommunications subsea cables industry is likely positively to impact the UK financial and insurance sector the most, while growth in the UK electricity subsea cables industry is expected to have its greatest positive impact on the UK manufacturing industry.

The qualitative stakeholder analysis allowed us to going beyond a monetary analysis of the potential benefits of the subsea cables industry. In the telecommunications sector there are benefits to businesses and households from better quality and speed of digital communication, as well as improved reliability of Internet connectivity. These benefits translate into improved business efficiency, improved ability to manage people and processes, as well as improved opportunities for the international communication of product and process innovations. In the electricity sector, the use of subsea cables is vital for the import and export of electricity, as well as to connect offshore electricity production to the mainland electricity grid system. Consequently, subsea cables ensure improved reliability and security of electricity supplies, as well as access to international markets. Given that offshore electricity production is a vital part of renewables electricity production in the UK, this production has environmental benefits and contributes to reduced pollution and the UK’s better ability to meet pollution reduction targets.

Yet a challenge remains to calculating the value of the UK subsea cables industry to the UK energy sector from the uncertainty surrounding the impact of ‘Brexit’. Currently the UK is bound by EU energy and environmental regulations that encourage investment in and use of energy from renewables, including offshore wind. Further, 5% of electricity is imported, predominantly from the EU and under the auspices of EU free trade agreements. The impact of ‘Brexit’ both on the desirability and feasibility of offshore wind, and on imports of electricity from the EU remain highly uncertain. Further uncertainty surrounds changes in legislation concerning the laying and maintenance of subsea cables that are expected in light of Brexit. However, in this respect Brexit offers an opportunity for greater transparency of legislation which would benefit the industry.

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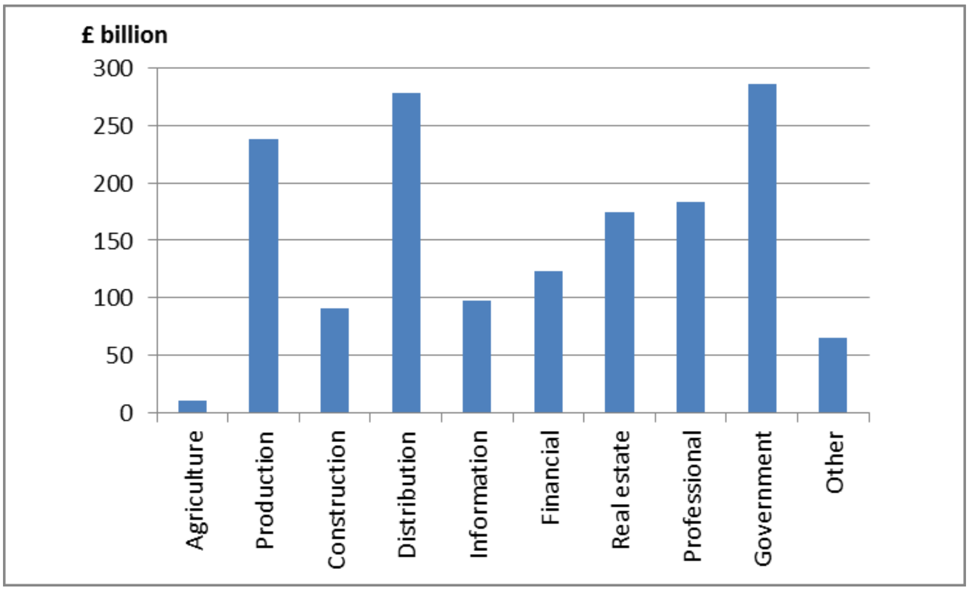
Appendix 1

Figure A1: Value of Industries to the UK Economy 2013[9]



Source: Office for National Statistics (ONS) United Kingdom National Accounts, The Blue Book (2015)

[9] Most recent year for which data are available in the ONS Blue Book at time of writing.

Appendix 2

A SAM is a summary table, which refers to a given period, representing an economy wide accounting of the distribution of the incomes and expenditures between various industries, factors of production, economic agents and the "Rest of the World" (ROW), incorporating foreign actors' influence on the economy. It differs from an input-output table analysis in that households are included and all accounts are fully balanced to represent the whole economic system of the country. Thus, in a balanced SAM there is an exact correspondence between columns and rows, implying that supply equals demand for all factors and goods, tax receipts equal tax payments, there are no excess profits in production, the value of each household expenditure equals the value of factor income plus transfers.

Table A1 illustrates the key content of the UK SAM used for further social-economic impact investigation of the SETCI. From an accounting perspective, the SAM is a two-entry square table which presents a series of double-entry accounts whose receipts and outlays are recorded in rows and columns respectively. Accounts in Table A1 refer to:

1. **Activities:** these are the production activities necessary for production of goods and services by the UK domestic industries. Goods and services are produced by combining the factors of production, added-value by comprising of the sum labour (wages) and capital (capital rent) expenses, and intermediate inputs.
2. **Commodities:** are UK economy's total supply of goods and services from domestic and international production (imports from the ROW). Sales taxes and import tariffs are paid on commodities.
3. **Factors of Production (e.g. labour (L) and capital (K)):** these accounts depict receipts from production activities, which pay for factor services, and payments to institutions, which provide those services. They are distinguished in labour and capital.
4. **Institutions (e.g. households (HH), enterprises (CORP), and Government (GOV)):** these accounts record incomes of institutions along the rows and expenditure on the columns.
5. **Taxes (e.g. Sales Tax (STAX) and Income Tax (YTAX)):** these accounts demonstrate government income from income and sales tax along the columns as well as households and corporation sales and income tax expenses along the rows.
6. **Capital accounts (e.g. Savings-Investment and Capital Stock (DSTK))** accumulation account, which records allocation of resources for capital formation and use of these resources for the purchase of investment products and building up stocks of goods. Capital stock demonstrates initial capital balance.

7. **The rest of the world account** or external account, in which the row records payments received by the rest of the world from the UK and the column records the outlays of the rest of the world towards the UK.

	Activities	Commodities	L	K	STAX	YTAX	HH	CORP	GOV	S-I	DSTK	ROW	Totals
Activities		Marketed Output											Activity Income
Commodities	Intermediate Input						Private Consumption		Government Consumption	Investment	Capital Stock	Exports	Total Demand
L	Value-added (Wages)												Labour Income
K	Value-added (EBT)												Capital Income
STAX		Sales Taxes											Sales Tax Income
YTAX							Private Income Taxes	Enterprise Income Taxes					Cumulative Income Tax Income
HH			Households Labour Income (Wages)	Households Capital Income (EBT)			Households Surplus	Enterprise Transfers to Households	Government Transfers to Households			Transfers to Households from abroad	Households Income
CORP				Enterprise Capital Income (EBT)			Households Transfers to Enterprise		Government Transfers to Enterprise			Transfers to Enterprises from abroad	Enterprise Income
GOV				Government Capital Income	Government Sales Tax Income	Government Income Tax Income	Direct Household Taxes	Surplus to Government Enterprise Taxes	Surplus to Government				Government Income
S-I							Households Savings	Enterprise Savings	Government Savings			Balance of Payments	Savings
DSTK										Capital Stock			Inventory Income
ROW		Imports					Households Transfers to the ROW		Government Transfers to the Rest of the World				Foreign Exchange Outflow

Totals	Activity Expenditure	Total Supply	Labour Expenditure	Capital Expenditure	Sales Tax Expenditure	Income Tax Expenditure	Households Expenditure	Enterprise Expenditure	Government Expenditure	Investment	Inventory Expenditure	Foreign Exchange Inflow	

Table A1: The Structure of the UK Social Accounting Matrix (2010), Macro View.

Appendix 3

The Price Block

The algebraic specification of the model begins with the price equations that define the underlying price system of the model. Prices in a CGE model differ according to their origin and destination of use. The domestic import price and the domestic export price are a function of the world import price and the world export price in foreign currency, the exchange rate, and a tariff adjustment on imports and a tariff adjustment on exports. The domestic price of imports is defined in Equation (1) as the world price of imports times one plus the import tariff rate and times by the exchange rate.

The domestic export price is similar in structure to the import price definition. The main difference is that the tax reduces the price received by the domestic producers of exports (instead of adding to the price paid by domestic demanders of imports). It is defined in Equation (2) as the product of world prices of export multiplied by the one minus the export tax rate and times the exchange rate. The domain of the equation is the set of exported commodities, all of which are produced domestically. The world price of exports is fixed for some sectors (small-country assumption) and declared as variable for others, reflecting Greece's market power for these sectors.

Equation (3) describes the supply prices for the composite commodities, which is defined as the sum of spending on domestically produced and imported commodities, times one plus the sale tax rates. (Equation (3) is to be divided by composite supply to derive prices). In Equation 4, the producer price is defined as the value of domestic sales plus the export value, divided by domestic output. Activity (output) price is the sum of producer price multiplied by yields per activity unit (Equation 5). Equation 6 characterizes the sectoral price of value-added which is the total activity's revenue minus the value of total intermediate inputs (divided by the value added for each activity).

Production and Trade Block

Production is assumed to be competitive and technology is specified by constant returns to scale. Consequently, producers are assumed to maximize profits subject to their technology constraints, thereby taking the prices of output, input and factors as given.

A producer's production function for a given good X_s is given by

$$X_s = f(K, L, QINT)$$

which shows the maximum amount of output that can be produced in a given period for alternative combinations of capital (K), labour (L) and intermediate goods (QINT).

Production is carried out by activities that are assumed to maximize profits subject to their technology, taking prices (for their outputs, intermediate inputs, and factors) as given. Equation (7) states that, for each activity, the quantity of value-added is a C-D function of disaggregated factor quantities. The choice of behavioural functions has been guided by several considerations: (i) the characteristics of the sectors and products under study and consequently the values of the related elasticities; and (ii) the restrictions of general equilibrium theory, according to which the function chosen must be non-negative, continuous and homogenous of degree zero in the prices and furthermore, Walras' law must be met.

The demand equations for the producers for capital and labour are captured by a CD function as shown in Equation (8). The intermediate input demand function is a fixed coefficient of activity output (Equation 9). In Equation (10), the activity level determines the quantity of commodity outputs produced by each activity.

Foreign Trade

Trade relationships are modelled using the Armington assumption that goods are differentiated by country of origin (Armington, 1969). Imperfect substitutability between imports and domestic output sold domestically is captured by a CES aggregation function, which is controlled by the share parameters and the elasticity of substitution parameter. In this CES function the composite commodity that is supplied domestically is produced by domestic and imported commodities entering this function as inputs. This aggregation is given in Equation (11). The optimal allocation of consumption between domestic and imported commodities is derived from the first order condition of the demand optimization problem. Solving this problem by ways of CES functions yields Equation (12).

As can be seen from Figure 3.1, aggregate domestic output is allocated between domestic and export markets. This is done under the assumption that suppliers maximize sales revenue for any given aggregate output level, subject to imperfect transformability between exports and domestic sales, expressed by a CET function. Differentiation between exports and domestically consumed goods may arise because of differences in quality. The combination between exports and domestic sales is be specified in Equation (13). The optimal allocation of domestic output between domestic and export markets is derived from the first order condition of the supplier's optimization problem. Solving this problem by ways of CET functions yields Equation (14). Thus, Equation (14) defines the optimal mix between domestic sales and exports, which depends on relative prices $\left(\frac{PE_{(c)}}{PD_{(c)}}\right)$. It is apparent from the equation that, an increase in the export-domestic price ratio generates an increase in the export-domestic supply ratio (that is, a shift toward the destination that offers the higher return).

After describing the production price system and the supply side, the income flows have to be specified. The next section describes the main features and equations of the income and savings for each category of institution in the domestic economy: households, enterprises and the government.

Income and Expenditure Block

Equations (15) and (16) capture the flow of income from value added, government and enterprises that is distributed to households as well as remittances from abroad. The households aim to sell all their endowed factors to the producers to earn income. More specifically, the receipts of households are composed of returns to labour, capital, as well as transfers from government, enterprises and rest of the world.

The consumption of different commodities is a function of income, marginal propensity to save and transfer (Equation 17). It is assumed that the utility function is of a Cobb-Douglas type. The volumes of commodities purchased for investment are determined by the volume in the base period and can be varied using an adjuster (Equation 18). Government revenue is defined as the sum of income tax, sales tax and transfers (Equation 19). The value of government expenditure is therefore equal to the sum of government demand for commodities plus its transfer payment to institutions (Equation 20). Equation (21) captures the flow of income from transfers to enterprise. Equation (22) defines the objective function.

System Constraint (Equilibrium Conditions)

The market clearing equations ensure the simultaneous clearing of all market. While recognizing that the model is a general equilibrium system, with all endogenous variables jointly determined, it is useful to think in terms of matching each of these equilibrium conditions with an 'equilibrium variable' (Robinson et al. 1995). Equations (23) to (26) define the market-clearing equilibrium conditions. We introduce one index, namely the consumer price index that can be used for price normalisation. The consumer price index (Equation, 27) is defined as a weighted sum of composite commodity prices in the current period, where the weights are the share of each commodity in total demand.

In a general equilibrium competitive market economy, variations in the prices or in the returns to factors ensure satisfaction of market-clearing conditions for each market. In the model specified here there are four relevant markets: factor and commodity markets, and capital market and rest of world accounts.

Equation (23) imposes equality between quantities supplied and demanded of the composite commodities, and thus defines market-clearing equilibrium in the product markets. The equilibrating variables for this equation are the sectoral prices. Total quantities demanded and total quantities supplied for each factor are balanced according to equation (24).

The exogenously set current account balance (the current account balance represents the flow of foreign savings) requires the country's total payments for imports to equal total receipts for exports plus foreign savings and borrowing (equation 25). The fixed current account hypothesis forces the difference between currency spending (imports) and earnings (exports) of the country to be preserved. Equilibrium of foreign trade is achieved through flexibility of price index and the resulting adjustment in the real exchange rate. The model is solved in GAMS.[10]

Indices

$a \in A$	activities
$c \in C$	commodities
$f \in F$	factors
$i \in I$	institutions (domestic, tourist and rest of the world)

[10]Generalized Algebraic Modelling System (GAMS) is a language of setting up and solving mathematical programming optimisation models. It is an all-in-one package that allows one to specify the structure of the optimisation model and calculate data that goes into the model.

Parameters Table

ad_a	production function efficiency parameter
aq_a	shift parameter for composite supply (Armington) function
at_c	shift parameter for output transformation (CET) function
cpi	consumer price index
$cwts_c$	weight of commodity *c* in the *CPI*
ica_{ca}	quantity of *c* as intermediate input per unit of activity *a*
$inta_a$	quantity of aggregate intermediate input per activity unit
iva_a	quantity of value-added per activity unit
mps_h	share of disposable household income to savings
pwe_c	export price (foreign currency)
pwm_c	import price (foreign currency)
$qdtst_c$	quantity of stock change
QG_C	base-year quantity of government demand
qbarinv(C)	exogenous investment demand
$\overline{qinv_c}$	base-year quantity of private investment demand
sE	enterprise saving rate
$shry_{if}$	share for domestic institution *i* in income of factor *f*
te_c	export tax rate
tm_c	import tariff rate
tq_c	rate of sales tax
tr_{ii}	transfer from institution i' to institution *i*
ty_i	rate of nongovernmental institution income tax
α_{fa}	value-added share for factor f in activity a
β_{ch}	share of commodity c in the consumption of household h
δ_c^q	share parameter for composite commodity supply (Armington) function
δ_c^t	share parameter for output transformation (CET) function
θ_{ac}	yield of commodity c per unit of activity a
ρ_c^q	Armington function exponent $(-1 \prec \rho_c^q \prec \infty)$
ρ_c^t	CET function exponent $(1 \prec \rho_c^q \prec \infty)$
ψ	per capita consumption of tourist
σ_c^q	elasticity of substitution for composite supply (Armington) function
σ_c^t	elasticity of transformation for output transformation (CET) function

Variables Table

EG	government expenditures
EXR	exchange rate (*LCU* per unit of *FCU*)
FSAV	foreign savings
GSAV	government savings
IADJ	investment adjustment factor
PA_a	activity price
PD_c	domestic price of domestic output
PE_c	export price (domestic currency)
PM_c	import price (domestic currency)
PQ_c	composite commodity price
PVA_a	value-added price (factor income per unit of activity)
PX_c	aggregate producer price for commodity
QA_a	quantity (level) of activity
QD_c	quantity sold domestically of domestic output
QE_c	quantity of exports
QF_{fa}	quantity demanded of factor *f* from activity *a*
QFS_f	supply of factor f
QH_{ch}	quantity consumed of commodity c by household *h*
$QINT_{ca}$	quantity of commodity *c* as intermediate input to activity *a*
$QINV_c$	quantity of investment demand for commodity
QM_c	quantity of imports of commodity
QQ_c	quantity of goods supplied to domestic market (composite supply)
QX_c	aggregated marketed quantity of domestic output of commodity
Walras	dummy variable
WF_f	average price of factor *f*
$WFDIST_f$	wage distortion factor for factor f in activity *a*
YE	enterprise income
YF_{if}	transfer of income to institution I from factor *f*
YG	government revenue
YI_i	income of domestic nongovernment institution
UU	utility (fictitious)

Equations Table

Price Block

Import price $PM_c = pwm_c(1+tm_c)\cdot EXR$ $c\in CM$ (1)

Export price $PE_c = pwe_c(1-te_c)\cdot EXR$ $c\in CM$ (2)

Absorption $PQ_c\cdot QQ_c = PD_c\cdot QD_c + PM_c\cdot QM_c\cdot(1+tq_c)$ $c\in(CD\cup CM)$ (3)

Market output value $PX_c\cdot QX_c = PD_c\cdot QD_c + PE_c\cdot QE_c$ $c\in CX$ (4)

Activity price $PA_a = \sum_{c\in C} PX_c\cdot\theta_{ac}$ $a\in A$ (5)

Value-added price $PVA_a = PA_a - \sum_{c\in C} PQ_c\cdot ica_{ca}$ $a\in A$ (6)

Production and Commodity Block

C-D technology: Activity production function $QA_a = ad_a\cdot\prod_{f\in F} QF_{fa}^{\alpha_{fa}}$ $a\in A$ (7)

Factor demand $WF_f\cdot WFDIST_{fa} = \frac{\alpha_{fa}\cdot PVA_a\cdot QA_a}{QF_{fa}}$ $a\in A$ and $f\in F$ (8)

Intermediate demand $QINT_{ca} = ica_{ca}\cdot QA_a$ $a\in A$ and $c\in C$ (9)

Output Function $QX_c = \sum_{a\in A}\theta_{ac}\cdot QA_a$ $c\in C$ (10)

Composite supply (Armington) function

$$QQ_c = \alpha_c^q\cdot\left(\delta_c^q\cdot QM_c^{-\rho_c^q} - \left(1-\delta_c^q\right)\cdot QD_c^{-\rho_c^q}\right)^{-\frac{1}{\rho_c^q}} \quad c\in(CM\cap CD) \quad (11)$$

Import-domestic demand ratio $\frac{QM_c}{QD_c} = \left(\frac{PD_c}{PM_c}\cdot\frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}}$ $c\in(CM\cap CD)$ (12)

Output transformation (CET) function

$$QX_c = at_c\cdot\left(\delta_c^t\cdot QE_c^{\rho_c^t} + \left(1-\delta_c^t\right)\cdot QD_c^{\rho_c^t}\right)^{\frac{1}{\rho_c^t}} \quad c\in CE \quad (13)$$

Export-domestic supply ratio

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c}\cdot\frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t-1}} \quad c\in CE \quad (14)$$

Institution Block

Factor income $YF_{if} = shry_{if}\cdot\sum_{a\in A} WF_f\cdot WFDIST_{fa}\cdot QF_{fa}$ $i\in I$ and $f\in F$ (15)

Household consumption demand for marketed commodities

$$PQ_c\cdot QH_{ch} = \beta_{ch}\cdot\left(1-mps_h\right)+\left(1-t_y\right)\cdot YH_h \quad c\in C \text{ and } h\in H \quad (16)$$

Investment demand $QINV_c = \overline{IADJ}\cdot\overline{qinv}_c$ $c\in C$ (17)

Government consumption demand $QG_c = \overline{GADJ}\cdot\overline{qg}_c$ $c\in C$ (18)

Government revenue

$$YG = \sum_{i \in I} ty_i \cdot YI_i + EXR \cdot tr_{gov,row} + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + shry_{gov,f} + tr_{gov,ent} + \sum_{c \in CM} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{c \in CE} te_c \cdot pwe_c \cdot QE_c \cdot EXR \quad (19)$$

Government expenditures

$$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in I} tr_{i,gov} \quad (20)$$

Enterprise revenue

$$YE = \sum_{i \in I} tr_{ent,i} + shry_{ent,cap} \quad (21)$$

Objective function

$$UU = -sqr(walras) \quad (22)$$

System Constraint Block

Factor market

$$\sum_{a \in A} QF_{fa} = QFS_f \qquad f \in F \quad (23)$$

Composite commodity markets

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + QG_c + QINV_c + qdst_c \qquad c \in C \quad (24)$$

Current account balance for rest of the world (in foreign currency)

$$\sum_{c \in CM} pwm_c \cdot QM_c + \sum_{i \in I} tr_{row,i} = \sum_{c \in CE} pwe_c \cdot QE_c + \sum_{i \in I} tr_{i,row} + FSAV \quad (25)$$

Savings-Investment Balance

$$\sum_{i \in I} MPS_i \cdot (1 - ty_i) \cdot YI_i + (YG - EG) + EXR \cdot FSAV = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c + WALRAS \quad (26)$$

Price Normalisation

$$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c \quad (27)$$