Uniwersytet Łódzki
Wydział Ekonomiczno-Socjologiczny

mgr inż. Paweł Lont

EUROPEAN UNION'S GAS SECTOR COMPETITIVENESS IN THE PROCESS OF DECARBONIZATION OF THE ECONOMY

Rozprawa doktorska napisana pod kierunkiem naukowym
dr hab. Agnieszki Kurczewskiej, prof. UŁ
oraz dr hab. Wojciecha Grabowskiego, prof. UŁ

Łódź, 2023

Table of Contents

List of abbreviations

ACER – Agency for the Cooperation of Energy Regulators
ADF – augmented Dickey-Fuller regression
BAU – Business-As-Usual scenario
CAM NC – Capacity Allocation Mechanism Network Code
CBAM – Carbon Border Adjustment Mechanism
CCS – carbon capture and storage
CCU – carbon capture and usage
CEEAG – Communication from the Commission establishing the Guidelines on State Aid for climate, environmental protection and energy
CEER – Council of European Energy Regulators
CEGH – Central European Gas Hub
CIEP – Clingendael International Energy Programme
CMP – Congestion Management Procedures
CSR – Corporate Social Responsibility
CWD – capacity-weighted distance methodology
DF – Dickey-Fuller regression
DG COMP – Directorate General for Competition
DG Energy – Directorate General for Energy
EBA – European Biogas Association
EC – European Commission
EFET – European Federation of Energy Traders
ENTSO-E – European Network of Transmission System Operators for Electricity
ENTSO-G – European Network of Transmission System Operators for Gas
ERGaR – European Renewable Gas Registry
ERGEG – European Regulatory Group for Electricity and Gas
ETS – Emission Trading Scheme
EU – European Union
EUAs – Emission allowances
EURAM – European American Model
FDI – Foreign Direct Investment
FERC – Federal Energy Regulatory Commission
GCI – Global Competitiveness Index
GDP – Gross Domestic Product
GHG – greenhouse gas

GO – Guarantees of Origin
GSCI – Gas Sector Competitiveness Index
HHI – Hirschmann-Herfindahl Index
IEA – International Energy Agency
IEM – Internal Energy Market
IGM – Integrated Gas Market scenario
IMD – International Institute for Management Development
INT NC – Network Code on Interoperability and Data Exchange Rules
IP – interconnection point
JRC – Joint Research Centre
LCA – lifecycle analysis
LCOE – levelized cost of energy
LNG – liquified natural gas
MECOS – Market Enabling, Connecting and Securing model
MMC – Monopolies and Mergers Commission
NBP – National Balancing Point
NC BAL – Network Code on Gas Balancing of Transmission Networks
NC TAR – Network Code on Harmonised Transmission Tariff Structures for Gas
NRA – National Regulatory Authority
NRRP – National Recovery and Resilience Plan
OECD – Organisation for Economic Co-operation and Development
Ofgas – The Office of Gas Supply
Ofgem – The Office of Gas and Electricity Markets
OFT – Office of Fair Trade
PFCs – perfluorocarbons
PoS – Proof of Sustainability
PSV – Punto di Scambio Virtuale
R&D – Research and Development
RBV – Resource-based view
RCA – Revealed Competitive Advantage
RDM – Regional Developed Market scenario
RED – Renewable Energy Directive
RES-E – Renewable energy share in electricity
ROA – Return on Assets
TAP – Trans Adriatic Pipeline

TFEU – Treaty on the Functioning of the European Union
TPA – third-party access
TRF – Trading Region France
TSO – Transmission System Operator
TTF – Title Transfer Facility
UDB – Union Database
UNCTAD – United Nations Conference on Trade and Development
VTP – Virtual Trading Point
WEF – World Economic Forum

Introduction

The threat of climate change has become of key concern to citizens and governments around the world, as it became commonly agreed that it stems from human activity and the related excess greenhouse gas emissions that have been on a constant rise since the days of the industrial revolution. The prevalent view is that further increase of Earth's average temperature may result in more extreme weather conditions, dangerous rise of sea levels and an irreversible damage to ecosystems, collectively threatening life on the planet as it is known to humankind. This is why many attempts to coordinate efforts to tackle climate change at a global level have been undertaken over the course of the past 35 years. Nonetheless, all these attempts have so far failed to sufficiently curb greenhouse gas emissions, making the risk of permanent climate change increasingly possible.

One of the key sources of excess emissions that cause the planet to overheat is fossil fuel consumption. This is why the efforts to reduce their use and replace them with climate-neutral technologies have also become central to many climate policies being developed, often targeting the largest source of greenhouse gas emissions – the energy sector. The most known manifestation of this shift is the booming deployment of renewable electricity sources (RES-E) such as solar panels and wind turbines that displace conventional energy sources based on combustion of coal, natural gas and oil. Advancements in RES-E technologies have resulted in spectacular reductions in their associated investment costs, fuelling further penetration and growing enthusiasm about the possibility of full electrification of the economy driven by low-cost, emission-free renewable electricity. Unfortunately, that optimism was quickly verified in practice, as it became apparent that full electrification of all energy applications would neither be economically nor physically possible in any foreseeable future. These applications include in particular the energy-intensive heavy industry, long-range transport and sectors using natural gas as feedstock. Consequently, technologies that could allow decarbonizing the so-called "hard to abate" (i.e. difficult to electrify) sectors of the economy have attracted a lot more attention.

Among the different alternatives to fossil fuels for hard-to-abate sectors considered and developed, biomethane (gas from anaerobic digestion of organic waste, purified to the quality of natural gas) stands out in a number of areas. First and foremost, unlike most alternative solutions, biomethane production technology is sufficiently mature for commercial applications at an industrial scale. Secondly it enables emission savings both through displacing fossil fuels and through using certain types of waste that would have been a source of greenhouse gas emissions on their own if not processed. Collectively, biomethane produced from certain types of waste can result in negative greenhouse gas emissions over its lifecycle, making it invaluable in the context of the fight against climate change. Thirdly, anaerobic digestion's by-product can serve as a natural fertilizer, underpinning the notion of circular economy. Finally, biomethane plants can create a considerable amount of job spaces, often in rural areas where different types of organic waste are available. It needs to be stressed, however, that these benefits are only achievable if biomethane is produced from properly sourced feedstock that does not result in damaging changes in land use or displacement of food production.

Attractiveness of biomethane as a potential technology of the future that fits the ambitions of the EU to turn Europe into a first climate-neutral continent by 2050 has been recognized in the most developed economies of the region. Over the past two decades countries such as the United Kingdom, Germany and Denmark have allocated funds to subsidize the development of biomethane production. The experienced gathered over time has also resulted in developing robust governance that ensures biomethane production is done sustainably and with clear benefit to the environment. At the same time, this sustainable characteristics of biomethane as a fuel has become recognized on the market, with some consumers willing to pay a premium for a climate-neutral fuel. Gradual success of this technology has more recently been recognized also at EU level, with the European Commission setting a very ambitious target for scaling-up its production in the coming years.

Although it might seem inconsistent with the climate ambitions of the EU, the use of natural gas in the economy is deemed unavoidable in the foreseeable future, not least because it is seen as a "transition fuel" that the necessary flexibility to the electricity system that, in turn, underpins further deployment of RES-E. Furthermore, natural gas remains an important feedstock for the chemical industry and fertilizers production. This residual demand for gas that needs to be framed into the future climate-neutral reality justifies the selection of EU's gas market as the core focus of this dissertation. It also underlines the importance of biomethane as a fuel that can displace fossil gas to a considerable extent. Most recent shifts in the geopolitical sphere also underline the importance of domestically produced gas such as biomethane that reduces EU's reliance on imports. Collectively, the pursued goal of developing an integrated internal market for gas in Europe remains valid and important as it improves supply security and creates better conditions for affordable decarbonization through the economics of scale.

With biomethane production expected to develop swiftly across the EU with the support of public funds, it is not clear how its development will affect the internal gas market and competitiveness of the national gas sectors over time. On one hand it is clear that costs of biomethane production will remain well above the costs of producing and importing natural gas, exerting upward pressure on end-consumer prices. These prices will likely be increased even further by the introduction of levies set to finance subsidies offered to biomethane producers. On the other hand, it can be assumed that the less carbon-intensive fuel supplied by the gas sector will be considered as higher quality, as it will also reduce the carbon footprint of the products and services offered. With sustainability features properly documented and recognized, biomethane can also enable other benefits such as exemption from climate-related taxes. The resultant impact on gas sector's competitiveness, however, remains unknown.

The aim of this study is to evaluate EU's national gas sectors competitiveness in the context of decarbonization. The governing assumption in this analysis is that less carbon-intensive gas supply is deemed as higher quality by the consumer. Such assumption follows literature review on the subject of competitiveness that confirmed that quality of the product offered by the industry can be a source of competitive advantage. An analysis of the net impact of decarbonization policies on gas sector competitiveness has been performed through using a dedicated synthetic indicator developed to capture the collective impact of end-consumer price shifts, emission savings achieved, infrastructure development stage and efficiency of different institutional setups. The resultant value of the indicator enabled comparative analyses of the competitive position of different countries analysed. Following research questions have been formulated:

1. Does sizeable domestic natural gas production ensure a competitive advantage over countries relying predominantly on imports?
2. Do direct pipeline connections to natural gas exporting countries support competitiveness of the importers when compared to countries further away from the production fields?
3. Can the development of biomethane production facilities support the sector's competitiveness despite the additional costs stemming from their subsidization?
4. Does an integrated market for biomethane support sectoral competitiveness versus the current national support schemes?

The dissertation has been divided into four chapters. First chapter presents the theoretical considerations around the very concept of competitiveness at different levels of economic activity. It provides an overview of different theories and the determinants of competitiveness that stem out of the theory. The theories discussed span from classical considerations around competitiveness to its more contemporary understanding, including the popular works of Michael Porter and their critique by Paul Krugman. Most recent considerations around phenomenon are also emphasised, as they attempt to capture the “beyond GDP” nature of competitiveness and as such are of key importance to this study. Second chapter outlines the process of gas market liberalization in Europe and the core rules that govern its functioning. Special attention is dedicated to the interplay between the progress in terms of effective implementation of the EU acquis and overall national gas market performance. This relationship becomes particularly apparent when comparing continental EU gas markets development level to intense competition established in the United Kingdom. In the third chapter, the challenge of gas market decarbonization is described from two different perspectives: one focusing on technologies and legislative solutions to date that enable the process of gas sector’s decarbonization and the other outlining the far-reaching legislative changes that have been put forward by the European Commission as part of the wider strategy to reach climate neutrality by 2050. Since many parts of the proposed reforms were still in the drafting phase at the time of preparing this dissertation, their analysis relied predominantly on the content of the consensus proposals that followed the discussions in the European Parliament and the Council. Final chapter is dedicated to the study of European gas sector’s competitiveness based on the dedicated synthetic indicator. Study is performed for the historical period 2008–2022 and the forecast period 2023–2030 for three different scenarios and a research sample of six European countries: France, Germany, Denmark, Italy, United Kingdom and Poland.

Several research methods were applied to achieve the goals formulated for this study. Desk research focused both on the extensive literature on the subject of competitiveness and the subject of liberalization of the energy sectors in general. These analyses had to be supplemented with a careful analysis of the legal documents that govern the gas sector of the EU and how these provisions have evolved over time. Draft legal documents were also analysed in this context, particularly since the ongoing overhaul of the EU acquis was still ongoing at the time of preparing this dissertation. Apart from qualitative research, statistics characterizing the different national gas markets were analysed. These information, published by both Eurostat and national statistics and regulatory offices of the countries in question, have provided valuable information about the overall gas demand, size of the national gas grids, sources of gas available, as well as the level of engagement in renewable gas production until the end of 2022. In addition qualitative scores reflecting the relative performance of the national institutions, as could be derived from the annual reports prepared by different international institutions (including the European Commission, ACER and the IEA) have been attributed to each country in the research group for each year between 2008 and 2022. These data have collectively formed the database that was essential to perform a multidimensional comparative analysis through designing a synthetic indicator evaluating gas sector's competitiveness. Multidimensional nature of such analysis reflects the complex nature of competitiveness in a contemporary economy facing the challenge of decarbonization. Nonetheless, since such an analysis is prone to subjectivity in terms of the way the weights are attributed to the different components of the indicator, the analysis has been performed for three scenarios, each putting a different emphasis on the variables used. Finally, for the forecast period 2023–2030 cointegration modeling techniques, as well as ordered choice model have been used to forecast the values of the continuous and discrete variables accordingly.

The study results appear to confirm the analytical value of the gas sector competitiveness index (GSCI) as a tool to evaluate the net impact of decarbonization efforts on the industry and the attractiveness of the less carbon-intensive fuel it is able to provide. It offers a useful tool to the authorities involved in designing the decarbonization strategies for the national energy sectors and regulatory authorities tasked with governing the related subsidy schemes and developing competition between the market participants. The proposed design of the index allows for its further extension to other technologies that in the future could enable production of renewable and low-carbon gases that could displace fossil gas such as synthetic methane. Collectively, the proposed tool can support analysing the expected consequences of different policy decisions on sectoral competitiveness. Future studies could focus on recalibrating the GSCI to analyse the future hydrogen sector that is expected to build extensively on the experience gained in the process of designing a competitive gas market model for the EU.

Chapter I.

1. The concept of competitiveness in economics

Competitiveness is an attractive concept to international organizations, governments and regional authorities, as well as individual businesses and their associations, even if they understand the phenomenon differently. There is an abundance of definitions of competitiveness in the literature that consider it at very different scales, reflecting both the broad interest in the subject and its significance to the modern economies. This chapter provides an overview of these definitions, leading to an identification of the key determinants of competitiveness, as well as different means, through which it can be enhanced and developed over time. It follows the research efforts over the years to understand better the concept of competitiveness through carefully examining the achievements paving the way towards competitiveness theory.

The aim of this chapter is to ensure a good understanding of the concept of competitiveness, setting the scene for the more focused analysis of this phenomenon that will be restricted to the European Union's (EU's) gas sector. The question of competitiveness will be particularly important to the gas industry both in view of the fact that the gas has become a globally traded commodity and because like all others in the EU, it will be facing the challenge of decarbonization in the coming years, possibly putting it at a disadvantage vis-à-vis third countries.

1.1. The idea of competitiveness and its evolution

The term "competitiveness" is being used at different occasions to describe distinct phenomena and processes that occur in the economy. Since the beginning of the 1970s, the concept has been analysed at different scales and levels, but no universally acknowledged definition has been established and the term can indeed have several meanings (Voinescu and Moisoiu, 2015). Such conclusion as an opening of the thesis does not encourage studying the phenomenon, in particular if ones take into consideration the famous quote by Paul Krugman (Krugman, 1996a, 1996b) that "economists, in general, do not use the word competitiveness" or even stronger statement of him that "concerns about competitiveness are, as an empirical matter, almost always unfounded…" or that "The obsession with competitiveness is not only wrong but dangerous... thinking in terms of competitiveness leads to bad economic policies on a range of issues" (1996a, p.5). However, lack of common understanding and critique by one of the most prominent economists have not deterred all the researchers from further attempts to define competitiveness or at least capture its main notion. Moreover, many experts all over the world have raised ‘competitiveness’ to the status of a natural law of the modern capitalist economy and see its roots in many schools of economics (Martin, 2005). Therefore, it is justified to begin the analysis by reviewing the existing definitions and search for common features.

First, it needs to be noted that the term ‘competitiveness’ can be understood differently at different levels of economic analyses. However, it needs to be noted that in social sciences, the division of economics into different scales is not always obvious or homogenous. Some authors even state that the commonly used division between the macro- and micro-level tends to be incomplete and misleading (Sheng and Geng, 2012). Vlados and Chatzinikolaou have prepared a comprehensive overview of definitions relating to three policy spheres that are to cover the different types of interactions in a contemporary economy - following the results presented thereof, one may conclude that (Vlados and Chatzinikolaou, 2020):

- macro-policy dimension relates to measures that affect the macroeconomic aggregates and are based on a set of quantitative variables describing both the general economy’s performance and the direction of its development;
- mesoeconomic dimension is more selectively focused on concrete organisations or sectors, with specifically tailored policies;
- micro-policy dimension is focused on individual actors and their performance. This may relate to companies, institutions or specific social groups, promoting and improving access to infrastructure, knowledge and technology.

The popular macro-, meso- and microeconomic distinction has also found its application in evolutionary economics (Dopfer et al., 2004). In this context, Dopfer et al. argue that the establishment of rules governing the economic system is neither exclusively a top-down nor a bottom-up process, since the choice of individual actors is usually limited by the environment they are active in. Therefore, a single rule in the economic context reflects the “micro” scale, whereas this rule along with the entire set of its actualizations constitutes the “meso” level. Macroeconomic level, in turn is typically formed through aggregation of the “meso” units, hence bypassing the mesoeconomic level can be possible only in exceptional cases. This conclusion underlines the importance of the meso- sphere, as it can help explaining processes both at micro- and macroeconomic level. It also underpins an important decision from the perspective of this study to focus on the sources of competitiveness and competitive advantages at a sectoral level.

In the spirit of evolutionary economics and apart from the traditional three-level distinction, some economists (e.g. Sheng and Geng, 2012), (Esser et al., 1996)) also proposed "metaeconomics" as an additional layer that studies the complex interactions within the economy and seeks sources of competitive advantage in human interactions that underpin rules and practices in an industry. While this distinction can help identifying the sources of competitiveness that are not reflected in statistical indicators, it also means that the necessary tools for quantifying these interactions are missing. Nonetheless, it needs to be acknowledged that the reference to the "meta" level unveils the complex nature of the subject of competitiveness, as it points to non-economic determinants that can affect the relative position of a company or a sector on the global market.

Competitiveness theories at macroeconomic level primarily build on the historical considerations around fostering economic growth and accumulation of wealth, yet, as will be presented, these can also be bottom-up processes. Consequently, the historical outline focusing on the macro-level will be followed by a more nuanced analysis of sectoral competitiveness and competitiveness of individual companies. The gradual evolution of the concepts before and after the term "competitiveness" was first used will be presented below.

1.1.1. Classical theory

Considerations around competitiveness per se are almost as old as trade itself. Polanyi (1963) argued that when international trade was at its infancy, competition was seen as something negative that could threaten the political arrangements that were primarily set to ensure safety of transactions, often at a fixed "price". However, in their book *Competition in the Ancient World,* Fisher and Wees (2011) go much further, arguing that competition (be it between individuals, or city-states) was an important factor of building a sense of identity and developing civilizations.

During the medieval times, country's supremacy in different spheres, including military and trade, were seen as a core source of welfare, since the global wealth was considered to be limited and thus could only be claimed through rivalry. Over the years, the phenomenon has become the centre of attention, particularly during the power struggles of the European nations between sixteenth and eighteenth century (O'rourke et al., 2008). The related political system, commonly referred to as mercantilism, was not built on any actual theory as such, but has important implications for the formulation of the definitions of competitiveness (Schumpeter and Schumpeter, 1954). For trade, mercantilism meant protectionist approach that encouraged exports and restricted imports, leading to positive trade balances and by that, to greater accumulation of money (Tomeš and Jandová, 2006). Accumulation of capital in general was, in turn, seen as the foundation of a prosperous economy (Negishi, 2001).

The mercantilist doctrine has been both popularized and contested by Adam Smith (Smith, 1776) who has introduced the concept of absolute advantage and specialization, thereby promoting free trade. His famous work on the division of labour underlines that this process does not precede the establishment of international economic ties but is constantly affected by them. Under this concept, a given good will eventually be produced in a country that can do it at lowest cost, leading to specialization. This was a revolutionary concept that has changed the mercantilist perception of trade and was instrumental in triggering a change in the economic relations around the globe (Cho and Moon, 2000). According to scholars that built on and expanded Smith's theory, international exchange of goods triggers price adjustment mechanisms that help establishing a trade balance. The mechanism has been popularized and explained by David Hume in his essay "Of the Balance of Trade" (Hume, 1742). Hume denounced the idea that freedom to export would deprive a nation of its goods, or that a country with a negative trade balance could only become poorer over time. Through simple, but convincing examples, he has argued that the distribution of gold and goods between countries reaches a balance through the exchange of flows and therefore any disruption of these exchanges can only be counterproductive in terms of improving national welfare. It needs to be noted that although the mercantilist approach was denounced as simplistic and inherently wrong, Keynes (Keynes, 1936) contested this criticism by arguing that in the past, accumulation of capital (through maintaining a positive trade balance) was the only way to effectively induce domestic investment, as the countries had no control over the level of interest rates. Keynes's approach was, in turn, criticized by Heckscher (Heckscher, 1955) who argued that unemployment during the mercantilist times was of very different nature than the one known since the start of the industrial era. The validity of this argument remains largely unresolved (Negishi, 2001).

In 1817 Daniel Ricardo modified Smith's concept of absolute advantage and specialization, introducing the idea of comparative advantage, under which specialization of production in each country happens through identifying areas of high efficiency vis-à-vis alternative products (Ricardo, 1821). Such bottom-up approach is particularly interesting when analysing competitiveness of a given company/country/region – they can show as competitive when analysing some products and uncompetitive when looking at other (Voinescu and Moisoiu, 2015). The approach also highlighted the fact that a country does not need to hold an absolute advantage in producing certain goods to benefit from international trade. What is particularly interesting in the discussions around Ricardo's concept, is that, regardless of a country's labour productivity, it can still benefit from trading with other countries by selling goods they have a relative advantage in producing (Irwin, 2017). Goods and services that are identified as comparably advantageous and attractive for exports (due to their comparative costs) support the process of a country's specialization.

Critics of Ricardo's work point out that he narrows his considerations on factors of production down to labour. It can be easily deducted, though, that the differences in the cost of labour need to result from a set of factors that underpin a given level of remuneration, be it rent, profit or wage (Negishi, 2001). Samuelson also points out that the way Ricardo phrased his principal example on how labour costs justify and trigger international trade, would in fact suggest that (at that time) the Portuguese economy was superior to the one of Great Britain, which was far from the truth (Samuelson, 1972). Nonetheless, the so-called Ricardian model offers a simple, yet useful analytical tool that can provide valuable insights about international trade (Matsuyama, 2008).

The third classical concept related to competitiveness is the Heckscher-Ohlin theory of comparative advantage, presented in the works of Eli Heckscher (Heckscher, 1919) and Bertil Ohlin (Ohlin, 1933). Contrary to Ricardo, Heckscher and Ohlin argue that countries tend to specialize in producing goods using the factors of production that are most abundant in their geographical location – consequently, international trade is an indirect arbitrage of (otherwise immobile) factors of production (Leamer, 1995). A study by (Morrow, 2010) argues that in fact neither the Ricardian nor the Heckscher-Ohlin model alone properly explain the roots of each country's specialization, but both approaches can be seen as complementary. In this approach, one can assume that a country's specialization in producing a given good stems from both having a relative advantage and high total factor productivity. The author presents the relative factor abundance and total factor productivity as two separate driving forces of specialization that can coexist and impact the result. The model presented thereby also shows that changes to the availability of the factors of production can cause a significant shift in the structure of a country's economy.

1.1.2. Neoclassical school

Over time, the interest in the mechanisms of competition has shifted onto the level of enterprises. John Clark saw innovations as a source of a company's competitive advantage, whereas Wroe Alderson expanded this list by product promotion and advertising targeted at the right customer segment (Hunt and Arnett, 2006). Overall, rivalry between the different stakeholders was seen as the core driver of economic growth, implying that business should be exposed to competition if they are to improve their performance. Neoclassical economists considered the case of a perfectly competitive market i.e. one where all the stakeholders hold all the necessary information about the choice of goods, their price and are free to select those that best match their needs (Tsoulfidis, 2011). Under such conditions individual companies cannot steer prices in any way and optimal consumer choice maximizes the welfare gains. Perfectly competitive environment, in turn, requires a large amount of competitors being active in a market – Cournot argued that infinitely large number of companies in competition would be forced to offer their products at marginal cost (Cournot, 1897). Ultimately, the neoclassical school considered the market mechanisms as working towards a state of equilibrium under the perfectly competitive market (Tsoulfidis, 2011). At the same time, though, Cournot was criticized for not being able to explain how the equilibrium could be reached and maintained on the actual market.

The point at which Cournot's concept of perfect competition failed to explain actual market reality was also the starting point for other researchers to seek theories that would bridge the gap. Marshall argued that Cournot's proposed mechanism whereby competing companies end up having nearly uniform unit costs of production does not exist in reality and if it would, any company capable of reducing its marginal costs in one way or another, would at the same time push the market out of balance monopolize it over a short period of time (Marshall, 1890). Instead, Marshall argued that the study of "perfect" competition is purely theoretical, since goods offered by competing companies are hardly ever homogenous and information held by the market participants is asymmetric. It can also be credibly argued that an innovator in a given sector can have a genuine interest in preventing potential competitors from entering its market.

Sraffa argued that the mechanisms that lead to an equilibrium under the perfect competition have been ill-defined, and the assumed marginal profit fall along with increasing production volumes (due to scarcity of factors of production) can only be true for an industry as a whole, not for individual companies (Sraffa, 1926). He also insisted that the assumption under which no individual producer would be willing and able to affect prices of the goods produced simply does not match the market reality, making the concept of perfect competition and the related equilibrium invalid (Newman and Vassilakis, 1988).

Marshall's critique of Cournot's concept, even if not well founded, has diverted further considerations around competition to "real", imperfect markets, particularly after his approach has been praised in Sraffa's article (Zanni, 2012). This change has shifted the focus towards a more practical approach to competition on the market that could better serve studying and anticipating the costs and benefits it can bring for the entire economy.

1.1.3. Austrian School of Economics and Schumpeter's view on competitiveness

Representatives of the Austrian school of Economics saw competition on the market as a process, the result of which is never given. In their works, beginning from Mises and Hayek in the 1930's, the neoclassical approach was criticized for being overly simplistic when bringing the complex market mechanisms down to considerations around supply and demand equilibrium as a target state of market-based competition (Kirzner, 1997). They saw the competitive market's central role in facilitating the dynamic process of matching supply and demand as participants on both sides of the transaction improved their performance (through gaining more knowledge and acquiring new skills). The success or failure of a given enterprise on the market depends, in turn on its ability to adapt to the market conditions, innovate and cater for constantly evolving needs of the clients (Kirzner, 1973). This, again, reinforces market competition mechanisms as a driver of economic growth and a concept worth studying.

One of the most popular views on competitiveness has been proposed by Joseph Schumpeter, who argued that in a dynamic, competitive environment, companies are forced to adapt to ensure their business continuity and inevitably some fail in that process. The author has presented and expanded the concept over time in several publications, arguing that this process of constant evolution is in fact the driver of economic growth. His theory points to the fact that the market power held by different companies is subject to constant change and the dynamics of competition challenges the regulatory authorities to timely react to instances of anti-competitive behaviour.

To Schumpeter, innovations, understood as improvements to existing or introduction of new goods/materials/production processes or services are the ultimate driving source of economic growth. The main driver of innovation, in turn, is the process of so-called "creative destruction", reflected in competition between large oligopolies in the struggle for dominance (Schumpeter, 1942). Although originally described by Wells (as argued by Perelman,1995), creative destruction underpinned several Schumpeter's studies seeking to explain a number of phenomena in contemporary market economies and became mainstream economic theories for many years.

1.1.4. Institutional economics

Market mechanisms and competition have been studied extensively by institutional economists, notably by Coase, Clark and Hamilton. In their research, however, the emphasis was placed on the actors on the market and interactions between them rather than the mechanisms of reaching a general market equilibrium (Rosińska-Bukowska, 2012). In his publication, Hamilton expressed his criticism of the neoclassical approach to competition since it did not make any reference to the actual structure of different markets. Instead, he argued, the economic mechanisms can only be explained by analysing the complex interactions that constitute the contemporary economy along with the institutions that govern these arrangements (Hamilton, 1919). His further works analysed the mechanisms of competition in different industries, since, as he argued, even the terms like "supply" and "demand" can have a very different meaning in different sectors (Hamilton, 1940).

In 1937 Coase has argued that not all actions on the market are driven by prices and every economic activity involves costs that affect the decision-making process (Coase, 1937). It is the efficient management of these costs that underpins the existence of companies. The capability to compete is therefore determined by the ability to manage the costs better than the competitors – a conclusion that implies that the competitive position is not something being determined solely by external market conditions.

Clark has argued that while perfect competition as a concept can serve as a starting point for theoretical analyses, it should be recognized that close to perfect market conditions can prove to lead to suboptimal results (Clark, 1940). It is therefore important to understand the types of imperfections on the market to seek the ones that can be administered in a way through which competition brings positive results. Just like Hamilton, Clark underlined the uniqueness of each industry and the fact that the "models" of competition can be counted in thousands. Out of the numerous variations of different determinants, he listed ten factor groups that should be used to characterize an industry with reasonable proximity:

1. Product's level of standardisation
2. Number and size of producers

3. Pricing method (i.e. whether the producer sells the produce at the best price possible, or quotes a price that is then adjusted to the supply to the demand observed)
4. Sales channels used
5. Quality of market-related information
6. Distance between production and consumption (to reflect how material transport costs are)
7. Elasticity of supply (i.e. to what extent it can adapt to changing demand)
8. Gravity of economics of scale for the cost of the product
9. Impact of short-term fluctuations on costs of production
10. Time required to develop new production capacity or divest.

When analysing these factors, Clark has defined several types of competition, categorized as follows:

1. Pure competition – products are homogenous, prices are transparent, multiple actors are active on the market and there are no barriers to enter it
   - 1.1. Perfect – full mobility of factors of production, prices equal marginal costs
   - 1.2. Imperfect – restrictions to factor mobility, inability of producers to sell their output at all times
2. Disrupted (modified), imperfect competition
   - 2.1. Standard products offered by few producers – this category relates to competition between oligopolies and regionally-restricted competition that stems from and results in sustained information asymmetry.
   - 2.2. Unstandardized products – here competition focuses more on product quality rather than its price. In this case, particularly when products are difficult to copy or substitute, the price mechanism is far from the neoclassical vision of supply and demand equilibrium, as the producer has significant control over the supply curve and can also shape the demand to an extent.

Clark concludes that perfect competition with critically low prices could be no less devastating to the economy than fully non-transparent monopolies whereas imperfect competition with an approximate level of price transparency could support economic development.

1.1.5. Contemporary understanding of competitiveness

Competitiveness has become of particular interest to scholars and managers during the intense competition between American and Japanese companies in the 1970s (Siudek and Zawojska, 2014). Early outright definition of competitiveness states that it is the ability of regions, nations and companies to generate wealth (Bobba et al., 1971). This early definition already points to the fact that competitiveness can be considered and both macro- and microlevel. It is worth to underline that even such early definition goes beyond the popular perception of competitiveness that connects it merely with price and cost categories (Aiginger et al., 2013). A more precise definition by Flejterski states that it is the capacity of a sector, industry or a branch to produce goods that find buyers thanks to their price, quality, or other categories that distinguish them from alternative goods offered by the competitors (Flejterski, 1984).

Along with the development of management science, the subject of competitiveness was no longer studied from the purely economic angle. Firm competitiveness has been defined as the capability of a company to meet the customer needs better than the competitors can and to adapt to these needs in a timely manner (Chikán, 2008). This definition ties in well with others discussed in this chapter, both because it builds on the same foundations of economic theory and because it analyses the same phenomenon at a different level of detail. At the same time, it emphasises the difference in approach between the two sciences, as scholars focusing on management theories consider competitiveness in the context of goods and services offered and the advantages they have vis-à-vis those offered by competitors.

The turning point in the discussions around the concept of competitiveness came along with Michael Porter’s publication titled Competitive Advantage of Nations (Porter, 1990). The author argued that competitiveness is the ability to introduce innovations, as they determine the capacity of a nation and its industries to outperform others. Innovation in this sense should typically be seen as a set of minor improvements rather than technological breakthroughs that can alter the very nature of an industry – and once competitiveness is improved via innovation, it can only be sustained through further improvements. Porter underlined that strong competition is the best catalyst for inducing innovation in the economy, hence local concentration of companies (“clusters”) fighting over their market share establishes a good environment for growth (Psofogiorgos and Metaxas, 2016). He also stressed that it is impossible for a country to be competitive in all sectors at the same time. Porter’s concept has developed over the years and the author has identified five forces driving competition that will be elaborated on further in subchapter 1.3.

The concept presented by Porter has attracted the attention of economists, politicians and even international organisations. At the same time, it has faced critique, primarily from Paul Krugman, who has argued that "competitiveness" is an attractive concept yet is wrong and can result in inefficient allocation of resources and protectionist policies (Krugman, 1994). It is worth mentioning that the critique of the original concept by Porter was much more widespread, yet it is the contradiction of Krugman's theories that has attracted most attention over the years (see Psofogiorgos and Metaxas, 2016). To Krugman, the term "competitiveness" was just another word for productivity[1], whereas international trade is built on mutually beneficial exchange, not on rivalry (Krugman, 1995). He also makes an important observation that competitiveness of a country is very different to competitiveness of individual companies and has different consequences. It can be therefore stated that the definition of competitiveness is most precise when identified and measured separately for the micro-, meso- and macroeconomic level. In this context, it is also worth noting that while the concept of productivity at the macroeconomic level, relating to the input-output ratio, is rarely contested, its application into actual studies can vary greatly and lead to different conclusions.

The conceptual dispute between Porter and Krugman has inspired different scholars to seek consensus positions that could make the concept of competitiveness more universal. Rugman and D'Cruz argued that Porter's model was incapable of explaining the competitive advantages held by small and open economies, as it ignores the international context that is of key importance to them (Rugman and D'Cruz, 1993). Tyson expanded Porter's definition of competitiveness by stating that it is the ability of a country to produce goods that can be attractive for export while offering the citizens a good and sustainable standard of living (Tyson, 1992). Such approach, although rather high-level, signals that a country's competitiveness should not be a goal that needs to be achieved at all costs.

Another attempt to improve the original model proposed by Porter has been undertaken by Cho (1994) who has expanded the list of competitiveness determinants originally proposed by Porter through adding human factors and signalling that events and conditions external to that list also impact the resultant ability to compete. The same author, together with Moon et al., has six years later proposed a generalised model of economy's international competitiveness (Cho and Moon, 2000).

---

[1] Productivity is typically defined as the ratio measuring how efficiently inputs (factors of production) in a given process are turned into outputs.

In 2001 Porter updated his concept of competitiveness by stating that a country's competitiveness is determined by its capability to use the factors of production it possesses effectively. Porter's own updated perspective on national competitiveness underlines that, while it is subject to efficient use of factors of production, it has different sources at different stages of economic development (Porter and Stern, 2001). While the sources of competitiveness along with original Porter's "diamond" and its proposed extensions, will be discussed in subchapter 1.3, it is important to underline that this concept evolved over time.

An interesting study by Baumann, Cherry and Chu has promoted concept of competitive productivity (term originally proposed by Baumann and Pintado (Baumann and Pintado, 2013), aiming to bring together the studies either productivity or competitiveness as such (Baumann et al., 2019). The "competitive productivity" at the macro level is defined as the attitude and behaviour targeted at beating the competition (Baumann et al., 2019). The success or failure of these actions depends on the factors at both macro- and micro- level. Indeed, Cho and Moon go a step further and state that competitiveness stems from the productivity that can be only defined at the level of industries and their segments (Cho and Moon, 2000). In both cases, scholars signal that competitive productivity, just as competitiveness as such, need to be analysed at macro-, meso- and microlevel. The authors argue that studies on productivity typically focus on the actual processes of producing goods, defining it as the efficiency of converting inputs into outputs. Studies on competitiveness seek ways through which competitors (be it a different economy, sector or company) can be outperformed. The authors conclude that these studies either ignore the broader market situation (when analysing productivity) or the actual capacity to maximize cost-efficiency (when focusing on competitiveness). In that sense, competitive productivity is an "(…) attitude and behaviour directed at outperforming the competition".

Popular definition describing macro-competitiveness refers to a country's ability to achieve economic growth over time, essentially drawing a parallel line between competitiveness and productivity that Krugman raised in his critique of Porter's work (Rusu and Roman, 2018). Ketels and Porter (2003) expand this definition by underlining that competitiveness understood this way requires proactive policy that improves economic productivity over time. Aiginger et al.(2013), on the other hand, define macroeconomic competitiveness as a nation's ability to (…) deliver beyond the GDP goals for its citizen. This is a broader definition that stresses that GDP cannot be a goal in itself and competitiveness as a phenomenon spans beyond strictly economic categories. Roszko-Wójtowicz and Grzelak conclude that broad definitions of the phenomenon make it very difficult to quantify and investigate (Roszko-Wójtowicz and Grzelak, 2020).

Instead, they underline that few factors are more important to establishing competitive advantage than the stability of the economic environment.

Competitiveness of a national economy is often considered in the context of its overall performance, typically measured by GDP or GDP per capita. The European competitiveness report speaks of the economy's capability to maintain a high rate of productivity growth (European Commission, 2004). Overall, such definitions have the benefit of being conveniently broad and its quantification poses no major problem as most economies around the globe already collect all the necessary information. Many scholars, however, argue that the approach is inherently wrong and a country that reaches high levels of GDP may see this level unsustainable in the long-term (see e.g. Stiglitz et al. (2018), Giannetti et al. (2015), Dynan et al. (2018)). The Aiginger et al. (2013) definition of competitiveness that speaks of "the ability of a country to deliver the beyond-GDP goals for its citizens" ties it in with the concept of welfare and the authors argue that their definition places the term in the economic context without narrowing it down to price or cost categories. Kulikov (2000) adds another layer of complexity to the problem by pointing to the fact that there are two kinds of macroeconomic competitiveness – nominal and real. In this approach, one can speak of real competitiveness if a country operates a free market that offers innovative and high-quality products and services and the quality of life of its citizens is on the rise (Kulikov, 2000). Only under such conditions a country can credibly be seen as being able to operate in the global context and its position is sustainable instead of being a "nominal" result of artificial subsidies, or trade barriers. In view of these definitions, it becomes evident that the concept of macroeconomic competitiveness cannot be evaluated exclusively based on statistical indicators.

Studies that built on Porter's definition of competitiveness have signalled that measures at a country level can be at odds with those taken at industrial or an enterprise level, making the net impact on the ability to innovate difficult to forecast. While some argue that the removal of barriers to trade would on its own create the right environment for the development of competitiveness (Sachs and Warner, 1995), others highlight that state would also need to stop intervening in the industrial spheres in order to allow optimal allocation of resources (Tupy, 2003). Barkema et al. (1990) state that the theory of comparative advantage is at odds with various government policies that do nothing less than distort the market mechanisms. On the opposite side there are economists who argue that it is the macroeconomic policy focused on creating a "business-friendly" environment that can best support establishing a strong competitive position in the global economy (Rodrik, 2002). This ongoing dispute around competitiveness points to the important conclusion that this phenomenon can be considered at different scales.

In spite of reaching no consensus over the appropriate definition of competitiveness or even its validity as a concept, the term remains popular also in the 21st century and it continues to be studied and measured both at the level of individual companies, countries and their associations. The OECD defines international competitiveness of a country as the degree to which it can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the longer term (Maarten De Vet, 1993). Schwab and Sala-i-Martin define it as the set of institutions, factors and policies that determine the productivity of a country – confirming the existence of the interdependence raised previously by Baumann and Pintado (Schwab, 2013). While the distinction between the term competitiveness and productivity at the macroeconomic level remains blurry, the subject is still seen as worth studying and attempts to quantify competitiveness are undertaken by different international organisations.

More confusion between competitiveness and productivity emerges at mesoeconomic level[2]. At mesoeconomic level, productivity is typically considered in terms of input/output ratios calculated for specific processes of production (Rogers, 1998). Since the ability to convert inputs into outputs effectively determines, or at least significantly impacts, the unit costs of a product, productivity can be seen as the key explainer of an industry’s ability to compete. Same approach is promoted under the European Commission’s guidance on assessing sectoral competitiveness (European Commission, 2012a). Competitiveness defined this way is relatively easy to measure and compare between different sectors yet does not point to any specific policies that would help sectors outperform their competitors.

To some researchers studying the concept of competitiveness, mesoeconomic level is of particular importance. Wolf argues that competitiveness is relevant only at the level of companies and that mechanisms of competition observable thereof cannot be transferred easily onto the level of entire economies (Wolf, 2004). Verhun et. al. (2020) go a step further by stating that competitiveness of a country, unlike that of a company, is a concept spanning beyond the input-output considerations and needs to take account of issues such as quality of

---

[2] Dopfer et al. define the mesoeconomic level as a (…) dynamic building block of the economic system (Dopfer et al., 2004). According to their definition, the meso level therefore covers a wide range of industrial districts, clusters, industry associations and even communities that function in today’s economy.

life of the citizens. To them, the term “competitiveness” should not apply to countries or their associations at all.

Manyika et al. (2010) define competitiveness at the mesoeconomic level as the ability of a sector to grow in a sustainable manner, with that growth reflected either in increased productivity or employment. The authors of this definition emphasize that while the concept is intuitive for tradable products and services, but it also applies to services and goods that cannot be traded freely, but contribute to economic growth nonetheless.

Different approaches to industrial competitiveness signal that it is a result of the internal setup of a given sector. Industrial Organisation theory[3] confirms the existence of a link between an industry’s structure, conduct and performance, pointing to internal rivalry between companies as the source of competitiveness (Kancs and Kielyte, 2001). This approach appears to be coherent with the broader definition of competitiveness used by the World Economic Forum and spelled out by Schwab – institutions that govern the functioning of a sector collectively create an environment for building advantages (Schwab, 2013). This conclusion is of particular importance from the perspective of this study and will be used as reference in further chapters of this study.

Baumann et al.’s “competitive productivity” at the meso- level is understood as an attitude to outperform both company’s competitors and its own past performance (Baumann et al., 2019). This approach, however, deviates from the more popular perception of mesoeconomic scale of operations, since the authors defined the phenomenon at this level with reference to individual companies. It is interesting to note in this context, however, that Porter’s updated works on industry’s competitiveness points to corporate strategies as an important source of advantages that a company may hold over time (Porter, 1990). While a strategy cannot be treated at par with an attitude, it is clear that both approaches seek sources of competitive advantage in the actions taken by individual firms. These definitions also establish an outright connection to the microeconomic competitiveness level.

At microeconomic level, competitiveness is determined as the ability to sell products and services in a market environment (Deniz et al., 2013). UNCTAD definition of corporate competitiveness speaks of the ability to establish a position on the market by delivering quality products at an acceptable price and on time (United Nations Conference on Trade and

---

[3] The Industrial Organization theory attempts to explain the influence the market structure has on the decision-making processes of companies active on that market. The theory assumes that the market structure is a key determinant of a company’s strategic choices (Raible, 2013).

Development., 2005). Another common definition relates to the relative economic strength of a company in a global market economy (Momaya and Ambastha, 2005). The latter definition also stresses that actual competitiveness can be considered in an environment where factors of production can move freely, and competitors do not benefit from exclusive subsidies. Only in such an environment companies can prove to be holding advantages that allow them to function in an open market. Such conclusion links back the definition to the ones discussed at mesoeconomic level – one can speak of competitiveness in an environment that allows for stakeholder rivalry. Similar approach stems from the systemic competitiveness theory[4] (Esser et al., 2013).

Adamkiewicz-Drwiłło (2002) perceives corporate competitiveness as a process of adapting the products and services to meet the requirements of the market in a given product range, quality and price. The dynamics of competitiveness has also been underlined by other authors, for example Barney who sees competitive advantage as a result of a proper strategy (backed by the necessary resources) that at the same time is not easy to replicate by the competitors (Barney, 1991). Similarly, Gál (2010) points to the fact that competitiveness stems from the ability to spot and anticipate changes in the external economic environment.

Some studies on competitiveness place more emphasis on the associated risks than others. Braendle et al. (2018) take the competitive environment as given and consider it to be driving force of innovation and progress, but also note its downsides that may lead to unethical behaviour. The authors argue that competitiveness at micro- level is in fact spelled out in the principal purpose of a company's existence, i.e. achievement of best economic results from the conducted activities. The definition by Hsu and Wang (2012) further states that competitive strength should in fact be considered in the global market context. Braendle et al. (2018) also refer to the Research Center for Competitiveness definition of corporate competitiveness that speaks of company's ability to sell products and services with a profit while ensuring that they activities remain socially responsible. Similarly Dang et al. (2020) underline that a company is competitive when it is capable of maintaining its position on the market while respecting the corporate social responsibility (CSR) principles. This underlines that CSR considerations add another layer of complexity in the context of competitiveness in the increasingly globalized economy. The concept deserves further analyses and is of particular importance from the

---

[4] Systemic competitiveness theory argues that the ability to compete is a result of a multitude of factors, often of non-economic (but rather social) nature. Esser et al. (2013) argue that this phenomenon should be analysed at a "metaeconomic" level, manifesting itself at the intersection of macro-, meso- and microeconomic factors that collectively affect the ability to outperform competition on the open market.

perspective of this study, as CSR considerations are expected to have a major impact on the gas sector in the future.

Flanagan et al. (2007) attempt to group the competitiveness theories into three categories:

- Competitive advantage approach – competitiveness is the ability of a company to formulate the right strategy to manage the risks of its economic environment and/or to seize opportunities to improve its market position;
- Resource-based view and core competence (RBV) approach – competitiveness stems from the resources developed and controlled by the company. Uniqueness of these resources makes their competitive position sustainable;
- Strategic management approach – competitive advantage follows a set of proper managerial decisions that collectively determine the strength of a company.

All three approaches point to different aspects of a company's functioning and all can help understanding what competitiveness is and how it is established. It is important to note that the approaches, although different, do not contradict each other and in practice they can also be seen as complementary. This would reinforce some of the previously quoted general definitions of competitiveness by stating that it is the ability to outperform the rivals through proper development and allocation of resources by the company's management and a combination of decisions that help the entity adapting to the changing external conditions. All three schools point to a different set of determinants of competitiveness that will be discussed in subchapter 1.3.

For the sake of completeness, it is worth to underline that at the microeconomic level, competitive productivity is defined by the concept promoters as attitude of an individual, directed at outperforming other individuals and improving own performance (Baumann et al., 2019). As such approach does not match the goal of this study, it will not be discussed further.

Synthesising, it can be stated that definitions of competitiveness at macro-, meso- and microeconomic level do not differ fundamentally from each other, yet they have different implications when it comes to determinants and the emphasis being placed on productivity. It needs to be noted that the most recent attempts to define competitiveness include multiple reference to sustainable development (Capobianco-Uriarte et al., 2019). Indeed, it seems that sustainability considerations are beginning to dominate the discussions around economic growth in general, suggesting that if any definition of competitiveness should become dominant in the 21st century, it should be one along the lines of that proposed by (Aiginger et al., 2013) or (Manyika et al., 2010), speaking of "beyond GDP" sustainable growth achieved through unrestricted, market-based competition. Such approach is also consistent with the analysis that will be presented in this study. It needs to be noted, however that (Aiginger et al., 2013) have emphasised themselves that their definition relates to macroeconomic sphere, whereas they analyse a bottom-up approach to generating welfare and "beyond-GDP" development. Such dichotomy is all the more appropriate for analyses at mesoeconomic level, where the macro-environment interacts with corporate strategies and sectoral regulations.

1.2. Determinants and measures of competitiveness

Ever since the concept of competitiveness was popularized, it is its determinants and inhibitors that have attracted far more attention than the academic deliberations around the very definition of the phenomenon. In fact, it could be argued that nowadays the concept is perceived as rather intuitive and the academic dispute over a common definition for competitiveness is of secondary importance to many (Siudek and Zawojska, 2014).

Traditionally, competitiveness could be treated as a synonym of productivity (as stressed by Krugman) and hence was measured by the outcomes compared to the inputs. At country level this relates to variables such as GDP. The popular, particularly per capita, categories describing the outputs of a given economy can serve as such "intuitive" measure of competitiveness at the macro level and offer an easily-accessible dataset for comparing the relative position of different countries or regions. Under such approach, the roots of competitiveness are therefore exactly those that, according to different approaches, contribute to economic growth. While GDP was historically believed to be fuelled by access to natural resources, accumulated capital, or workforce, the list of potential determinants is much longer (Boldeanu and Constantinescu, 2015).

Many of the fundamental features that contribute to developing the skilled workforce, capital accrual, efficient usage of natural resources or indeed inducing technological breakthroughs are considered to depend on policy decisions, as well as cultural and sociological factors. Smith (1776) claimed that productivity has its roots in the division of labour as it allowed people to better specialize in concrete activities, gain experience and introduce improvements to the way they work. His famous work referred to the three circumstances that collectively enable increased productivity through the division of labour – these were worker's dexterity, time-saving and development of new tools. First point related to the skills of the workers, whereby over time they gained experience and improved their ability to perform their tasks well. Second related to the fact that switching between different tasks was time-consuming – through the division of labour, where workers would attend to a limited number of tasks, considerable amount of time could be saved. Finally, the third point related to the fact that specialized workers could seek ways of improving their work and come up with innovative solutions, such as tools and machines that increase their output. This, naturally, represents a very bottom-up approach to the subject of competitiveness, yet it carries a number of implications at macro-, meso- and microeconomic level that will be discussed further.

1.2.1. Macro-level competitiveness

At macroeconomic level, according to Smith's argumentation, the dependence between the division of labour and competitiveness is self-reinforcing - economic development enhances the opportunities for greater division of labour whereby the markets grow larger and become better interconnected. On such markets, there ease of finding a counterparty to trade one's surplus production is much greater. Economic development also supports the employment of advanced tools, machinery and solutions that improve productivity and competitive position of an economy – same number of people can produce more and more. This also leaves room for greater division of labour in different branches of the economy.

Working from a different starting point, abundance of specific raw materials and/or factors of production more in general, helps establishing a relative advantage in certain processes (as per Ricardo (1821), followed by works of Heckscher (1919) and Ohlin, (1933)) and specialization of companies, sectors and economies in general. In this case competitiveness can be determined by a combination of factors, a lot of them (such as raw materials) remaining beyond immediate control of either companies or national authorities, particularly in the short-to-medium-term.

The renaissance of the theories around the intrinsic nature of competitiveness came along with the Austrian school of economics. Here, the ability to compete was directly linked to the ability to adapt to the changing conditions on the market (Kirzner, 1973). Schumpeter's concept of "creative destruction" pointed directly to innovations as the key determinant of competitiveness, making the notion very popular to both companies and authorities interested in fostering economic growth.

Different modern theories of growth point to the fact that, in practice, the success or failure of an economy can rely heavily on the existence of institutions, as well as other, non-economic factors such as culture. North emphasised the importance of institutions, both formal and informal, that collectively set the boundaries for the legislative and economic reality of a given country (North, 1989). He defined institutions as *(...) humanly devised constraints that structure political, economic and social interaction* (North, 1991). He underlined that these constraints define the available set of choices, ultimately determining the production and transaction costs associated with any economic activity. As such, they could also be viewed as the most fundamental determinants of competitiveness and indeed different studies that built on his work tended to highlight that it is the existence of institutions that often makes the difference between success or failure of attempts to achieve prosperity (see e.g. Acemoglu and Robinson, 2012). In this context, North pointed to the interactions between the political and economic sphere - the interplay between both areas of the economy, according to North, can often determine the development path of a country, particularly where strong ties exist between politics and certain interest groups. This approach has powerful explanatory power when it comes to analysing the economic development level of countries around the world and can shed light on the competitive position they have achieved.

In 1997 Diamond has presented a geographical hypothesis of wealth that was to explain the existing distribution of wealth around the world (Diamond, 1997). He has pointed to a number of factors that determined human progress over the course of history, primarily relating to ease of food production and capability to store food surpluses. The possibility to feed a growing number of people has, according to Diamond, opened up new possibilities for development. This is where the argumentation of Diamond coincides with the one presented by Adam Smith on the division of labour. Increased productivity and technological advancements have put some nations on the path of economic growth, leaving others behind. The geographical hypothesis can also be viewed as complementary to those seeking source of advantages in the existence of institutions. Favourable environmental conditions enabling sufficient and stable food supply have led to the development of more complex social networks and interactions, revolutionizing over time the way people organized themselves, supporting the establishment of formal and informal institutions, as defined by North.

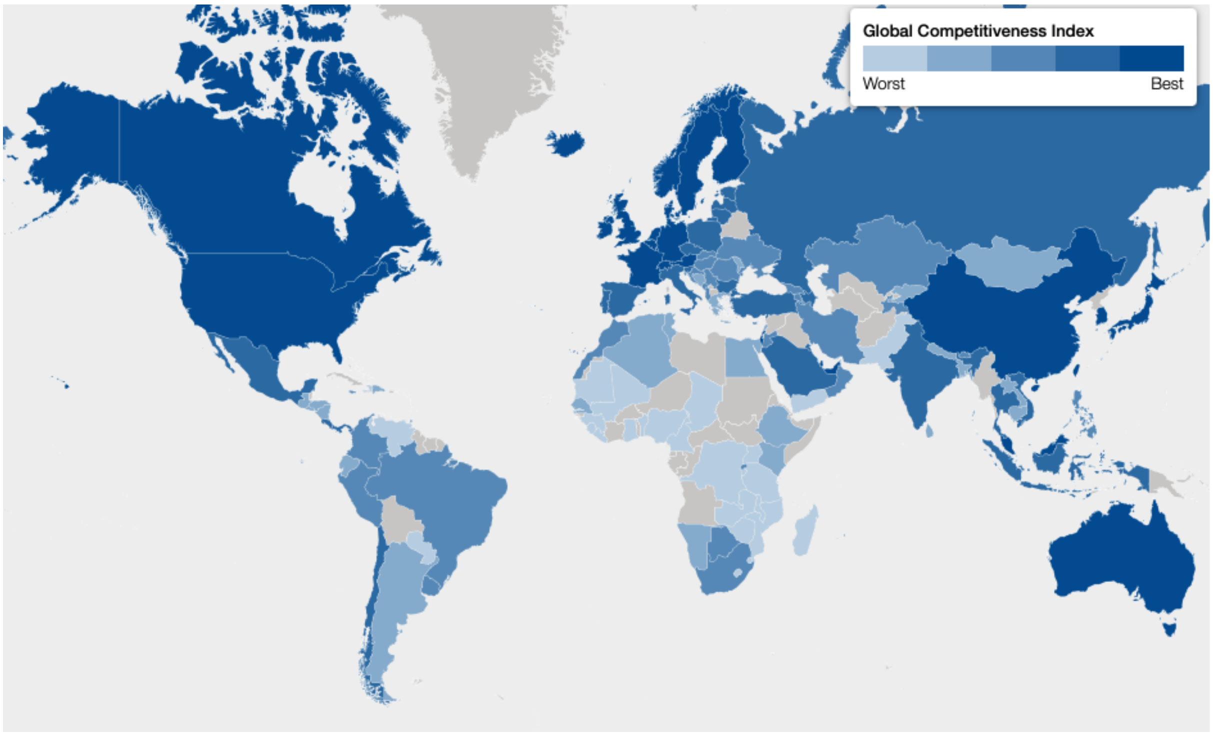
It is worth emphasizing at this point that the literature review on the subject of competitiveness determinants that the phenomenon is also being analysed with a more practical approach as well. Since competitiveness is of significant importance to the authorities of most, if not all countries around the world, the World Economic Forum publishes an annual report on the competitive position of the economies around the globe (World Economic Forum, 2017). The official rank builds on the so-called Global Competitiveness Index (GCI), building on 12 categories of factors assigned different weights depending of their perceived significance to macroeconomic competitiveness. These 12 pillars include:

1. Institutions – this category reflects the North's definition of formal institutions and covers the entirety of legal and administrative boundaries for economic decisions and administering the way through which wealth is being distributed amongst the society;
2. Infrastructure – this element is to reflect the state of infrastructure that facilitates the functioning of the economy, including transport, telecommunication and energy supply;
3. Macroeconomic environment – this category includes factors that are to characterize the stability of the economic environment, the value of the currency and the soundness of public finance. This approach corresponds with the approach applied by Roszko-Wójtowicz and Grzelak (2020). The authors of the report also make the important conclusion that stability is neither the source nor the driver of productivity, but a prerequisite for sustainable growth;
4. Health and primary education – under the GCI, health and access to primary education are among the fundamental features of a competitive economy, as both impact the efficiency of the workforce;
5. Higher education and training – this category is to reflect the capacity to engage in complex production processes and the ability to adapt to changing economic conditions as a consequence of having broad access to higher education and specialized trainings. This group also reflects the so-called endogenous (or new) theory of economic growth proposed by Martin and Sunley (2008) that identifies knowledge as the key driver of progress and increased outputs;
6. Goods market efficiency – this category refers to the overall freedom to compete on the goods market, both domestically and across borders, as this ensures that only the most efficient companies sell their goods and therefore resources are efficiently allocated. The authors of the report also underline that additional challenges stemming from the sophistication of the demand side can drive the competitiveness even further;
7. Labour market efficiency – the workforce needs to be flexible and motivated to remain efficient and the labour market cannot discriminate against employees e.g. on the grounds of their gender. Such approach can ensure that no talent remains uncovered and no related opportunities for innovation are missed;
8. Financial market development – a well-functioning financial market facilitates the capital flows in a modern economy and enables access to funds necessary for

investment. The importance of a resilient financial sector cannot be overestimated, as is underlined in many studies (see e.g. Ingram (1973), (Marcinkowska et al., 2014), Zielińska-Lont, (2021));

9. Technological readiness – this pillar is set to reflect the economy's ability to implement existing technologies in the production processes, or to attract these technologies from abroad in the form of foreign direct investments (FDIs);
10. Market size – under this pillar, the economics of scale on larger markets is recognized as an important driver of competitiveness. This recognition is in line with Adam Smith's understanding of interdependence between competition and economic growth on large markets;
11. Business sophistication – this category relates to developed economies and comprises factors such as quality of business networks, the existence of clusters and ease of market entry;
12. Innovation – a category that reflects the quality of the overall economic environment set for spurring innovation, including the scale of investment in research and development, presence of scientific institutions etc.

Figure 1. Global Competitiveness Index for 2017-2018



Source: World Economic Forum (2017).

It is worth pointing out that, just as the GCI is ultimately presented as a single value for the given country, all the components grouped under the 12 pillars remain interrelated and jointly determine competitiveness of an economy. It is also worth to highlight that the composition of the GCI reflects many, if not all, of the determinants quoted under the different definitions of competitiveness that have been discussed in this chapter. Exemplary results of the GCI value calculated for the periods preceding the economic turmoil of the following years are presented on Figure 1. The infographic has been prepared for the latest, most complete available dataset that the World Economic Forum was able to collect preceding the Covid-19 pandemic.

Figure 1 confirms that the level of economic development corresponds well with the popular perception of competitiveness – the most developed countries of the world are identified as the most competitive using the GCI. The GCI also appears to properly reflect the fact that competitiveness in the modern world is not related to the size of the domestic market or the abundance of natural resources, as can be observed on the examples of many European countries.

In the broader context, the macroeconomic environment is an important determinant of sectoral competitiveness. Factors, such as fiscal and financial stability, or indeed inflation, can severely affect the overall investment appetite and therefore the development pace of an industry (Bieńkowski et al., 2008). It should be stressed here that factors characterizing the macroeconomic environment are of different significance to different sectors (Fischer, 1993).

Apart from that wider external context, a report for the European Union on sectoral competitiveness depicts its determinants in categories that are much along the “input-output” understanding of the term (Peneder et al., 2009). These include:

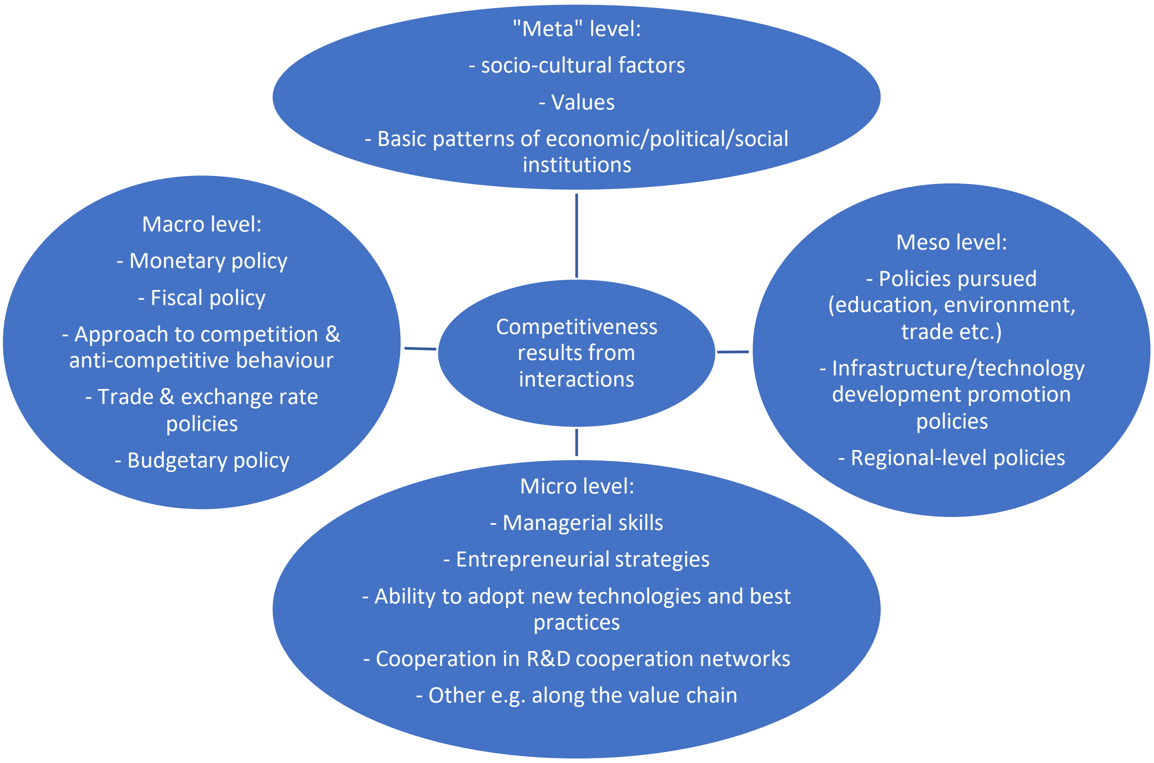
- Production inputs – understood as the available asset base, capital and human resources that are employed in developing the value added;
- Demand structure – according to the authors, it is in fact the demand size and composition that determines the allocation of resources in an economy, be it coming from the domestic or foreign consumers, investment appetite or government’s spending. Since the demand side can also be affected directly or indirectly through sectoral policy, it attracts a lot of attention and is often the focus of separate studies (Santiago and Weiss, 2018). The means through which competitiveness can be supported will be discussed in further in subchapter 1.3;

- R&D – expenditures on research and development are commonly associated with the concept of competitiveness, since innovation and improvements to the overall production processes can become a source of major advantage versus the competitors; This is also a fundamental assumption of endogenous economic growth theory whereby knowledge is the source of growing productivity (Martin and Sunley, 2008);
- Market structure – the possibility for a consumer to have a choice between the competing products is a major impulse to improve and innovate;
- Openness of the economy – related to the previous point, the openness to competition from abroad further broadens the consumer choice and increases the pressure to optimize the production processes and innovate. Both features are also quoted as the core features of the definition of sectoral competitiveness proposed by Biukšāne (2016) which states that it is the ability to sell the products more efficiently than domestic and international competitors.

1.2.2. Meso-level competitiveness

At mesoeconomic level, the subject of competitiveness attracts a lot of attention through its interplay with the institutional setup. Regulatory policy has an important impact on the way many industries are functioning, as they introduce constraints to economic decisions i.e. they facilitate an important part of the formal institutions that North spoke of. The common perception of these constraints is that they either limit the industry's ability to compete, or they constrain their exposure to international competition (Aghion et al., 2015). Over time, this assumption has been challenged (Rubashkina et al., 2014). In fact, for the intra-sectoral rivalry to exist as a mechanism to induce competitiveness, regulation is in many cases inevitable (Dabbah, 2011). In that sense, regulation can be viewed as one of the core determinants of sectoral competitiveness, even if this approach cannot be seen as universal. Aghion et al. conclude that competition and well-designed industrial policies can be complementary in driving the productivity and innovativeness of a given sector (Aghion et al., 2015). (Esser et al., 2013) go a step further, arguing that without an environment that inspires innovation (i.e. an environment created collectively by the state regulation and market participants) no form of "constructive" competition would be possible. As the promotors of systemic competitiveness theory, (Esser et al., 1996) proposed supplementing the analysis of the phenomenon with "meta" level factors, such as work ethics, capacity to pursue a specific policy over the long-term etc. (see figure 2).

Figure 2. Factors determining systemic competitiveness



Source: own elaboration based on (Esser et al., 1996)

In a report for the European Commission, it is stated that the measures of mesoeconomic competitiveness are universal only to an extent and are to differ between sectors (Peneder et al., 2009). This, according to the authors, is the root cause for huge global variations in terms of industrial performance and growth rate. The following “universal” measure categories have been taken into account when assessing the competitive performance in the underlying study:

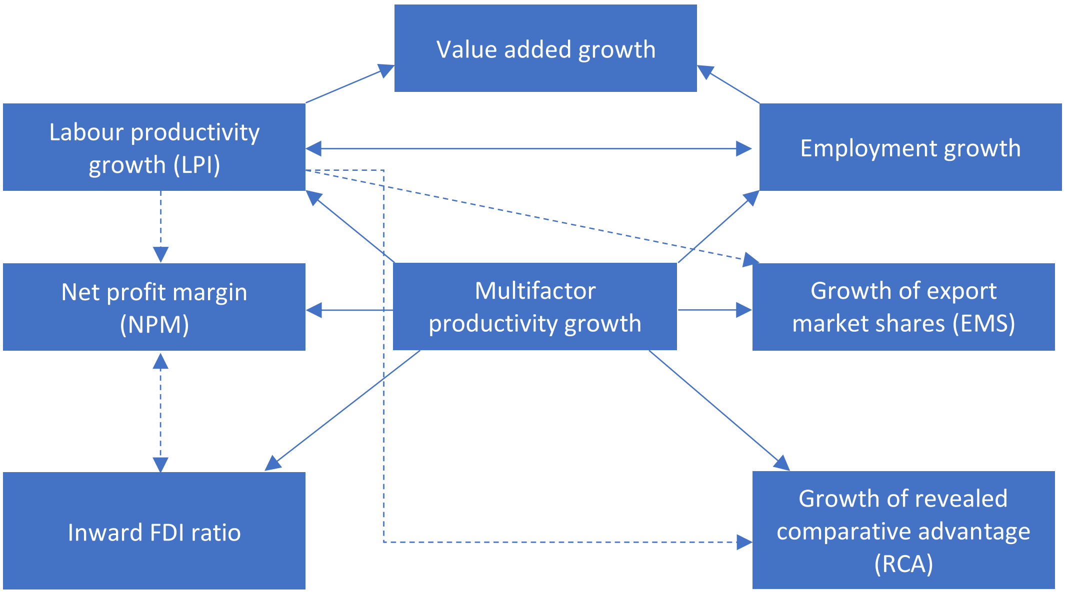
- Growth – understood as both the sector’s contribution to the economy’s overall growth and as its capacity to offer a sustainably growing employment level with no negative consequences to the overall productivity. This approach is coherent with the previously discussed competitiveness-economic growth interplay at the macroeconomic level;
- Productivity – this is a category related to growth indicators, where labour productivity is taken into account as a standard input/output ratio. That variable is supplemented by a multifactor productivity indicator that assesses the productivity of capital invested in the sector. The fact that productivity is treated as a factor in this context would confirm that indeed productivity is not a synonym of competitiveness, but one of its determinants (Dresch et al., 2018);
- Profitability – the category includes two values: net profit margin (i.e. ratio of pure revenue after taxation plus any related deduction and overall sales) and return on assets (ROA) (calculated against the same profit as the first category). The presence of these

indicators is rather intuitive – no industry or business can be viewed to be competitive if it is unable to make profit on the goods produced and at a scale corresponding to the investment made in its asset base;

- International trade – reflecting trade specialization through the revealed comparative advantage (RCA) indicator – the ratio reflects the relative export-to-import position of a country's sector vis-à-vis the same value of all sectors. The second variable in this category is the export market shares ratio i.e. the share of the global export that can be attributed to a country's industry;
- Foreign Direct Investments – encompassing two measures reflecting the ratio of inward and outward FDI respectively to their value added understood as a shift in capital flows, employment and know-how transfer. While incoming FDIs are generally considered to have an outright positive impact on competitiveness, outgoing FDIs are more controversial. A growing number of studies, however, provides evidence that domestic company's expansion to foreign markets is beneficial to the home country's competitiveness (see e.g. Knoerich, 2017).

Finally, it is important to underline that special attention has been dedicated in the report to explore the interdependencies between the different measures of competitiveness (Peneder et al., 2009). The analysis was based on studying the statistical interdependencies between the different ratios and the results have been depicted on the figure 3.

Figure 3. Interrelationships between different measures of sectoral competitiveness



Source: own elaboration based on Peneder et al. (2009).

Figure 3 also points to the fact that the measures of competitiveness can be both positively and negatively correlated (e.g. labour productivity and employment growth). This observation has important consequence for the authorities, especially since the character of different sectoral policies can prove to be at odds with each other and the industries themselves can respond differently to the incentives they are offered.

1.2.3. Micro-level competitiveness

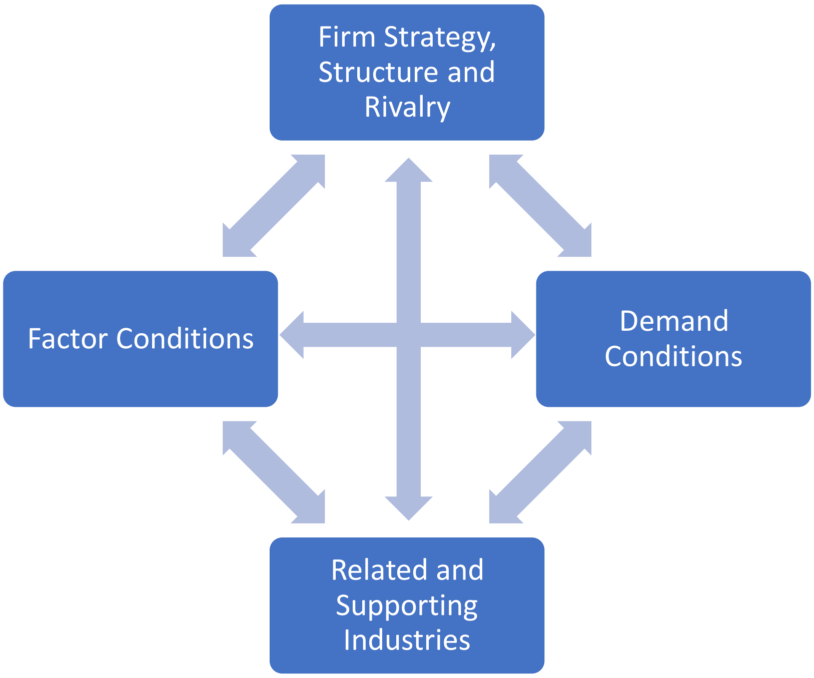
Considerations around the determinants of microeconomic competitiveness should begin with an analysis of the works of Michael Porter, as it is considered to be one of the most important in this field (Psofogiorgos and Metaxas, 2016). In his article titled "The Competitive Advantage of Nations" Porter presented the results of his works that focused on studying the sources of leading global companies success (Porter, 1990). The author identified key features of these firm's strategies that altogether contributed to establishing competitive advantages on a global scale – and the source of that advantage was always innovation, much in the spirit of the endogeneity of economic growth proposed by Martin and Sunley (2008). Just like the new theory of growth, Porter's conclusions point to the fact that a series of minor improvements to a company's performance are far more likely to form the foundations of its success than a single revolutionary reform or discovery. What also needs to be underlined is that Porter's theory of economic advantage explicitly attempts to explain the phenomenon through referring to "(…) *certain companies based in certain nations*" signalling from the outset that the macro- and mesoeconomic levels inadvertently impact the ability to induce innovation (Porter, 1990). Indeed, the author has proposed a set of factors that both individually and collectively contribute to establishing a nation's competitive advantage – they are the following:

1. Factor conditions – the availability of factors of production, as well as the development level of the national infrastructure;
2. Demand conditions – understood as domestic demand for products and services developed by a given sector;
3. Related and supporting industries – reflecting the existence of a network of suppliers, producers of complementary goods or other sectors that can positively affect the competitive position of a sector;
4. Firm strategy, structure and rivalry – a factor that perhaps attracted the most attention in Porter's theory and indeed the only one directly related to the microeconomic sphere.

It relates to the ease of setting up and managing a company in a given country, as well as the ability to compete on the domestic market.

The actual diamond depicting the interdependencies between the abovementioned factors has been presented on figure 4.

Figure 4. Diamond of competitive advantage



Source: Own elaboration based on (Porter, 1990).

Altogether, Porter's diamond describes an environment in which companies are likely to introduce innovations and improve their competitive position indirectly affecting the competitive position of the country they are based in. The interdependencies within the diamond are of utmost importance, especially for recognizing the fact that disadvantages in certain areas do not seal the fate of a nation's economy.

In terms of factor conditions, Porter's theory diverts quite far from the classical economic growth theory dating back to Adam Smith. Here, the author stressed that in modern economies, the most important factors of production, such as skilled labour, are created, not discovered or inherited. Indeed, it may well be the scarcity of some basic resources that can force companies to innovate and find alternative ways of development. Disadvantages in terms of certain factors of production could also result in seeking advantages in other elements of the diamond. A corresponding argument stems from the so-called resource curse theory according to which abundance of natural resources can incentivise trade-restricting policies and discourage investment (see e.g. John, 2010; Polterovich et al., 2010).

The domestic demand side, to Porter, remains an important determinant of competitiveness also during times of globalization, as it has an important impact on the way companies perceive the overall economic situation and how they plan their business. The roots of this phenomenon are in the fact that the domestic market is typically more transparent to the local companies that are at the same time more familiar with the domestic consumer preferences. In the context of innovativeness, however, it is the level of consumer's sophistication that pushes the companies to improve and expand their offer. In particular, if the domestic demand precedes or inspires changes in demand elsewhere, it can become a powerful source of international context.

The presence of supporting and related industries is another source of competitive advantage that links back to the factor conditions – Porter's examples largely refer to the presence of domestic suppliers that already hold a relatively strong competitive position on an international scale. Presence of such companies triggers the development of downstream entities that benefit from their proximity and/or accessibility on the domestic market. Cooperation between these entities supports establishing closely located industrial clusters characterized by close ties and possibly intense competition. At the same time, these clusters should be open to competition from external parties both on the domestic and global market, where both the suppliers and the customers would aspire to maintain the most advantageous business relationships.

The corporate strategy, structure and rivalry reflects the conditions of operating a company in a nation's economy, including the customary approach to running a business that determines its typical size, ownership structure and approach to management. While Porter admits there is no universal model of corporate management, different models are a better fit to particular processes, depending on whether they rely more on e.g. quantity or quality of mass-produced goods. The other side of the corporate management factor relates to the way company goals are defined and how their attainment is renumerated. On one hand, the duration of the relationship with the shareholder determines the focus on short- or medium- to long-term goals and affects the way managers set their strategies. On the other hand, the way work performance is promoted may affect the ability of a company to attract the type of talent that is needed to foster innovation. In both cases, there may be industries and individuals that would favour one model over the other and it comes down to choosing the best fit that affects the competitive position of a company (Michalski, 2019).

Finally, the existence of competition within the company's sector is a crucial determinant of competitiveness both from perspective of Porter himself and in the context of this study. At the same time, it proves to be the least intuitive condition for most policymakers, that often see merit in limiting domestic rivalry or promoting certain companies (Aiginger et al., 2013). Ultimately, though, it can be argued that it is the threat of losses or an opportunity for exceptional, as two sides of the same coin, can be viewed as the key driving force of innovation and progress.

The insistence on the existence of a competitive environment in Porter's diamond, is in fact an outcome of his previous work, that links his theory on competitiveness more firmly to the microeconomic level. In his famous article on competitive strategy, he stated that the very reason for having a corporate strategy is to handle competition, spanning beyond a given sector onto potential entrants, substitute goods and even the strength of suppliers and customers (Porter, 1979). Forces that shape the competitive environment a company operates in have been depicted on figure 4. These factors, according to Porter, determine the intensity of competition a company is exposed to and affect the management's approach to setting up its strategy. By knowing the strength of each of the determinants along with the sources of this strength, companies should be able to position themselves for different scenarios in the future. It is therefore important for the managers to begin formulating a strategy by properly assessing the importance of each of the factors on the overall competitive environment.

Figure 5. Determinants of competition in an industry

Source: Porter (1979).

Starting with the threat of new entries, the ease of access a given industry needs to be assessed – this includes analysing (Porter, 1979):

- Economies of scale i.e. how much capital needs to be invested to effectively commence a given activity without being exposed to large cost disadvantages;
- Brand identity – a strong brand existing in a given market is not easy to overcome;
- Capital intensity of a given business – i.e. how much resources are needed to e.g. innovate or cover for losses that are unavoidable in certain activities;
- Other (non-size-related) cost disadvantage stemming from lack of experience, access to certain suppliers and other factors;
- Accessibility of distribution channels through which the goods can reach the clients;
- Government policy that can deliberately restrain or foreclose market entry in a given sector.

Evaluation of these barriers should allow the company to evaluate the threat of potential changes to the competitive environment going forward, whereas for new entrants it should help reaching the initial investment decision.

Bargaining power of customers and suppliers relates to their capacity to affect the profitability of a given endeavour. On the customers side, they can have the strength to demand better quality or a price discount. Suppliers can utilize the scarcity of the goods they offer by driving the prices up and overtake an important share of the producer’s profit. It is therefore important for a company to carefully choose suppliers and target customers groups, so that their concentration does not expose the company to the abovementioned threats.

The last element – substitute goods – limit the freedom to set the prices of the products, unless a company can come up with credible means of differentiating these products to an extent at which they are no longer considered substitutable. In either case, the existence of such goods can severely limit the profitability of any business and over time even push out the “original” product out of the market.

All the factors setting the scene for the actual rivalry over the market share and for implementation of the different corporate strategies. Porter proposed three strategic approaches in the competitive environment that can either aim at:

a) Retaining the established position on the market;

b) Implementing an offensive strategy by attempting to influence or exploit the factors determining the existing competitive environment. It needs to be noted here that decisions in this approach only to an extent refer to the sphere under company's control;
c) Focusing on anticipating changes to the competitive environment and exploiting this change to the benefit of a company.

It is interesting to note that the macro-micro interplay is often stressed in different studies on competitiveness, as summarized by Żukowska and Pindelski (2011). The authors state that competitiveness of a country is mirrored in the performance of its domestic enterprises. In other words, an economy can be viewed as competitive if it hosts companies, who's products and services attract demand on the global market. Indeed, the literature overview the authors provide in their research shows, similarly to the overview presented in subchapter 1a, that both approaches are equally popular and well combined in Porter's diamond.

Coming back to the competitiveness determinants at microeconomic level, Żukowska and Pindelski (2011) list the following factors as key:

- Innovativeness
- Business partners
- Prices and quantities of products and services offered
- Ability to attract funding – both capital and external funding that fuel business's further expansion
- Business environment – understood in the context of available subsidies

Olszewska (2011) expanded this list by a set of more elaborate features, such as uniqueness of the products or services, competence of the entity's management and finally, and perhaps most importantly from the perspective of this study – trust. Building on the works of Arrow (1972), the author stressed that trust is of paramount importance to both establishing good relationships with business partners and ties with the clients. Trust can then be seen as both a factor streamlining the exchanges within a given value chain and cementing the established competitive position – a trusted product or service has a potential to attract the customer even if its price is higher than of competing or substitute goods (Sprenger, 2007).

In conclusion, it needs to be stated that the increasingly dominant view over the determinants of competitiveness at micro-, meso- and macroeconomic level are closely correlated, therefore difficult to analyse in isolation (Kassalis, 2010). It can be argued that an analysis focusing at a single level of economic activity will inevitably need to refer to the other two levels if it is to present a complete picture of the actual situation. The case of sectoral competitiveness can be particularly interesting in this context, as it cannot be analysed without a reference to the wider macroeconomic conditions, or the strategies chosen by the participating entities at the microeconomic level.

1.3. Means of supporting competitiveness

Competitiveness at the mesoeconomic level attracts a lot of attention, as it is a sphere, in which the government can be directly involved in and have tangible influence on economic performance of the country. Such notion has been promoted e.g. by (Porter and Ketels, 2003). This involvement can be manifested in different forms, through regulation, subsidization, fiscal and labour policy, but also directly through ownership (Balcerowicz and Sobolewski, 2005). The goal of such interventions can be very different from sector to sector, although in theory they would aim to improve the performance of companies and sectors in general. There can be many other reasons for government intervention in the functioning of different sectors, yet policies incentivising competitiveness will be in focus of this chapter.

As argued before, the confusion between competitiveness and productivity is most profound at the mesoeconomic level - EU Commission's toolkit ("toolkit") for studying competitiveness even states that sectoral competitiveness stems directly from its productivity (European Commission, 2012a). At the same time, the toolkit serves as a good starting point for an analysis of the measures that are to induce competitiveness - building on the wording of the Treaty on the Functioning of the European Union (TFEU), the Commission indicates that long-term growth in the standards of living relies on the ability to improve productivity reflected in the capacity to produce at a lower cost, produce unique or higher quality goods. In that sense, the link between competitiveness and productivity is indeed intuitive and the means to improve competitive standing on the broader market are much the same. From the outset, the toolkit recognizes that any targeted policy will have both positive and negative consequence for different stakeholders and it will have implications to the domestic, regional and international competitiveness (European Commission, 2012a).

1.3.1. Role of the government in enhancing competitiveness

Competitiveness at the mesoeconomic level can to a be either enhanced or constrained by government policies – Esser et al. (1996) see the government's role as truly central to building competitive advantage of different sectors. It is clear, however, that it cannot be the sole source of competitive advantage in the long-term (Kancs and Kielyte, 2001). One example of such unsustainable policy can be administered exchange rates to either protect domestic producers or to promote exports. Instead, institutional theories of economic growth are frequently quoted when it comes to fostering economic growth – the right environment for entrepreneurship, rule of law and a stable legal and economic environment are all listed as important means through which governments can support developing competitive industries (Aiginger et al., 2013).

One of the areas of government's direct involvement in fostering competitiveness at mesoeconomic level are clusters, which is related both to Porter's theories related to economic growth and Coase's studies on transaction costs. Weresa et al. (2017) propose a multi-level division of cluster initiatives aiming at fostering development of close interactions between different actors in a given (geographically concentrated) sector (i.e. clusters, as defined by European Commission (2008)):

- International level – fostering transnational cooperation of clusters.
- National level – incentivising funnelling investments into specific locations that are to form the future cluster.
- Macroregional level – focusing on a specific region in the country that can hold certain prerequisites to develop synergies between clusters.
- Regional level – focusing within the boundaries of a single administrative area, often orchestrated by, or in cooperation with the local authorities and less focused on outright support for large investment projects.

The authors emphasize that at mesoeconomic level, cooperation and competition ("coopetition") concentrated within clusters result in spillover effects whereby initiatives undertaken by a single entity participating in the cluster improve the performance of its counterparties and positively influence the economic development of the entire region (Weresa et al., 2017).

There have also been more comprehensive attempts to provide theoretical guidance on encouraging competitiveness. The International Institute for Management Development (IMD) has proposed a set of "golden rules" that should be followed by any state if it was to become competitive (Garelli, 2002). Although by default they refer to competitiveness at macro level, the rules actually set the scene for developing a modern economy through establishing a favourable business environment – these include:

1. Stable regulatory environment – an important aspect, particularly for capital-intensive sectors, where investments are depreciated over several decades and are therefore exposed to significant risks stemming from changing policies;
2. Invest in traditional and technological infrastructure – in both cases an important determinant for establishing a competitive position and join the rivalry at a global, or at least regional scale. That factor also links the IMD principles back to Porter's "factor conditions" that support innovativeness (Porter, 1990);
3. Encourage exports and foreign direct investment (FDI) – joining international competition requires access to funding and possibly favourable regulatory treatment, whereas FDI bring in new technologies and more intense rivalry on the domestic markets. International activities of transnational corporations in the field of research and development have proved to have tremendous capacity to induce innovations and apply them in business processes, making FDI an attractive form of improving competitiveness by the host countries (Zorska, 2017);
4. Timely, high-quality and transparent administration – stable and consequent policy from the government that is open to dialogue with the stakeholders on the market adds to the stability described under rule no. 1;
5. Sustain a link between wages, productivity and taxation level – while clearly supportive of improved performance of companies and sectors, the responsibility for establishing and maintaining such a link falls between individual companies, sectoral trends and fiscal authorities, making the entire rule difficult to take action on.

It deserves to be mentioned here that the IMD rules list entails five other points, yet directly related to a truly macro-level policy that holds no obvious link to sectoral competitiveness being discussed in this subchapter. A truly "hands-on" recommendation stemming from IMD's golden rules is that the state's interventions in competitive mechanisms should be limited to ensuring and maintaining a fair competitive environment (through legislative and regulatory transparency), adequate infrastructure and remaining open to foreign competition.

Literature studies of the subject seem to confirm that the government has an active role to play in supporting mesoeconomic competitiveness. In their analysis, Balcerowicz and Sobolewski (2005) study several spheres of government's involvement at the sectoral level, impacting the way it works at different levels:

- Owner of companies – as an actor directly involved in commercial activities in the given sector, the state can have significant impact on the level of competition within a given branch. State's extensive engagement in a given sector can also result in its preferential treatment;

- Fiscal policy – determines the burden that sectors need to carry, but also the contribution they make to the state budget. For different sectors, fiscal policy can bring additional taxes and levies for their activities, but possibly also discounts that can protect them from competition;
- Targeted subsidies – taking the form of direct or indirect financial support, the subsidy schemes are a popular manifestation of the state's actions to promote competitiveness, although they can serve a number of other purposes as well. It is worth noting here that subsidies can target both the supply and the demand side (as raised by (Peneder et al., 2009))

Policies targeted at improving competitiveness of a given sector are often bound to have their consequence on other sectors as well. This can relate to supporting industries that can indirectly benefit or suffer from the changing capacity of its counterpart to produce or invest. It can also be argued that favourable legislative and/or regulatory changes for one sector, could add to the detriment of the other, even if they are not related – e.g. favourable policy towards expansion of raw materials productions, could damage the performance of the agricultural or tourism sectors through additional damage to landscape and/or environment in general.

To governments and politicians, subsidies have become an attractive way of supporting sectoral competitiveness, particularly since they establish a link between the sector's international success and the authorities, who can then take credit for it to an extent in the eyes of the society. It needs to be remembered, however, that incentives on its own, can be seen as a form of distortion to the market mechanisms. A study by (Möller, 2012) argues that there are trade-offs between the impact on competitive balance and the benefits the incentive brings on a larger scale. In his theoretical model, the author argues that incentives do not give immediate advantages to the beneficiary, but they improve its capability to compete over time. To him, this is already a sufficient conclusion in support of attributing incentives through competitive bidding processes.

1.3.2. International and sector-specific considerations

It is interesting to note that subsidization often also has an international dimension. On one hand this relates to state aid rules agreed upon and executed by different international organizations that restrict the extent to which different activities could be subsidized. On the other hand, joint efforts can be undertaken to support innovativeness, in order to share the financial burden and the associated risks. One example of such coordinated effort that is particularly interesting from the perspective of this study is the European Union support for development through the European Structural and Investment Funds. The efficiency of such solution to date has been criticized in literature, yet has also triggered a discussion around potential solutions that could improve the competitiveness of EU Member States (Sarul, 2017). This issue will be studied further in chapter 3.

It is also very important to recognize that some sectors are subject to strict regulation that can affect e.g. the freedom to commence activities in a given sphere, liberty to set prices for goods and services, or to selectively pick counterparties or customers. This rigidness towards certain branches of the economy can be motivated by different reasons (strategic character of the given branch, particularly high threat that certain activities can pose to the environment etc.) but also from the fact that their structure is incomplete and unrestricted competition could lead to suboptimal results (Wettstein, 1995). Indeed, the imperfections of market mechanisms have been studied extensively, with different authors arguing that the result of "pure" competition on an underdeveloped market could be not much closer to optimal allocation of resources than the outcomes in a centrally planned economy (see (Giraud and Stahn, 2003) for further reference). For this reason, such sectors are particularly prone to the ability of the authorities to set up institutions that determine and monitor the conditions for competition (i.e. as per Schwab's definition of competitiveness (Schwab, 2013)).

A specific structure of a sector may require a particularly careful approach to stimulating and maintaining competitiveness. An individual approach to studying different sectors is something that Hamilton and Clark have argued for long ago, as mentioned in section 1.1 of this study. This, in turn, implies that means of supporting competitiveness of such sectors are studied separately and consider different, often dedicated tools. This will be the case for the sector in focus of this study - European Union's gas sector – the competitiveness of which will be analysed in detail in chapter 4.

Conclusions

In conclusion, no dominant definition of competitiveness exists, just as there is no consensus over the validity of the concept in the academic sphere. Nonetheless, since the notion has become popular enough to be referred to as a "natural law", it is an interesting subject to be studied. While the concept has different facets at different levels of economic activity, the mesoeconomic sphere seems to be most attractive from an academic perspective, as it inevitably binds together all the different factors that can affect the ability to compete.

The definitions of competitiveness typically span beyond purely economic categories of price, cost, or revenue, signalling that it is a complex phenomenon with far-reaching consequences. Therefore, any strategy, be it at macro-, meso- or microeconomic level, should attempt to achieve more than ensuring growing financial returns, if it is to result in creating competitive advantage in a sustainable manner. This conclusion points to the fact that with the rising importance of CSR and considerations around climate change threat in general, the link between micro- and macro-level strategies is possibly stronger than ever.

There are many determinants of competitiveness in a modern economy, but it is also apparent that competitive position nowadays increasingly relies on the intrinsic ability to adapt, innovate and develop skills that cannot be replicated easily. Both the multitude of possible determinants of competitiveness and the means to improve it signal that the different sectors of the economy have their own peculiarities and deserve an individual approach. In other words, no one-size-fits-all policy exists that could help building a competitive advantage in different branches of the economy.

The EU's gas sector is a fascinating object to be studied in the context of sustaining competitiveness, as it is soon to face the challenge of decarbonization, while being exposed to truly global competition over the commodity. The condition of that sector also has a significant impact on other parts of EU's economy, since gas remains an important fuel in electricity generation and is an important feedstock particularly in the chemical industry. The future shape of the EU's gas sector can therefore significantly affect the competitive position of the entire economy in the coming years.

Chapter II

2. The process of establishing competition on the European gas market

Disputes on sources of wealth, competitiveness and economic growth have inspired a lot of studies around their practical dimensions. Positive results brought about by competition, both on the domestic markets and across the borders, have inspired discussions around whether the same mechanisms could be introduced in spheres that were traditionally monopolized, at least on a national scale. One field that was targeted first was the energy sector that has been developed and governed by vertically integrated companies that operated across the value chain starting from production and ending with end customer supply (CMA, 2016). Energy is by default a very heterogenous product, the delivery of which entails a number of services, often of very different nature depending on the carrier involved. Situation is, however, less complex when one considers a specific carrier (such as electricity or natural gas) separately, as homogeneity of the product becomes less of a problem. Early attempts at introducing competition to the electricity and gas sectors in the United Kingdom and the USA have brought positive results and motivated other Western economies to follow suit (Ishwaran et al., 2017).

Historically, the gas sectors of different countries around the world were developed through a single, state-owned entity that was tasked with ensuring a stable supply of the resource to the end-users. Such monopolies interacted and competed against each other, yet the entire industry was relying on long-term arrangements, with prices being determined by the sides and/or indexed against oil prices (Mete, 2020). For years, the link to the already available oil price made economic sense, as both oil and gas were substitute goods for power production and their value was closely correlated. Over time both commodities became increasingly decoupled and oil (or oil product) indexation began creating problems to either side of the contract. As gas started playing an increasingly important role in different economies, the need for it to have an accurate price reference kept growing.

Liberalization of the gas markets is a process with a relatively long (more than 20 years) history, particularly in the USA and the most developed European countries. In each country the process followed a different path, reflecting the different fundamentals driving each individual market (IEA, 2019c). Growing importance of gas, driven both by these developments and technological advancements encouraging fuel switching towards gas have invalidated oil price as a reference for gas-related transactions (Lyons and Durusut, 2018). As markets grew in liquidity, they have started offering a reliable price reference of their own and now underpin a growing share of short- and long-term transactions.

The aim of this chapter is to provide a comprehensive overview of EU's experience thus far with establishing competition in the gas sector and explain the fundamental principles governing the functioning of the gas markets that have stemmed from this process. It also points to different sources explaining the different development stage reached by different national markets.

2.1. The process of gas market liberalisation

Development of natural gas sectors in different countries was typically coordinated through vertically integrated (often state-owned) companies, who have been set up to manage the construction, operation and maintenance of the infrastructure, as well as contacts with the consumers (de Hauteclocque, 2013). Historically in Europe, the sector has been developed in two segments i.e. transmission (high-pressure system for large-scale transactions) and distribution (lower-pressure, local and regional networks used for gas deliveries to end-customers). Same approach in this respect could be observed in many countries around the world, especially since natural gas was seen as model example of public good offered by a "natural" monopoly. As indicated by Posner (1968) this naturalness stems from the supply method, where pipelines for different pressure levels are developed to deliver the commodity from the producers to the end-users. Since the development of such gas transportation grids is expensive and faces opposition from the society stemming from the land use, establishment of competing, parallel routes would neither be logical nor possible.

Market-based competition would bring no viable results in the field of gas transportation in a given region, so the natural choice was to keep this area monopolized but regulated. Such approach was tested again over time by Gordon et al. (2003) in the context of subadditivity, reconfirming that gas transmission is in fact a natural monopoly. An interesting study by Künneke (1999) has speculated over the future naturalness of electricity transmission grids in the context of new technologies being developed and cross-commodity competition – yet the need for having a single, regulated gas transportation system should not be seen as contestable in the foreseeable future. The conclusion is that for competition to develop in the gas sector, it has to be broken into a monopolistic part related to gas transportation and competitive part related to gas production, supply and trading (Thomas, 2005).

2.1.1. Gas market liberalization in the USA and UK

The idea of establishing a competitive market for gas was first pursued in the USA with the adoption of the Natural Gas Policy Act of 1978 (Hasegawa, 2002). In fact, earlier experiences with the establishment of gas infrastructure spanning between state borders has encouraged the US authorities to establish a regulatory authority tasked with preventing abusive behaviour by the gas monopolies already in 1938 – the successfulness of its operations in this sphere, however, remained very volatile until the Natural Gas Policy Act reformed its structure and powers. The newly established Federal Energy Regulatory Commission (FERC) has made two significant contributions towards establishing a future market for gas by issuing two orders that first "encouraged" the gas companies to offer gas transport services through their pipelines in a non-discriminatory manner (1985) and then made it a formal requirement in 1992 (FERC Order 636: The Restructuring Rule). The Restructuring Rule has also stipulated that the provision of transmission and gas storage services should be offered separately from any gas transactions.

It is worth noting that FERC Order 636 has encouraged the establishment of "market centers" at the intersection of different pipelines, where there are many potential buyers and sellers of gas. This last point marks the most notable difference between the US and European gas market design (that will be the focus of this chapter), with the former being of physical nature, bound to specific points in the gas network where a multitude of pipelines are interconnected, naturally bringing together a number of market actors on both the buying and selling side (IEA, 2019a). The clear distinction between producers, gas network operators and suppliers has created room for establishing trading companies, that have served as intermediaries between all these actors and dealt with purchasing gas from the producers, contracting for its transport and further sales to final customers or their suppliers. As the number of market actors grew, the "market centers" became liquid markets with a growing number of products on offer and the most significant of them, the Henry Hub, developing reliable price indices for many gas transactions around the world.

Soon after the gas transmission infrastructure began to develop in Europe, discussion in the United Kingdom (UK) have started in order to explore, whether the state monopoly in the gas sector ensures cost efficiency and cost-reflective prices to the consumers (Haase, 2008). The monopolist proved to be performing well financially, although was accused of being non-flexible towards smaller customers and of being inefficient in terms of managing its operational costs (Black, 1992).

The UK, acting as a prime mover in the sphere of establishing a market for gas (in Europe), has gained important experience that proved to be helpful to other countries that pursued a similar reform. As of 1948 the process of integrating different regional pipeline networks into a single system was ongoing and in 1972 it was centralized under a state-owned British Gas Corporation (further referred to as British Gas). In 1982 the Oil and Gas Enterprise Act has laid down formal rules for enabling competitors to use the gas transportation pipelines to encourage new potential entrants to extract oil and gas in the north of the country (Arapostathis et al., 2014).

In 1986 another reform of the UK gas sector has commenced to make it fit for competition. Interestingly enough, the reform did not unbundle British Gas, but privatized it and divided the sector into three segments (Juris, 1998):

- the wholesale market (for transactions between producers, British Gas, independent suppliers and traders),
- contracts market (for supply of the largest customers) and
- tariffs market (for supplying smaller consumers by the former incumbent under a price cap).

Alongside these three segments, a national regulatory authority (NRA) called Ofgas has been set up to control the monopoly by administering the price cap in the tariffs segment and intervening in case the incumbent would prevent a third party from using their pipeline network (Pearson and Watson, 2012). Similarly, powers were given to the competition authority (namely Monopolies and Mergers Commission, MMC, part of the Office of Fair Trading, OFT) to react to instances of uncompetitive behaviour on the contracts market. In practice, this was still not an environment for establishing competition due to information asymmetry between the incumbent, the potential competitors and the clients that allowed British Gas to retain complete discretion over prices offered to different (non-tariff) customers until it has been obliged in 1988 by the MMC to publish its price schedules for large customers for the upcoming year (Bossley, 1999). The other problem was that British Gas has contracted for the entirety of the gas produced in the country, with the contracts covering the entire lifetime of the gas fields. The MMC addressed this problem with the introduction of a 90/10 rule that obliged producers to sell at least 10% of their output from any new field to independent suppliers (Black, 1992). While the rule did not result in any significant increase in competition on the British gas market, it has pointed to an important feature of a competitive market design that needs to ensure that access to the commodity by new entrants is not hindered by the former incumbent holding significant market power.

With the additional regulations introduced by the MMC, larger consumers in the UK have begun benefitting from having a choice between gas suppliers. This ability to choose gave such tremendous advantage to these customers that certain tariff consumers have been reported to flare gas to pass the consumption threshold and become part of the contracts segment (Black, 1992).

Second reform was initiated by the OFT in 1991 who has concluded that not enough gas was being made available to independent actors so that they could successfully compete with British Gas over supplying domestic consumers. The incumbent was committed to (among other things) (Bossley, 1999):

- separate the trading and the transmission/storage activities by splitting these into two companies. Entity tasked with gas transportation has been further obliged to introduce a single, transparent pricing formula for all system users;
- Limit its share in the contracts market segment to 40% by 1995. The majority share of the supply contracts was to be auctioned to ensure non-discriminatory access to this segment by British Gas's competitors.

Overall, it can be stated that British Gas was given considerable flexibility in terms of the way it was to become compliant with the reform, yet soon found itself struggling to live up to all its commitments. Historical obligations under long-term contracts have proved to have considerable consequences to the companies emerging from the unbundling of the vertically integrated business.

Further legal grounds for the development of competition on the gas market in the United Kingdom came along with the revision of the Gas Act that entered into force in 1996. The revised act has equipped Ofgas with new tools in form of the right to issue licenses for production, transportation and trading activities (Bossley, 1999). The regulator has further stated that it is not legal for a single entity to hold the transportation and trader/supplier license at the same time, marking the need for clear separation between the monopoly and the competitive sphere. The licensed operator of the transmission system has, in turn, been obliged to ensure non-discriminatory access to the pipeline system through preparing and updating a Network Code that governs the relationship of the operator with all the network users (Juris, 1998). British experience in developing competition in the gas sector has served as an important reference to other countries in Europe.

2.1.2. Gas market liberalization in the European Community countries

The European Community countries have been observing the general trends of market liberalization taking place in UK and the US and have agreed on an action plan aiming at establishing a Single Market, free of barriers to the movement of goods, services and labour between these countries in order to enhance competition (Vasconcelos, 2005). With the necessary reinforcements to the Treaty brought about by the Single European Act of 1987 that gave grounds for enhanced economic integration also in terms of energy policy, the plan has taken a more targeted form, with the 1988 publication of a Commission Working Document on The Internal Energy Market (COM(88) 238 final)[5]. The Single European Act has also given grounds to adopting the Single Market 1992 Program and the establishment of independent regulatory authorities – also in the energy sphere – although did not translate into any immediate legal requirement in that sphere (Vasconcelos, 2005).

The Internal Energy Market (IEM) working document of 1988 makes some valuable observations from the perspective of this study. The Commission notes that both the electricity and gas value chains entail the operations of monopolies that were perceived as a potential barrier to the integration of these sectors between the Member States. Different fundamental features of each market (such as the energy mix, fuel sources, demand structure) has also been recognized as a reason for considerable differences between the national energy sectors of the European Community and a potential threat to greater integration. Nonetheless, it was exactly the creation of a single market for these commodities that was seen as a way of improving their competitiveness on the global market. It should be noted here that the Commission’s aspiration was to establish a truly competitive market for these commodities i.e. one that brings together multiple suppliers of a homogenous products, neither of which holds a market share that would allow it to steer the product’s price (Scherer and Ross, 1990). The expected outcomes of establishing a competitive internal market for electricity and gas were to:

---

[5] It deserves to be mentioned that the legitimacy of the energy policy at the Community level was still perceived as weak and contestable, perhaps explaining why it has gained a more decisive tone only in 2009 after the reinforcement of the Lisbon Treaty (Yafimava, 2013). Before that happened, the Commission built its energy policy in the energy sphere on the basis of the powers it was granted with respect to establishing a single market between the Member States.

- contain energy costs – a particularly important aspect from the perspective of overall macroeconomic competitiveness, since at the time the costs of energy were estimated to make up for approx. 30% of the production costs on average (for metals, glass and construction materials);
- monetize the complementariness of the national power and gas systems and optimize the Community's energy mix, further reinforcing the competitive position of the Member State's industries over the medium- and long-term;
- improve security of supply through better interconnectedness between national markets and through making energy supply a common interest of the Member States;
- additional welfare gains through an increase in intra-community trade.

Overall, the expectation was that having a common market for energy would improve economic convergence between the European Community countries, leading to greater coherence in terms of living standards (Jamas and Pollitt, 2005). In this context, the establishment of an internal market for power and gas would support competitiveness within its more contemporary ("beyond-GDP") understanding. This is further reinforced by the emphasis the Commission has placed on retaining the energy-environment equilibrium as well. Finally, it is important to underline that the Commission sought resilient competition policy as a key warrant of maintaining a common market for power and gas in a sustainable manner. The Commission also recognized its role in policing fair competition between power and gas market participants, through verifying the permissibility of state aid granted to energy companies, as well as tackling any barriers to free movement of goods (Huhta, 2021).

On a more technical level, the IEM working document made a first reference towards exploring the concept of allowing independent entity access to the electricity and gas transportation systems – the document highlighted that the existing monopolies in gas transmission could effectively constrain or block the free flow of gas across the borders of the European Community (Maltby, 2013). While the monopolistic nature of gas transmission and distribution activities has not been questioned, the Commission suggested that third-party usage of the gas networks in exchange for a fee should be explored in order to ensure optimal usage of the existing assets, as well as to exert pressure on prices offered to large customers. Indeed, ensuring transparency over the price of gas delivered by the monopolies was seen as a prerequisite for kick-starting fair competition (over industrial customer supply) on this market. At the time the Commission also saw room for competition between subcontractors for investments made by the monopolies – it was believed that public procurement procedures in this field would improve the cost efficiency of the incumbent.

Legal enforcement of some of the IEM working document recommendations for gas was agreed in 1998 at the European Union (EU) level, through the adoption of the first Gas Directive (Directive 98/30/EC). As will be discussed in further sections of this chapter, the idea of introducing competition to the gas market was facing strong opposition from the Member States, hence the aspirations spelled out in the first Gas Directive have been quite modest when compared to the initial IEM working document presented in 1988. It should be noted here that the very concept of economic integration had different interpretations at the time and both were quoted as arguments for or against different attempts to harmonize the internal market performance (Molle, 2006):

- according to the "dynamic" interpretation, economic integration envisages gradual elimination of national discretion over regulating its own market and passing on these powers onto a supranational level;
- "static" integration refers to harmonizing national regulations to help the (still national) markets operate in a coordinated manner.

Judging by the experience of the past decades, it can be stated that the "static" approach to integration finds a lot more support from the Member States that are not very willing to give up their sole right to have a final saying about their internal matters. Haase (2008) makes an important observation in this context, pointing to the fact that North's path dependence concept can help explaining the national authority's reluctance to give up its discretion over regulating the national economy – existing institutional constraints and specific conditions encourage each state to make adjustments to even the "best practice" market model, with the liberalization process resulting in very different regimes, bringing different benefits to individual economies.

Coming back to the first Gas Directive, it has introduced the following set of core principles with the aim to establish a competitive market for gas:

- Companies operating transmission, storage, or LNG infrastructure were to enable non-discriminatory access to these assets. They were also to allow for access to information needed for ensuring compatibility of each of these assets. One notable decision in this context is that the directive did not call for any legal separation of system operators as entities from their former vertical setup – the only requirement in this context was to keep separate accounts for transmission-, distribution- and storage-related services.

- Two network access regimes (Member States could chose to apply either or both at the same time):
    - Regulated access – the terms of connecting to and using the transmission systems, along with all the related costs are regulated by law, are the same for all eligible network users[6] and are being published upfront;
    - Negotiated access – the terms under which an eligible customer is allowed to connect to and use the transmission system are negotiated each time with the system operator, although the main commercial terms applied by the operator need to be published.

  In either case the refusal to enter a contract for using the transmission system had to be duly justified and be based on the reasons related to supply security or economic hardship that such additional load to the system would bring. An independent authority was to be designated in each Member States to resolve any potential disputes around accessing or using the gas transmission system;
- The mechanisms that were to ensure efficient regulation of the market and its transparency were to be established by the Member States but have not been specified;
- Member States that were not connected to the broader interconnected gas network of the other Member States and were supplied by one main external supplier (with a market share over 75%) could apply for a derogation from applying the provisions of the Gas Directive until at least one of these conditions was no longer valid. Similarly, countries with nascent gas markets (i.e. those who have not been supplied with natural gas under a long-term contract within the last ten years) could also apply for temporal derogations – at the time this related to Portugal and Greece, whereas Finland was granted a derogation on the grounds of having only one supplier (Thomas, 2005);
- Additional temporal derogations from participating in a competitive gas market could also be granted to new investment in infrastructure that would otherwise not take place.

Overall, it can be stated that the first Gas Directive has offered little guidance on how competition should be established on the gas market. This likely reflect the unwillingness of

---

[6] Eligibility of a customer to apply for transmission network access and usage was to be defined each time by the Member States, with a minimum customer pool comprising gas-fired power plants and customers consuming over 25 million cubic meters of natural gas per year at a given offtake point. The expectation was that the eligible customer pool defined this way shall comprise at least 20% of the national gas consumption in each Member State. It is worth noting that the Member States have reserved the right to modify the definition of an eligible customer to temporarily limit the scope of such liberalization to 30% - proving that there were still considerable concerns around introducing competition on the gas market back in 1998.

some Member States to introduce competition in the field of gas, as it was often of strategic importance to the national supply security and had growing importance to the overall economic performance. Limited independent customer pool together with weak separation of transmission activities from the former structure of vertically-integrated incumbents, could not enable the development of a competitive gas market or further cross-border integration. It is also important to note that no formal requirement to establish a regulatory authority has been introduced (Heddenhausen, 2007). Even more importantly, that even if non-discriminatory third-party access to the gas network was to become possible in a given country, no one bothered verifying whether there were any uncontracted gas volumes that could still be purchased by the new entrants. This proves that the EU has not learnt much on the UK experience and that further reinforcements to the Gas Directive were clearly required.

The so-called second Gas Directive (Directive 2003/55/EC) has been adopted in June 2003. In the preamble, the Parliament and the Council recognize that significant work still had to be done to address monopolistic behaviour and ensure network access on equal and transparent terms. Since it was non-discriminatory third-party access to gas infrastructure that was seen as a key obstacle to establishing a competitive gas market, the emphasis has been largely put on resolving that issue. Key provisions of the second Gas Directive from the perspective of this study are the following:

- Legal separation of transmission system operators – this has stipulated for unconditional independence of the system operators in their decision-making process within the scope of maintenance, development, as well as granting network access. This related specifically to issues around tariffs for using the gas network and balancing the system supply and demand. These issues will be discussed in more detail in the latter part of this chapter. A clear distinction from the ownership unbundling requirement has also been spelled out, proving that the willingness to retain vertically integrated structure remained strong among the Member States;
- Establishment of regulatory authorities tasked with safeguarding the integrity of the market, particularly the fair gas network access conditions. In this context, the idea was to establish a minimum set of regulatory powers shared by all the national designated institutions, in particular the right to approve the tariffs charged (or at least the way these charges are to be calculated) to network users for using the gas transmission system before they enter into force;

- Protection of vulnerable customers through minimum common customer protection standards (spelled out in annex A to the directive) and gradual market opening. Additional incentives and state aid tools were also permissible, yet in most cases had to be notified to the Commission;
- Clear indication that liquified natural gas (LNG), biogas and other gases that can be safely injected into the natural gas grid should all constitute part of the competitive gas market.

According to the second Gas Directive, eligibility to choose a supplier was to be granted to all non-household suppliers by July 2004 (i.e. the date by which compliance with the directive was to be achieved by all Member States) and to all customers three years later, although the derogations for isolated and emerging gas markets from applying the provisions of the directive remained in place.

What seems to be the most striking in the wording of the second Directive is that it stresses the importance of end customer supply competition without giving much consideration to the development of a wholesale market and breaking the dominant position of the vertically integrated companies. Such partial opening could do little to develop competitive markets as the institutional setup was wrong from the outset, not addressing the monopolistic power of the historically dominant player and not guaranteeing non-discriminatory access to either the infrastructure or the commodity itself. These deficiencies of the Directive have contrasted strongly with the good practices recommended by the European Gas Regulatory Forum (commonly known as the Madrid Forum) that gathers key European gas market stakeholders (including the European Commission and NRAs) to discuss the issues around internal gas market development annually/bi-anually as of September 1999. The Madrid Forum has come up with a list of "Guidelines for Good Practices" for establishing a sustainable gas market that has first been published in 2002 and then revised in 2003, serving as a valuable reference document for establishing improvements to the existing legislation. While these and further recommendations from the Forum will be discussed in the latter parts of this chapter, it is worth underlining several that have resulted in EC introducing amendments to the EU acquis:

- TSO should be transparent about ensuring system balance both in terms of resources it acquires to ensure system integrity and vis-à-vis network users on their individual network injection and withdrawal requests (and the related information exchange);
- TSO should offer the same range of services to all network users at prices that ensure coverage of the costs incurred and a reasonable return on investment where applicable;

- Allocation of the rights to use the network capacity at the given point in time ("capacity products") should be done in a transparent, non-discriminatory manner that matches the market mechanisms (i.e. periods for which gas is contracted and traded through both short- and longer-term products);
- Network capacity should be offered with a granularity of at least monthly products at first and daily products as of July 2005. Once acquired, the capacity products should be traded freely between the network users on a secondary market and at the same time should not be withheld by the owner if the given product is not being used.

Following the recommendations from the Guidelines, the Commission has adopted a new Regulation (EC) 1775/2005 on conditions for access to the natural gas transmission networks. The Regulation has indeed stipulated for cost-reflective and transparent tariffs for network services, yet has not in any way restricted the way through which they should be established within individual Member States. Minimum TPA service list has not been specified to any meaningful extent, yet more specific high-level provisions have been introduced with reference to network balancing and capacity products being offered by the system operators. As recommended by the Madrid Forum, the new Regulation required that all the information related to capacity product offering are published and can be freely traded or sublet on the secondary market. More specific provisions in terms of tariffs and capacity allocation have been annexed to the Regulation as guidelines. It is worth highlighting here that Regulation (EC) 1775/2005 makes a first reference towards establishing common network codes governing network tariffs and capacity allocation rules.

In practice, Member States have largely proved to be slow in implementing the second Gas Directive – 18 out of 25 Member States have been notified of their non-compliance in October 2004 and 10 were still found lagging in May 2005 (Thomas, 2005). The second Gas Directive created an obligation for the Commission to present an annual progress report in establishing a common electricity and gas market and up until a third revision of the Directive was adopted in 2009 all these progress reports have signalled little success in establishing a competitive market. For example, the 2008 Report from the Commission to the Council and the European Parliament on the progress in creating the internal electricity and gas market (COM (2008) 192 final) signals that even legal compliance with the Directive has not been achieved, let alone the overall market performance (that in some cases was not even measured in any way). The report that followed (COM(2010)84 final) concluded that the non-compliance with the Directive remained so widespread, that the Commission has started an infringement procedure in this field against 21 Member States in 2009 (a summary has been published on 26 June 2009 in the Commission’s official Memo/09/296). Apart from pure legal compliance, an Energy Sector Enquiry ran by European Commission’s Directorate General for Competition (DG COMP) as of 2005 (the results of which were published in 2007) has confirmed that effective competition could not develop largely because the structural problem stemming from the market power of the former incumbents has not been addressed properly (Pelkmans and Correia de Britto, 2012). These conclusions are in line with Schwab’s definition of industrial competitiveness and show that faultiness of the institutional setup of an industry prevents developing competitive advantages and those held by the vertically integrated companies were both artificial and unsustainable.

The announcement of the infringement procedure against the Member States followed the formal adoption of a more widespread reform that was to overwrite and reinforce the provisions laid down in the second Gas Directive. In June 2009, a new directive and regulation (collectively referred to as the “Third Energy Package”) have been issued with the intention to liberalize and integrate the gas market by the March 2014. The revised Gas Directive (Directive 2009/73/EC) has recognized that the proposed market design is simply insufficient for establishing the right environment for developing efficient competition. To address that it has (among others):

- Called for full (legal and functional) separation of transmission from production and supply services to ensure that TSOs are truly independent and focused on efficient system development and management – with a deadline set for March 2012 (with certain extensions still permissible). It is worth noticing that ownership of the transmission network was not a condition in this case, provided that the entity designated to operate the network was certified as independent within the understanding of the Directive;
- Placed level-playing field for all the market participants as the overarching goal of any market design implemented by individual Member States (provided that all are compatible with EU acquis);
- Reemphasized the need to ensure NRA’s independence from the government and equipping it with the necessary powers, particularly with reference to transmission tariffs and charges related to system balancing;
- Underlined the need for additional measures to address the structural imperfections of national markets that remain foreclosed as the vertically integrated companies have contracted for the entire available gas supply;

- Encouraged harmonization of rules governing the market through granting the Commission the right to issue guidance notes on specific aspects of the sector's functioning;
- Refers to the Agency for Cooperation of Energy Regulators (ACER) as the entity tasked with ensuring compatibility between national regulatory regimes governing their gas sectors.

It is interesting to note that while the Directive aspired to establish an internal market for gas, it has not established any universal market model that was to be pursued. Instead, it has referred to the need for establishing compatibility between the national markets. In order to facilitate that, ACER has been established by a dedicated Regulation (EC) 713/2009 to formalize the previously voluntary cooperation between NRA's called European Regulatory Group for Electricity and Gas (ERGEG) and equip it with actual regulatory powers. These related to having decision making powers on disputed cross-border issues and an advisory role on a number of subjects related to overall market functioning both at EU and individual Member State level. It was also tasked with monitoring the gas market in cooperation with the national regulators to ensure market integrity and prevent abusive behaviour.

Similarly, the revised Gas Regulation (Regulation (EC) 715/2009) has aimed at bridging the gaps in the regulatory framework and ensure greater convergence among Member States by (among others):

- Establishing formal cooperation between national TSOs, coordinated through a Community agency called European Network of Transmission System Operators for Gas (ENTSO-G) that was to be supervised by ACER;
- ENTSO-G has been tasked with the coordination of TSO cooperation at EU level, preparing non-binding network development plans and providing updates on the overall gas supply and demand situation;
- With ACER and ENTSO-G established, creating network codes that were to constitute detailed rules governing cross-border and market integration issues within the EU. ACER has been tasked in this respect with preparing framework guidelines for the respective network codes whereas ENTSO-G was to propose concrete provisions to the European Commission.

Common regulatory authority and an institution facilitating cooperation between the system operators were clearly a necessary improvement to the institutional setup of the EU gas market. Although neither ACER nor ENTSO-G can be perceived as truly supranational NRA and TSO respectively, their establishment with certain specific tasks and powers ceded onto them has created an environment for better harmonization (Bouzarovski et al., 2015).

Third Energy Package's recognition of the need to address the structural deficiencies of the national gas markets, signalled that the authorities have recognized the importance of having a proper institutional setup for the development of a competitive market - much along the understanding of Clark (1940). With that change of perspective, the updated Gas Directive and Regulation have attempted to address the most significant barriers to the development of competition on the gas market and have over time enabled for gradual development of liquidity on those markets, where their provisions have been properly transposed. Experiences with the transposition of the EU acquis have been described in more detail in subchapter 2.2.

2.2. Fundamental principles governing the functioning of a gas market in the EU

While the Third Energy Package has laid down the high-level principles that were to govern the EU gas market, Ascari and Glachant (2011) note that it has not proposed any single, coherent vision of the desired gas market design (the "target model") that should be pursued by the Member States. For the more detailed rules, it has stipulated for establishing network codes along the guidelines prepared by ACER that were to govern cross-border trading environment. Discussions on the network codes and the desired target model have started at the 2010 Madrid Forum, where two dominant approaches have been discussed (Ascari and Glachant, 2011):

- Market Enabling, Connecting and Securing (MECOS) model that seeks to ensure regulated market access to network capacities on equal terms to all the interested parties (ex-ante approach). Shorter-term trading should develop in response to price spreads between regions, over time leading to price (and ultimate even national market) integration, whereas investment in new capacities should follow analyses of commercial interest backed by long-term commitments that would ensure economic viability;
- European American Model (EURAM) – a model that focuses on market-driven development of both the infrastructure and liquidity of traded products, with the regulation focusing on ensuring an enabling environment. In essence, it differs in the approach towards developing new and utilizing the existing infrastructure, where the EURAM model assumes degree of supply route competition that does not need to secure long-term contractual arrangements upfront (ex-post approach);
- In addition, Clingendael International Energy Programme (CIEP) has presented a dedicated discussion paper on the subject, which has emphasised that the ability to

ensure gas supplies will be a key determinant of EU gas market's competitiveness (Clingendael International Energy Programme, 2011). Harmonized, liquid national markets were considered key to attract the commodity to Europe at a pace sufficient to substitute the continued decline in domestic production. In this context, physical infrastructure could only be perceived as a facilitator of commercial arrangements and the target model should ensure that market participants have the freedom to buy or sell gas as they see fit.

In practice, the actual target model of the EU had to constitute a consensus between the two approaches, striking the right balance between commercial interests and consumer rights, particularly if it was to lead to internal integration of national market, often facing very different market fundamentals, particularly relating to infrastructure development stage and the availability of alternative supply sources. Finally, Dignum et al. (2018) signal that the "target model" as a visionary document developed jointly through an inclusive stakeholder dialogue, constituted an additional policy tool that combined the high-level policy sphere with the existing institutional setup of the gas sector.

2.2.1. Gas Target Model in the EU

The process of defining the desired gas market design for the EU (the target model) was able build on a set of features that were common for the EURAM and MECOS models and have been effectively in operation in several regions of Europe already. This has been confirmed in the 2010 Madrid Forum conclusion paper that stated that the EU market should be composed of interconnected, liquid, national or regional trading regions that facilitate gas flows towards the regions where it is valued most, while enabling the right environment for infrastructure investment (CEER, 2011). In this spirit, the following fundamental market features are worth mentioning:

1. Access to the gas infrastructure has been organized around the physical system of entries into the infrastructure and exits (entry-exit system) where interested parties could signal their interest in injecting and withdrawing gas respectively over a given time. The rights to use the system at a given entry or exit are marketed by the TSO as standard products covering specific time periods, spanning from annual products, through quarterly and monthly, down to daily capacity products. It is worth noting that an infrastructural point at the border of two trading zones (called an interconnection point, IP) is an exit at one side of the border and an entry on the other. While this may seem trivial, the definition

of the technical capacity made available to the market on each side of the border may lead (and indeed has often led) to mismatches leading to suboptimal utilization of the gas infrastructure. Rules governing the process of allocating and revoking the rights to use the capacities at entry and exit points of the EU gas network have therefore been laid down in a dedicated network code;

2. The fees for using the gas infrastructure are charged at entries to and exits from the gas network. Their levels should be reflective of the costs borne by the TSO in its responsibilities for technical operation and maintenance of the gas network, as well as its necessary reinforcement and expansion. Fees for using the network need to be published upfront, ahead of the actual sale of the rights to use the capacity. The actual methodology for setting the level of the fees that are to be charged in a given time period tends to be complex and the permissible forms of distributing the costs between the entries and exits have been spelled out in a separate network code as well;
3. Market participants are required to balance their demand and supply for each day of the year, whereas the TSO monitors the overall network balance in the area it is responsible for and intervenes when the imbalance can affect the overall supply security. The costs or profits resulting from such interventions are by default to be distributed between the parties that push the system out of balance. A dedicated network code on balancing the transmission system has also been prepared, also allowing for additional economic incentives that would encourage market participants to keep track of their balance on a given day and attempt to net their supply and demand on their own;
4. Transactions transferring the ownership of gas in the network take place at a single, virtual point in the network (Virtual Trading Point, VTP) where the supply and demand side would meet. These transactions can either be bilateral ("over the counter") or concluded in standardised products via an exchange. In the first case, the conclusion of a trade is notified to the TSO directly by the sides of a transaction, in the latter the notifications are done by the exchange. National and regional VTPs functioning in the EU are commonly referred to as hubs, although it is worth noting that the term is often misused as a reference to exchange-based trading exclusively.

With these principles in mind, the conclusions of the 2010 Madrid Forum favoured a design along the lines of the MECOS model (Dignum et al., 2018). The EU gas market was defined as a set of interconnected entry-exit zones, each with a single VTP set up to facilitate all buy and sell transactions in that area. No physical congestion should exist between individual zones, hence the market design should ensure that the TSOs and NRAs can receive the necessary investment signals. Interconnection points need to be easily accessible to the market participants of both sides of the border on a non-discriminatory basis. TSOs have been obliged to ensure that the maximum available capacity is being offered to the market and that those who acquire capacity from them, are not doing so to prevent competition from the neighbouring area. Collectively, these principles were to establish liquidity on the VTPs.

The establishment of a vision for a functioning gas market in the EU as a combination of well-connected national "hubs" rather than a truly single and integrated market has attracted some criticism that has been analysed several times since. Indeed, CEER's paper on the draft target model has noted that a "functioning wholesale market" can be one characterized by the following categories (CEER, 2011):

1. Low level of market concentration, reflected by a Hirschmann-Herfindahl Index (HHI) below 2000;
2. At least 3 different gas supply sources;
3. Collective demand for gas within an entry-exit zone of at least 20 bcm that can be satisfied by any combination of short- and long-term products.

The abovementioned set of categories signalled that by default, there would be a strong preference for relatively large entry-exit zones that would pool the demand and expand the number of actors active on a given market from the outset. Table 1 provides an overview of the gas demand size in different EU Member States vis-à-vis its desired level of 20 bcm.

The large discrepancies in the demand size, often very distant from the preferred 20 bcm levels, have pointed towards regional, rather than national markets in most cases. In practice, however, such market merger entailed also political considerations and other challenges, such as establishing a mechanism for distributing the costs of managing a common entry-exit system. Three options have therefore been left available for the Member States to pursue:

- the "default" national market, integrated with neighbouring zones under the common rules and through open access to cross-border capacities;
- a trading region i.e. common entry-exit zone merging the national transmission systems of two or more Member States and operating a common VTP, yet retaining national end-user markets and separate balancing responsibilities;
- fully integrated cross-border market area, including the domestic market.

Table 1. Annual inland gas demand of different Member States [bcm]

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Belgium	18.31	20.48	17.80	17.89	18.13	15.85	17.21	17.45	17.82	18.36	18.50	18.39	18.45
Bulgaria	2.65	2.82	3.22	2.99	2.91	2.86	3.11	3.21	3.32	3.14	2.93	3.02	3.42
Czechia	8.33	9.84	8.31	8.39	8.47	7.52	7.87	8.49	8.73	8.27	8.68	8.82	9.46
Denmark	4.36	4.95	4.15	3.89	3.73	3.17	3.21	2.99	3.20	3.17	3.10	2.83	2.89
Germany	88.84	92.43	84.85	84.98	88.87	76.90	78.91	85.13	95.41	92.84	95.50	91.19	96.21
Estonia	0.64	0.70	0.63	0.66	0.68	0.53	0.47	0.52	0.49	0.50	0.46	0.42	0.48
Ireland	5.00	5.50	4.86	4.76	4.55	4.42	4.41	5.14	5.23	5.43	5.50	5.48	5.21
Greece	3.56	3.85	4.76	4.36	3.86	2.95	3.17	4.10	4.95	4.86	5.26	5.83	6.45
Spain	35.95	35.77	33.26	32.85	30.07	27.20	28.20	28.78	31.35	31.13	35.52	32.11	33.82
France	44.56	49.61	42.20	43.44	44.08	36.98	39.66	43.27	43.48	41.64	42.40	39.46	41.97
Italy	78.02	83.10	77.92	74.92	70.07	61.91	67.52	70.92	75.16	72.69	74.47	71.27	76.40
Cyprus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	1.53	1.82	1.60	1.51	1.47	1.31	1.33	1.38	1.22	1.43	1.35	1.11	1.19
Lithuania	2.68	3.06	3.34	3.26	2.66	2.54	2.50	2.20	2.31	2.14	2.23	2.37	2.27
Luxembourg	1.27	1.36	1.18	1.21	1.03	0.98	0.88	0.81	0.79	0.78	0.78	0.71	0.76
Hungary	11.33	12.13	11.56	10.33	9.41	8.53	9.14	9.72	10.37	10.07	10.25	10.63	11.26
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.35	0.37	0.38	0.38
Netherlands	49.58	55.95	48.96	46.82	46.71	40.77	40.07	42.04	43.46	43.04	44.91	44.13	42.34
Austria	9.02	9.90	9.34	8.93	8.59	7.84	8.36	8.73	9.38	8.88	9.28	8.78	9.33
Poland	16.09	17.22	17.17	18.24	18.24	17.87	18.32	19.14	20.14	20.94	21.09	22.12	23.54
Portugal	4.84	5.14	5.11	4.52	4.34	4.07	4.69	5.02	6.25	5.76	6.07	5.95	5.72
Romania	13.31	13.58	13.96	13.56	12.41	11.79	11.26	11.37	12.00	11.99	11.22	11.74	12.08
Slovenia	1.02	1.06	0.91	0.87	0.85	0.77	0.82	0.87	0.91	0.89	0.90	0.90	0.95
Slovakia	5.40	6.10	5.63	5.29	5.51	4.54	4.64	4.72	4.97	4.91	4.91	4.89	5.47
Finland	4.28	4.72	4.12	3.69	3.49	3.07	2.72	2.51	2.35	2.64	2.59	2.57	2.59
Sweden	1.21	1.63	1.30	1.13	1.09	0.89	0.81	0.92	1.04	1.10	1.05	1.40	1.30

Source: Eurostat 2022.

In can be stated that CEER’s recommendation in the context of establishing spanning beyond national borders was pragmatic and recognized the potential complexities stemming from any attempts to impose national market mergers onto the Member States. Instead, a lot of emphasis has been placed on interconnectivity between the individual trading zones along the lines of the then to be established network codes.

2.2.2. Gas network codes

The establishment of the network codes as a set of common principles that were to govern cross-border trading were an important step in spelling out the fundamental EU gas market principles and will be discussed next. Before that, however, it is important to underline one other legislative novelty that has preceded the establishment of the network codes. In October 2010, Regulation (EU) No 994/2010 has been adopted, addressing gas security of supply considerations in view of growing EU’s dependence on gas imports. Apart from encouraging greater gas import and storage capacity, this regulation has introduced a requirement for the interconnections between the Member States to be bi-directional (i.e. capable of facilitating gas flows from country A to B and the other way round). Apart from outright benefits to supply security by enabling cooperation during a crisis, such change enabled the integrated gas market to perform much better through enabling gas flows towards market areas with the highest price (Rodríguez-Gómez et al., 2015).

All of the network codes prepared by ENTSOG had to follow the framework guidelines prepared by the EU regulatory authorities cooperating under ACER. The final provisions of the codes that have been outlined in this chapter have undergone public consultation and have received the approval of the NRAs before being submitted to the European Commission. Altogether, the network codes have regulated four different areas of cross-zonal gas trading that will be discussed below, with the emphasis placed on the market-related provisions of these documents.

A) Capacity Allocation Mechanism Network Code (CAM NC) and Congestion Management guideline

The CAM NC has been implemented through the adoption of a Commission Regulation (EU) 984/2013, further amended by Regulation (EU) 2017/459. The revised regulation of 2017 has clarified some of the definitions used, added further rules on investment in new capacities and stipulated for closer harmonization of the contractual terms under which capacity products are offered by the TSOs. For the sake of transparency, only the provisions of Regulation (EU) 2017/459, as the one in force at the time of preparing this dissertation, will be discussed. This decision also stems from the fact that the expected benefits brought about by the establishment of the network codes were expected to become tangible only after all four of them have entered into force.

CAM NC has established a standard, transparent capacity allocation procedure for all interconnection points (IPs, i.e. points connecting the entry-exit areas within the borders of the EU), as well as points connecting LNG terminals and storage facilities to the EU transmission system. By default this allocation is done through ascending clock auctions[7] held simultaneously for relevant points, following a predefined auction calendar. Products on offer have been standardised, covering the duration of yearly, quarterly, monthly, daily and within-day products, offered in that order for the same periods and in common unit (kWh/h). In practice, the default approach stipulates for auctions of the standard capacity products defined as outlined in table 2.

Apart from establishing a common calendar and list of capacity products, CAM NC has also obliged the TSOs to ensure that at least 10% of the technical capacity at a given point of the system is offered during the nearest upcoming annual auction and another 10% at the upcoming annual quarterly auction. For ease of operations, adjacent TSOs have also been obliged to offer the respective entry and exit products on the border they share as a bundle, so as to avoid potential mismatches that could have resulted in part of the capacity acquired at one side of an interconnection point becoming redundant. For the same reason, if more than one interconnection exists on the profile between the adjacent TSOs, capacity of these interconnections was to be auctioned jointly under the same auction procedure. NC CAM has also stipulated for a transparent incremental capacity process that was to ensure that investments in new transmission capacity are underwritten by sufficient commercial demand to ensure satisfactory return.

Although the capacity products described above have been defined as standard and default to be used, NC CAM has allowed for “interruptible” day-ahead products to be offered to maximize network utilization. Unlike the standard products (called “firm”), interruptible

---

[7] In an ascending clock auction, participants bid for the quantity of capacity they are interested in under consecutive rounds held consecutively, each with a growing price (called a price step). The TSO is obliged to define large and small price steps – if in a given round the aggregate demand exceeds the available capacity, next round begins with a price supplemented with the large price step, if the demand is lower, small step applies in order to maximize the amount of capacity sold.

products allow access to network capacity provided that the network can still accommodate for the additional flows at a given point in time i.e. these products are sold without guaranteeing that the capacity will be always available on demand. These products, however, need to be offered with a discount and only after the entire available firm capacity has been sold.

Table 2. Standard capacity products

Product	Starting date(s) of the products offered	Duration	Number of auctions, auction mechanism
Yearly	1 October	Gas year (1 October year Y until 30 September year Y+1); capacities should be auctioned for at least five upcoming years.	Once per year. Ascending clock auction.
Quarterly	1 October, 1 January, 1 April, 1 July	Three months in the given quarter, offered concurrently for the entire gas year.	Four times per year. Ascending clock auction.
Monthly	1st day of each month auctioned	Upcoming calendar month.	Auction held each day of month M before the start of the auctioned month M+1. Ascending clock auction.
Daily	Beginning of the gas day (5:00 UTC)	Gas day (5:00 UTC on day D+1 until 5:00 UTC on day D+2)	Auctioned each day D for day D+1. Uniform price auction[8].
Within-day	From the auction finish until the end of the gas day	Within the given gas day until the end of that day.	Auction held each hour on the day D (until 00:30) for the remaining hours of day D, starting from auction hour +4. Uniform price auction.

Source: own elaboration based on Regulation (EU) 2017/459.

---

[8] At an uniform price auction, participants submit their bids through defining the amount of capacity they are interested in and the price they are willing to pay for a single bidding round. Up to 10 bids can be submitted by a single auction participant. The lowest price out of all the bids accepted at the auction is the price paid by all the participants, who’s bids have been accepted.

Finally, NC CAM has signalled that the auctions for capacity products in question should be organized at "(…) one or a limited number of joint web-based booking platforms" set up by the TSOs. Adjacent TSOs have been obliged to agree on a single platform at which the capacity at the interconnection point between them was to be sold. If they fail, decision is left to the respective NRAs and ultimately to ACER. Although the establishment of a single EU capacity platform has proved to be possible on the power side, NC CAM for gas has limited the number of auction platforms down to three.

Annexed to the Regulation (EC) 715/2009 (with further changes of 24 August 2012) are the Congestion Management Procedures (CMP) Guidelines. These guidelines apply to all IPs and govern instances when demand for capacity at a given point in time exceeds its availability for that time period, because a certain share of capacity has been contracted for. In such contractual congestion situations, contracted, yet unused capacity should be made available back to the market in order to maximize network utilization. These measures are important from the perspective of establishing an internal market for gas, since efficient cross-border capacity utilization supports price convergence and gradual integration. The guideline has proposed the following solutions:

- Implementation of oversubscription and buy-back schemes under which excess (i.e. beyond technical) firm capacity is being sold to the market participants and bought back from the holders on a voluntary basis when all nominations could not be accommodated for at a given point in time;
- Short-term use-it-or-lose-it mechanisms whereby holders of capacities that do not use them over extended period of time are restricted to use them in the future and these capacities become offered to the market again as day-ahead products;
- Long-term use-it-or-lose-it – consequently underutilized long-term capacity products are withdrawn from the original holder and offered back to the market. Long-term capacity is consider systemically underutilized if on average 80% of the contracted capacity is not nominated and that behaviour cannot be justified in any way;
- Surrender of contracted capacity – a voluntary solution whereby the TSO becomes obliged to accept the surrender of yearly/quarterly/monthly capacity sold to a network user and offer it to the market again. All the rights and obligations stemming from holding the capacity rests with the surrendering user until it becomes sold again.

B) Network Code on Gas Balancing of Transmission Networks (NC BAL)

The next area to be harmonized via the introduction of network codes was the way system operators ensured that gas supply and demand within their entry-exit zones were in balance on each day. These mechanisms can have tremendous impact on market liquidity, as it determines the degree to which system users can match the supply and demand within their own portfolio. Therefore, the Commission Regulation (EU) No 312/2014 establishing a Network Code on Gas Balancing of Transmission Networks (NC BAL) has introduced a set of common rules that were to govern the way EU entry-exit areas (called "balancing zones") should maintain a supply-demand equilibrium. NC BAL has attempted to harmonize the operations of EU balancing zones in a number of areas – those that are most relevant from the perspective of a efficient wholesale gas markets shall be described below. By default, the responsibility to maintain a balance between the inputs to and offtakes from the transmission system has been placed directly on the system users. When conducting gas transactions, both the seller and the buyer (or a trading platform acting on their behalf) notify the TSO of the transfer of ownership of a respective portion of gas in the system (called a trade notification) for the given gas day. The system operator maintains a record ("balancing portfolio) of gas volumes owned by each market participant or their organised groups and amends them according to the notifications received.

For physical deliveries, market participants submit nominations specifying the amount of gas injected into or offtaken from the system at a specific point and over a defined period. In this respect, NC BAL harmonizes the way gas quantities should be nominated at interconnection points. Market participants can also instruct volumes of gas to be injected into or offtaken from the transmission system at interconnection points. In either case, a nomination needs to specify the network point in question and the intended direction of flow, identify the counterparts and the time period to which the nomination is referring to on the given gas day. Notifications for IPs need to be submitted on the previous day by 12:00 UTC and the notifying market participant needs to be in possession of sufficient capacities at the respective point for the request to be accepted. Each balancing portfolio manager needs to ensure that its offtakes (both within the balancing zones and at IPs) are offset by corresponding injections on a given gas day, otherwise it will be out of balance and as such, will push the overall balancing zone out of balance as well.

Under NC BAL the TSO has been tasked with resolving any remaining imbalances existing within the respective entry-exit zone in order to ensure safe operations of the gas network. Identified imbalances can be addressed by the TSO through taking balancing actions i.e.:

- Buying on selling gas using short-term standardised products i.e. day-ahead or within day gas products offered on a trading platform. In essence, the system operator can enter the market to sell surplus gas or buy the missing volumes through accepting bids and offers placed by the market participants at the time when balancing action is taken;
- Contract for balancing services that can be called upon when necessary, as agreed with the service provider. Acquisition of such services is to follow a public procurement procedure in order to ensure non-discriminatory treatment of all the interested market participants.

It is worth noting that the trade in short-term standardised products are the preferred balancing action as they promote the use of the market mechanism to bring back the system into balance. Balancing services have been proposed as an alternative wherever more specific, tailor made actions were deemed necessary, or where it could be reasonably assumed that short-term products would not be available to the TSO when necessary. In any case, the costs of balancing actions are charged onto all network users, hence NC BAL has allowed the NRAs to offer incentives to the system operator to offer incentives for the system operator to balance the system efficiently.

From a network user’s perspective, the requirement to maintain a daily balance between the injections and offtakes has also been supplemented with an economic incentive in the form of an imbalance charge. For any imbalance calculated as the difference between inputs and offtakes on a given gas day, the responsible balancing portfolio holder is required to pay (for negative imbalance) or entitled to an imbalance charge calculated for that gas day following a transparent calculation methodology, as approved by the NRA. The charge is to be reflective of the costs incurred by the TSO to address the imbalance and in case of short-term standardised products it is the marginal price:

- For negative imbalances, it is the higher of the two:
    - highest short-term standardised product[9] offer accepted by the TSO on a given gas day;

---

[9] It needs to be noted that a reference to short-term standard products in the context of marginal prices used for imbalance charge calculation is a deliberate simplification for the sake of clarity – in practice, the code refers to

    - weighted average gas price on a given gas day, supplemented with a small adjustment.
- For positive imbalances, it is the lower of the two:
    - Lowest short-term standardised product bid accepted by the TSO on a given gas day;
    - weighted average gas price on a given gas day, minus the small adjustment.

Both the bid/offer and the weighted average price used for determining the marginal price is taken from a trading platform selected by the TSO and approved by the NRA when determining the balancing terms. The small adjustment is the additional commercial incentive to ensure that the market participants have an ongoing and undisputed interest in attempting to self-balance their portfolios. In certain cases, NC BAL allows the NRAs and TSOs to also impose additional obligations on the market participants to support maintaining system balance also within-day (within-day obligations). Such measures, however, create additional burdens on network users, do not support establishing competitive markets and have been implemented only in several balancing zones, hence will not be discussed further.

NC BAL envisaged balancing schemes that would be financially neutral to the TSOs. In order to ensure that neutrality, system operators have been obliged to pass on any costs and revenues stemming from the balancing actions onto the network users (one exception being the financial incentives that the NRA might chose to offer to the TSO for efficient balancing of the system). The net financial profit or loss stemming from balancing the system, is to be recollected from/returned to the network users in form of a so-called neutrality charge (paid proportionally to their share in network utilization).

With the obligation placed on network users to self-balance their position on each day, information they are equipped with have started to play a prominent role in establishing efficient balancing mechanisms for the EU entry-exit zones. Since network users have been made directly responsible for maintaining system balance, they needed to have access to the relevant information on their inputs and offtakes for the given day. This fact has also been recognized by NC BAL that required the system operators to provide information on the overall system balance, any balancing actions taken and the balance recorded for each participants for the given gas day. The network code has further specified that these information need to be provided free of charge, available also in English and the quoted volumes should be published using a

---

title products in general, hence can also entail locational and temporal products. These instruments are specific to different balancing zones and are used in exceptional cases and as such, fall outside the scope of this study.

common unit (kWh or kWh/h and kWh/d). It needs to be noted that the granularity of information on inputs and offtakes for different point in the system varies, since some of them are metered within-day and others once per day or less frequently. In practice, NC BAL has harmonised the requirements on the publication times of the metered information (for intraday and daily metered points) and forecasts (for non-daily metered points). Information provision on the balance situation of each network user used for settlements has also been harmonized to an extent, although this has limited impact on market development and performance, hence will not be discussed in detail.

Another determinant of efficient balancing relates to access to flexibility services to react to potential mismatches between their inputs and offtakes on a given day. Market participants informed about their balance on the given day should have the option to use the assets in the system that can help addressing temporal surpluses and shortages, such as storage facilities or so-called linepack. The latter refers to the technical capacity of the gas transmission network to accommodate physical volumes spanning beyond the typical hourly demand that can be utilized to even out temporal imbalances by the network users. According to the provisions of NC BAL, the TSO may offer this service for a fee that would at least cover the related costs and needs to offer it on a transparent, non-discriminatory basis.

Finally, since effective, market-based balancing relied on a number of conditions, including liquidity of short-term markets, NC BAL has introduced a set of interim measures that could be implemented in the EU balancing zones until the TSOs could rely on the availability of gas sold through the trading platforms. Different interim measures could be implemented concurrently, although all of them were to be duly justified and should be phased out within five years from NC BAL’s entry into force. The following interim solutions have been considered:

1. Balancing platform – a separate platform for trading in balancing products could be set up and managed by the TSO, whereby the TSO would be a side to each transaction;
2. Interim imbalance charge – if the available market prices do not offer a reliable price that could be used for imbalance charging, the authorities may chose to replace it with a different price (e.g. fully administered or derived from transactions cocluded on the balancing platform);
3. Tolerances – wherever the network users cannot rely on gas market liquidity, flexibility services or the necessary information to manage their daily imbalances as envisaged by NC BAL, a certain imbalance tolerance can be introduced. Deviations from the portfolio

balance which do not exceed the tolerance level defined, were not to be subject to an imbalance charge.

C) Network Code on Interoperability and Data Exchange Rules (INT NC)

The third network code that has been established for the benefit of cross-border trading is the network code on interoperability and data exchange rules (INT NC, Commission Regulation (EU) 2015/703). INT NC sought to harmonize the technical and operational standards implemented across the EU, together with the data exchange channels used. The code has sought to harmonize, among others, the gas quality standard across the EU, thereby expanding beyond pure cross-border considerations.

In essence, INT NC has addressed many of the operational aspects of managing the gas flows by the system operators. Although not quite visible to the entities conducting transactions and not central to the presented study, it is important to underline that the harmonization on the operational side is a key facilitator of cross-border flows and market integration. One of the main provisions of the code that facilitate these flows relate to a requirement to sign interconnection agreements between adjacent TSOs. Such an agreement needs to govern the rules on coordinated matching and allocation of volumes on the IP, control of flows, communication in case of exceptional events or dispute settlement process.

From the perspective of wholesale market, coordinated matching procedures under the interconnection agreements are key enablers of gas trading across different balancing zones. Matching arrangements cover the scope of information exchange between the TSOs on the nominations received and the procedure to govern any potential mismatches on both ends of the IP in question. The agreement also governs settlement procedures for the deviations between the allocated and measured flows for the given day.

The INT NC introduces a common set of units that should be used for information publication and data exchange related to transactions at interconnection points. Although such provision might seem trivial, the possibility to quote all the flows across Europe using a common set of units reduces the risk of potential mismatches stemming from conversions when crossing borders between different balancing zones. In addition the code has obliged the TSOs to cooperate in preventing any trade restrictions that might result from quality mismatches, or differences in gas odourisation practices. Finally, for ease of information exchange, ENTSO-G has been task with developing common network operation tools to facilitate safe and efficient data exchange. NC INT entered into force on 1 May 2016.

D) Network Code on Harmonised Transmission Tariff Structures for Gas (NC TAR)

Once entry-exit systems have been established, with charges being applied every injection and offtake point in a given section of the transmission system, there was a need to establish a clear methodology according to which network costs are being distributed between these points. Coordination in this respect has proved to be particularly problematic and well reflected by the time it took to prepare Regulation 2017/46 that established a network code on harmonised transmission tariff structures for gas, so-called NC TAR.

Despite its name, NC TAR has managed to provide for a limited level of harmonization in terms of tariff-setting and its provisions focus more on transparency requirements (Mosácula et al., 2019). NC TAR allows for several methodologies through which the transmission service costs are divided between the entry and exit points of a given system, resulting in major differences between the transmission service costs across Europe. The tariff regimes have been divided into two types – non-price cap and price cap regimes. The first type is most frequently applied and allows the TSO to earn a predefined level of revenue, typically defined as an absolute value or a certain rate of return. Any under- or overrecoveries recorded for the given tariff period need to translate into an additional charge or discount respectively over the next period to ensure that the allowed revenue level is reached, yet not exceeded. Price cap regimes treat revenue as a target and a maximum tariff that can be charged by the system operator is set. A combination of both regimes can also be applied. Under each regime the allowed/target revenue is defined for certain period.

The choice of a given methodology has to be prepared by either the TSO or the NRA and approved by the NRA following a public consultation where the proposed methodology is explained and justified. As part of the justification, the authorities also need to provide a comparison to a reference capacity-weighted distance (CWD) methodology to improve transparency and allow for better benchmarking of the methods eventually applied to different entry-exit zones. The selected reference price methodology is to apply to all entries and exits in the given area, although NC TAR does allow for discounts to be applied at entries to and exits from storage facilities and to entries from LNG terminals. Costs of applying the discount (defined as at least 50% discount for storage entry and exit) is then redistributed onto the remaining points in the system. NC TAR also allows applying a separate fee directly related to the actual volume of gas being transported over the network – so-called commodity charge. The commodity charge usually represents a fraction of the resultant transmission tariff and by default is to represent the cost associated with physical shipment of the molecules (i.e. largely the cost of fuel used in compressor stations). As such, the commodity charge is not allocated to any particular entry or exit, but it is a single value that is used for calculating the volume-related fee for moving gas through the system.

TAR NC stipulates that the price stemming from the reference price methodology and applied at interconnection points should serve as the reserve (starting) price for yearly capacity products (as defined under CAM NC). For shorter-term capacity products this reserve price can be adjusted with seasonal factors and multipliers. Since natural gas is a major energy carrier used for heating purposes, the seasonality of its demand should not be surprising and the difference between the demand peak during the summer and winter periods is quite substantial especially when winters are particularly cold (Moreno et al., 2019). Multipliers, on the other hand, reflect the gas industry's gradual move towards operating in the short term – the development of market-based competition, growing volatility of the gas demand (often resulting from intermittency of power generation from renewable energy sources) and the expiry of the long-term take-or-pay contracts altogether have caused a shift in the gas supplier's preference, reflected in higher demand for capacity products in the short-term (quarterly, monthly, daily and within-day)[10]. Both the shift towards short-term and the increased network utilization during winter are factored in the transmission service cost through multiplying the abovementioned reference price by the applicable factors i.e.:

$$P_r = P_{ref} \times M \times S$$

where:

P_r – reserve price of a capacity product

P_{ref} – reference price of a capacity product

M – multiplier

S – seasonal factor

---

[10] The gas sector's shift towards operations in the short-term is a result of many different circumstances that cannot be fully explained and listed without diluting the focus of the presented study. Nonetheless, it is worth explaining the two aspects of this shift that are of critical importance to the competitiveness of gaseous fuels studied here:

- Take-or-pay contracts were the standard business arrangement before the gas market liberalization, where the supplier contracted gas from the producer for multiple (usually 15 to 25) years with a clause obliging to offtake or pay for a certain minimum volume of the contracted commodity (going up to 90% of the contracted amount) during that period (Checchi et al., 2009).
- Intermittency of renewable power generation affects the demand for gas since the sudden surges in the renewable energy sources output are often covered by gas-fired power plants that are technically capable of delivering power in a very short time, often counted in seconds (Pelka et al., 2019).

For bundled products, the reserve price is calculated as the sum of reserve prices applicable to the products comprising the bundle.

The resultant reserve price also serves as the minimum price for a given product and applies in situations where the capacity demand is no larger than the capacity offered at a given point by the system operator. The value of multipliers that can be set by the TSOs for the products they offer has been capped at values indicated in table 3. It deserves to be stressed, however, that NC TAR does allow for the multipliers to exceed the cap in duly justified cases. The cap on the seasonal factors, in turn, is derived from the value of multipliers applicable in a given timeframe and refers to the arithmetic mean of the product of the applicable M and S.

Table 3. Multipliers applicable to different capacity products

Product	Maximum multiplier*
Quarterly and monthly	1,5
Daily and within-day	3

Source: own elaboration based on Regulation 2017/46.

Finally, NC TAR introduces detailed rules on the times and scope of periodic consultation that need to be run by the NRAs and/or TSOs. Once consulted, the proposed tariff methodology, together with the feedback collected from the market participants, are to be submitted to ACER for an opinion. After receiving the opinion the NRA takes a final decision on adopting the methodology. Similarly, the network code also lists the type of information that need to be published ahead of the yearly capacity auctions and before the tariff period respectively. NC TAR’s complete text has entered into force on 31 May 2019.

Collectively, the Third Energy Package and the four network codes have established detailed rule governing the functioning of the gas market and preparing it for further integration. The problem, however, remained with implementation of the Package by the Member States and with the willingness to address the market power that the former incumbents still held within certain EU Membe States. In order to better explain the process of developing liquidity on the different national markets and the consequences this might have for competitiveness, several examples will be discussed in the following subsection.

2.3. European gas market development stage at the end of 2021

Adoption of the Third Energy Package and the network codes has also entailed a set of monitoring requirements imposed on both ACER and ENTSO-G in order to ensure better compliance and timely implementation (Costescu A et al., 2017). These reports had to be periodically presented to the Commission and also made publicly available. Information from these reports, supplemented with information from independent studies and reports by industry associations can help understanding the institutional setup of the different markets that, in turn, helps explaining their success or failure in establishing liquidity in gas trading over the past decade.

In 2022 both the Third Energy Package and the network codes were still in force, laying down the principles for the gas market. As of 2008 the European Commission is preparing periodic updates on EU gas sector covering quarterly periods. However, since many of the provisions of the Third Energy Package (including full unbundling of TSOs) had a formal deadline set for the year 2012, it seems appropriate to begin the analysis from that year onwards.

2.3.1. Progress driven by gradual implementation of the EU acquis

Year 2012 was a peculiar time for the gas markets, both because of an ongoing recession stemming from the financial crisis (that affected demand) and because it was the year following the Fukushima nuclear accident that has resulted in a significant shift in demand for liquified natural gas on the global market, diverting considerable volumes of gas from Europe to Japan (Hayashi and Hughes, 2013). Despite the conditions, the Commission report for Q4 2012 has stressed that the EU gas markets have started to converge, with the day-ahead hub price difference between the most expensive and the cheapest market dropping below 1 EUR/MWh. While this price convergence could not be perceived as a reliable indication market development (the same report signals that nearly half of gas volumes imported over the same period were using oil price as index) the introduction of hub trading and competitive prices already had two tangible effects (DG Energy, 2013):

- Growing short-term prices in response to weather-driven demand spike have successfully attracted additional imports and flows towards regions where gas was most needed;

- With hub-traded gas prices more accurately reflecting the gas supply-demand interplay, Norwegian gas producers have started moving away from oil indexation towards market prices, challenging the traditional setup tying the gas market to oil prices.

Apart from that it can be stated that only the UK's virtual trading point, called the National Balancing Point (NBP), was working its way towards becoming a competitive market. Total volume of gas traded at the NBP over 2012 covered for over 68% of the total gas volume traded in all of the EU over the same period (DG Energy, 2013). Leading position of NBP in this context appears to reflect the time and effort that the stakeholders in Great Britain have spent to develop competition on the gas market.

A more in-depth analysis of the gas market development stage is typically offered under ACER's annual market monitoring reports. For 2012 the Agency made a valuable observation that the gas market, although increasingly global, remained constraint by limited capacity to transport the commodity over long distances that frequently existed between the points of production and offtake, restrictions to cross-border trade and historical, yet still widespread, reliance on oil prices as a reference for gas transactions. All these constraints (i.e. limited cross-border capacities, regulatory barriers to trade and oil-indexed supply contracts) were valid for the EU gas market not only as the international context, but also as internal barriers to convergence and development of liquidity. As a result, price spreads both between Europe and other regions of the world, as well as between individual EU Member States could reach very high levels, affecting the competitiveness of national economies. Indeed, ACER has pointed to the fact that lack of adequate price signals for the different balancing zones sometimes resulted in gas flowing against the direction price spreads would suggest, leading to welfare losses. In the context of barriers to trade, the Agency has pointed to one area that was not addressed under the Third Energy Package and that related to licensing requirements. The 2012 report could not even provide a precise indication of the scale of discrepancies existing in that field between the Member States but clearly signalled that entities wishing to operate inside different balancing zones were very likely to be facing different regulatory regimes.

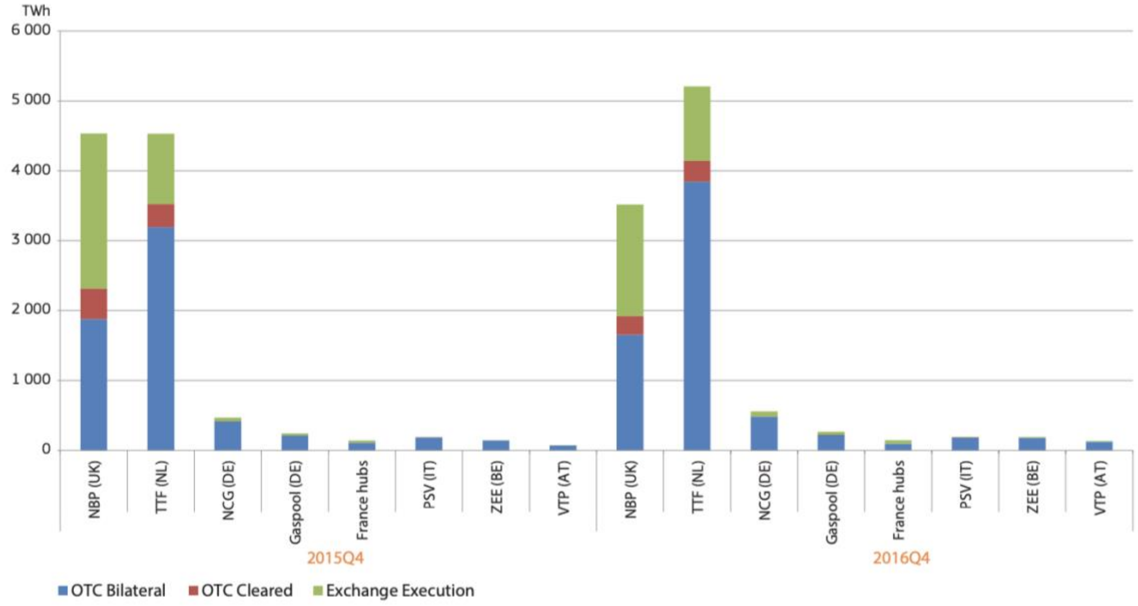
Looking at the churn ratios calculated for the existing hubs, ACER has also found that the Dutch virtual trading point called the Title Transfer Facility (TTF) has surpassed the NBP in Q2 2012 (Agency for Cooperation of Energy Regulators, 2013). This impressive liquidity was attributed largely to the fact that the country benefitted from having several supply sources, some of which were already delivering the commodity using the short-term TTF gas index. Otherwise, the other hubs were reported to be at relatively early stages of development, gradually setting up their balancing markets (such as the Italian PSV) or beginning to auction cross-border capacities (Austrian CEGH) (ACER, 2013). On the example of Austria and Italy ACER has also signalled, however, that expansion of capacity availability and accessibility between zones with VTPs established has a positive effect on price convergence and liquidity.

As works on reforming the regulatory framework for the gas market continued, the position of NBP was no longer as central as reported for 2012. The following reports, beginning from the one covering the second half of 2013 and first half of 2014 have recorded a notable diversion of trade volumes towards hubs in continental Europe and swift expansion of the Dutch virtual trading point, TTF. Improving liquidity in North-West Europe seemed to reflect the fact that with having several sources of gas supply there was scope for competition that encouraged abandonment of oil-indexation. Considerable advantages brought about to consumers able to sign supply agreements quoting hub-based pricing have exerted significant pressure on suppliers to readjust their offers. In the case of Gazprom, the move away from oil-indexation became more attainable after its 2013 loss in arbitration court against Germany's RWE, where the latter, as the client under a long-term supply contract, has challenged the oil-indexed price formula (DG Energy, 2014). The court ruling has reportedly supported Poland's PGNiG, Italy's ENI and France's GDF renegotiation of the pricing formulas. That tendency was particularly important since in 2013 there were still ten Member States that relied on a single supply source to cover for more than 75% of their annual demand (ACER, 2014).

Over the course of 2015 TTF has surpassed NBP in terms of volumes traded and growing reliance on hub-based trading (with an increasing share of long-term contract using hub indices as reference) market liquidity was on the rise – see figure 6. It is worth to emphasise that over-the-counter (OTC) transactions have historically dominated the gas markets and covered significantly larger volumes than exchange-based trading.

2015 was also the first year for analyses monitoring progress in implementing NC BAL and NC CAM. First of them was to be implemented by October 2015 and the latter by November 2015. Both are of significant importance for development of liquidity and market integration, hence were closely monitored by ACER and their early implementation was encouraged via regional initiatives for enhanced cooperation.

Figure 6. Traded volumes on the main European gas hubs [TWh]



Source: European Commission (2017).

First implementation report for NC BAL was particularly interesting as it stressed from the outset that the code's implementation for the sake of pure legal compliance should not be a goal of any balancing market reform. The target of an efficient balancing scheme should be supporting liquidity of short-term trading, that supports market participant's ability to balance their portfolios (ACER, 2021a). The Agency has recognized the fact that establishing a working balancing scheme is complex and takes time for the market participants to gain experience in managing their positions. In terms of market integration, it became clear that the number of derogations and interim solutions made possible under NC BAL could not lead to harmonization in the field of balancing. ACER has also pointed to different interpretation of the code's provisions leading to inconsistent and incomplete implementation of its provisions across the EU.

The challenge of establishing a well-functioning balancing scheme frequently related to the existence of a market for short-term products. Without liquid short-term trading and access to flexibility services, even complete and timely information on a portfolio's imbalance would not allow the responsible party to react accordingly. Different interim measures have indeed been implemented in response to this problem as a result. In fact, the discrepancies were so significant, that ACER has decided to analyse and compare the implementation stage of the code after dividing the Member States into three groups (see table 4).

With the NC BAL implementation progress spanning from full compliance (UK, BE) to nearly no progress towards establishing a market for gas (BG, RO), the fact that the Commission's reports do not even quote liquidity for many of the Member States listed in table 4 should not come as a surprise. Therefore, while the monitoring report on NC CAM was far more positive in terms of the level of compliance achieved across the EU, the resultant market design remained far from perfect (ACER, 2016). Consecutive editions of the monitoring reports continued to signal that the design of the balancing mechanisms remained suboptimal in most countries, including those operating reasonably liquid and mature hubs (ACER, 2021b).

Table 4. NC BAL implementation stage by 2016

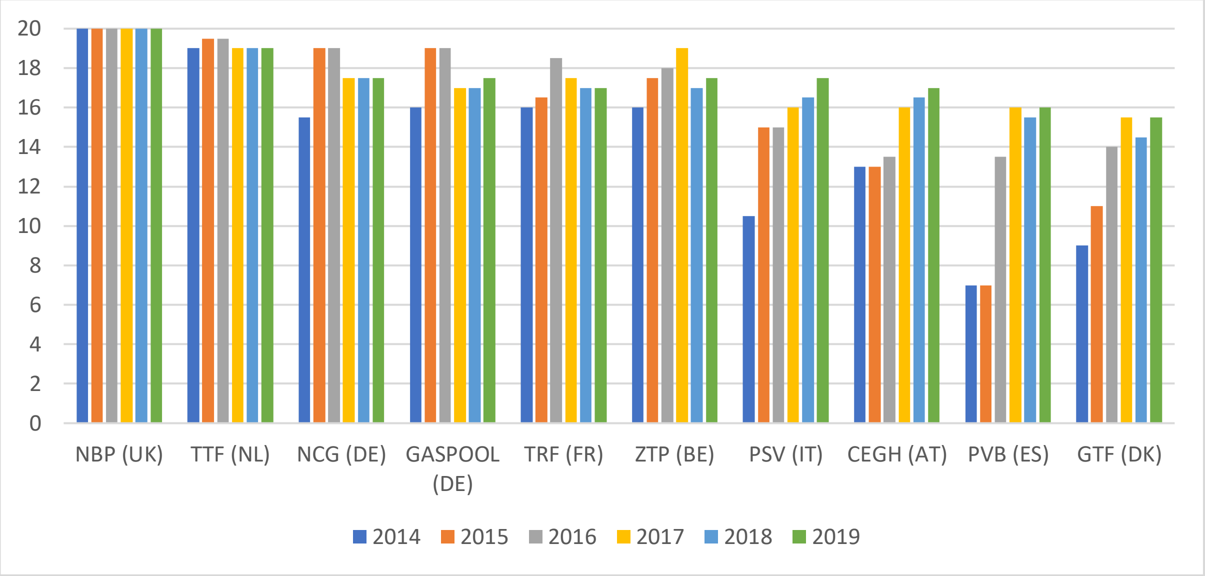
Group	Compliance level	Countries	Critical comments
Implementation in 2015	>80%	UK, FR, DK, BE	Regime very rigid in AT, hindering trading.
	<80%	DE, NL, SI, HU, AT	
Implementation in 2016	>70%	ES, CZ	Low visibility of TSO balancing actions, no clarity over the future use of short-term standard products for balancing in IT and PT
	<70%	IT, HR, PT	
Interim measures	>70%	PL	Balancing platforms approved yet in most cases not implemented or not functioning. BG, RO and GR have not established VTPs
	<70%	SK, LT, IE, SE, EL, RO, BG	

Source: own elaboration based on (ACER, 2021a).

2.3.2. Improving gas market performance and a shift towards market-based pricing

In terms of actual market performance, the industry association called the European Federation of Energy Traders (EFET) prepares an annual Gas Hub Assessment, that evaluates the ease of trading at different virtual trading points set up in the EU. The study is much in the spirit of ACER's "beyond legal compliance" approach, focusing on the actual performance under the regulatory regime applicable to the given VTP using a set of criteria common to all hubs being analysed. The study is published as of 2014 and attempts to attribute a score on a scale 0 to 20 describing the relative successfulness of each hub. The methodology used (although altering slightly over the years) is set up to evaluate the "quality" of the regulatory regime underpinning a given VTP on one hand and its actual performance (in terms of liquidity, options to conclude trades, widespread use of standard contracts for OTC transactions etc.) on the other. While by default the performance indicators should stem from and follow the market liberalizing reform, the study proves that this is not always the case. The scores prepared by EFET have been divided into "developed" and "developing groups for ease of presentation (on figures 7 and 8 below) and analyses, not least because the first group has been attributed a score early on and their scoring has ceased in 2019. It should be noted that the score for the French hub is presented in a simplified form for the years 2014-2018 since until then the country functioned as two separate balancing zones with dedicated VTPs. Such division inside the country is not uncommon and historically followed physical constraints that prevented effective operation of the national transmission network as a single balancing zone. For example, the German hubs mentioned on figure 7 emerged from the initial 20 zones in the past, through 6 zones before 2010 and only managed to merge into a single zone in 2021, as will be discussed in more detail in chapter IV (Heather, 2021).

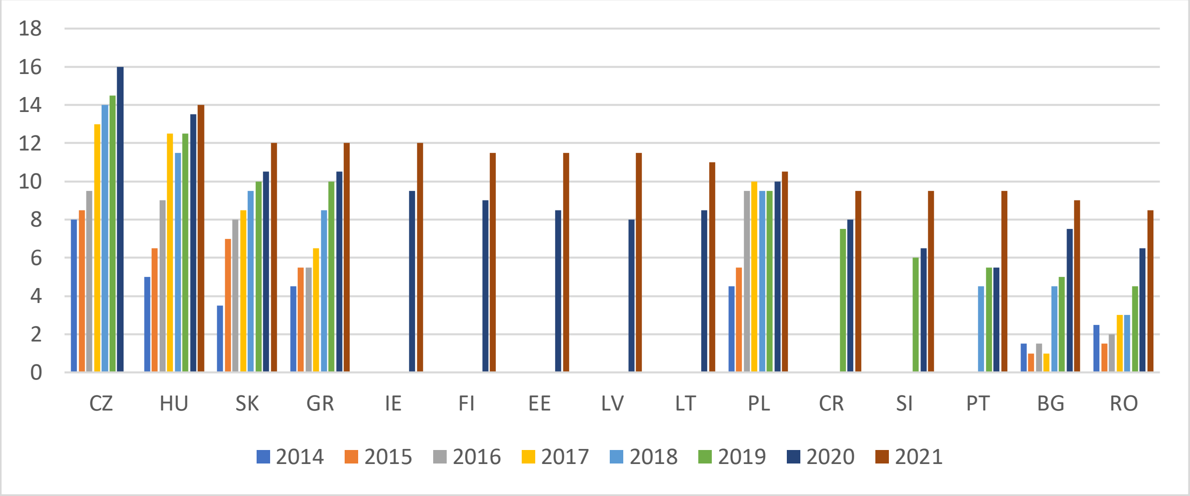
Figure 7. Established hubs evaluation by EFET



Source: own elaboration based on (EFET, 2023).

The historical scores for the "developed" hubs confirms the dominance of NBP and TTF as the most liquid hubs in Europe. Their relative score difference reflects the slight difference in the perceived transparency of the market design and regulatory changes envisaged, as the use of English as a language for publication and consultation is scored separately - and the preference for the use of Dutch language as the primary, often sole language for these communications continued to exist and has its grounds in the national legislation. The perceived deterioration of the German hubs (NCG and Gaspool) over the years related largely to changes to the categories being scored by EFET as of 2017, but also from the fact that new legislation allowed for additional measures to be used for network balancing that spanned beyond the pure use of short-term standard products trading on the market. In general, the hubs depicted on figure 7 have collectively been excluded from further analyses, since their score level indicated that the overall market design has reached the stage at which compliance with the principles promoted under the Gas Target Model and the remaining points (reflecting market performance indicators such as liquidity, activeness of price reporting agencies and brokers supporting gas trading) would likely develop over time. It was since assumed that the last recorded score would carry forward without notable changes, while the focus was shifted onto the underdeveloped hubs depicted on figure 8.

Figure 8. Developing Hubs evaluation by EFET



Source: own elaboration based on (EFET, 2023).

The situation for the developing hubs depicted on figure 8 reflects the fact that many of these countries have pursued the gas market reform relatively late (not least because some of them benefitted from a derogation from applying the EU acquis that stemmed from their isolation from the other Member States and reliance on a single supply source). Out of the list presented on the figure, only Czechia’s gas hub has been attributed a score signalling it maturity and has not been attributed further score as of 2021. Polish hub is peculiar in this groups, as they have started reasonably well and early on in the region and its attributed score over the years reflected improving compliance, removal of interim balancing measures and other barriers (such as limited use of English). In practice, the score achieved by the Polish hub already in 2016 remained largely stagnant, showing that despite the regulatory regime for the market has been designed reasonably well, the attractiveness of the market as such remains low. This underperformance stems from the revised obligation on gas trading license holders to maintain strategic gas stocks that effectively cemented the market power of the former incumbent and discouraged most competitors from participating in the Polish gas market (Lont, 2020). Such kind of market interference could not be properly reflected by EFET's study, yet Poland's example confirms that pure legal compliance with the provisions of the Third Energy Package and the network codes is not enough to establish a competitive market.

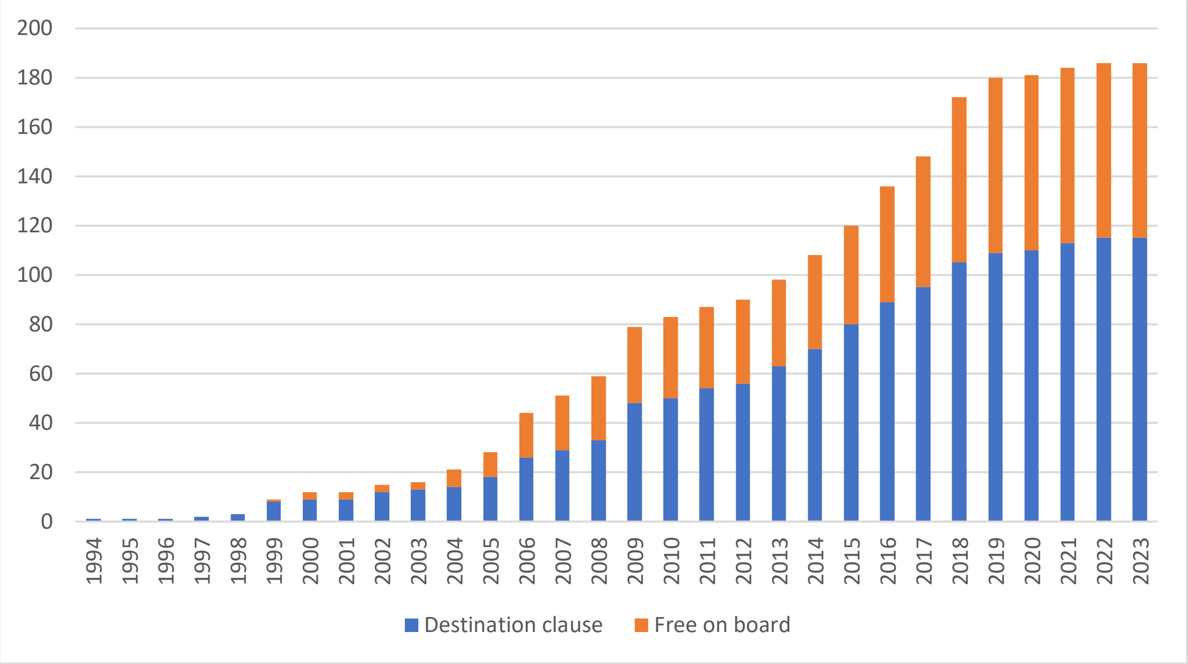
In the broader context, it should be noted that, whereas the internal market for gas was to induce market-based competition within the EU, it is also part of the wider environment where the market participants are also competing, primarily over gas supplies. The roll-out of liquified natural gas (LNG) technologies and trading have gradually turned natural gas into a globally traded market. Ever since the first LNG carrier had been constructed in 1959, gas trading over long distances began to develop. Although commercially shipping gas in cargos rather than pipelines seemed like a poor alternative, significant distance between points of production and consumption particularly in Asia, have made the use of liquified gas the only viable option to countries like Japan. Over time, costs of new vessels and related infrastructure fell, particularly after South Korean shipyards began to compete over contracts for LNG vessels and technology allowed for larger ships to be built (Gardner, 2017, pp. 7-11). In addition, the development of floating LNG solutions (i.e. mooring LNG vessels to serve as mobile terminals that could serve as liquefaction/regasification facilities) have tremendously lowered the costs of developing new terminals and making access to remote gas fields commercially viable. Collectively, these developments have led to a significant increase in LNG infrastructure and the number of carriers in operation between 2010 and 2020 (Sönnische, 2020). It needs to be noted that roll-out of international gas trade would not be possible without international agreements that supported free movement of goods and technical standardization.

Gradual market liberalization in the US and Europe have supported the need for having an adequate price reference for gas and over time a growing preference for short-term transactions. LNG was most popular in Asia, yet just like in other parts of the world, the related infrastructure developed under long-term, oil-indexed contractual arrangements. In fact, it was argued that the contractual constraints were even stronger in the context of ship-based gas trading. Apart from the take-or-pay and destination clauses (predefining the delivery point for the cargoes) such arrangements could also include adjustment mechanisms that could prevent or limit potential competition between the seller and the buyer within the zone where gas was delivered by e.g. requiring additional consent before further volumes are sold outside the contract in question (Sullivan, 2017).

As markets began to offer a reliable price signal for gas and the number of LNG carriers grew (both in capacity and in number) monetization of the price spreads between Asia, Europe and the Americas became possible and attractive. Gas trading entities exerted pressure to remove the restrictive clauses from the sales contracts and replace them with so-called free-on-board clauses where the transfer of ownership and responsibility for the cargo was transferred onto the buyer as soon as gas was loaded onto the ship (Javid and Shahmoradi, 2016). This allowed the companies to divert the acquired gas towards the region with the highest price, establishing competition over the commodity on a global scale. It deserves to be mentioned here that some gas purchase agreements still deliberately entail destination clauses that prevent the commodity from being diverted elsewhere – such arrangements may also be needed to support project financing, particularly since the LNG infrastructure is capital intensive. Other restrictions on the freedom to ship gas also exist (such as geographically limited insurance scope for the carrier or technical incompatibility with some receiving terminals) yet these are increasingly being overcome with market arrangements that allow cargo swaps between the trading entities. Technical developments allowing ship-to-ship LNG transfers (so-called lightering) also improve the possible geographical reach of gas transactions.

With natural gas becoming a globally traded commodity, European countries have a growing interest in having the ability to attract additional gas deliveries at times of increased demand. High liquidity of the EU hubs, particularly TTF, have established the gas price indices they publish as a reference for a growing number of gas transactions concluded globally. With the global LNG market moving increasingly towards short-term volumes underpinned by flexible supply contracts with no predefined destination (see figure 9), European gas markets have to remain competitive in order to satisfy the demand.

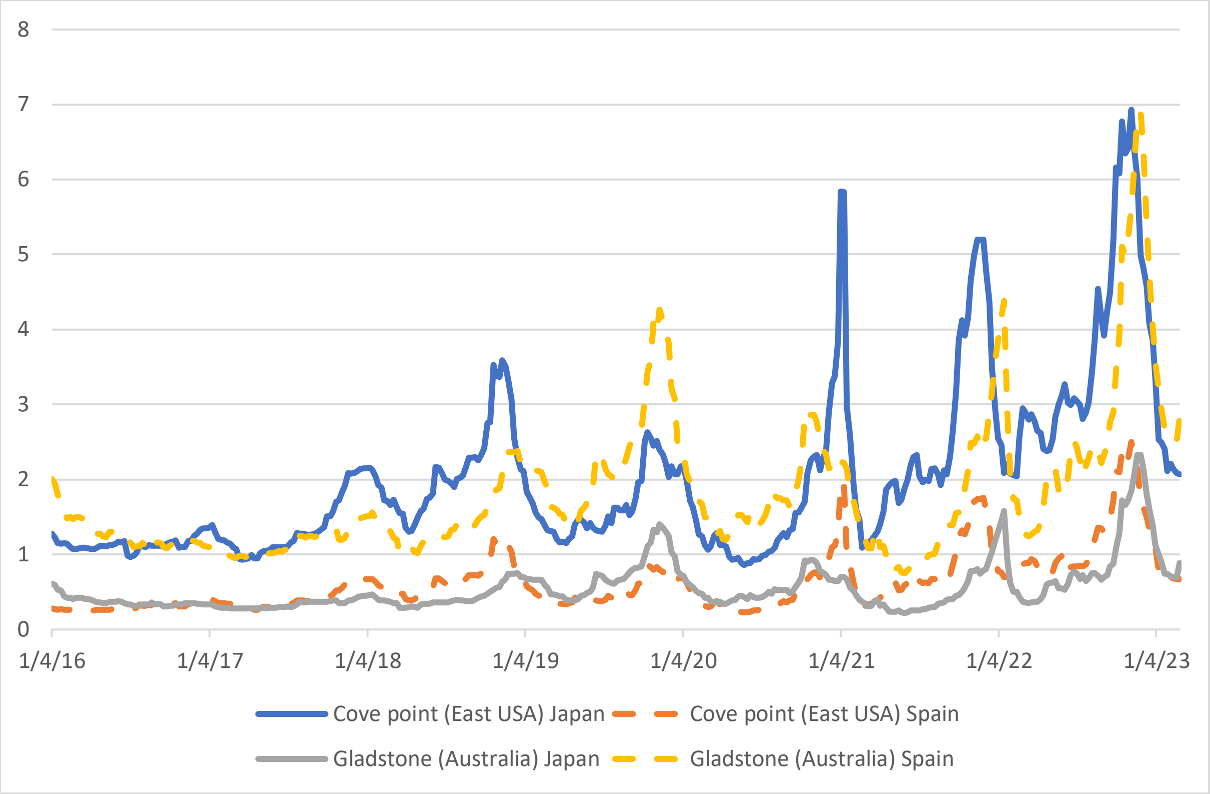
Figure 9. Number of contracts in force globally with a predefined destination vs. free-on-board



Source: own elaboration based on Refinitiv Eikon data (2023).

When considering the competitive position of Europe over gas deliveries from different parts of the world, one needs to consider the delivery costs that can weigh heavily on the actual attractiveness of the prices being offered vis-à-vis different importing countries. This becomes particularly apparent when comparing the delivery costs to the two largest LNG importing regions of the world – EU and Japan. Figure 10 depicts a comparison of the historical costs of shipping gas into Spain and Japan from Australia and USA, showing that distance plays an important role in the context of competition over gas cargoes at times and that the related transaction costs can prove to be significant. This is an important feature of the global gas market that needs to be kept in mind when analysing the competitive position of Europe as one of the largest LNG importers.

Figure 10. Comparison of delivery costs into Japan and Spain [USD/MMBtu]



Source: own elaboration based on Refinitiv Eikon data (2023).

Conclusions

The ambition to develop competitive gas markets across the EU have proved to be far-fetched and the overall degree of market harmonization between the Member States remains patchy. Countries in Western Europe that have started their works on developing competition earlier that Member States from Central and South-Eastern Europe are largely performing well and have developed a satisfactory degree of competition on their national markets that, in turn, have become more integrated. An analysis of the historical developments around gas market regulation seem to confirm that in practice, the success or failure of a given regime stems largely from the degree to which the national authorities are truly wiling to open up to competition. UK’s hard stance on breaking up the gas monopoly contrasts with the Polish approach, where the former has quickly exposed the unbundled entity to competition and the latter retains a strong protective policy favouring its interests.

Apart from pure economic determinants that should be kept in mind when studying the competitive position of the European Union on the global gas market, it needs to be remembered that the contemporary perception of competitiveness spans beyond GDP considerations.

Existence of a competitive market for gas has significant political implications and offers may countries that for years have been reliant on a single supplier an option to source gas elsewhere and seek better commercial prospects. This supports the concept of an internal market for gas inside the EU and to improve its attractiveness as a direction of LNG shipments. The 2022 war in Ukraine has resulted in an unprecedented energy crisis that has largely ended EU-Russia cooperation in terms of gas supply for the foreseeable future and interconnectedness of the Member States and their access to alternative gas supplies has become the top priority.

Despite the considerable concerns over gas supply security in the context of 2022 and 2023, EU continues its aspirations to develop a sustainable market compatible with the goal of achieving climate neutrality. A number of initiatives have been undertaken in this context to pursue that goal and all of them either already have or will have considerable impact on EU's gas sector in the coming decades. These matters will be discussed further in chapter III.

Chapter III

3. Competitiveness of the European gas sector in the context of decarbonisation

The question about the future of gas in the European Union has been raised in different contexts over the years. First, its place in the national energy mix was questioned, due to decreasing national reserves and imminent growth in reliance on imports. The second time the subject came up, the role of natural gas was questioned at the verge of renewable electricity revolution – on one hand it was seen as a transition fuel that provided the necessary flexibility to the electricity systems on the way to fully-electrified, carbon-neutral future, on the other, the reliance of renewable generation on fossil gas was seen as a vicious circle. Eventually, as full electrification of the economy was no longer deemed possible, the debate has focused on replacing fossil gas with more sustainable alternatives. When it became clear that renewable gas is an indispensable part of the EU's energy mix in the foreseeable future, works have commenced on fostering the decarbonization of the entire gas sector, so that it could accommodate for the needs of the consumers in hard-to-abate sectors.

The aim of this chapter is to provide a comprehensive overview of the different policies and strategies aimed at gas sector's decarbonization and to evaluate their coherence and adequacy in the context of the sector's competitiveness. Such analysis will be performed in view of the competitiveness theories discussed under chapter I.

3.1. Demand for gas in the process of decarbonisation of EU's economy

Before the different options for the gas sector's decarbonization are discussed in more detail, it needs to be noted that a certain residual gas demand is expected to exist even under the most optimistic scenarios for electrification of the economy by 2050 and beyond. This demand was frequently associated with the fact that gas-fired power generation is the only technology thus far capable of offering the necessary flexibility to the electricity system with a growing share of intermittent renewable electricity generation (IEA, 2022). Such association of the two technologies that made the RES-E development (deemed as sustainable) reliant on co-existence with natural gas, attracted a lot of attention as a vicious circle, particularly to import-reliant Europe (Li and Mulder, 2021). Nonetheless, even though the problem is not trivial to resolve, it is far from being the only source of gas reliance, with heating and cooling, industrial usage of gas as feedstock and industries depending on controllable sources of high-heat temperatures, being the three other areas that in many cases have found few alternatives to gaseous fuels to date (Honore, 2019).

3.1.1. Sustainable alternatives to natural gas

The fact that demand for gas will not disappear remains true even at the verge of the much-expected "hydrogen revolution", where many difficult to electrify sectors are expected to be able to decarbonize through the use of hydrogen. The new fuel, however, still does not offer a universal alternative to natural gas and this is evident also when looking at new national hydrogen strategies, none of which envisage any material fuel switching from natural gas within a time horizon of 2030 and beyond (ENTSO-G and ENTSO-E, 2022). This, however, does not mean that hydrogen should only be viewed exclusively as an alternative to natural gas in the future – in the process of methanation, hydrogen can be blended into so-called synthetic methane, with qualities and properties of natural gas, which at some point could make the fossil fuel obsolete (Becker et al., 2018). The challenge here lies in the fact that contemporary hydrogen production processes that are ready for commercial applications at scale, are reliant on fossil fuels themselves. In other words, synthetic methane will only be able to facilitate a sustainable alternative to natural gas once the technologies for producing renewable hydrogen become sufficiently mature and their output is sufficient to cover a very sizable demand. While this is becoming increasingly more likely in the future, it should be borne in mind that, as will be explained in more detail in this chapter, such new technologies are facing considerable regulatory risks, not least because the definition of what constitutes "sustainably produced" gas is neither common for different production technologies nor stable over time (Zhou and Baldino, 2022). This combination of uncertainties both from the perspective of technology readiness and regulatory environment, makes economic analyses of a hydrogen market at a wholesale level prone to many mistakes and possibly more credible several years from now (Truby et al., 2022).

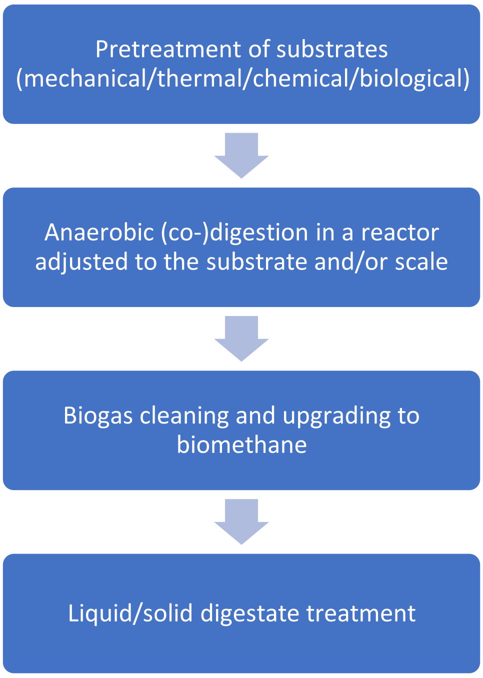
The second alternative to natural gas, similarly prone to regulatory risks, but based on technology readily available for commercial application is biomethane – product of anaerobic digestion of organic waste, that is further cleansed and adjusted to the quality of natural gas (Kabeyi and Olanrewaju, 2022). Once upgraded into biomethane, this fuel has the chemical features and physical qualities of natural gas, making it a good substitute of the existing fossil fuel that would not require the end consumers to adjust their appliances. Production of biogas (i.e. product of anaerobic digestion before it is cleansed and upgraded) already offers a number of economic, social and environmental benefits, considering that (Sobczak et al., 2022):

- It supports the displacement of fossil fuels in the economy, be it through its direct use as a fuel for electricity production, or through its upgrading to biomethane that can be injected into the existing gas grid;
- It entails treatment of different forms of waste, be it from agriculture, food industry and other, as well as sewages. Furthermore, the post-production digestate that is left from the biogas production process is a natural fertilizer that supports the circulation of nutrients in agriculture;
- It supports job creation in rural areas, particularly since biogas and biomethane plants can be quite sizable. It deserves to be noted, however, that in spite of the benefits, the deployment of biogas plants still faces multiple obstacles, including from the local communities that are afraid of the plant’s downsides, such as noise or bad smell.

Although predominantly reliant on subsidies over the past years, biogas plants can benefit from different sources of income (i.e. for the energy delivered, sale of certificates of origin, sale of fertilizers and sometimes from charging fees for collecting waste that would otherwise have to be disposed of), potentially making them commercially viable in the future (Daniel-Gromke et al., 2019).

In short, the biomethane production process can be outlined as depicted on figure 11. Different technologies for pre-treatment of the substrates for the anaerobic digestion process can be applied depending on its composition – the goal is to maximize the biogas yield. Since substrates are essentially different forms of waste from different sources and/or processes, they may contain different forms of “contaminants” that can inhibit the production process (Khan et al., 2022). The core anaerobic digestion process is in fact a sequence of different biological processes of biological degradation of organic matter in the absence of oxygen (Kumar and Ankaram, 2019). The complexity and sensitivity of this process has been widely recognized, particularly in the context of co-digestion, where different substrates are used in a single reactor to maximize the biogas yield (Kangle et al., 2012). The resultant gas, apart from methane and carbon dioxide, includes traces of other chemicals, sometimes dangerous pollutants (such as nitrogen oxides and sulphur oxides), that need to be removed before gas can be accepted in the gas network (Gkotsis et al., 2023). The number and efficiency of technologies that enable cleansing biogas keeps increasing over time, yet it needs to be noted that they all tend to be expensive, leading to only a fraction of biogas plants making the necessary investment (Khan et al., 2021). In any case, the cleansing and upgrading technology used naturally depends on the end use of the gas, as this dictates the required level of purity (Lisowyj and Wright, 2020). Finally, the digestate, i.e. the by-product that is left after biogas is being produced, can be processed to serve as fertilizer, as it is naturally rich in nutrients, such as nitrogen and phosphorus. This stage, once again, relates to a whole spectrum of technologies suitable for the preparation of the digestate for safe usage and/or commercial distribution – this process on its own can also prove to be quite costly, as it can be energy intensive and can carry material costs related to transport and storage. (Törnwall et al., 2017). Collectively, it can be stated that the complexity of the process requires comprehensive planning from the potential investors, who need to find locations for the installation that would allow both access to the substrates and proximity of the customers for the energy and fertilizer produced.

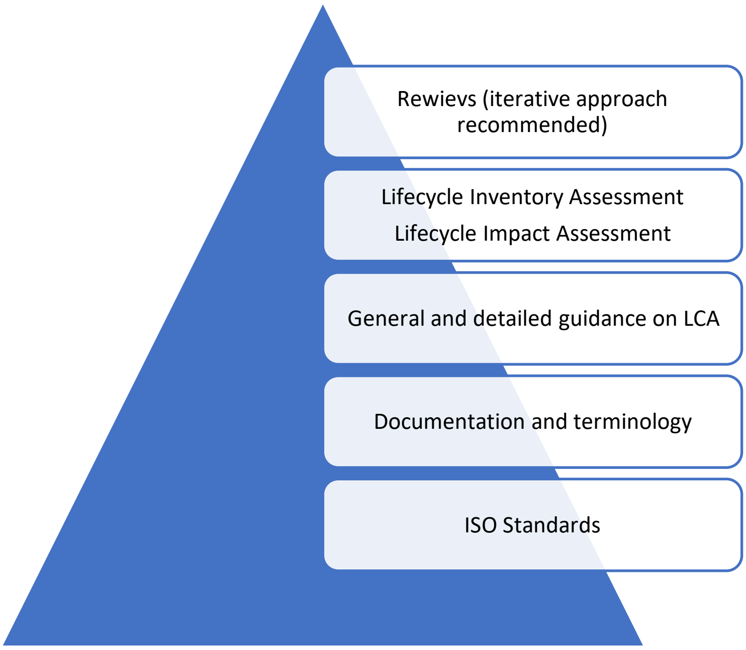
Figure 11. Biomethane production process



Source: own elaboration based on (Lisowyj and Wright, 2020).

On the downsides, it needs to be stated that biomethane can indeed support the decarbonization of the gas sector if its production leads to emission savings throughout the entire value chain. In the context of biogas and biomethane, this primarily relates to the feedstock used, but it also factors in the different technologies used that affect the amount and composition of the emissions resulting from a given plant’s operation. Such assessment of environmental analysis of product’s lifecycle (i.e. all the consecutive stages from acquiring raw materials, throughout their processing, up until treatment of waste past the final product consumption) follows the internationally-acknowledge procedure of lifecycle analysis (LCA) governed by the ISO standards 14040:2006/Amd 1:2020 ("Principles and framework) and 14044:2006/Amd 2:2020 ("Requirements and guidelines"). This approach been long acknowledged by the European Commission as appropriate to assess the actual impact of products and services on the environment. More detailed principles governing the different processes and data collection have been prepared in 2010 (figure 12). Commission's guidance documents prepared in this respect have been designed to be in line with the ISO standards, although some of the requirements have been made stricter and others have been added (JRC, 2010). One aspect to be stressed as of critical importance to this study is the fact that the LCA approach does not factor in any emissions offsetting along the process that might be stemming from e.g. the acquisition of carbon credits – such actions can only be recognized upon the final product consumption (JRC, 2010). This means that at each stage, the related associated emissions need to be recorded and passed onto the next stage until the final good is used. In order for that to be possible for biomethane, the respective amount of emissions related to a given consignment of gas produced in a facility over a defined period of time needs to be properly recognized and recorded on a certificate issued by an authorized body.

Figure 12. European Commission's overarching guidance governing the LCA



Source: own elaboration based on (JRC, 2010).

In the context of biomethane, the LCA is the default method set to verify whether gas produced in a given facility can be eligible for support as a contributor to the economy's decarbonization under EU rules (Directive 2018/2001). The EU acquis sets a number of thresholds that need to be met in terms of greenhouse gas intensity depending on usage, for a given energy carrier to be deemed renewable or low-carbon. This also explains while the environmental impact of a given good or fuel is only evaluated upon its final consumption – the way the fuel is consumed affects the emissions level. For biomethane, these thresholds are as follows[11] (JRC et al., 2019):

- 94 gCO_2e/MJ for transport fuels
- 9,7 gCO_2e/MJ for the outright supply of natural gas (used as feedstock)
- 56,2 gCO_2e/MJ for natural gas combustion

All the values quoted above set the default comparative value of emissions, versus which the savings stemming from the usage of biomethane are to be calculated. Intuitively, the higher this value is, the easier it becomes to meet the savings threshold of 80% or more. At the same time, it should be stressed here that the both the reference values and the GHG savings thresholds are subject to reviews over time, making the regulatory environment for biogas and biomethane production unstable (Zhou et al., 2021). Similarly, different default carbon intensity values are also set for the different types of feedstock used – this issue will be discussed further in the context of the former and upcoming revisions of EU directives and regulations that ultimately govern what types of biomethane can be deemed sustainable.

When discussing the sustainability features of biomethane, one cannot forget to mention the so-called food-feed-fuel trilemma, alternatively the food-energy-climate change trilemma (Harvey, 2014). This issue manifests itself in the fact that production of different forms of biofuels, including biomethane, can offer substantial additional yields, if specific, dedicated plants (commonly referred to as energy crops) are used as feedstock (Das, 2017). The problem is that planting dedicated crops for energy production affects the land and water use, potentially displacing food and/or feed production. Although significant technological advancements have been made in terms of efficient use of energy crops since the problem was first raised, different restrictions are introduced in the legislation to ensure that biomethane production is primarily based on residues and use of dedicated crops is marginalized and possible only in certain exceptional cases (Blesh et al., 2019).

---

[11] The CO_2e unit mentioned here refers to CO_2 equivalent, an artificial value used to compare the global warming potential of different greenhouse gases, that brings it down to the same potential as presented by CO_2. This metrics is to ensure that the greenhouse gas emissions variable used in the LCA also captures the emissions of gases such as NO or CH_4, the global warming potential of which is many times higher than of CO_2.

Finally, before the reforms of the legislative environment for renewable and low carbon gases are discussed in more detail, it should be mentioned that the LCA approach does allow for the application of technologies that prevent the emission of GHG into the atmosphere. This means that carbon capture and storage (CCS) or usage (CCU) can still allow for the usage of natural gas or relatively carbon-intensive biomethane in the future (Butnar et al., 2020). Both terms relate to a variety of technologies that enable capturing carbon dioxide from combustion processes, whereby the CO_2 is separated with a varying level of efficiency and subsequently directed to a location where it is to be stored permanently or is subsequently used in a different industrial process (Lerche Raadal and Saur Modahl, 2022). These processes are facing a lot of criticism, particularly if they are used in combination with fossil fuels, as they only address the emissions into the atmosphere and not the environmental impact related to sourcing and transporting fuels such as coal, oil or natural gas. It needs to be acknowledged, however, that given the urgency of actions to prevent irreversible changes to the climate, their application may be the only available solution in the medium term (Cuéllar-Franca and Azapagic, 2015). In any case, the application of CCU/CCS technologies may also have considerable upsides when combined with sustainably produced biogas and biomethane, given that the lifecycle emissions of such combination may be negative, potentially making up for the surplus emissions taking place elsewhere. Such positive effects relate to the fact that during the growth phase, plants absorb and process CO_2 during photosynthesis, while the CO_2 that could then be released back when these plants are processed as biomass is captured, resulting in a closed carbon cycle without additional emissions into the atmosphere – the process of sourcing the biomass, however, requires a thorough analysis and different factors, such as the duration of the plant's growth phase, need to be duly taken into account (Liptow et al., 2018). In other cases, such as biomethane produced from wastewater or manure, negative emissions can also stem from the fact that untreated residue of this sort can be a major source of emissions on its own – as such, their further processing should not be merely deemed useful, but necessary (Zhou et al., 2021).

3.1.2. Decarbonization solutions to date – subsidization and emission taxes

The existing regulatory environment for the support of biogas production and/or penalization of greenhouse gas emissions have collectively allowed for the process of gas sector decarbonization to already start in some countries, although on a modest scale. There are several legal documents that together establish a framework for the deployment and use of biogas at EU level, yet the key provisions may be found in the Renewable Energy Directive (RED) and its amendments that have inherited the provisions of directives governing the uptake of biofuels in transport. Indirectly, the EU's scheme for taxing the emission of greenhouse gases also supports the uptake of sustainably produced biogas through penalizing the more carbon-intensive alternatives e.g. in electricity production.

The renewable energy directives in the EU have been introduced to promote the uptake of "clean energy" defined as energy used for electricity, heat or (gaseous or liquid) biofuel production that do not result in any net greenhouse gas emissions (European Commission, 2020a). It's first edition (2009/28/EC) constituted a first "all-encompassing" document covering electricity, heat and biofuels, inheriting many of the provisions from the renewable electricity directive (Directive 2001/77/EC) and directive on the promotion of the use of biofuels (Directive 2003/30/EC). It has introduced a first binding target for biofuels at the level of 10% calculated against petrol and diesel consumption in the national transport sectors by 2020. The first RED (RED I) also made it clear that only sustainably produced biofuels could count against the related target and be eligible for subsidies. The directive also made it clear that land should not be converted to acquire biomass necessary for biofuels production and made such conversions possible only in limited instances where the process could credibly lead to emission savings over a predefined period of time (see section C of Annex V to RED I for further details). Finally, even with all the other conditions met, sustainable biofuels needed to ensure greenhouse gas emissions savings of at least 35%, growing to 50% as of 2017 and to 60% the following year for all production facilities which commenced operations as of 2017 (Article 17 of Directive 2009/28/EC).

Overall, a number of detailed requirements have been introduced to factor in the emissions from acquiring the biomass and any related land use, fuel production and its transport in the GHG calculations. Sustainably produced biogas could be used for electricity generation or cleansed and injected into the gas grid or processed into a fuel for transport in a compressed or liquified form. From the perspective of this study, biomethane injected into the gas grid and competing against natural gas will be of key focus, as this is the form in which the biofuel is in direct competition with natural gas at a wholesale level. Nonetheless, measures stimulating the demand for biofuels in general can support the demand for biomethane (or indeed competition over it), hence can still be deemed relevant in the context of competitiveness.

In order to encourage the uptake of biofuels, the RED has supported the establishment of a scheme enabling their efficient trading (i.e. ensuring that it can be sold to the highest bidder) with a premium over fossil-fuels. In order to do that, a robust methodology for evidencing the time, place and type of clean energy produced had to be established to underpin unrestricted trading of sustainability characteristics of the fuel on an open market. Such mechanism was necessary to ensure that a complete chain of custody, as required under an LCA, could be provided for different products and services, offering a comprehensive overview of their environmental impact from sourcing raw materials down to end consumption and waste disposal. Several systems of making this possible for energy products have been considered and eventually two different have been applied to biogas used as biofuel and as fuel for electricity production. These schemes offer a different degree of information granularity and include (Scarlat and Dallemand, 2011):

- Book-and-claim – under a book-and-claim scheme, the green value of the biofuel's consignment is detached from the molecules upon leaving the production facility and is traded separately (figure 13). In other words, under this setup, the chain of custody for the sustainability of the fuel ends upon its production and the related emissions are captured only up to that point. A consumer acquiring the document issued under the book-and-claim system (called Guarantee of Origin, GO) can use it against a corresponding volume of a (fossil) fuel consumed within the validity of such record. Similarly, a supplier can acquire GOs to fulfil an obligation to support renewable energy production or for marketing purposes;
- Mass balancing – a mass-balance scheme is a more nuanced form of evidencing sustainability. Here the emissions related to a given consignment of biofuel are also certified at the point of production (on a document called a sustainability certificate) and the certificate is used at point of consumption, yet a physical link needs to exist between the production facility and the consumer wishing to use the certificate (figure 14). As will be explained further in chapter 3.2, this "physical link" for biomethane means that both the producer and the consumer need to be connected to the interconnected EU gas network;
- Track-and-trace // identity preservation – most detailed scheme for evidencing sustainability, where each consignment of the biofuel can be traced from the biomass source all the way until it reaches the consumer (figure 15). In such a setup, certified molecules under different consignments cannot be blended with others, hence are only appropriate for biofuels transported in separate vehicles or vessels.

All three models have distinct pros and cons and have been design with a different goal in mind. Book-and-claim schemes focus on the need to produce truly sustainable fuels while emphasizing that this is sufficient to tackle climate change, as each consignment displaces fossil fuel consumption. This implies that no credible attribution of sustainable fuel consumption can be done under such scheme, as the chain of custody for the product essentially breaks upon the fuel's injection into the grid. Hence, the RED makes it clear that the related certificates under the scheme (GOs) can only be used as an accounting tool for disclosure of the energy mix supplied or consumed (see figure 13). Under this setup, the issuing body needs to ensure that each unit of energy produced only receives a GO once i.e. its environmental contribution is not accounted for twice. The book-and-claim is frequently criticized for being a weak form of evidencing sustainability, prone to fraud, since the consignment gets separated from the certificate documenting its environmental features (Hamburger, 2019). One needs to keep in mind, however, that the scheme has never been designed to document the chain of custody or to allow the consumer to make any claims about the energy mix physically used. On the contrary, it was set up as a scheme to document the renewable energy produced with no consideration given to whether physical delivery of that energy to the GO holder would be possible. In some countries, the scheme was introduced to impose obligations on suppliers to source a certain amount of energy from renewable sources, in others the acquisition of GOs is purely voluntary. In either case, though, it is true that a robust scheme is needed to ensure fraud prevention and this should include educating the public on what a GO truly documents and that such instrument does not provide for any form of evidence of the type of energy delivered and consumed on-site. Eventually, RED I made it clear that GOs should be available to evidence electricity and heat production, making them usable only by biogas plants using the fuel they produce onsite to generate electricity.

Figure 13. Book-and-claim scheme for GOs trading

Source: own elaboration based on (Pechstein et al., 2020).

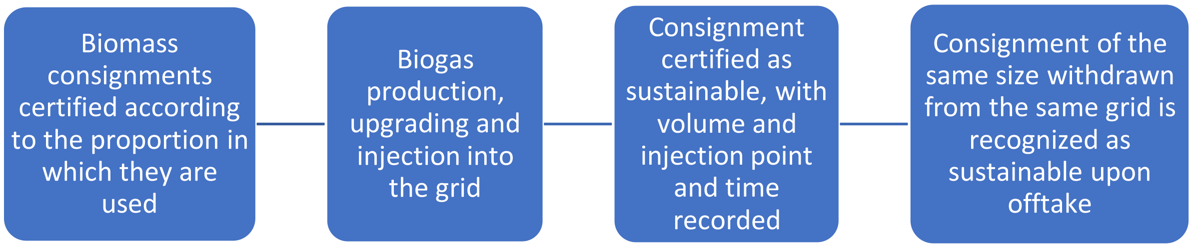
The scope of information captured by the GO has been defined in RED I, although specifically for electricity and heat production – these include (art. 15 of Directive 2009/28/EC):

- The type, size and location of the asset in which energy was produced;
- Whether the asset in question has received any form of state aid;
- Date when the asset was commissioned;
- Identification number of the issuing body and issuance date.

Although this scope might seem limited, it may allow consumers to choose the technology to be supported and also the geographical origin of the energy. If available to consumers and retailers directly, GO can also serve as a form of marketing tool, evidencing support to e.g. local farmers producing electricity from biogas (Jansen, 2017). This also allows for a better understanding of the difference between a GO and a sustainability certificate, whereby the latter also needs to document the place and form of consumption.

The mass balancing scheme offers an intermediate solution between book-and-claim and physical separation schemes, that has eventually been selected as the right approach for biofuel trading (art. 18 of Directive 2009/28/EC). Under this scheme, a physical link is retained between the biofuel consignment leaving the production facility and the point of final consumption (figure 14). This allows the both the biomass and the resultant fuel to be blended with different consignments, as long as the facility and the consumer are connected to the same grid and the documented track record is uninterrupted from the biomass's source down to final consumption. For biomethane this implies that within the certificate's validity period (typically 12 months) it can be used against a corresponding amount of gas withdrawn from the gas network to which biomethane was injected despite the fact that in most cases it is a different set of molecules. This allows for much greater flexibility in terms of supply and trading the fuel, while offering much more detailed information about the sustainability of the fuel attributed to a given consumer under the scheme. Through ensuring that technically the biofuel can be delivered to exit point at which the chain of custody is continued, the conditions for running a credible lifecycle analysis for the products can be met, while allowing pooling of supply and demand to an extent that could match the functioning of a wholesale market.

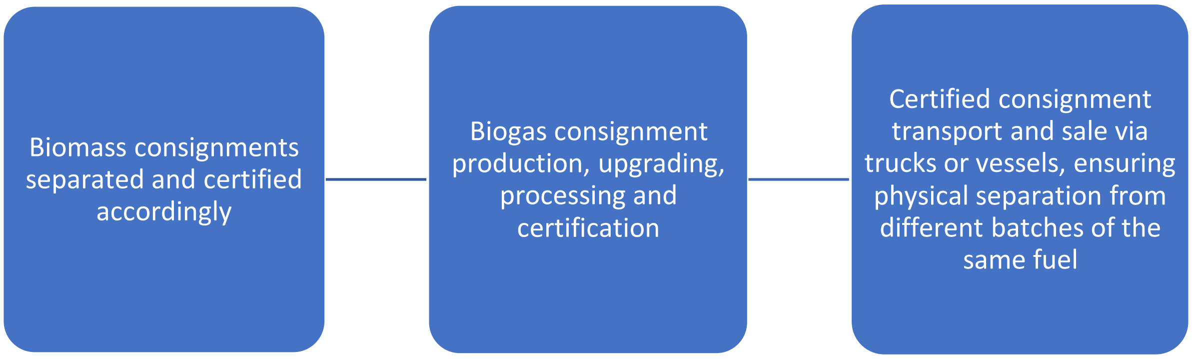
Figure 14. Mass balancing scheme for sustainability certificates trading



Source: own elaboration based on (REDcert, 2021).

While it would seem that a track-and-trace scheme would be a natural choice for evidencing sustainability and promoting decarbonization, its physical implementation is difficult and can only underpin markets restricted in size, particularly for biomethane (Amirkhizi and Olczak, 2020). While the scheme holds the potential to evidence the lifecycle emissions of the fuel in great detail, it also means its application is limited to regions where favourable production conditions are paired with sizeable demand, as all consignments need to remain physically separated until final consumption (figure 15). It deserves to be noted that some versions of this scheme do allow for sustainably produced fuel batches to commingle e.g. at a fuelling station, yet not with low-carbon, or fossil fuels (see (REDcert, 2021)).

Figure 15. Track-and-trace (physical separation) scheme



Source: own elaboration based on (REDcert, 2017).

The documents issued by the certifying bodies under a given scheme (GOs or sustainability certificates) can become a binding document under national and EU law after it becomes approved as compliant with the underlying legislative requirements by the European Commission (European Court of Auditors, 2016). There are different national schemes in operation across Europe, even though no common approach governing the trade of biomethane that would ensure its sustainability characteristics would be recognized internationally exits just yet (Lovegrove et al., 2020). Until now, subsequent cross-border trading of the certificates requires additional bilateral agreements and/or participation in a common scheme coordinating the operation of initiatives at national level. This may yet change under the new legislative changes, as will be discussed under subchapter 3.2.

The debate around the upsides and downsides of the three approaches to keeping track of emissions related to biofuels in the value chain has been ongoing for years and was subject to refinements, not least because such schemes have typically first been set up by private entities or their consortia (Lovegrove et al., 2020). Eventually though, RED I has explicitly selected a mass-balancing approach as obligatory for schemes evidencing sustainability of biofuels. Nonetheless, even if not formally stipulated by the directive, GOs for biomethane could also be issued for disclosure purposes, although not to evidence sustainability. The possibility of "upgrading" a GO into a sustainability certificate was also discussed as the dialogue around the new legislative package for gaseous fuels commenced, yet, as will be described in subchapter 3.2, this option has been ruled out and the possibility of retaining a book-and-claim system alongside mass balancing for the EU gas network has been questioned.

RED I was amended in 2013 and 2015 in areas that are not within the core focus of this study, although it deserves to be mentioned that the latter amendment (Directive (EU) 2015/1513) has imposed more stringent requirements on agricultural-sourced biomass for biofuels production, as well as higher thresholds for facilities producing biofuels that have been commissioned past 5 October 2015. Nonetheless, since further amendments were still deemed required, particularly in the context of the new commitments made under the so-called Paris Agreement[12], a comprehensive recast of the RED was facilitated through the adoption of Directive (EU) 2018/2001, commonly referred to as RED II. Among the most important changes, RED II has:

- Further specified the rules on the types of biomass that can be used for the production of biofuels, yet also revised their definition so that it no longer relates explicitly to gaseous fuels, for which the term "biogas" was established. That said, it needs to be stated that the term is applied inconsistently, whereby reference to

---

[12] The Paris Agreement on Climate Change following the 21st conference of the Parties to the United Nations Framework Convention on Climate Change that has led the European Union to setting for itself a binding target of 40% emission reduction versus the 1990 levels by 2030.

“biomethane”, “renewable gas”, “biogas for transport” or simply “gas” are made throughout the Directive with no outright definition provided;

- Has reemphasised that GOs cannot be used to deceive the consumers about the nature of the energy delivered;
- Established that in order to provide accurate information on the renewable energy supported through the acquisition of GOs, these instruments should be issued upon request of any type of installation deemed as renewable within the understanding of RED II, including biogases (article 19).
- Called for the establishment of a Union Database (UDB) that would facilitate a centralized record of sustainability certificates issued for biofuels and biomethane, thereby preventing double-counting of the environmental contribution stemming from each consignment of renewable energy produced across the EU;
- Reiterated that any additional permissible land use for the benefit of biofuels production should result in net GHG emissions reduction without threatening material land use change or food/feed production;
- Has proposed a binding target for biofuels and biogases use in transport, in order to establish a stable, baseline demand for these fuels, indirectly improving the attractiveness of investment in these fuels;
- Stipulated that harmonized rules for sustainable production of biofuels should ensure that its value recognized and treated on equal terms in all the Member States;
- Introduced periodic reporting obligations for the GOs and certificates issuing bodies to improve harmonized oversight over renewable energy production and audit.

RED II makes it clear that all forms of renewable energy used in electricity or heating and cooling generation, as well as in the transport sector, should count towards the renewable energy target that was to be reached by 2030. Outright recognition of biomethane’s contribution to decarbonization supports the notion of its significance to the gas sector, provided that the sustainability criteria are met. The concept of a centralized database for certificates is also an interesting concept, yet that requirement was never supplemented with a binding timeline according to which it should be established, hence the deliberation around its application has spilled over to 2023 – the related discussion will be summarized in subchapter 3.2.

If deemed sustainable within the understanding of the RED, biomethane was entitled to financial support that would make the technology economically viable and more competitive against natural gas. While there were different forms of support offered by the different Member States, several types can be identified (Gustafsson and Anderberg, 2022):

a) Direct investment support – this relates to either outright financial support, covering a share (in some cases up to 50%) of the investment expenditures or preferential/subsidized access to investment financing (e.g. zero- or low-interest loans);
b) Feed-in-tariff – fixed payment defined per MWh of biomethane injected into the gas network over an agreed period of time (typically from 10 to 20 years) (Couture et al., 2010). This type of agreement can either be signed after a positive verification of an application for financing or won through competitive auctions or tenders that promote most cost-efficient solutions. Under such setup, the production facility is entirely protected from the market-related risks and is guaranteed to sell the agreed volumes. This also means it is completely detached from the related price signals and/or demand swings. The resultant attractiveness to investors has historically proved the schemes potential to swiftly develop new capacities, although typically at a significant cost (Simon, 2019);
c) Feed-in-premium – a more elaborate form of a feed-in-tariff, whereby the financial support is paid on top of the market price. That premium may either constitute a fixed amount per MWh produced or be referenced against market prices and the producer is only entitled to a premium covering the gap between the price observed on the market and the price agreed in the underlying contract with the authorities (Proietti et al., 2020). Allocation of financing under the feed-in-premium schemes is typically done via competitive tenders to contain costs and promote only the most commercially viable projects;
d) GOs / sustainability certificates – the issuance of certificates for the gas injected into the gas grid can either exist alongside the other forms of support or be mutually exclusive (where the certificate is subsequently issued and cancelled for the biomethane produced to simply count under the country’s renewable energy commitments). Through the sale of a GO or certificate the producer receives an additional revenue stream that needs not burden the state budget, as the demand for the renewable fuel can come from the private sector. This demand, in turn, can reflect the consumer’s preference for the use of sustainable fuels, be stimulated through state-imposed quotas on suppliers and/or large consumers to cover a share

of the gas they use with sustainably sourced biomethane, or be a combination of both (Menanteau et al., 2003). Here, however, it needs to be stated that the efficiency of a certificate scheme depends heavily on the market depth, as the scheme retains a major share of the market risk with the investors (Proietti et al., 2020). In addition, the price of a certificate can reasonably be expected to be much higher than of a GO, since sustainable energy supply may also entitle the consumer to different benefits and tax exemptions;

e) Tax exemptions – targeted tax exemptions can be offered to certain level of revenue stemming from the sale of biomethane. Additional tax incentives can also be offered to the users of biomethane to stimulate demand (CEER, 2021).

The level of support offered to each facility can depend on its planned capacity, size, location, feedstock used and energy actually delivered over time (Gustafsson and Anderberg, 2021). Historically, the subsidy offered to in the context of renewable gases was primarily designed to support biogas-based electricity production and not outright biomethane injections into the gas grid (Pablo-Romero et al., 2017). This had its consequences for the deployment of upgrading technologies, as these remain very capital-intensive while their added value could have been undervalued – as will be discussed in detail in chapter IV, the result is that while production of biogas is quite widespread throughout Europe, in 2022 biomethane production at a meaningful scale was taking place in a narrow group of the most developed Member States.

Any support scheme also needs to be notified for the European Commission's approval under State aid rules that are stemming from the provisions of Article 107 of the Treaty on the Functioning of the European Union (TFEU). These rules are to ensure that any permissible state aid does not result in distortions to competition on the internal market. For a large part of the period throughout which biomethane generation has been developed, European Commission's Guidelines on State aid for environmental protection and energy 2014-2020 were in force (2014/C 200). Despite the name, the Guidelines applied until the beginning of 2022 and outlined the approach towards verification of state aid permissibility in light of the TFEU (the revised rules will be described in subchapter 3.2). In terms of support for renewable gas:

- State aid could be granted as investment or operating aid and the scheme can be authorised by the Commission for a period of ten years, after which it can be notified again;
- Investment aid had a limit defined as a share of total expenditures, depending on the investing entity's size (from 45% for large to 65% for small enterprises) and the

allocation procedure (whereby the support could cover 100% of the investment if the support was to be allocated through a competitive bidding process);

- Operating aid would be deemed permissible if all the following conditions were met:
    - Operating support per unit of energy could not be higher than the difference between the levelized cost of energy (LCOE[13]) from the supported technology and the market price of the energy it was competing against on the market. The LCOE considered for the calculation could also include a modest level of return on capital to encourage investment;
    - The production costs included in the calculation are periodically updated, at least annually;
    - Aid does not exceed the depreciation period applicable to the supported installation, unless a Member State proves that the operating costs of a plant remain higher than market prices.
- State aid could take the form of certificates through guaranteeing demand for the renewable energy produced (e.g. through introducing supplier obligations), provided that the resultant revenue stream does not result in overcompensation for any form of technology covered by the scheme;
- Aid could also be granted in form of tax exemptions, including from environmental taxes, or tax refunds, provided that these would not weaken the discouraging effect of such taxes from causing damage to the environment;
- For the calculation of reference values applicable to biofuels and biomethane, the Commission would be willing to consider more elaborate comparative analyses to properly reflect the actual additional investment and/or operating costs of a given technology supported (see annex 2 to communication 2014/C 200).

Apart from adopting rules underpinning state aid to biogas and biomethane and in an attempt to deliver on the Kyoto Protocol[14] commitments, the European Commission has also pursued a project aiming to internalize the costs stemming from the damage caused by greenhouse gas emissions related to different industries and technologies. he Emissions Trading

---

[13] The LCOE is a popular tool for comparative analyses of the true costs of energy from different sources. In order to make that possible, the calculation of a given technology's LCOE envisages summarizing all its operating, capital, and decommissioning costs over a project's lifetime and dividing it by the total expected energy produced over that period (Ebenhoch et al., 2015).

[14] Kyoto Protocol is an agreement under the aegis of the United Nations to reduce the greenhouse gas emissions by at least 5% versus 1990 levels, whereby the European Union has jointly committed to a group GHG reduction of 8% by 2012 for the Protocol's first commitment period (Council Decision 2002/358/EC).

Scheme (ETS) (Laing et al., 2013) was set up to, among others, weaken the competitive advantage of fossil fuels over RES, thereby inducing investment in the latter. For biogas and biomethane, the implications of the ETS can be twofold:

- on one hand, if properly produced, these gases do not result in material net emissions of CO_2, hence do not fall under the obligations stemming from the ETS, making them more competitive against natural gas;
- on the other hand, the acquisition of sustainability certificates (and in some cases in the past, of GOs) for the energy consumed can also release the consumer from the ETS-related obligations, potentially underpinning a minimum value for these instruments. This link, however, by the end of 2022 was neither the default nor a standard approach taken in different European jurisdictions.

The ETS entered into force in 2005 as a cap-and-trade system, where a gradually decreasing amount of greenhouse gas deemed as permissible emission each year becomes reflected in the amount of emission allowances (EUAs) issued and allocated to the economies taking part in the scheme (Directive 2003/87/EC). Its economic impact is taken into account by the Commission when evaluating the eligibility of state aid – in particular, the EC assumed that until there is evidence to the contrary, the EU ETS is by far thought to be limiting, but not covering the competitive gap between fossil-based and renewable energy-based technologies.

The ETS has been implemented in phases, aiming at a gradual increase in EUA prices and the scope of application of the scheme, although for most of the time the prices actually observed were well below the desired levels (Burtraw and Themann, 2018). Phase I (2005-2007) and phase II (2008-2012) related to CO_2 emissions exclusively, whereby the EUA enabled the emission of 1 tonne of CO_2 (1 tCO_2) and the scheme covered only largest entities from the power and heat generation sectors, as well as certain energy intensive industries (Vlachou and Pantelias, 2017). After that, the EUA was referring to the emission of 1 tonne of CO_2 equivalent to also cover other major greenhouse gases, namely nitrous oxide (N_2O) and perfluorocarbons (PFCs). It is worth noting at this point that the ETS does not cover methane emissions, that are of particular concern to the gas sector and can constitute a considerable share of biogas and biomethane facilities lifecycle emissions. European Union's actions in this respect have been laid down as part of the so-called Fit for 55 legislative package in a Proposal for a Regulation COM/2021/805 spelling out the strategy to address methane emissions through improved monitoring, leak detection and prevention – works on this, and other proposals from the package, however were still ongoing in the European Parliament at the time of preparing this dissertation, but will be highlighted in subchapter 3.2.

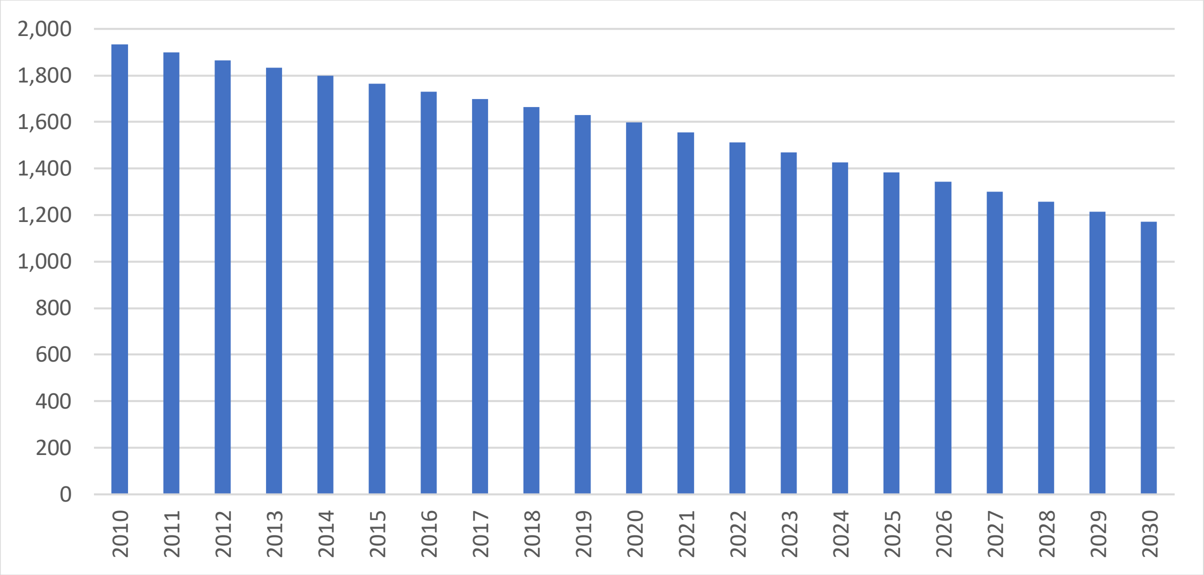
Over the first two EUA trading phases, the allowances were largely allocated freely by the Member States to the assets covered, with only a limited amount being allocated through auctions. The allocation, transfer and cancellation of allowances was to be traced under national transaction logs. A penalty of 100 EUR per tonne of CO_2 (40 EUR/tCO_2 for phase I) was envisaged for each tonne of emissions exceeding the amount of emissions held. In general, the scheme is organized as follows (Hintermann and Ludwig, 2023):

- Every February, Member States issue allowances in the agreed amount for the given year and distribute them among the obliged installations functioning within their jurisdiction;
- Every April the obliged entities are to submit the amount of allowances covering their emissions for the previous year back to the official register;
- Within each trading phase, entities are free to trade (bilaterally or via exchanges), and carry forward the emission allowances they hold on their accounts for the following year, but not between phases (Ellerman and Joskow, 2008);
- Alongside outright EUAs allocation and trading, a range of derivatives (futures, forwards, swaps, options) has also gradually developed to support risk management (Uhrig-Homburg and Wagner, 2008).

The first phase had a rather marginal impact on emission costs, is not coincidental that phase II covered the same period as the Kyoto Protocol's first commitment period, as it was the first true period to deliver tangible results on the side of emission reductions. While criticized for underperformance in the early years of the cap-and-trade scheme's operation, it should be borne in mind that particularly the first period was treated as a "trial" during which the necessary infrastructure and governance was to be developed and it can be stated that ETS was successful to that end (Ellerman and Joskow, 2008). Phase II witnessed periods of considerable price volatility and while the emission savings targets have been met, the scheme's contribution to that success was questioned (Ellerman et al., 2010). Overall, while the contribution from the cap-and-trade scheme was difficult to disentangle from the overall reduction stemming, in part, from the global economic crisis, a study by Dechezleprêtre et al. (2023) concluded that the ETS has played a notable role in reducing the emissions in the first years of operation.

Phase III (2013-2020) envisaged an expansion of the ETS onto other sectors and, more notably, has established that the total cap size was to be regulated by the European Commission and not by individual Member States. In addition, that cap was reduced annually by a linear reduction factor of 1,74% (see figure 16)(Ellerman et al., 2010). Nonetheless, at the beginning of phase III it was already apparent that the ETS is underperforming as the EUA price was way too low to incentivise investment in renewable energy and related R&D (Flachsland et al., 2017).

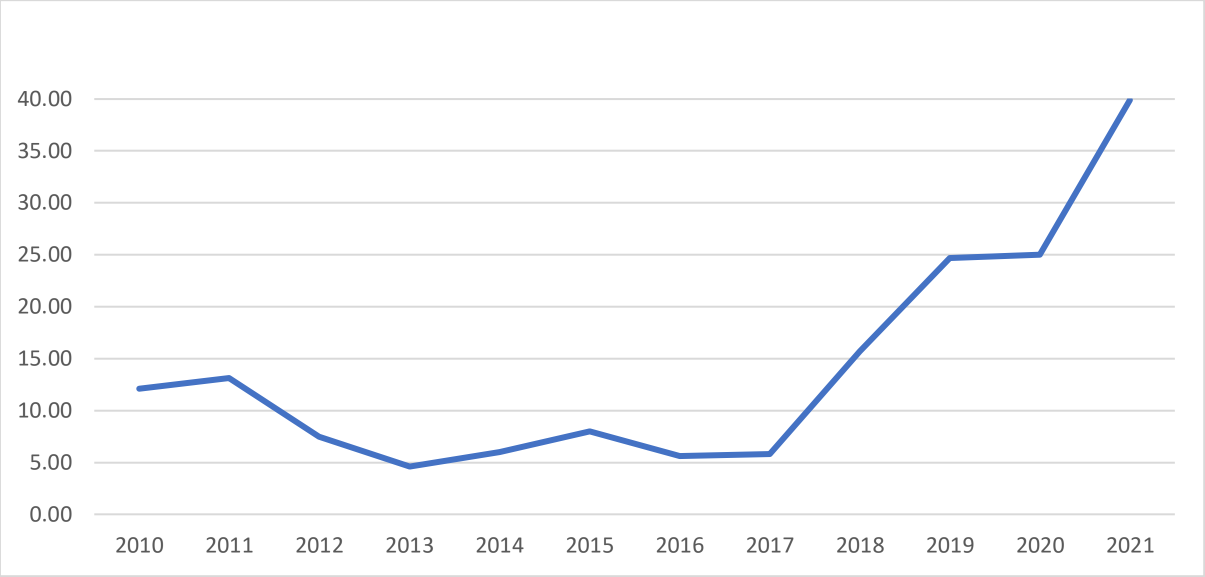
Figure 16. ETS emissions cap for stationary installations in the EU-27 [GtCO$_2$e]



Source: own elaboration based on (EEA, 2022).

In order to increase the EUA price, it was first decided that the issuance of part of allowances envisaged for the years 2014 to 2016 would be postponed (Regulation (EU) 176/2014) and that concept was used to contribute to establishing a market stability reserve (MSR) as of 2019 in order to address the overall oversupply of allowances throughout the EU (Decision (EU) 2015/1814). The reserve was to be established through deducting 12% of the EUAs from the volumes to be auctioned for each year and it should be reintroduced to the market during periods of scarcity. In addition, the free allocation of allowances was to follow a common methodology, with an aspiration to replace it entirely with auction-based allocations over time (De Clara and Mayr, 2018). Collectively, study findings from Mirzaee Ghazani and Jafari (2021) confirm that over the course of phase III the ETS has matured, with prices of EUAs rebounding and growing considerably (figure 17).

Figure 17. Average closing spot prices of European Emission Allowances [EUR/tCO_2e]



Source: own elaboration based on (IBISWorld, 2022).

Phase IV (2021-2030) scaled up the linear reduction factor to 2,2% and reinforced the MSR, whereby the amount of allowances excluded from auctions was set to double (Directive (EU) 2018/410). The fact that the United Kingdom is no longer part of the EU was also factored in when establishing the size of the total cap. The common output-based free allocation methodology became subject to more frequent reviews, while the auctioned share of the EUAs was set at the level of 57% (De Clara and Mayr, 2018). In addition, a dedicated Innovation Fund was established through auctioning a modest percentage of EUAs separately to enable additional funding to new technologies supporting renewable energy production. Collectively, the upscaled ambitions under phase IV were set to support achieving higher climate targets that have over time been revised, particularly under the establishment of the Green Deal strategy of growth as presented in late 2019 (COM/2019/640). The Green Deal strategy is to turn Europe into a first climate neutral continent by 2050 and reinforce its position of a global leader of a fight against climate change and as such it has triggered a number of initiatives that will be discussed in subchapter 3.2.

3.2. New legislation aimed at decarbonising the economy

The Green Deal strategy was formally adopted through agreeing on the so-called European Climate Law that has introduced a new intermediate climate target of 55% emissions reduction compared to 1990 levels by 2030, and full climate neutrality by 2050 (Regulation (EU) 2021/1119). The European Climate Law has also obliged the European Commission to conduct a comprehensive review of all the relevant legislation that has been introduced to tackle climate change. With the agreement reached on the Green Deal to make Europe the first climate-neutral continent by 2050, biomethane has received more attention than ever before. The commitment to a goal of no net GHG emissions by 2050 means that processing of waste will need to be scaled up considerably, while at the same time, much greater emphasis will need to be placed on technologies resulting in negative emissions to cover for the pollution that cannot be avoided in the short-to-medium-term. Since, as argued before, biomethane technologies can fall under both categories, the new legislative landscape under preparation will inevitably affect them in a number of ways. The overview of the legislative changes pursued under the Green Deal presented in this subchapter is focused on actions having direct impact on biomethane and its competitiveness going forward, yet it deserves to be underlined that the scope of changes pursued under the strategy is much broader and underpinned by an impressive budget of at least 1 trillion euro for the period 2021-2027 alone (Janda and Sajdikova, 2022).

A comprehensive revision of the legislation that followed the announcement of the Green Deal has resulted in a whole set of projects that were to help delivering on the new interim climate target. Under the Fit for 55 legislative package that was briefly mentioned in the previous section, a whole set of proposals has been tabled by the European Commission, including (COM/2021/550):

- Proposals to expand the EU ETS to other sectors (COM (2021) 551, COM (2021) 552) and reinforce the MSR (COM (2021) 571) – the proposals are set to expand the ETS further into different sectors, including aviation and maritime, as well as to further limit the availability of EUAs through the use of MSR;
- Proposal for an Effort Sharing Regulation (COM (2021) 555) that further specifies how the additional emission reductions stemming from the increased interim climate target are to be distributed between the EU Member States. The Regulation is expected to be adopted by the end of March 2023;
- Proposal to amend the Renewable Energy Directive (COM (2021) 557) – the proposal is, among others, set to sanction the new climate targets and is expected to move into interinstitutional negotiations in Q2 2023. Since the RED continues to be of key importance to biomethane producers in the EU, the provisions of the proposed recast directive will be discussed in more detail in this subchapter;
- Proposals on the production and uptake of sustainable and alternative fuels in the aviation (COM (2021) 561) and maritime (COM (2021) 562) sectors – the proposals

suggest establishing regulations that would impose a requirement to use a minimum share of sustainably produced fuels (including biofuels) for ships and airplanes entering and/or leaving the territory of the EU. In both cases the interinstitutional negotiations are ongoing, with works on fuels in aviation being more advanced and expected to be agreed in Q2 2023;

- Proposal for an Energy Taxation Directive (COM (2021) 563) set to gradually establish a minimum tax on different energy products and electricity that would also be referring to biogases and biofuels that have not been certified as sustainable. Discussions on the proposal are ongoing and the final text has been provisionally scheduled for adoption in second half of 2023;
- Proposal for a Carbon Border Adjustment Mechanism (CBAM, COM (2021) 564) – set to introduce an EUA tax equivalent on unsustainably produced goods imported from third countries, including electricity, different types of fertilizers and hydrogen (all of which can be of relevance to the competitiveness of EU-produced biomethane). Provisional agreement on CBAM has been reached in February 2023.

Bearing in mind that all of the abovementioned legislative proposals are still under discussion and subject to changes, it needs to be emphasized that the key provisions outlined in this subchapter may deviate to some extent from the final documents that are scheduled to be adopted in the coming months. This, however, reflects the regulatory instability that biomethane and other renewable energy sources have been facing over the course of the past few years.

In terms of the new set of rules governing the recognition of different gases as renewable and their subsequent tradability across the EU, these appear to be falling in between the two ongoing legislative processes: the revisions of the Renewable Energy Directive (frequently referred to as RED III) and the new Hydrogen and Decarbonised Gas Markets Package (i.e. the recast of the gas directive and regulation that formed part of the Third Energy Package described in chapter II). First, the proposed amendments under RED III will be discussed, as they set the reference for the type of fuels that can be deemed sustainable and promoted as such, thereby forming the basis for the future sector's functioning under the new gas package.

3.2.1. Revision of the Renewable Energy Directive

At its core, the revision of RED II proposes to scale up the interim GHG emission reduction target to 55% and increase the share of renewable energy in the final energy consumption from 32% to 40% by 2030. The latter was further scaled up over the course of negotiations and in view of the announced REPower EU[15] plan to 45% in May 2022 (COM (2022) 222). Apart from scaling up the renewables target, REPowerEU has also been supplemented with a Biomethane Action Plan (SWD (2022) 230) that encourages a swift development for biomethane production throughout Europe, so that it reaches the level of 35 bcm by 2030 – this target has also been quoted in the draft RED III version adopted by the European Parliament in September 2022[16]. In addition, the rules for biomethane and biogas production are to be stricter through requiring all existing and future installations to ensure at least 70% GHG emissions savings until the end of 2025 and at least 80% afterwards (Lorin, 2021). Further restrictions have also been imposed on the possibility to use of biomass sourced from highly biodiverse regions, or lands will high carbon stock, so that the resultant emission savings support climate preservation rather than damage it. To counterbalance that, the recent proposal also increases the expectations towards future pickup of biomethane supply and demand through:

- Introducing a definition of renewable hydrogen that includes hydrogen produced from biogas, potentially opening up further demand areas;
- Implying that biogas upgrading into biomethane and injection into the grid should be preferred over its direct use for electricity production to better utilize the associated climate benefits;
- Further specifying the biofuel and biogas target for transport to reach at least 2,2% in 2030 and potentially even higher, should the list of permissible feedstock be expanded;

In the context of the RED revision it is also worth to note that going forward, under a separate process, the European Commission will also likely propose a revision of Annex IX of the RED that specifies the type of feedstock that can be processed for the production of biogas and biofuels. The extended list would, among others, allow for sustainable biomethane and biofuel production from biomass sourced from severely degraded lands, as well as the use of food and drink production wastes, provided that these cannot be used in further food or feed

---

[15] The REPower EU plan (COM (2022) 230) was proposed in May 2022 as an additional work plan to swiftly put an end to EU's dependence on fossil fuels imported from Russia. Apart from scaling up the renewables target, in envisages, among others, further cooperation in diversifying sources of supply, encouragement of greater energy savings and unlocking additional funding to cover for the damages caused by the energy crisis.

[16] The Biomethane Action Plan does quote a set of areas through which biomethane deployment could be promoted, including improved access to financing, reduced costs of injecting biomethane into the grid and encouraging Member States to develop national biomethane strategies. However, with no concrete timeline and actions defined, it is not clear why this document is referred to as an action plan specifically for biomethane.

production – public consultation on the subject has ended in January 2023 (European Commission, 2023).

As the works on the Green Deal advanced, works on the RED II-required Union Database (UDB) for biofuels and bioliquids have also picked up considerably, not least because the RED III revision also envisages its expansion from the transport sector onto all end-use sectors (Lorin, 2021). At the time of preparing this dissertation, it has been proposed that the UDB is to be based on the operations of the existing voluntary schemes that have been approved by the European Commission under RED II (Commission Implementing Regulation (EU) 2022/996). Certification bodies operating within each such scheme are to be obliged to provide the information on the certified volumes of fuels entering the mass balance system governed under the UDB. As per art.18 of the Implementing Regulation 2022/996, the goal is to ensure that the entire value chain from the sourcing of biomass, through the fuel production and injection into the grid (in the case of biomethane) to its final consumption upon offtake is documented in the centralized database. This also means that the Implementing Regulation confirms that the European gas network should be treated as a single logistical facility that can underpin a mass balancing scheme for biomethane trading.

Regulation 2022/996 sets forth a number of operational requirements that are to underpin the functioning of the UDB, although their implementation appears to be very challenging and eventually may well threaten biomethane's tradability and development instead of fostering it – this has been raised in a joint open letter of different business associations submitted to the European Commission in February 2023 (European Biogas Association et al., 2023). The associations emphasise that:

a) the implementation timeline set for the UDB is very short, especially since most of the works thus far have been done with limited participation of the future system users, some of which likely remain unaware of the requirements to register with the system being set up;
b) it is still not clear whether the existing and upcoming rules underpin separate tradability of the certificates and biomethane after the gas is injected into the grid but before it is withdrawn;
c) the links between the UDB and the voluntary schemes are still under development and the new system cannot become operational before they are firmly established and tested;

d) the legislation underpinning the functioning of the UDB is severely fragmented between different types of legislative acts that are currently under review.

Overall, it can be stated that the UDB brings together a whole set of open issues in terms of unresolved interactions between the national schemes, future recognition of sustainability and interactions with the EU ETS that collectively contribute to a highly unstable regulatory environment for biomethane.

3.2.2. Hydrogen and Decarbonised Gas Markets Package

The second considerable amendment to the regulatory environment for biomethane stems from the upcoming agreement and adoption of the Hydrogen and Decarbonised Gas Markets Package i.e. a revision of the Gas Directive (2009/73/EC) and Gas Regulation (715/2009) from the Third Energy Package with a strong focus on the deployment and use of renewable and low-carbon gases. The new Directive (COM (2021) 803) and Regulation (COM (2021) 904) have been tabled towards the end of 2021 following an extensive public consultation held over the course of 2021. At the time of preparing this dissertation, the new gas package has not yet entered interinstitutional negotiations, although the Council was expected to be finalizing its position towards the end of Q1 2023. Out of the key aspects concerning biomethane that deserve to be highlighted (although still may be subject to changes prior to adoption):

- the concept of pursuing the establishment of an internal market for gaseous fuels following the same set of core principles (as outlined in chapter II) has been retained, not least because it is believed to facilitate consumer choice and ensure supply security while maintaining mechanisms that underpin the functioning of other policy instruments such as the ETS;
- the fact that a number of end-user applications cannot be electrified is explicitly recognized as the core motivation for having the package introduced – its central goal is to facilitate the deployment of renewable gases that would allow the EU for shifting from natural gas;
- in order to enable market mechanisms to support the transition, consumer needs to be allowed to choose between the different renewable gas alternatives offered on a competitive market, through having access to information about of the sustainability features of the fuel offered;
- network access for biomethane is to be guaranteed, provided that it does not compromise the technical and safety rules. Once injected into the grid, biomethane

should be traded freely at the virtual trading point regardless of whether it is injected at the distribution or transmission level;

- transmission- and distribution-related tariffs for biomethane should be reduced to improve the technology's attractiveness;
- to ensure unhindered market integration, the package promotes harmonised approach to gas quality and its active management in face of a growing share of renewable gases in the interconnected EU grid.

The abovementioned provisions of the Hydrogen and Decarbonized Gas Markets package are merely a fraction of the entire set of the updated rules that are to govern the gas and hydrogen markets, which are expected to exist in parallel. Nonetheless, even these points have proved to be controversial both to the existing and prospective market participants, as well as to the sides of the upcoming interinstitutional negotiations. From the perspective of biomethane, two issue are of key importance that still need to be resolved. First, the aspiration to facilitate consumer choice through the use of sustainability certificates does not clearly state whether such instruments could form the basis of independent trading of the commodity and the green value (Banet, 2023). Until this is resolved, it is not clear to what extent different consumers will actually be able to manifest their preferences as has also been raised in the context of the discussions around the functioning of the UDB. The other issue is that while the draft package proposes tariff discounts to biomethane, it links their application to the use of sustainability certificates, which is not reflective of how the gas market works (Frontier Economics, 2019). Under such setup, only the entity cancelling the certificate upon final consumption of biomethane would be entitled to a discount (or to be exact: to a refund on the tariff paid) and that entity will not be the biomethane producer, but the intermediary between it and the end consumer.

3.2.3. Revised Guidelines on State aid and the Emission Trading Scheme

Alongside all the changes to the legislative environment underpinned by considerable funds, the rules under which they should be distributed also had to be updated. The time left to deliver on the new climate commitments is very short when considering how ambitious they are, hence the strategy is to be backed with a considerable budget. On the subsidies front, the new Communication from the Commission establishing the Guidelines on State aid for climate, environmental protection and energy 2022 (C/2022/481) have loosened the approach towards backing renewable technologies in face of the urgency of the fight against climate change. Under the new guidelines (commonly referred to as CEEAG):

- By default, state aid needs to be allocated through open, competitive tenders, that also specify the minimum number of bidders, where appropriate;
- Introduce obligation to consult the public on new schemes if their annual support value exceeds 150 million EUR before seeking the Commission's approval (as of July 2023);
- For certificate schemes driven by supplier obligations, it is required that:
  - the induced demand is set at a level below the expected supply and
  - penalty price for non-compliance cannot be set at levels that would significantly exceed the modelled funding gap, resulting in excess revenues;
- Where tax exemptions are offered, Member States need to establish an annual evaluation process that verifies whether the related benefits are still necessary and do not result in market distortions;
- Any new form of aid granted needs to take due account of financial support already granted to renewable energy installations.

Interestingly enough, the revised legislation still recognizes the role of natural gas in the transition period towards climate neutrality in 2050. This means, that in duly justified cases, investment in natural gas infrastructure and assets can indeed be granted state aid, not least when it can support the uptake of biomethane and/or ensures compatibility with the future transport and use of hydrogen.

Finally, it deserves to be noted that while the ETS expansion into other sectors does not directly changes the regulatory environment for biomethane, it can improve its competitive position if only the UDB becomes fully functional to facilitate trading of sustainability certificates, since biomass-derived emissions factor is zero under the ETS Directive. This notion has been reinforced by the updated Guidance Document on Biomass issues in the EU ETS issued in October 2022 that governs the way through which emissions from the use of biomass are to be treated under Implementing Regulation (EU) 2018/2066 that accompanied the implementation of EU ETS Phase IV. According to the Guidance Document, biomass-derived fuels are to be considered emission-free if the sustainability criteria as per the RED II Directive are met.

Conclusions

Considerations presented in this chapter reinforce the notion that natural gas and its substitutes of biological and synthetic origin will have continue to be part of EU's energy mix for decades to come. The fact that the market design established under the existing rules is not expected to experience fundamental changes also suggests that competition on an internal market for gas serves its purpose even though the implementation of the existing acquis remains patchy among the Member States.

Combination of subsidies and GHG emissions tax can potentially offer a powerful incentive for the development of biomethane production although it needs to be noted that the combination existed already over the past decade under some jurisdictions and, as will be shown in chapter IV, the results have been modest. This, however, justifies the need for a comprehensive overhaul of the EU acquis that is pursued under the Fit for 55 strategy and signals that the emission allowance price will likely need to be much higher to support the competitiveness of biomethane.

Going forward, competitiveness of the EU gas sector will depend more on the value attributed to sustainability features by the consumers and the way through which these features can be transferred end reflected in the final goods and services. With a functioning chain of custody under the mass balancing scheme governed by the UDB and in view of the provisions laid down in the Hydrogen and Decarbonised Gas Markets package, all biomethane producers connected to the EU gas network (regardless of whether at distribution, or transmission level) should be able to sell the certified fuel throughout the EU and expect high and growing demand in the coming years. Such setup should both further integrate national markets and encourage investment in biomethane production, particularly since the product would have access to a large pool of demand that can be expected to compete over scarce sustainability certificates. Such setup would enable the natural gas sectors to compete on grounds of supply quality, much in the spirit of Flejterski's definition of sectoral competitiveness (Flejterski, 1984).

If the amendments outlined in this chapter, albeit fragmented throughout different legislative documents, are adopted, biomethane should become a very attractive fuel that should attract investors. Achieving the 35 bcm biomethane target by 2030 spelled out in the REPowerEU strategy, however, will not be easy, since the investment costs remain high and the regulatory environment remains far unstable. Considerations around the future development of biomethane and the impact it may have on gas sector competitiveness will be the focus of chapter IV of this dissertation.

Chapter IV.

4. Consequences of gas market decarbonisation to the sector's competitiveness

Competitiveness of gas markets in European countries is not easy to capture, not least because of the sector's distinct nature in a number of aspects. Unlike many existing measures, an approximation of the gas sector's competitiveness cannot refer merely to measures of productivity since the majority of the commodity on the market comes from multiple external sources, the efficiency of which lies beyond the jurisdiction of the countries being analysed. For the same reason, measures referring to standard input-output calculations or labour productivity do not entirely capture the nature of the European gas sectors. Finally, it is necessary to recognize that the changes in competitive position of the European gas sectors can be viewed differently from a regional and global perspective, as decarbonisation becomes a priority to both politicians and consumers. Considering the growing pressure of European citizens on fighting climate change, it can be reasonably assumed that, unlike until now for many strategic commodities around the world, quality will increasingly become a key feature determining national sector's competitiveness.

Going forward, the improvements to gas supply quality can manifest themselves in the amount of greenhouse gas (GHG) emissions savings enabled through the introduction of technologies displacing natural gas (i.e. a fossil fuel), making the national gaseous fuel mix less carbon intensive. That new feature is expected to reshape the perception of the national energy sectors, yet it is still to be one of several factors that together define the competitive position of the gas sector. Accordingly, the central part of the thesis is to design a new synthetic competitiveness measure that would take into account different aspects of a gas market functioning and its potential to decarbonize over time. A synthetic measure design this way would also be expected to properly the "beyond GDP" features of contemporary competitiveness, as discussed in chapter I.

4.1. Gas sector competitiveness index

Several approaches to quantifying competitiveness have been mentioned under subchapter 1.2, although not many would bring tangible results when applied at sectoral level, particularly when it comes to the EU gas sector that is largely reliant on imports and the "default" input-output considerations would bring little added value. Nonetheless, since examining competitiveness intuitively implies comparative analyses, introduction of a synthetic measure that could allow scoring and ranking national gas sectors according to a single value presents an interesting alternative. This chapter will present the process of designing a new, dedicated synthetic measure designed specifically to support evaluating competitiveness of the EU gas sector in the broader geopolitical context of the third decade of the XXI century.

First the design of a dedicated synthetic index will be described, building on the established methodology prepared and used by the World Bank to run their annual comparative analysis of national economic competitiveness. The design of the sectoral index will be tailored to the reality of the European gas sector, namely its strong and growing reliance on imports and a growing emphasis on limiting greenhouse gas emissions. Such analysis will be prepared primarily for the prime-moving countries in the field of developing biomethane production facilities over the course of the historic analysis period between 2008 and 2022. In order to test the analytical power of the tool, an additional analysis will be performed for the forecast period 2023-2030. The factors used for these analyses will build on the available quantitative data from Eurostat, national statistics offices disclosing information on biomethane deployment, as well as industry associations databases describing the past, present and future expected capacity of the gas networks across Europe. Quantitative information will also be used in the process, building on the available opinions expressed by the European Commission, International Energy Agency, as well as associations of network users, that together are expected to reflect the institutional setup and performance of the national gas sectors. The resultant values of the index calculated for the selected group of six countries will then be analysed separately for the historic period and the forecast and conclusions are drawn on the impact different decisions had for the competitive position of each country over time.

The concept of a synthetic measure reflecting relative competitive position follows the logic used for determining national competitiveness under the Global Competitiveness Index (GCI) described in chapter I of this dissertation. While the GCI is a measure designed to capture the competitiveness of the entire economy, it considers a wide spectrum of quantitative and qualitative factors that can also be of relevance to the mesoeconomic level competitiveness, including for the natural gas sector.

For the current study only biomethane production technologies will be considered to have a tangible and measurable impact on the gas sector competitiveness. Unlike hydrogen, sustainable biomethane production technologies are established and ready for commercial application, even if their actual deployment vis-à-vis the ambitious decarbonisation targets is thus far very limited in most countries. This also limits the number of countries that can form the basis of an ex-post competitiveness analysis for the study. At the same time, as outlined in chapter III, biomethane production is facing a very unstable regulatory environment in the coming years, making projections on its future developments very challenging. In view of these limitations, the proposed timeline for the analysis has been defined for years 2008 ÷ 2030 in order to reflect the process of implementing the Third Energy Package and at the same time trace the deployment of biomethane among the prime-moving countries in this field across Europe. These countries will also form the core focus group for the analysis – these include United Kingdom (UK), France (FR), Germany (DE), Italy (IT) and Denmark (DK). Poland (PL) has also been selected to support comparative analyses and drawing conclusions for many other European countries, since despite having the largest biomethane production potential, Poland does not have a single biomethane production facility in operation at the time of preparing this analysis (2022/2023). The 2030 horizon for the forecasts is also not incidental, as it is the reference date for the EU's ambitious 35 bcm biomethane production target spelled out in the RePower EU plan (European Commission, 2022a).

4.1.1. Research sample

The choice of countries selected for this study is predominantly dictated by their experience in fostering the development of biomethane production facilities in a market environment. While the technology has so far seen limited applications, when compared both to the domestic demand and the related feedstock availability, the size and profitability of some of these facilities reinforces the notion that biomethane offers a tangible option to decarbonize part of the gas demand already today (Stockler et al., 2020).

United Kingdom was an obvious choice for the study on gas market competitiveness, not least because it was among the world's pioneer countries in liberalising the natural gas sector. Additionally, according to a study by the NNFCC, there were already eight biomethane plants in operation in the UK in 2008 and approximately 175 are scheduled to be in operation by 2026 (Hopwood, 2022). The country also holds considerable experience in introducing different forms of support schemes for renewable energy, including for biomethane (Munoz Garcia et al., 2022). These include both obligations on large consumers to cover a proportion of their supply with biomethane, as well as feed-in-tariffs. Most recently, a modified form of the feed-in-tariff regime has been introduced to promote the deployment of biomethane, conditioning the size of the subsidy on the plant's capacity (BEIS, 2021). Going forward, the UK is also pursuing ambitious projects for further expansion of biomethane production, possibly also through establishing several clusters for its production throughout the country (Munoz Garcia et al., 2022).

France has been selected for the analysis both because it has tremendous biomethane production potential of nearly 6,4 bilion cubic meters per year (bcm/y) (Gas For Climate, 2022) and because it pursues a very ambitious biomethane development policy according to which its production is to reach 40 TWh per year by 2030 corresponding to 10% of the country's estimated gas demand (*Law no. 2015-992 on Energy Transition for Green Growth*, 2015). France is also of particular value to this study, since it has achieved an impressive biomethane production capacity development rate despite having only negligible volumes produced until 2015 when the new support scheme was introduced (Phan and Plouhinec, 2021). This enhanced deployment rate stems from a combination of tenders for new production facilities and the establishment of a traded certificates scheme that, over time, is expected to become the default form of support to renewable gas producers (CRE, 2022). It also deserves to be noted here that while France positions itself as one of the prime movers in terms of biomethane production in Europe, its certificates scheme is being implemented ahead of a pan-European solution, risking the national records being incompatible with others across the EU in the future.

Germany has by far the largest biomethane production in the EU, with an estimated 7,8 bcm by 2030 (Gas For Climate, 2022). It is also the world's largest biogas producer and one of the first countries in Europe to have biogas-to-biomethane upgrading facilities deployed (IEA, 2021a). The example of Germany can be viewed as an important reference for other countries, particularly since it has been severely affected by Russia's invasion of Ukraine and the gas supply cuts that followed. Facing a massive natural gas supply shortage in the medium term, Germany has the ambition to develop biomethane production up to its full potential, not least to resolve the internal congestion that currently prevents sufficient volumes being transported between the north and the south of the country (European Commission, 2022b).

Italy has been selected for the analysis primarily because of the so-called BiogasDoneRight concept that has been developed by its biogas association (Consorzio Italiano Biogas, 2017). BiogasDoneRight outlines a clear concept of proper, sustainable and affordable form of biogas production that relies on residues and sequential crops, thereby retaining and possibly even enhancing food and feed production. The approach spelled out by Consorzio Italiano Biogas is being adopted and copied around the world as a pragmatic and effective way of ensuring that biogas and biomethane truly contribute to decarbonization over their entire lifecycle. In addition, Italy's biomethane production potential is the third largest in Europe (Gas For

Climate, 2022).The country also operates an GO and certificates scheme for supporting biomethane production as of 2018 (Benedetti et al., 2021). Going forward, biomethane has been defined as one of the key technologies to be supported under the National Recovery and Resilience Plan (NRRP) - direct investment incentives are offered to new plants, biogas-to-biomethane converted plants and projects improving overall production efficiency (European Commission, 2021).

Although **Denmark's** biomethane production potential is far lower than of the other countries analysed (approx. 0,8 bcm per year) it is quite sizeable when compared to the domestic demand and considering country's size and population. Furthermore, the country can boast a relatively long and highly successful biomethane deployment strategy that has been pursued between 2012 and 2020 (Mathieu and Eyl-Mazzega, 2019). In 2021, a comprehensive Green Gas Strategy has been adopted, setting a very ambitious 2030 biomethane production target that is to cover as much as 70% of the national gas demand. While it might seem overly ambitious when compared to other countries (that, like France, can deem a 10% demand target as very ambitious), it needs to be noted that around 25% of gas demand has already been satisfied with biomethane production over the course of 2021 (Danø, 2022). By the end of 2022 that share has increased to over 32% and the country's coverage with biomethane facilities is improving fast (Energinet, 2022).

Finally, **Poland** is a market selected for a comparative analysis in order to observe the shifts in the assumed relative competitive position between the five prime-moving countries in terms of biomethane production and other countries that have not yet begun supporting the deployment of biomethane. The choice of Poland for this comparison is not incidental – Poland has over the past years invested heavily in its gas infrastructure and diversification of gas supply sources. Its interconnectivity with neighbouring Member States has improved considerably over the analysed period. At the same time, the country's biomethane production potential is among the highest in Europe, estimated at 3,1 bcm/year by 2030 (Gas For Climate, 2022). It also needs to be noted that while the gas market liberalisation is a process ongoing in Poland for years, the country's national market remains largely foreclosed for competition, retaining the central role of the national incumbent as the key importer of gas and a dominant supplier (Lont, 2020).

4.1.2. Components of the Gas Sector Competitiveness Index

The aim of this study is to evaluate the national gas sector's competitiveness and the way it is changing over time. In order to do that dedicated synthetic measure of gas sector's competitiveness will be established to allow evaluating the relative competitive position of the countries analysed in view of the changing external economic conditions as well as legislative and regulatory decisions taken at the national level. Such synthetic index for the gas sector's competitiveness is to help answering the following research questions:

1. Does sizeable domestic natural gas production ensure a competitive advantage over countries relying predominantly on imports?
2. Do direct pipeline connections to natural gas exporting countries support competitiveness of the importers when compared to countries further away from the production fields?
3. Can the development of biomethane production facilities support the sector's competitiveness despite the additional costs stemming from their subsidization?
4. Does an integrated market for biomethane support sectoral competitiveness versus the current national support schemes?

The application of a synthetic indicator that would characterize the gas sector's performance with a single number, appears to be an attractive tool particularly if it is to facilitate comparative analyses of the national sectors. However, the approach proposed for the construction of the GCI cannot be simply translated onto the mesoeconomic level without making certain changes to its design. Unfortunately, no similar study pursuing such transition has been identified, so the selection of determinants that are deemed relevant at the sectoral level was based on a careful analysis of the methodology underpinning the construction of GCI in the context of the macro- and mesoeconomic competitiveness theory as outlined in chapter I. What is particularly worth noting at this point that the global index uses both quantitative and qualitative information to arrive at a synthetic score that, apart from the different types of statistics, also reflects the more or less subjective feedback on the relative performance of different institutions in each country (World Economic Forum, 2017). As this is a factor that according to theory (Kancs and Kielyte, 2001) is of significant importance to sectoral competitiveness, a similar approach will be taken in this study.

The following determinants have been considered as components of the synthetic measure, further referred to as the Gas Sector Competitiveness Index (*GSCI*), drawing from a careful analysis of the factors considered under the macro-level GCI index:

- Gas price (*Gp*)
- Emission savings (*Es*)
- Gas infrastructure (*Ginfr*)
- Institutions (*Ins*)
- Job creation (*Jc*)

Other factors, as discussed under chapter I, were not deemed suitable for an analysis at sectoral level, as they either relate to the broader aggregates (such as health and education, overall labour efficiency), or refer to features that might not take strong effect on the research group's relative competitive position due to strong economic ties (such as business sophistication or market size).

Gas Price remains of key concern to different consumers and since the commodity has many uses as both fuel and feedstock, it is an important determinant of competitiveness for the national economy. It is also important to recognize that the once injected into the network, gas of both fossil-based or of biological origin becomes co-mingled and is delivered to the end-customer as a homogenous product. Hence, no distinction is made between the price of the two commodities, as they are inseparable. Different assumptions, however, had to be made with reference to the potential support schemes and the impact they may have on prices paid by consumers. It needs to be noted here that the price taken for the competitiveness measure is not the hub-based wholesale price of gas in a given country, as these are closely correlated for the studied countries and not reflective of the different decarbonization policies that often manifest themselves in the form of levies and charges imposed on industrial end consumers. Instead, the average of the industrial consumer prices paid by large consumers, categorised by Eurostat within bands I5 and I6 based on their annual gas consumption[17] has been taken as reference for the countries analysed. The other reason for choosing only the large consumers is that usually they are targeted by different forms of climate policies that either oblige them to consume a predefined share of renewable energy or to pay an increased share of the renewable levy and/or

---

[17] Band I5 includes entities consuming between 100 000 and 1 000 000 GJ of natural gas, whereas band I6 covers consumers using up to 4 000 000 GJ annually. Prices are considered excluding VAT and other recoverable taxes and levies, as defined by Eurostat in order to reflect the true cost of gas supply in a given country.

additional taxes aimed at internalising the costs their activities cause to the environment (Grave, 2016).

The choice of the industrial consumer price as reference for the competitiveness indicator poses a number of challenges with regard to its level in each country going forward. International gas price forecast has always posed a tremendous challenge, yet the geopolitical turmoil stemming from Russia's invasion of Ukraine in 2022 has made it even more difficult. Nonetheless, it is assumed that after a period of excessively high prices, market fundamentals will bring the gas market back to its long-term development pathway, as assumed by the International Energy Agency for the years 2030 and 2050 under different climate policy scenarios (Gottlieb and Krogulski, 2022). Therefore, these assumptions will support defining the wholesale gas consumer price pathways in the countries analysed up until 2030. The annual dynamics will, in turn, be referenced against the forecasts of the peak domestic demand related to the domestic GDP for the coming years, relying on the price elasticity of gas demand and the price spikes that stem from high peak winter consumption, as summarized in (Department of Energy and Climate Change, 2016). Further enhancements for each year of the forecast will also be considered as a consequence of the selected support scheme for biomethane, that can impact the price either being included in the final bill directly as a levy or be paid separately through the acquisition of the guarantee of origin. While the net impact on the gas price will need to be assumed in line with the perceived efficiency of the support scheme, the difference in the impact this factor will have on the synthetic measure will manifest itself in the weight attributed to each component. These weights, in turn, will need to reflect the support scheme selected for each scenario, making each of them a separate storyline of its own for the deployment of biomethane in different countries – the scenarios will be described in more detail in part 4.2. of this chapter.

Emission savings – sustainably produced biomethane that displaces natural gas in the national energy mix carries no emissions into the atmosphere over the commodity's lifecycle. This means that each MWh of biomethane produced leads to approximately 246 kg of CO2 equivalent savings on part of the gas sector, according to EU legislation (JRC et al., 2019)[18].

---

[18] It needs to be noted here that such one-to-one emission savings feature follows a simplifying assumption when it comes to the feedstock mix typically used to produce biomethane and its final form of consumption i.e. combustion. Following the JRC methodology, this entails a feedstock mix of 30% maize and 70% wet manure translating into emissions savings between 86% and 110% versus the combustion of natural gas (JRC et al., 2019). Savings versus combustion (and not e.g. consumption as compressed natural gas) is a reasonable assumption as this is the most common use of biomethane today, yet it needs to be noted that the numbers can be inflated vis-à-vis different forms of consumption (Ricardo Energy & Environment, 2016).

The more emissions are avoided, the better quality of the product is being delivered to the end customers according to the base assumption for this study. It needs to be reemphasised at this point that although biomethane production is based on an established technology that has been tested and proved resilient in numerous commercial applications, its actual deployment in most countries is still at early stages. Nonetheless, most countries considered already have experience in operating this technology, reflecting their "technology readiness", as is evaluated under the GCI indicator. The actual pace at which different countries will be able to encourage or enhance biomethane production depends on a whole set of factors, that are either not collected at all or not made available publicly. Furthermore, there is a lot of uncertainty about the regulatory environment for biomethane in the future, both nationally and at the EU level. This means that the pace at which different national sectors will decarbonize will need to be simulated following a set of assumptions for the future. The determination of these scenarios will, on the other hand, allow for better consistency between the components of the synthetic measure. In terms of the design of a forecast, the resultant pace at which biomethane plants will develop will be derived from the gas price forecasts, since this factor will ultimately drive the economics of each investment.

Gas infrastructure – one of the greatest advantages of biomethane as a sustainable fuel in the coming years is the fact that chemically it is very similar to natural gas and as such, it can be transported through the existing gas network and used in the same appliances[19]. This also retains the gas infrastructure as an important asset and a determinant of competitiveness in the future, particularly since the development stage of this network will impact the pace of biomethane deployment – proximity of the network and its ability to absorb the biomethane produced are important determinants of making an investment decision. It also needs to be emphasised that the existence of the gas infrastructure enables access to different sources of gas, giving customers a choice and as such, constituting the "backbone" of a competitive gas market for many years now. Given the complex nature of this determinant, this will also need to be a synthetic measure of its own, reflecting a separate subset of components, namely:

- **capacity of the network on cross-border points** – calculated as the average value of the technical physical cross-border entry and exit capacity on the cross-border interconnection points with neighbouring countries (measured in GWh/d). That average

---

[19] The only tangible difference between biomethane and natural gas is the difference in oxygen content where it is typically higher for biomethane, as a consequence of certain biogas's desulphurization methods. This difference, however, has a limited effect on most appliances and can be treated at the network level as part of the system operator's day-to-day activities (Okoro and Sun, 2019).

daily value will further be referenced against maximum daily demand recorded for the given year (also in GWh/d) to ensure comparability between the analysed countries, as well as to reflect the flexibility the infrastructure offers to its users;

- **storage capacity** that often contributes substantially to dealing with seasonal demand swings in the analysed countries and offers additional flexibility to the market participants. That capacity is referenced against the annual inland consumption as reported in Eurostat data in order to properly reflect the market size. It should be noted here that this component already entails a simplifying assumption that the entire storage capacity as reported for the countries analysed can be used to deal both with seasonality, as well as short-term price swings, whereas different types of gas storage facilities are used for each of these purposes (ACER, 2022).

Although the core elements of the infrastructure in the countries analysed have already been built by the end of the year 2022, historical alterations of the gas network’s topography over the period analysed is considered to have had considerable impact on sectoral competitiveness. Going forward, major investments have been announced particularly in terms of LNG terminal regasification capacity, although this will likely displace the use of pipeline capacities for gas imports from Russia. In practice, a forecast for both the infrastructure capacities and the maximum demand in a given year, will be established based on panel cointegration techniques, through verifying their cointegrating relationship with readily available forecasts of GDP per capita. For the sake of completeness, however, it needs to be noted that excess infrastructure capacity, just like excess storage capacity, may well act to the detriment of sectoral competitiveness, as the underutilised infrastructure still needs to be amortised in full and requires maintenance, weighing heavily on the tariff the network users are forced to pay. The issue of excess capacity is in fact expected to become of major concern to the gas consumers across Europe as an increasing share of domestic energy consumption will become electrified and the amount of gas flowing through the existing network will drop, forcing the remaining users to pay an ever-growing tariff to keep the system in operation (Grote et al., 2022). Nonetheless, while the issue will weigh heavily on the gas sector’s competitiveness in the future, the assumed forecast period of the upcoming 8 years will not likely witness multiple instances of gas pipeline decommissioning or repurposing that would be capable of shifting the relative competitive position of the analysed national sectors substantially (European Hydrogen Backbone, 2022). Furthermore, given the challenges brought about by the increased tensions between EU, UK and Russia, the historical largest supplier, it can be reasonably assumed that the challenge of large parts of the gas infrastructure becoming stranded within the study's 2030 horizon is unlikely to materialize and that the gas network will be a stimulus to sectoral competitiveness[20].

Institutions – the experience with developing the national gas markets thus far has evidenced that institutions are indeed of central importance to the success or failure in developing a competitive gas market (see chapter II for further reference). It is therefore logical to assume that they will continue determining the competitiveness of the gas sectors in the future, not least through facilitating or hindering the speed at which biomethane production facilities will develop. This is by nature a qualitative factor that also needs to be designed as a composite index, reflecting the quality of the market design within the understanding of the EU acquis, as well as market performance as viewed by the market participants. In order to make that possible, a ranking of the analysed countries will be prepared for the previous years:

- Two rankings will be prepared to reflect the perceived **market design compliance and development stage**. One score will be awarded following a review of the quarterly gas market monitoring reports from the European Commission, focusing much on the country's compliance with the EU acquis. Where available, these scores will be further verified with conclusions stemming from periodic Network Code Implementing Reports, prepared periodically by the Agency for Cooperation of Energy Regulators (ACER). Another score will be awarded based on conclusions stemming from IEA's periodic National Energy Policy Reviews, that focuses on the overall resilience of a given market, both in view of the competition level achieved and supply security. Both reviews will result in attributing a score on a scale of 1 to 6 for each country in a given year, evaluating legal compliance and market development, where the highest score would be attributed to the best institutional setup. Thusly defined rank would also support the intuitive perception of this factor, for which higher values are preferred.
- Third ranking is set to reflect the **market performance**, spanning beyond the pure legal compliance. The rank will be attributed on the basis of a score attributed to each country analysed under the annual Gas Hub Development Study prepared by the European

---

[20] It deserves to be noted that the study will not consider how the issue of the main import routes from Russia to the analysed Member States (NordStream 1 and 2 pipelines from RU to DE, Yamal pipeline from RU to DE and PL, as well as sizable elements of infrastructure crossing SK and AT to deliver gas to IT and FR from the Brotherhood and Soyuz pipelines) can be resolved. These assets have become a very politically-sensitive subject and even though some of them may not be coming back into operation, their legal status and the related responsibility for decommissioning will likely be subject of long legal disputes, resolution of which will not likely be seen before 2030.

Federation of Energy Traders (EFET) and reflecting the market participant's experience with operating in different markets (EFET, 2023).

Available annual studies from EFET on the different EU hubs have been used to the extent to which each annual score refers to aspects of the overall market design efficiency. EFET's annual gas hub study attributes a score of 0 to 20 to European gas markets based on a common scorecard looking at different aspects of a competitive gas market functioning. For this study the following measures have been deemed relevant, as essentially reflecting the efficiency of institutions responsible for establishing an efficient market design – these include:

- scores rating relative transparency of different authorities i.e.:
    - the regulatory authority and/or the relevant ministry as appropriate – criterion 1a. of the scorecard;
    - the TSO and the market operator as appropriate – criterion 1b. of the scorecard;
- the establishment of a single virtual trading point (VTP) to which all the transmission network entries and exits are connected to without additional conditions attached (point 1c. of the scorecard);
- use of market mechanisms to balance the network (criterion 5. of the scorecard) and commercial terms incentivizing obliged network users to maintain a daily balance (criterion 4. of the scorecard);
- efficiency of measures taken to address the issues around market concentration (criterion 7. of the scorecard).

While some other points are also of relevance to the overall market functioning, they have a strong trading-related focus that might bias the overall score, particularly from the perspective of production facilities development. The other downside of the remaining criteria on the scorecard is that they have changed over time as the markets developed. Finally, it needs to be noted that for the years for which EFET study has not been published (2008–2013) – the attributed market performance score has been set to zero, making that factor irrelevant during these years. While this decision stems from the information constraint, it also reflects the fact that by 2014 most countries analysed were still at early stages of market development and the main two EU Member States that could be attributed a "positive" score following the EFET methodology would be the United Kingdom and the Netherlands.

- Forth score will evaluate **the reliance of a country on a single supply source** – that value will be represented by the share of the largest import source in the imported gas mix. It is to reflect the dependence on a single source, hence indirectly the supply side competition that creates a downward pressure on prices on one hand and supply security on the other. While historical values do not reflect whether the highest share from a single source is a matter of economic choice or lack of alternatives, recent experiences of Europe prove that high dependence on one supplier cannot be seen as positive in either case, due to security of supply considerations. From an institutional perspective, this dependence should therefore be actively tackled either through ensuring access to different gas sources or limiting importer's ability to rely exclusively on a single source. Such diversification requirements are known e.g. from Polish legislation (Lont, 2020). The percentage value reflecting reliance on a single source is based on Eurostat data and will act to the detriment of country's Ins score the higher that value is.

Since the Institutions factor reflects qualitative features of national markets, its future values are not easy to forecast. In order to avoid oversimplifying assumptions on these determinant's invariance, a polynomial regression model will be used to forecast the future value of the Ins index's components (McKelvey and Zavoina, 1975). In terms of import dependence, it is assumed that its value will reduce at least at a pace reflecting the demand drop under a given scenario, with the exception of Denmark, which is expected to regain the status of an exporting country already in 2020 and retain it beyond 2030 (IEA, 2021b).

The process of establishing a score for the institutional setup for the gas market, although building on external sources and following a common methodology as described above, is prone to subjectivity, not least because the EFET study carries a degree of subjectivity on its own. Nonetheless, as the institutional design has over the years proved to be central to the national markets performance, the Ins variable has been deemed crucial to the proposed *GSCI* index. It also needs to be noted that the analysis of the countries for the purpose of establishing ranks on the basis of market development stage factors has provided further evidence that institutional efficiency was key in developing competition and liquidity on the different national gas markets. Some examples include:

- tackling behaviour of former incumbent that has prevented new market entries (e.g. the enquiries leading to Germany's E.ON reselling previously withheld network capacity as of 2010);

- prevention of locking in the gas in long-term transactions outside of the traded market (e.g. introduction of obligations to offer gas through the virtual trading point in Italy in 2008 or in Poland in 2016);
- ensuring a stable regulatory environment for the market participants (e.g. the British Gas Act of 1986 has seen a major overhaul only in 2017, otherwise facilitating a benchmark for gas market liberalisation in other countries);
- reforming the previously onerous requirements on market participants without consequences for transparency or supply security (e.g. the reform of storage obligations in France in 2018).

On the negative side, the institutional consequences for the development of a competitive market include:

- introduction of market foreclosing measures giving advantage to the incumbent (e.g. the reform of storage filling obligations in Poland from 2017);
- retaining fragmented regional networks guaranteeing a minimum market share to the former incumbents and a dominant role for the main suppliers (e.g. the historical fragmentation of the German market until 2009 and beyond, often attributed to the weak legal grounds for NRA monitoring operations (Heather, 2015));

Overall, it can be stated that the right set of legislative and regulatory decisions founded on an open dialogue with the market participants has typically marked the turning points in different markets development.

Job creation – following the examples of different measures of competitiveness discussed in chapter I, sector’s ability to create new job opportunities can be a good proxy for its competitive position. Although until now the European gas sector contributed to developing a modest, yet relatively good quality employment rate on the services side (given modest domestic production size in most European countries over the past fifteen years), development of biogas and biomethane production can change the picture dramatically. Biomethane plants are typically sizeable units that are capital intensive and at the same time require an entire set of qualified employees to facilitate and overlook the process. Indirectly, where plant residues and sequential crops are used as feedstock, they also contribute to employment in the agricultural and transport sectors (Sørensen and Jørgensen, 2022). Finally, it needs to be stressed that most of these facilities will likely need to be located close to the source of the key feedstock i.e. in the rural areas, creating work opportunities in places that are frequently in most dire need of them. For the purpose of this study, the conclusions stemming from the Navigant study on the job creation potential related to the deployment of renewable gases in Europe will be used (Navigant, 2019). The study finds that 1 TWh of sustainably-produced biomethane creates between 775 and 1050 jobs in rural areas of Europe and that assumption was reinforced by similar conclusions published by the Italy's Consorzio Italiano Biogas (Consorzio Italiano Biogas, 2014), the authors of the aforementioned BiogasDoneRight initiative. Similarly to emission savings variable, forecasts for job creation will build on the industrial price forecasts, as the driver of investment in new production facilities.

Based on the outline presented thus far, the *GSCI* would take the following form:

$$GSCI = Gp + Es + Ginfr + Ins + Jc, \tag{4.1}$$

where:

Gp – gas price;

Es – emissions savings;

Ginfr – infrastructure for gas (synthetic measure);

Ins – institutions (synthetic measure);

Jc – job creation.

Moving onto the structure of the additional synthetic indicators (*Ginfr* and *Ins*), their design has been proposed as described below.

$$Ginfr = Ic + Sc, \tag{4.2}$$

where:

Ic – interconnection capacity related to domestic demand [%];

Sc – storage capacity related to domestic demand [%].

The synthetic measure reflecting the institutional variable *Ins* is as follows:

$$Ins = LcEC + LcIEA + Mp + Sd, \tag{4.3}$$

where:

LcEC , *LcIEA*– legal compliance and development stage according to the European Commission and IEA/ACER accordingly;

Mp – market performance according to the EFET scorecard;

Sd – highest dependence on a single supplier related to total import dependence [%];

4.1.3. Calculation of the Index

Once the components of the *GSCI* have been defined, they need to be divided into categories that either support sectoral competitiveness (i.e. stimulants) or act to its disadvantage (destimulants) (Bluszcz, 2020). Based on the description thus far, this is a simple, yet important step in defining the synthetic indicator – hence, for the sake of transparency, the division results in two groups of variables used:

- stimulants: emission savings (*Es*), infrastructure for gas (*Ginfr*), including cross-border and storage capacity (*Ic* and *Sc* respectively), institutions (*Ins*) and job creation (*Jc*);
- destimulants: gas price (*Gp*) and the supplier dependence subcomponent (*Sd*) of the Institutions measure (*Ins*)

Once grouped in the two types of variables, they need to be normalized to ensure their additivity into a synthetic index. Following approach has been implemented, as proposed in (Strahl, 1996):

$$\mathrm{i_{xc}} = \frac{\mathrm{v_{xc}}}{\max \mathrm{v_x}} \qquad \text{(for stimulants group),} \tag{4.4}$$

$$\mathrm{i_{xc}} = \frac{\min \mathrm{v_x}}{\mathrm{v_{xc}}} \text{ (for destimulants group),} \tag{4.5}$$

where:

$\mathrm{i_{xc}}$ – normalized (additive) value of variable x for country c,

$\mathrm{v_{xc}}$ – value of variable x calculated for country c,

max $\mathrm{v_x}$ – maximum value of variable x among all the countries in a given year,

min $\mathrm{v_x}$ – minimum value of variable x for all the countries in a given year.

In addition, the Sd variable (destimulant) had a maximum threshold defined at a level of dt = 33% to support the selection of countries with well diversified supply sources, the largest of which could still be relatively easy to replace. This follows both the trends in EU's overall gas supply mix and the aspirations stemming from different EU policy proposals for moving away from Russian gas supplies (Ratner, 2020). The further away a given country is from the chosen threshold in a given year, the bigger the "penalty" it receives for its Ins variable value i.e.:

$$\begin{cases} \mathrm{i_{Sdc}} = \frac{\min \mathrm{S_d}}{\mathrm{v_{Sdc}}} \ for\ S_d \leq\ dt \ \ , \\ i_{Sdc} = \frac{d_t}{v_{Sdc}} - 1\ for\ S_d\ >\ dt \ \ , \end{cases} \tag{4.6}$$

where:

dt – maximum desirable share of a single source in the country's gas supply mix

Once the values are normalized, the value of the *GSCI* is established through calculating the weighted average of the normalized i_x values for each country in a given year i.e.:

$$GSCI = \sum_{x=1}^{n} \frac{(i_{xc} \times w_x)}{n}, \tag{4.7}$$

where:

GSCI – gas sector competitiveness index

i_{xc} – normalized value for variable x calculated for country c,

w_x – weight assigned to the variable x,

The weight for each component under the *GSCI* will be established under the different scenarios envisaged under this study, as they will be used to place emphasis on different aspects of the competitiveness score. Before the scenarios are analysed, however, the proposed set of variables needs to be analysed in terms of their cross-correlation. This is to ensure that each component used in the final set comprising the *GSCI* introduces a distinct set of information about the sector's competitive position and that no single aspect is being accounted for twice.

Correlation matrixes for the *Ginfr* and *Ins* synthetic measures, as well as the final *GSCI*, have been collected in annex I. Results indicate very low coefficient between the components of the *Ginfr* indicator, making them suitable for establishing a synthetic measure. For the Ins variable the coefficients are higher, particularly between the scores derived from the IEA reports and European Commission's quarterly reports where it reaches nearly 60%. Nonetheless, since both sources focus on different type of information (i.e. issues around supply security versus legal compliance and market performance), the decision was taken to treat this level of correlation as tolerable.

Correlation matrix for the five components under the *GSCI* (already including the synthetic *Ins* and *Ginfr* values), however, identified perfect correlation between the emission savings (*Es*) and Job creation (*Jc*) variables. This is a natural consequence of the fact that both categories are related to biomethane generation capacity, thereby representing the same information scope under the *GSCI*. Emissions savings variable is deemed crucial for the *GSCI* index as it represents the additional quality of the gas supply delivered by the given sector. It was therefore necessary to remove the *Jc* variable from further analyses as an index of lesser significance to the conclusions of this study.

The final correlation matrix for the remaining four variables still does signal a relatively strong, negative link between the *Ginfr* and *Ins* components of nearly 56%. However, since both are of a very distinct nature, this correlation is considered to be largely incidental, having negligible or no impact on the quality of the synthetic indicator. With the final set of components confirmed, the next subchapter will outline the scenarios for the forecasts along with the weights attributed to the factors included in the *GSCI*.

4.2. Scenarios

As mentioned previously, EU's gas sector is facing a period of tremendous uncertainty both because of the ongoing works on the overhaul of the legislative package underpinning the gas market, but also because of the difficult geopolitical situation stemming from Russia's invasion of Ukraine in 2022. This makes any forecasts and assumptions for the future prone to error and hence forces the decision to build several scenarios to work with.

Scenario analysis in a highly unstable environment has become the default approach to strategic planning and making investment decisions in oil and gas projects over half a century ago (Noone and Ackerman, 2013) . More generally, the policy-related risks are often addressed through applying scenario-based analyses, since, given the multitude of options the authorities often need to choose between, predicting the exact final policy mix is highly improbable (Bodde, 2007). In addition, it is worth mentioning that scenario-based sensitivity analyses are often used for biomass-reliant supply chain modelling both to secure the feedstock and to prepare for different policy changes that can limit the option to use certain materials and residues (Balaman, 2019).

At the core of each scenario will be the assumption of whether and to what extent the national markets for renewable gases can converge, as this will likely have significant impact on the relative competitive position of the countries analysed. Another important aspect for the underlying assumptions in this study is that, given the scarcity of biomethane within the 2030 perspective, no assumptions are made in terms of whether the acquisition of GOs by the industrial consumers are purely voluntary or whether they stem from an obligation to cover a proportion of the gas consumed with biomethane. This assumption is underpinned by the fact that, given the limited options to decarbonize gas consumption within the envisaged timeline, biomethane producers are assumed to find a buyer for both the commodity and the related green value at all times. It needs to be noted that the subject of voluntariness of buying GOs is subject to a heated discussion where many argue that the initial (voluntary) demand for renewable gases will be too low to provide the necessary incentive for potential investors (Herbes et al., 2021). That potentially limited efficiency of the EU GO scheme, however, is set to be reflected in the pace at which biomethane production can develop in the analysed countries under different scenarios.

Finally, it needs to be emphasised that at the time of preparing this study, the intended functionalities of the Union Database are still under discussion, particularly since the declared functionality of the database does not seem to match its physical features of the tool that has initially be set to go live by October 2023 (ENTSOG, n.d.). The discussed discrepancy is fundamental from the perspective of this study as it questions the ability to trade the GO freely before it is transformed in to Proof of Sustainability (PoS). If not ensured, the future setup for the trade of green value would reflect point-to-point transactions, done potentially under long-term contracts, effectively blocking the development of a common market for the green value of biomethane. Since, however, this physical application appears to be far from the intended functionalities of the UDB as spelled out in the gas package, it is assumed that the new scheme will enable streamlining and convergence of national schemes for the issuance, transfer and cancellation of the GOs, as well as their upgrade into PoSs upon consumption (REDcert EU, 2021).

4.2.1. Business-As-Usual (BAU) Scenario

Scenario titled Business-As-Usual is primarily set to reflect the fact that the support schemes designed for biomethane remain national. These support schemes going forward are to mainly consist of auctions awarding fixed tariffs or feed-in-premiums[21] to the winning bidders. This assumption is reflecting the fact that fixed feed-in tariffs have proved to be expensive and guarantees of origin for renewable gases have not been widely picked up outside France, Denmark and Sweden and have so far shown limited efficiency in terms of fostering renewable energy deployment in general. It is further assumed that any biomethane plant benefitting from

---

[21] The difference between the two schemes lies in the fact that a feed-in-tariff guarantees a fixed price for the volumes of gas injected into the gas grid, whereas a feed-in-premium offers an additional subsidy on top of the price at which biomethane can be sold on the competitive gas market. The latter approach reflects a more contemporary, cost-containing approach to fostering biomethane deployment. Additional variations of feed-in-premia such as contracts for difference are also considered whereby subsidies exceeding the pre-agreed threshold are returned to the state budget – such solutions, however, are so far mainly considered for renewable electricity generation which is both more mature and widespread across Europe.

a feed-in premium is not entitled to receive a GO for its output or that the certificate they receive cannot be sold. This tendency in support schemes also reflects the decisions taken in the UK as of November 2021 and the popular trend of switching to auctions on the side of renewable electricity. Under the BAU scenario:

- The development of renewable gas generation translates into additional levies on end-customers, thereby increasing their bills without offering them any choice. As such, it can be assumed that that the Gp variable remains the key determinant of sectoral competitiveness, since in principle the consumers may not notice or appreciate the additional “quality” of the gas stemming from a less carbon-intensive mix in the network.
- The emissions savings variable follows the pattern determined based on historical values where available, ensuring a steady increase in biomethane generation capacity known thus far. Separate assumption for Poland is made, set to reflect a modest build-up of generation capacity in the initial years.
- Infrastructure for gas reflects several improvements in the 2025 time horizon that have been announced or are already under construction. This relates primarily to Germany’s ambitious LNG terminal deployment plan that is to help the country displace Russian gas supplies. The decision to exclude projects envisaged to go live beyond the 2025 horizon is made to filter the numerous projects being announced down to only those that may realistically be completed and will not be abandoned as the energy crisis is overcome.
- Under the BAU scenario, the compliance and performance variable forecasts stemming from the polynomial regression model applied, will be used without any further alterations. For the supplier dependence subcomponent, its value is set to reflect the expected drop in demand expected in the coming years.
- Finally, jobs creation reflects the development pace of biomethane generation capacity in each country.

With *Gp* set to be the key component for the *GSCI* index, other elements are set to have the same weights. Such distribution is set to emphasize the importance of price as a central variable for the gas sector’s competitiveness. Therefore, the weights attributed to each component have been presented in table 5.

Table 5. Weights attributed to *GSCI* components under the BAU scenario

BAU scenario	***Gp***	***Es***	***Ginfr***	***Ins***
Weight	0,4	0,2	0,2	0,2

Source: own elaboration.

In addition, the following assumptions for the sensitivity analysis are made:

- Expected annual demand drop is set to 2% per annuum after the turmoils the European gas market is expected to be witnessing by 2024. For the years 2022-2023 it was assumed that the demand will have dropped by the agreed 15% versus 2021 levels stemming from the EU's winter preparedness package, half of which would be set to recover in 2024.The assumption for years 2023 and 2024 is also reflected in other scenarios, as the duration of the energy crisis is deemed universal for all the forecasts proposed under this study.
- Additional upward price pressure of 4% on top of the modelled prices is assumed to reflect the growing costs of developing and accommodating biomethane production in the national gas grids.
- Development pace of biomethane production in Poland is set to increase modestly starting from 2024 at a pace known from the first years of biomethane deployment in Italy i.e. as of 2014.

4.2.2. Integrated Gas Market (IGM) Scenario

The IGM scenario is set to be in stark contrast to the BAU scenario through assuming that the declared aspirations to establish a well-integrated market for renewable and low-carbon gases, as spelled out in the Hydrogen and Decarbonised Gas Markets Package, becomes a reality swiftly after the legislative package enters into force. The key reference support scheme under this scenario is a fully integrated GO market with instruments that are traded freely and separately from the commodity and at the same time treated at par both across the EU (through the functioning of a Union Database) and in the UK (through a mutual recognition agreement). The scheme further allows evidencing carbon abatement through the use of PoS certificates that are derived from the GOs through meeting and documenting additional sustainability criteria.

Under the IGM scenario:

- The development of renewable gas generation weighs heavily on many industrial consumers prices (*Gp*), yet the effect is largely offset by the benefits brought about by the use of GOs for disclosure purposes and the PoSs through evidencing carbon abatement and reducing the obligation to acquire EUAs. While the net effect on the price is impossible to model within the framework of this study, it can be reasonably assumed that the *Gp* variable will be of lesser significance to the gas sector's competitiveness. This assumption is set to be reflected by attributing a smaller weight to this value.
- Emission savings variable becomes of much greater importance, as industrial consumers can expect tangible benefits stemming from additional prices paid for the instruments evidencing the origin of gas. Apart from evidencing emission savings, the common market for GOs unlocks multiple marketing opportunities to the gas-intensive industry through the ability to focus e.g. on supporting certain source of biomethane on the grounds of its origin. This facilitates a considerable improvement to the "quality" the gas sector offers to its customers, hence E_s is attributed a higher weight than other *GSCI* components under this scenario. In addition, a larger market for the green gas value that offers additional benefits to the purchaser, is expected to enhance the pace at which biomethane generation capacity is being developed across the EU. This will be reflected in the calculations through assuming an additional annual 10% increase in emission savings above the modelled values. Although this premium might seem quite substantial, it deserves to be noted that even under such an assumption all the countries analysed would fall short of the volumes they would be expected to be able to produce if the EU would want to reach the 35 bcm biomethane production target as mentioned in chapter III.
- No deviations from the BAU scenario are assumed for the G_{infr} variable under the IGM setting, although the widespread marketing of the decarbonization options for gas may increase social and political pressures to reduce fossil gas consumption. Since the network throughput will be lower, some of the previously considered projects may no longer be economically viable – yet it can reasonably be assumed that this will primarily affects the projects that have already been disregarded as scheduled past 2025[22].

---

[22] It should be noted here that the assumption under each of the scenarios never assume renewable gas imports from third countries that could increase throughput at import infrastructure. This follows the notion that by 2030 potential recognition of GOs issued in different parts of the world is a highly improbable possibility. This includes

- Since the IGM scenario envisages improved compliance with the EU acquis and mutual recognition of GOs with UK, it is assumed that the Ins component becomes less significant, as part of the responsibilities for the shape and efficiency of the subsidy scheme fall under common arrangements.
- As per the BAU scenario, jobs creation (Jc) reflects the development pace of biomethane generation capacity in each country.

Consequently, the assumed variable weights have been presented in table 6 – according to the proposed distribution of weights, emission savings become the top component determining competitiveness, followed by gas prices. The remaining two have lesser impact on the relative competitive position of the analysed countries, as they are assumed to be engaged in close cooperation.

Table 6. Weights attributed to *GSCI* components under the IGM scenario

IGM	***Gp***	***Es***	***Ginfr***	***Ins***
Weight	0,25	0,4	0,2	0,15

Source: own elaboration.

The following additional assumptions for the sensitivity analysis are made:

- Expected annual demand drop is increased to 5% per annuum after the turmoils the European gas market is expected to be witnessing by the end of 2024. This is to reflect the previously described increase in the importance of gas's origin to the consumers, exerting downward pressure on fossil gas consumption. It needs to be noted that this variable is also reflected in the assumed annual drop in supplier dependence;
- Additional upward pressure on industrial consumer prices is assumed to be lowered to 2%, since under a well-integrated gas market the supply side is expected to grow faster and the acquisition of certificates is expected to enable avoiding other costs originally designed to internalise the environmental impact of different economic activities;
- Development pace of biomethane production in Poland is set to accelerate faster than in BAU scenario, with the first production still set to appear in 2024 and increase considerably under the GO scheme as per the biomethane production in France post

---

Energy Community Contracting Parties, since the most advanced market from that group, Ukraine, is likely to join the European Union sooner than it will be able to unlock its biomethane export potential.

2015. Similarly, a modest acceleration in emission savings of additional 4% per annuum for other countries versus the values modelled under the BAU scenario.

4.2.3. Regional Developed Market (RDM) scenario

Finally, the third scenario envisages that efficient implementation of the revised EU acquis is partial and done primarily in the developed markets of Germany, France, Italy and Denmark. Poland is expected to be lagging behind both because there is no biomethane production in operation at the beginning of the forecast and due to weak institutional setup known from the past years, leading to partial compliance and/or inefficient market design. United Kingdom, on the other hand, is assumed to fall outside the scope of the common market with certain trade barriers still in place and – more importantly – the assumed absence of mutual recognition of GOs issued at either side of the EU-UK border. Also here, the converged market is set to run a common GO and PoS market offering the same benefits to the consumers yet fostering a lower pace of biomethane development due to considerably lower liquidity of the market for the green value[23]. UK retains the current auctions system, while Poland implements an auction scheme and pursues a decarbonization pathway as per the BAU scenario. Therefore:

- G_p retains a considerable impact on the *GSCI* (reflected in the attributed weight) since different schemes remain in operation across the EU, translating in greater divergence in gas price paid by the industrial consumers;
- E_s variable remains of notable significance, yet lower than assumed under the IGM scenario. The increased pressure on prices can be effectively offset in the regionally integrated countries, putting Polish and British gas sectors at a disadvantage. This also means that the assumed development speed of biomethane production in the integrated countries would be higher than modelled, but would be left unchanged for the national markets of Poland and the United Kingdom;
- Assumptions for the gas infrastructure development remains unchanged versus the BAU scenario, as the national markets remain partially fragmented;
- The institutional setup is retained at levels stemming from the model without additional assumptions. Instead, the potential divergence between the institutional performance

---

[23] The assumed drop in liquidity stems not only from the exclusion of Poland and UK from the common scheme, but also from the assumed “two speeds EU” approach – since inefficiency of Poland is considered to be retained and impacting the adoption of the revised gas package, the same should apply to other notoriously underdeveloped gas markets of Romania, Bulgaria, Slovakia or Greece. Collectively, the efficiency of the GO scheme needs to be lower than assumed under the IGM scenario.

within the closely integrated regional market versus the UK and Poland is set to be reflected in an increased weight attributed to the Ins variable;

- No changes are assumed on the side of job creation (Jc) variable.

Overall, it can be stated that the RDM scenario represents a moderate set of assumptions i.e. neither outright negative (as per the BAU scenario) nor outright positive (as per IGM scenario) forecast for the future, placing it in between of the two other setups considered. The assumed weights for the different components have been presented in table 7. The proposed distribution of weights is more balanced, marking that while the gas price still remains of key importance, the regional divergence in approach to developing biomethane production has a more profound impact on the relative competitive positions of the analysed countries.

Table 7. Weights attributed to *GSCI* components under the RDM scenario

RDM	***Gp***	***Es***	***Ginfr***	***Ins***
Weight	0,3	0,25	0,2	0,25

Source: own elaboration.

Finally, the additional sensitivities are assumed as follows:

- Expected annual demand drop is set to 3% per annuum past 2024, reflecting the fact that the RDM is to facilitate an "intermediate" scenario between the BAU and the IGM;
- Development pace of biomethane production in Poland returns to the values envisaged under the BAU scenario (i.e. reflecting the historical development pace known from Italy) while the UK retains its support scheme known from 2021;
- Additional price premium assumed for the regionally integrated countries is assued at the level of 3% since both the supply and demand size would be lower than under the IGM scenarios. Gas price variations modelled for Poland and UK are set to be burdened with an additional 4% year-over-year price premium versus the calculated values (i.e. as per the BAU scenario) in order to reflect the fact that their markets for the green value of gas remain national.

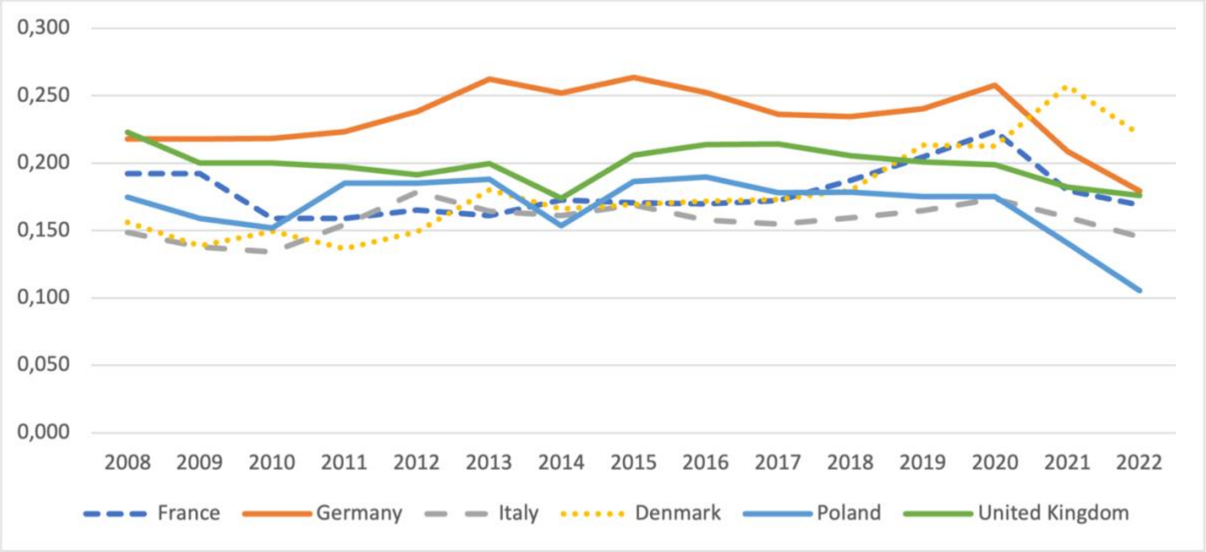
4.3. Results based on data for the period 2008–2022.

First, the resultant *GSCI* scores will be analysed for the years where historical data was available i.e. years 2008 – 2022. Although the scenarios used for this study were primarily designed to govern the forecasts, they also included a set of weights for the competitiveness index's components (tables 1, 2 and 3) that placed a different emphasis on the different aspects of the overall competitiveness score. Therefore, the scenarios will also be used for the discussion around historical values with a disclaimer that they are only set to govern the calculation of the synthetic measure.

4.3.1. Results for BAU scenario, years 2008–2022

Figure 18 presents calculated *GSCI* index for the analysed countries over the period 2008-2022 under the BAU scenario.

Figure 18. ***GSCI* results under BAU scenario for years 2008-2022**



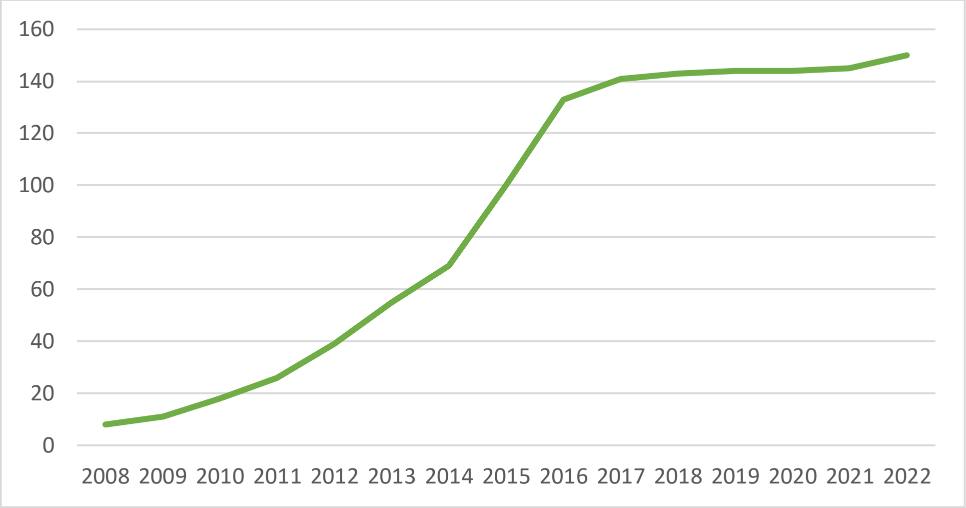
Source: own elaboration.

The historical analysis focused on prices under the BAU scenario allows for drawing interesting conclusions. To begin with, **Germany** records a remarkably strong competitive position up until 2021 despite its strong reliance on imports. This supports the frequently raised assumption that Russian gas supply prices have been particularly attractive for Germany and that this economic partnership has acted to the benefit of the local industry (McWilliams et al., 2022). Such arrangement, in turn, already indicates that proximity of the production fields does not need to justify competitive advantage as raised under research question 2 (i.e. by default such advantage would be notable for Poland). This is also why the energy crisis of 2022 has been particularly damaging to the German economy and shows why the country was so reluctant to abandon the participation in NordStream2 project that would have secured cheap gas supplies for years to come (Lan et al., 2022). Additional improvements to the competitiveness score have been brought about by the mergers of the six market areas to just two as of 2013 (IEA, 2013). The final merger into a single market area as of October 2021, on the other hand has not brought about the expected benefits, as these have been likely offset by the rising gas prices in response to the swift economic recovery after the COVID-19 pandemic (Heather, 2021).

At the lower end of the competitiveness evaluation for the period 2008-2012 is **Denmark** – which is quite surprising, particularly since the country was a net exporter of the commodity for most of the analysed period. This further reinforces the notion that classical theories pointing to resource abundance as the ultimate source of competitiveness were wrong. In fact, the competitive position began to grow when the country was forced to import gas – this coincides with the go-live of the first gas exchange (2011), ownership unbundling of the TSO (2012), but also Norway's Statoil first proposals to offer supplies under a gas market price rather than oil indexation (European Commission, 2012b). Another notable change in the policy came along with the Danish Energy Agreement of 2012, offering financial support of 10,6 EUR per GJ of biomethane produced and injected into the gas grid, marking the start of the country's successful build-up of production plants (Danish Energy Agency, 2012). Finally, it needs to be noted that the country has undergone a market merger with Sweden in 2019, creating a single balancing zone, thereby increasing both its market size and interconnectedness. Altogether, the Danish example signals that sizeable domestic gas reserves does not warrant any competitive advantage (as was to be verified under research question 1).

The **United Kingdom** appears in this analysis as the next best gas market until the end of 2018. The apparent decline in competitiveness until 2014 reflects the continued decline in domestic production – despite holding considerable production capacity, the UK is a net importer of gas as of 2004, not least because gas is the key source in the national energy mix and domestic demand was in the range of a 100 bcm by 2010. What is quite prominent for the UK, however, is the maturity of its gas market, with the country's VTP (the National Balancing Point, NBP) reaching a churn rate of 14 already in 2010 i.e. at a time when most other countries in Europe still had their gas production, transmission, supply and trade integrated in a single entity. A feed-in-tariff support scheme for biomethane has been in place since 2010 up until November 2021, resulting in a considerable number of production facilities being developed. Figure 19 presents the number of plants in operation each year, derived from the assumed annual output of 40000 MWh per plant. It is worth highlighting here that the quick ramp up of biomethane production in the country between 2008 and 2014 is also a period when the overall *GSCI* score was falling, signalling that, at least in the past, biomethane production development did not translate into notable competitiveness gains (as raised under research question 3).

Figure 19. **Number of biomethane plants in the United Kingdom**



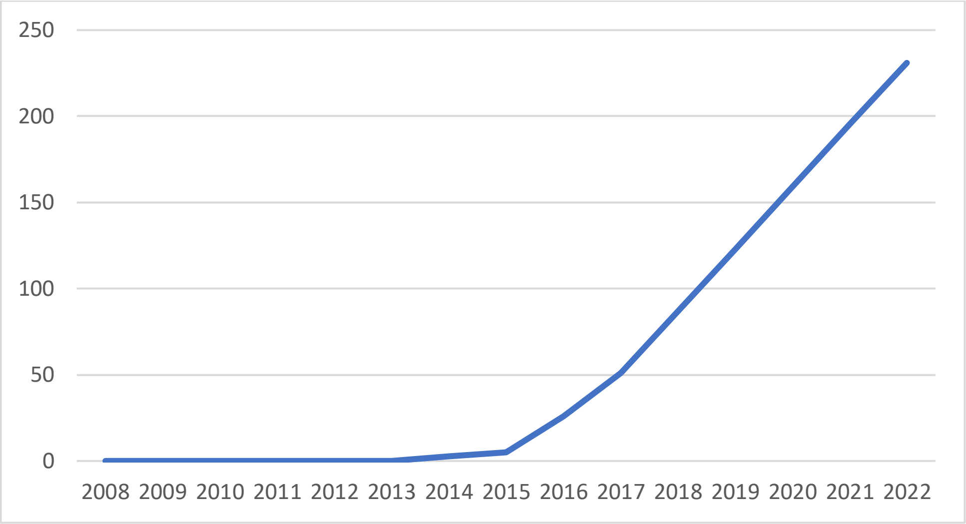
Source: own elaboration based on (Munoz Garcia et al., 2022).

In addition, it needs to be noted that the UK has started gas market liberalisation already back in 1986 and the fact that the related Gas Act remained in force without a fundamental revision until 2017 reflects that the country was able to ensure considerable legislative and regulatory stability to the market participants (IEA, 2019b). It is also worth to point out that with ample LNG import capacity, the country held considerable flexibility that could be offered also to other EU consumers, through reexporting volumes of gas through the pipeline connections with Belgium and the Netherlands. Finally, the downward trend of the *GSCI* score in the UK as of 2020 is a consequence of the country leaving the European Union and the internal market – this had a negative impact on market liquidity, prices and also on the number of active market participants, with further issues brought about by the energy crisis rollout since the final quarter of 2021.

In the first years of analysis, **France** went from mid-ranked country to the worst-performer alongside Italy between the years 2011 and 2015. The perceived fall reflected the increase in gas prices for the industry. In general, though, the gas sector's structure at the time was suffering from being partitioned into three balancing zones, with internal congestions most notable between the north and the south of the country. The historical position of the incumbent has not been addressed and much of the transmission system's capacity was inaccessible to third parties (IEA, 2009a). In addition, the country has introduced very cumbersome storage obligations on the suppliers, which have left no room for commercial use of the storage facilities until the related act was amended in 2018 (IEA, 2021c).

Apart from the revision of the storage obligations, France has undergone a series of reforms, including the gradual merger of the balancing zones into two at first in 2015 and into a single market area named Trading Region France (TRF) as of November 2018. This has been made possible both through additional investment and better congestion management procedures at the bottlenecks (IEA, 2015). In addition, through the joint initiative of the French and the German exchanges, a common PEGAS platform has been launched in 2016, offering gas products under common specification, encouraging more trading activities. Additional investment have also been made for import capacity, in particular the go-live of a large LNG terminal in Dunkirk. Finally, France's large ambitions in becoming one of the largest biomethane producers, has resulted in an attractive feed-in-tariff offered to the investors, leading to a speedy deployment of facilities across the country (figure 20). Interestingly enough, the accelerated development of biomethane generation did not translate into any outright competitiveness score loss providing some counterbalance to the implied negative correlation stemming from the UK's example (with reference to research question 3).

Figure 20. Number of biomethane plants in France



Source: Own elaboration based on (CRE, 2022).

Italy's position according to the *GSCI* under the BAU scenario is not surprising, considering that the country's wholesale price was consistently, and sometimes significantly above the market prices recorded at the liquid hubs of North-Western Europe (European Commission, 2009). Despite having a virtual trading point established already in 2004, the country was struggling to establish a liquid gas market for years, with the strong position of the main importers being pointed to as the main reason (IEA, 2009b). Price premiums that Italy was forced to pay for their gas supply can be a fascinating subject to be studied on its own – despite having a direct pipeline connection to the production fields in Algeria and Libya, the country was paying more than its neighbours to satisfy the gas demand (offering further evidence under research question 2). Over time, with additional investments made to improve interconnectedness with other EU Member States, the situation has improved, but not to a level that would entirely eliminate the premium paid versus the most liquid hubs. Nonetheless, Italy has undertaken considerable efforts to improve market liquidity and diversify its supplies. With reinforced import capacities from Libya coming online after the war in late 2013, three LNG terminals with considerable import capacity, over 15 bcm of storage capacity and the go-live of the Trans Adriatic Pipeline (TAP) that allows for gas imports from Azerbaijan as of 2020, the country has diversified its supply sources well (European Commission, 2020b). This has apparently paid off during the energy crisis of 2022, since its detrimental impact on Italy's competitiveness score is visibly lower than on Germany, France or Poland.

Finally, **Poland** records a relatively stable, low competitiveness score measured by the *GSCI* over the analysed period. It needs to be noted, however, that this stagnation is not a consequence of inability or unwillingness to timely adopt the EU acquis – in fact, Poland has finalized the unbundling of its TSO already in 2005 and allowed for supplier switching as of 2006, ahead of the deadline envisaged by the 2nd Gas Package (IEA, 2011). The country was largely supplied under a long-term contract with Gazprom until 2010 which was then renewed for a period of 12 years – strong veto from the European Commission over the negotiated terms have brought about multiple improvements to the otherwise foreclosing arrangement (e.g. removal of export bans), but the price agreed was clearly way above the price offered to other EU countries and still linked to oil prices. The premium paid versus other countries despite being relatively closer to the Russian production fields is naturally of relevance when attempting to answer research question 2. In any case, this price premium under the supply contract has led to arbitrage cases against Gazprom, forcing it to either loosen the terms or pay fines (Yermakov and Sobczak, 2020). Nonetheless, the national authorities were delaying any decision to open the market to competition, resulting in a monopoly status of the historical incumbent throughout the analysed period. The apparent drop in competitiveness in 2014 that coincides with a similar drop in the UK and, to a lesser extent in other countries, reflects the price shock brought about by Russia's invasion of Ukraine and annexation of Crimea.

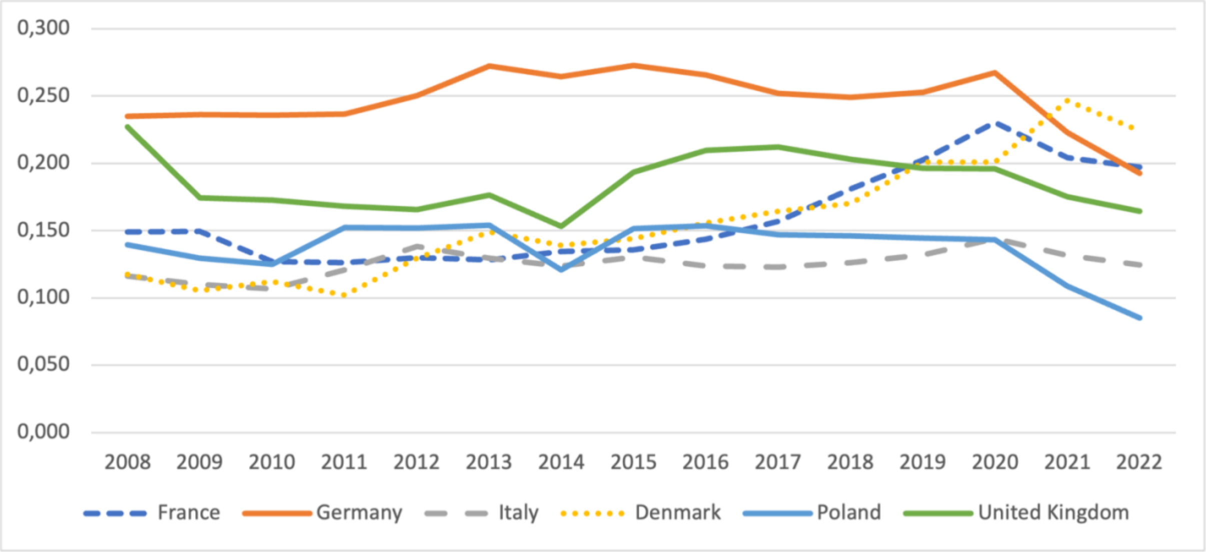
On the positive side, the country has drawn lessons from the supply cuts experienced over 2009 and has worked hard to develop and reinforce import capacities and interconnections that would break its reliance on Russian gas. By 2022, the country has established and expanded an LNG terminal, developed bidirectional interconnection points with all its neighbours (except Belarus and Russia) and finalized the Baltic Pipe project allowing it to import gas from Norway. The other notable difference from the other countries analysed is the fact that gas demand in

Poland has been on a stable and robust rise for most of the years analysed under this study. Unfortunately, with the legislative setup as it stood at the end of 2022, the country could rely almost exclusively on the imports made by the incumbent, since competitors were being held back by the cumbersome storage obligation and a complex and time-consuming licensing procedure. The obligation to resale part of the imported gas at the hub has also been weakened in 2022, further limiting competition over retail customers. These conditions weigh heavily on the competitiveness of the Polish gas market and will require decisive actions from the government and the regulator if they are to be overcome.

4.3.2. Results for the IGM scenario, years 2008–2022

Results for the years 2008-2022 have been presented on figure 21. The IGM scenario based on historical values does not create major changes to the ranks of the analysed countries in the analysed years, not least because it was primarily designed to govern the forecasts. For historical values, however, it does alter the weights applied to each component of the *GSCI*, affecting the amplitude of the year-to-year changes in the index value. It further creates larger differences between the scores attributed to each country, marking the difference in time and pace of at which biomethane production was developing.

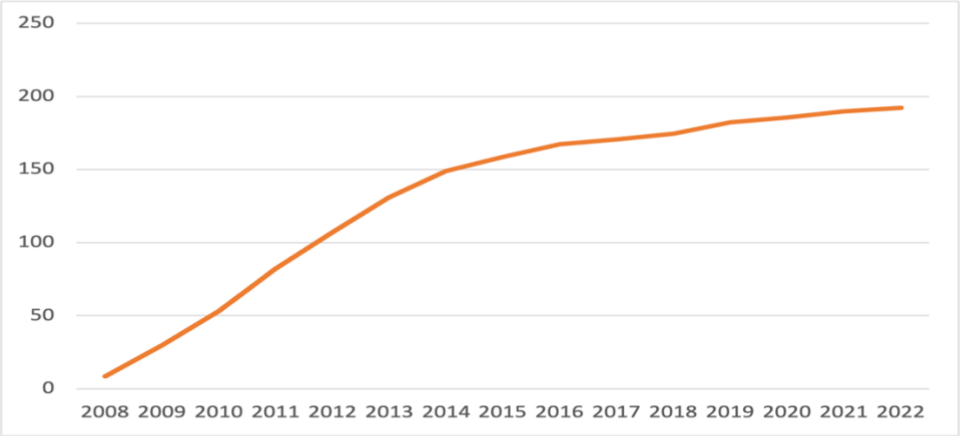
Figure 21. *GSCI* results under IGM scenario for years 2008-2022



Source: own elaboration.

With the emphasis now placed on emission savings, no meaningful changes are observed for **Poland**, since there was no biomethane production over the analysed period. **Germany** retains its position as the most competitive market, particularly since its biomethane production remains largest until 2021 (see figure 22). This also reinforces the notion that the country has been benefitting from particularly cheap gas supply, since even the additional levies paid to finance the related subsidies have not undermined the price at which gas could be supplied to the local large consumers.

Figure 22. Number of biomethane plants in Germany



Source: own elaboration based on (Bundesnetzagentur, 2023).

Secondly, **UK** improves its competitiveness score versus other European hubs, but at the same time finds itself more distant from Germany, signalling that the pace of biomethane plants deployment was slower and had stronger impact on industrial prices. This conclusion needs to be kept in mind when attempting to answer research question 3. The country further lost its position to France and Denmark, as the first feed-in-tariff based support scheme was targeted under a cost-cutting policy and the new capacity-related support scheme of November 2021 secures fewer new contracts than originally expected (Ofgem, 2023).

Thirdly, **France's** score improves more swiftly after the introduction of a GO scheme for supporting biomethane development in 2015, allowing it to overtake Denmark's position already in 2017, then United Kingdom as of 2019 and eventually Germany in the final year of the analysis (Ministere de la Transition Energetique, 2022a). This was possible in large part by the aforementioned merger into a single market area, TRF, but also by the swift development of biomethane generation capacity that has exceeded German production potential already in 2021. This is yet another instance of a contradictory conclusion versus the UK example, suggesting that indeed it is the design of a support scheme that ultimately governs the cost-benefit equilibrium studied under research question 3. **Denmark**, in turn, remains the only country, who's *GSCI* score is not adversely affected by the energy crisis in the final year of the analysis, therefore allowing it to become the most competitive among the analysed group. This seems to confirm that biomethane has the capacity to significantly improve the supply security of EU countries.

Finally, **Italy's** score is lower than under the BAU scenario, not least because the country's first biomethane plant went into operation only in 2017, while the related support scheme was made available as of 2018. However, with the country's huge ambitions in terms of fostering biomethane deployment under the agreed National Resilience and Recovery Plan (NRRP), the country can reasonably be expected to improve its emissions savings capacity going forward (European Commission, 2021). It also deserves to be noted that a lower emphasis on the price component, results in Italy's *GSCI* score only mildly affected by the energy crisis of 2022, proving that the efforts to diversify the country's supply sources have paid off, leaving its *GSCI* score just below the one calculated for the UK in the final year of the analysis.

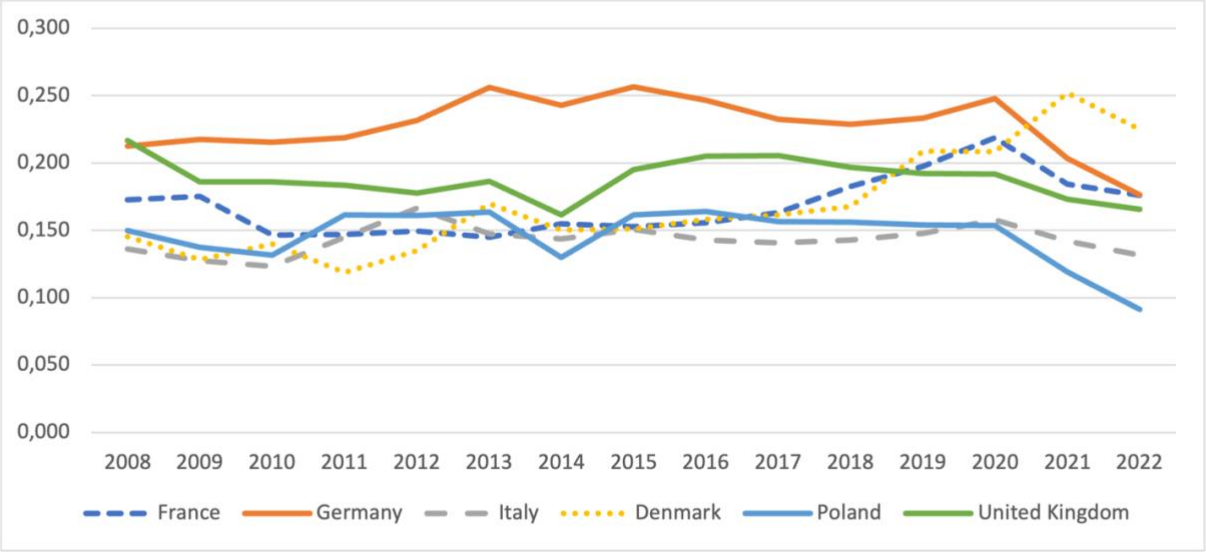
4.3.3. Results for the RDM scenario, years 2008–2022

As per the IGM scenario, the RDM merely shifts the weights applied to different *GSCI* components when calculated for historical data (Figure 23). With the gravity of each subindex more streamlined, this scenario brings the national competitiveness scores more closely together once again.

Germany and **Poland** remain the two countries most severely hit by the energy crisis that followed the war in Ukraine. This result seems reasonable since the two countries remained most reliant on supplies from Russia out of the countries analysed (di Bella et al., 2022). Poland still sees a stagnant competitive position with no biomethane production in place and strong position of the incumbent facing no competition over gas imports into the country. Germany, on the other hand, manages to defend its second place in the final year of the analysis with the score just marginally above the one calculated for France.

United Kingdom and **France** experience a similar downward trend in the *GSCI* value post 2020, with the gap slowly widening in favour of the latter. This reinforces the notion that UK remains more prone to price shocks on the global market – this can be observed both during the 2014 spike caused by Russia's invasion of Ukraine's Crimea and in the final year of the analysis. Conversely, the 2014 shock is not reflected in France's score at all, whereas the energy crisis of 2022 affects it to a lesser extent. Both the market consolidation efforts from the past and the gas sector decarbonisation policy bring France from the lowest rank in 2013 (marking the year when storage obligations block commercial use of these assets) to second place in 2020, when the market development stage was deemed mature enough to enable the removal of any form of fixed tariffs (Ministere de la Transition Energetique, 2022b).

Figure 23. ***GSCI* results under RDM scenario for years 2008-2022**



Source: own elaboration.

Denmark and **Italy** remain least affected by the energy crisis, which again appears to be in line with the expectations, given that both countries are directly connected to producer countries i.e. Norway, Algieria, Azerbaijan and Libya. Danish system, further to exports of own production during the years when the country was producing surpluses, also offers considerable capacity to reexport gas from Norway. For Italy, this additional bidirectional capacity to reexport gas to neighbouring countries was under development over the analysed period. As mentioned before, Denmark has also started its gas decarbonisation efforts much sooner, which over time has helped the country move from last place in 2011 to a leading position in 2022. With biomethane covering 34% of the domestic demand in 2022, Denmark proves that decarbonisation of the gas sector is possible and that it can further reinforce supply security of the European countries that until now have relied primarily on imports (Robb, 2022). This conclusion, together with the fact that the country manages to reach the top competitive position over the analysed period reinforces the notion that the roll-out of biomethane does not need to be done at the expense of the sector’s competitiveness.

4.4. Results for forecast period 2023-2030

Before forecasts for the period 2023-2030 are calculated, short description of the econometric techniques used in the estimation and forecasting process will be presented.

4.4.1. Econometric techniques used in the estimation and forecasting

Historical data covering the period 2008-2022 used in the estimation process

According to subsection 4.1.2., the gas sector competitiveness index consists of five components. Data concerning these five components are available for six countries (Germany, Italy, France, Denmark, Poland and the United Kingdom) and years 2008-2022. These information have been used in the estimation process. Moreover, data concerning Gross Domestic Product in constant prices, as well as Gross Domestic Product per capita in constant prices have been used as independent variables in the system. These variables reflect the size of the economies, as well as their economic development level. Historical values of these independent variables have been collected from Eurostat. Values of these variables for the forecast period 2023-2030 are also made available by the International Monetary Fund and have been used in the forecasting process.

Ordered choice models applied for forecasting the "Institutions" component

As explained in subchapter 4.1.2., variables reflecting the efficiency of institutions are qualitative and can be treated as ordered discrete variables. Values of the *Ins* variable establish a scale according to which countries can be attributed a score on a scale of 1 to 6, where 6 is the highest score. Therefore, the ordered choice model (see (Cameron and Trivedi, 2005)) was used in order to estimate the parameters of the regression explaining the probability of high and low levels of institutional performance. The following ordered choice model for years 2008-2022 was considered:

$$Ins_{it}^{*} = \boldsymbol{x}_{it}\boldsymbol{\gamma} + \varepsilon_{it}, \tag{4.8.1}$$

$$Ins_{it} = \sum_{k=1}^{6} k * I\{\mu_{k-1} < Ins_{it}^{*} \leq \mu_k\}, \tag{4.8.2}$$

$$\varepsilon_{it} \sim N(0,1), \tag{4.8.3}$$

$$\mu_0 = -\infty, \mu_6 = +\infty,$$

where Ins_{it} denotes value of ordered variable for country *i* in period *t*. $\boldsymbol{x}_{it}$ is the vector of variables affecting the level of development of institutions. After parameters are estimated and vector of estimates $\hat{\boldsymbol{\gamma}}$ is known, value of the latent variable is forecasted for years 2023-2030 on the basis of the following equation:

$$\widehat{Ins_{iT+J}^{*}} = \boldsymbol{x}_{iT+j}\hat{\boldsymbol{\gamma}}, \quad j=1,2,\dots,8, \tag{4.9}$$

where *T=2022*.

If value of latent variable is known, and estimates for threshold parameters $\hat{\mu}_1,\ldots,\hat{\mu}_4$ are known, forecasts for the variable Ins_{it} in the years 2023, 2024, … , 2030 are calculated.

Testing for cross-sectional dependence and the use of panel cointegration techniques

To forecast the values of continuous components of the *GSCI* index, advanced econometrics techniques have been used. Due to the fact that the time series for these components are often realizations of stochastic processes integrated of order 1, the use of panel cointegration techniques was deemed necessary. Panel unit root tests proposed by(Levin et al., 2002), (Im et al., 2003) and (Breitung, 2000) have been used in order to determine the order of integration of the components of the *GSCI* index. In case of most variables, first differences were stationary (see annexes II to V). It means that the use of panel cointegration techniques was reasonable. To choose appropriate panel cointegration techniques, testing for cross-sectional dependence was conducted. The test of cross-sectional dependence proposed by (Pesaran, 2004) was applied. Depending on the results of the cross-sectional dependence analyses, tests proposed by (Kao, 1999) or (Westerlund, 2005) were run to verify whether cointegration occurs.

In order to test whether cross-sectional dependence occurs or not, the following standard panel model is considered:

$$y_{it} = \alpha_i + \boldsymbol{x}_{it}\boldsymbol{\beta} + \varepsilon_{it}, \quad i = 1, \ldots, N, \quad t = 1, \ldots, T. \tag{4.10}$$

It is assumed that error terms are independent and identically distributed over periods, as well as across cross-sectional units. Cross-sectional dependence means that error terms ε_{it} are correlated across sections, but there is no serial correlation. When the presence of cross-sectional dependence is verified, the following hypothesis is tested:

$$H_0\colon \rho_{ij} = 0, \ \text{for all } i \neq j, \tag{4.11}$$

$$H_1\colon \sim H_0,$$

where ρ_{ij} denotes correlation coefficient between ε_{it} and ε_{jt}.

In the case of the test proposed by Pesaran, the following statistic is applied:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right), \tag{4.12}$$

where $\hat{\rho}_{ij}$ is the estimate of correlation coefficient for residuals for sections i and j. Under the null hypothesis of no cross-sectional dependence the (4.12) statistic follows standard normal distribution.

Kao test verifies the existence of a shared cointegrating vector $\boldsymbol{\beta}$ between the variables, implying that they are characterized by a common long-run covariance matrix. The regression model is as follows, with γ denoting the stationary effects for each specific panel:

$$y_{it} = \gamma_i + \boldsymbol{x}_{it}\boldsymbol{\beta} + e_{it}. \tag{4.13}$$

Five test statistics have been proposed by (Kao, 1999), four of which are based on Dickey-Fuller (DF) regression verifying the presence of an unit root under an autoregressive time series:

$$\hat{e}_{it} = \rho\hat{e}_{i,t-1} + v_{it}, \tag{4.14}$$

where ρ is the common autoregression parameter of the residuals. The four DF-based tests are constructed as follows:

- DF t regression and Modified DF t regression

$$DF\ t = \frac{t_p + \frac{\sqrt{6N}\hat{\sigma}_v}{2\hat{w}_v}}{\sqrt{\frac{\hat{w}_v^2}{2\hat{\sigma}_v^2} + \frac{3\hat{\sigma}_v^2}{10\hat{w}_v^2}}}, \tag{4.15}$$

$$Modified\ DF\ t = \frac{\sqrt{N}T(\hat{\rho}-1) + \frac{3\sqrt{N}\hat{\sigma}_v^2}{\hat{w}_v^2}}{\sqrt{3 + \frac{36\hat{\sigma}_v^4}{5\hat{w}_v^4}}}, \tag{4.16}$$

where $\hat{\rho}$ is the estimated value of ρ, $\hat{\sigma}_v^2$ and $\hat{w}_v^2$ are scalar terms that are consistent estimates of $\hat{\sigma}_v^2 = \sigma_u^2 - \sum'_{u\in}\sum_{\in}\sum_{u\in}$ and $w_v^2 = w_u^2 - \Omega'_{u\in}\Omega_{\in}\Omega_{u\in}$ and t_ρ is the t statistic for testing H0: ρ=1.

- Unadjusted DF t regression and unadjusted modified DF t regression

$$Unadjusted\ DF\ t = \sqrt{\frac{5t_\rho}{4}} + \sqrt{\frac{15N}{8}}, \tag{4.17}$$

$$Unadjusted\ modified\ DF\ t = \frac{\sqrt{N}T(\hat{\rho}-1) + 3\sqrt{N}}{\sqrt{\frac{51}{5}}}. \tag{4.18}$$

The fifth test is based on the augmented Dickey-Fuller (ADF) regression as given by:

$$\mathrm{\hat{e}_{it} = p\hat{e}_{i,t-1} + \sum_{j=1}^{p} p_j \Delta\hat{e}_{i,t-j} + v_{it}^*}, \tag{4.19}$$

Where p is the number of lagged difference terms. The ADF-based test is defined as:

$$ADF\ t = \frac{t_{ADF} + \frac{\sqrt{6N}\hat{\sigma}_v}{2\hat{w}_v}}{\sqrt{\frac{\hat{w}_v^2}{2\hat{\sigma}_v^2} + \frac{3\hat{\sigma}_v^2}{10\hat{w}_v^2}}}. \tag{4.20}$$

where $t_{ADF} = \frac{\hat{\rho}}{\widehat{SE}(\hat{\rho})}$.

In Westerlund's approach all panels have their own specific cointegrating vectors and the test statistics are derived from verifying whether cointegration exists between specific panels or alternatively whether it is the same between all the panels analysed i.e.:

- Panel-specific autoregression test statistic

  $$VR = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{E}_{it}^{2} \hat{R}_{i}^{-1}. \quad (4.21)$$

- Same autoregression test statistic

  $$VR = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{E}_{it}^{2} \left(\sum_{i=1}^{N} \hat{R}_{i}\right)^{-1}. \quad (4.22)$$

where $\hat{E}_{it} = \sum_{j=1}^{t} \hat{e}_{ij}$,$\hat{R}_{i} = \sum_{t=1}^{T} \hat{e}_{it}^{2}$ and $\hat{e}_{it}$ are the residuals calculated under the panel-data regression model.

Asymptotic distribution of all the abovementioned test statistics converge to N(0,1).

If (Kao, 1999) test was applied, forecasting was based on the estimated parameters of long-run equation linking categories constituting the gas sector competitiveness index. In the case of (Westerlund, 2005) test, parameters of the panel error correction model are first estimated and then used in the forecasting process.

If H0 hypothesis about lack of cointegration is rejected, the coefficients for the forecasts could be calculated. Results of the estimation of parameters, testing for cross-sectional dependence, testing order of integration of variables, as well as tests for cointegration have been presented in annexes II to V respectively. The annexes also include regression models for fixed effects of the panel data analysed i.e. individual-specific effects for each country that stem from the panel data collected that should be factored in the forecasts to improve their quality (Schmidheiny, 2022).

Assumptions used in the estimation and forecasting process

Cointegration techniques have been applied to forecast the maximum demand values and gas network entry and exit capacity variables. In both cases, the independent variable used was the national GDP value in different formats[24] to arrive at most reliable forecasts. Maximum demand value was further used as an independent variable for modelling the industrial consumer price. While the average gas demand fluctuations have historically proved to explain only a fraction of price volatility, periods of high demand can often lead to notable price premiums paid by the industry (Department of Energy and Climate Change, 2016). If high demand exerts pressure on the infrastructure to a level at which it exceeds physical capacities, it is exactly this maximum

---

[24] i.e. GDP in PPP values for entry capacities and maximum demand and GDP in current prices for exit capacities.

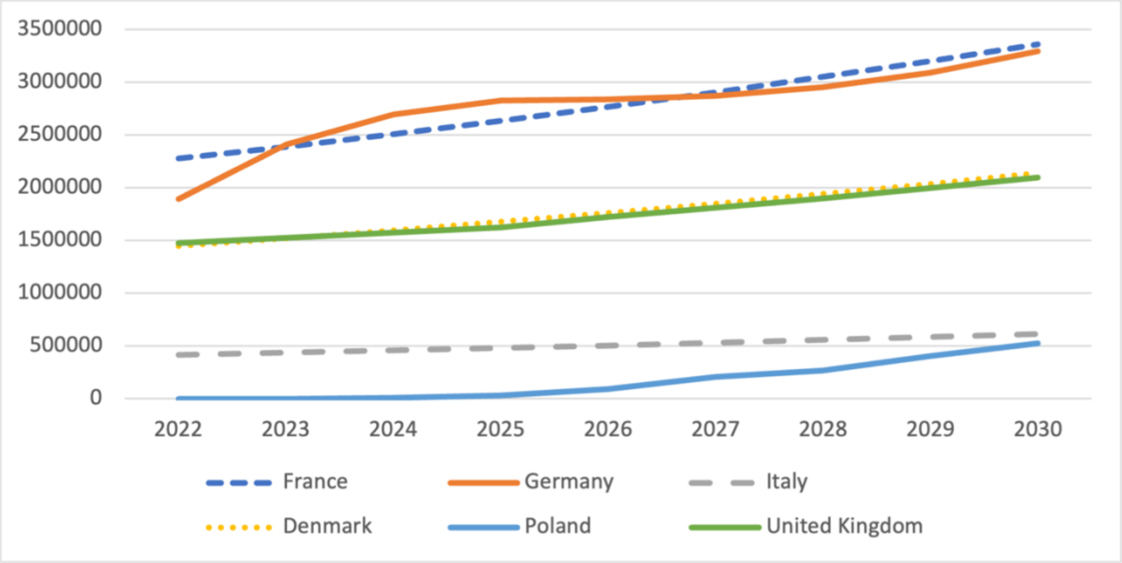
demand that leads to notable price differences across the EU, as the Italian example has shown over the past years (European Commission, 2012b). To test and utilize the interdependence between these variables, maximum demand was first divided by the GDP to reference its value against the national economy size. Stata program was used to perform all the necessary tests and estimations.

4.4.2. Results of the forecasts

With the validity of cointegration modelling confirmed, the coefficients for the forecasts could be calculated. Both the tests and the regression model results for the four variables: maximum demand, gas price, gas infrastructure entries and exits, have been included in annexes II to V respectively. The annexes also include regression models for fixed effects of the panel data analysed i.e. individual-specific effects for each country that stem from the panel data collected that should be factored in the forecasts to improve their quality (Schmidheiny, 2022).

It needs to be noted that, while the cointegration tests have worked well for the emission savings forecast, the model had a natural tendency to result in negative values at certain periods, that would simply not match the governing assumption that the Es variable reflects the speed of investment in biomethane production capacity. Therefore, a supporting assumption was made, that, where the model would return negative values, the forecast would be replaced with a default increment of 5% per annuum. Such modest increase in generation capacity would reflect e.g. the investment made exclusively by the state-controlled entities, not necessarily for economic reasons – such forced/induced investment is known from the EU power market and the related capacity mechanisms (see Simoglou and Biskas (2023) for further reference). The resultant values of the *Es*, *Gp* and *Ginfr* variables under the BAU scenario have been presented on figures 24,25 and 26.

Figure 24. Emission savings (Es) variable forecasts

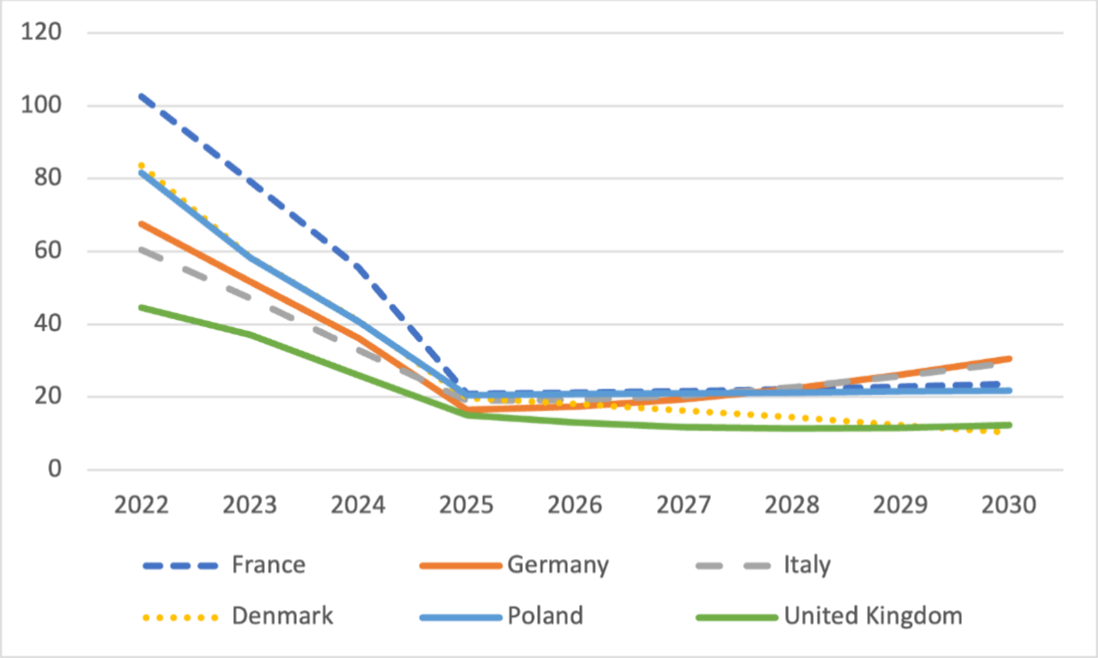


Source: own elaboration.

The modelled biomethane development under the BAU scenario suggests a rather modest increase in biomethane production over time, with only France expected to carry on with the production capacity deployment pace achieved before the beginning of the forecast period. Even still, it deserves to be noted that the calculated emission savings under the assumptions made would correspond to approx. 2 bcm of biomethane being produced per year in 2030 i.e. 50% short of the ambitious target the country has set for itself (CRE, 2022). It also deserves to be noted here that already under this scenario, Denmark would be nearly reaching its total biomethane production potential of approx. 0,9 bcm in 2030 (Gas For Climate, 2022). At the same time the modelled industrial consumer price for the country was expected to become lowest among the entire research group.

Gas price forecast figures (figure 25) reflects the prevalent view that the gas market would rebalance past 2024, with prices returning to the values known from before the energy crisis. The modelled values appear to reflect that properly as of 2025, with Italy and Germany expected to see the highest gas prices for their industrial consumers out of the entire studied group. Although this was not an outright feature of the model, this forecast seems reasonable, particularly since both countries will no longer benefit from comparably lower prices offered under supply agreements with Russia. At the lower end of the comparison are Denmark and the United Kingdom, i.e. countries still benefitting from considerable domestic production and relatively large (and growing) biomethane production.

Figure 25. Gas price forecasts

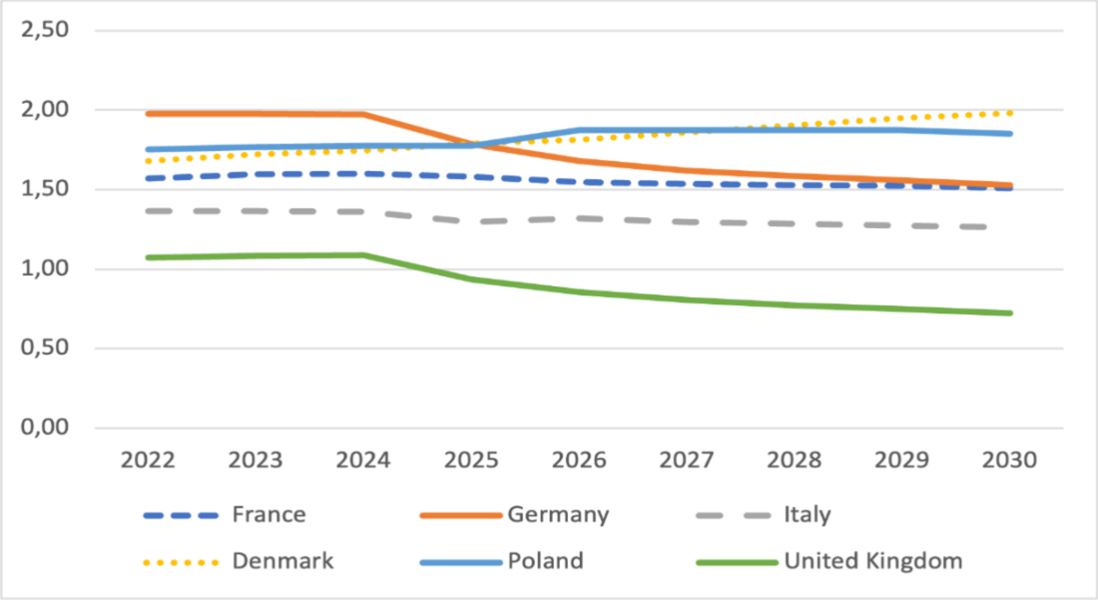


Source: own elaboration.

Overall flexibility offered by the gas infrastructure is expected to be experiencing to minor fluctuations as depicted on figure 26. While this synthetic component is rather stable for most countries, some downward adjustments are expected for Germany and the United Kingdom, which could be attributed to smaller demand and lower cross-border flows when compared to the past years. Certain improvements are still notable in Poland, with additional storage volumes and domestic grid expansions set to accommodate for growing gas demand. For Denmark, the additional throughput could be attributed to increased investment in gas production, both in terms of fossil gas and biomethane.

Qualitative components under the Ins component are a typical example of variables displayed on an ordinal scale, hence requiring a different approach to the one applied to the other *GSCI* components, as explained in (Winship and Mare, 1984). Following the recommendation thereof, the forecast for the *Ins* components has been based on ordered probit regression, where the variations of the modelled dependent variables would be linked to the available GDP per capita forecasts for each country analysed. The resultant values (annexes VI for *LcEC*, *LcIEA* and *Mp* subcomponents respectively) establish a scale according to which countries can once again be attributed a score on a scale of 1 to 6, where 6 is the highest score.

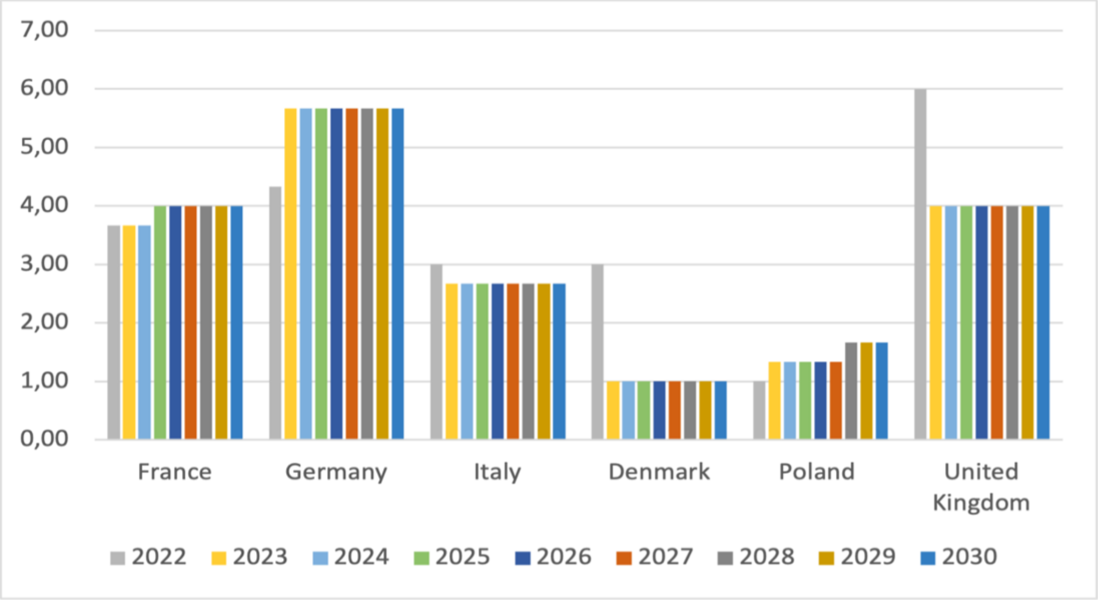
Figure 26. Gas infrastructure (*Ginfr*) variable forecasts



Source: own elaboration.

The resultant Ins scores for the forecast period reflects considerable stability in the scores along the forecast, also reflecting the fact that no notable changes in the institutional setup could be reasonably assumed for this type of qualitative components (Figure 27).

Figure 27. Forecasted *Ins* score attributed to each country

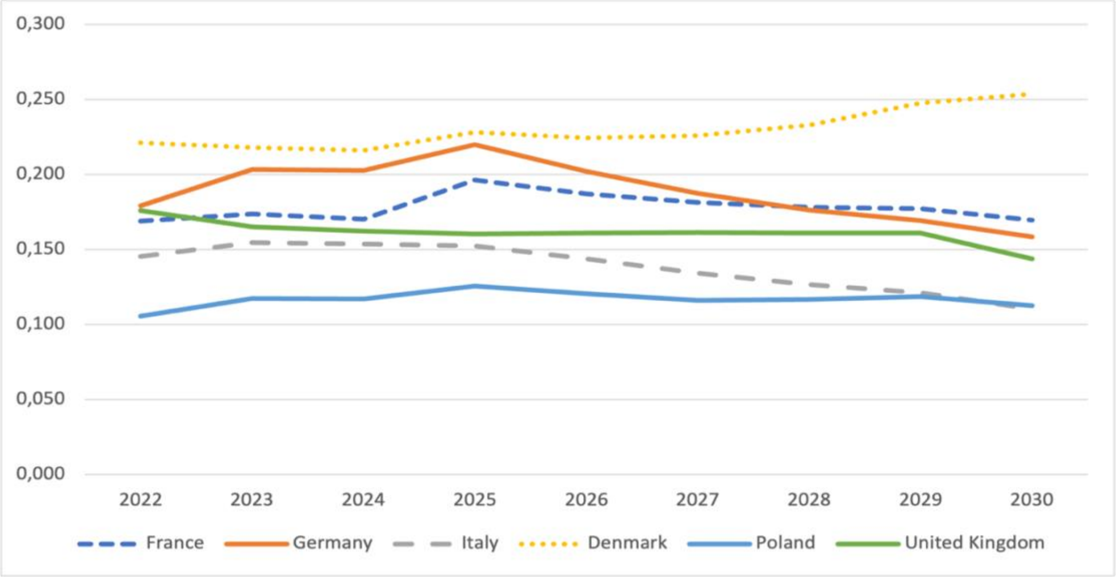


Source: own elaboration.

4.4.3. Results under the BAU scenario.

The *GSCI* values for the forecast period under the business-as-usual scenario have been presented on figure 28. With the strongest emphasis placed on the gas price, Germany experiences a steady downward drop in competitiveness as of 2025 as the situation on the global market is set to stabilise. Similarly, Italy's competitiveness suffers from the additional price premium its industrial consumers are set to pay under this forecast. With only marginal expected annual increments to the biomethane production capacity, the country would lose its competitive position to Poland, despite having much more experience in promoting renewable gas generation.

Figure 28. *GSCI* results under BAU scenario for years 2023-2030



Source: own elaboration.

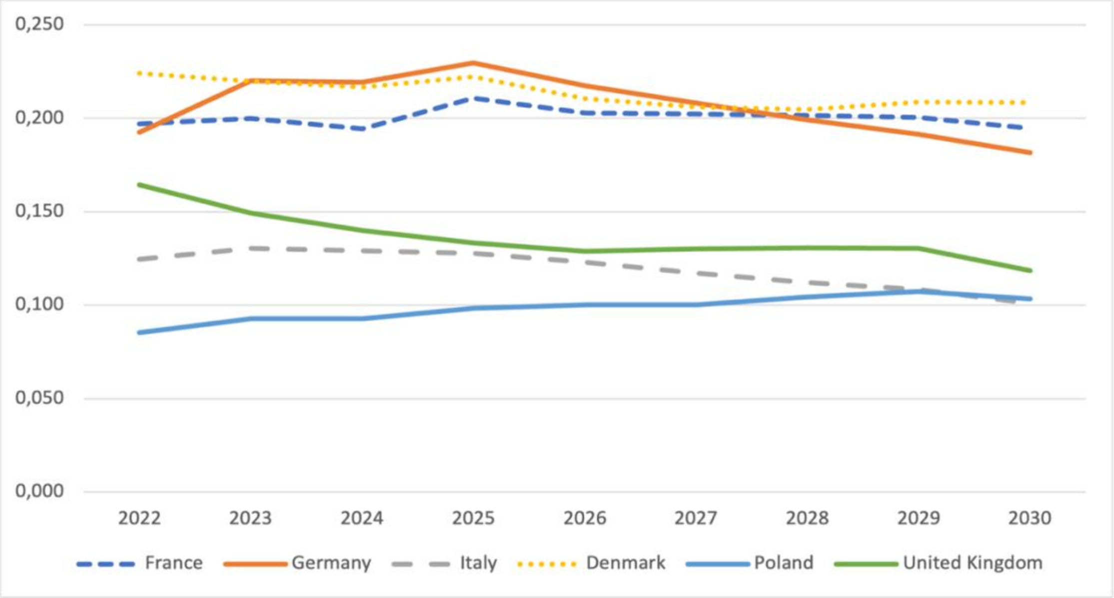
The country that stands out under the BAU scenario is **Denmark**, expected to reach its full biomethane production potential, as limited by feedstock availability, in 2030. Over the forecasted period, Denmark is also expected to hold a net gas exporter position, possibly allowing it to offset part of the price increment that would otherwise be passed on to the domestic consumers. Overall, with no reliance on imports and the least carbon-intensive supply of gas, the country can be expected to hold a leading competitive position for years to come, not least because the Gas for Climate forecasts expect the Danish feedstock availability to double by 2050.

Finally, it is worth to have a closer look at the **French** position, as it appears to be striking the right balance between the growth in biomethane production and the upward pressure on industrial consumer prices. Despite missing the ambitious, nearly 4 bcm biomethane production target by 2030, the country is able would be able to gain competitive advantage over Germany. It is also worth noting in this context that, in spite of having notably lower feedstock availability potential, France would still be expected to produce as much biomethane as Germany (as per figure 7). Altogether, also the forecast for the French gas sector seems to confirm that a GO scheme is able to induce the rollout of biomethane generation without having a negative effect on sectoral competitiveness.

4.4.4. Results under IGM scenario

The Integrated Gas Market Scenario results have been presented on figure 29. What immediately stands out from the presented score is the fact that, despite making considerable changes to the distribution of weights attributed to each *GSCI* component, the final ranking in 2030 remains unchanged versus the BAU scenario. The IGM scenario results for the forecasts also divide the research group into two subgroups, with Germany's, France's and Denmark's *GSCI* score fluctuating around the value of 0,2 and the other country's *GSCI* remaining considerably below 0,15 along the entire forecast period. This disparity would reinforce the notion that indeed, larger, more integrated markets offer a better environment for decarbonising the gas sector at a comparably lower cost when compared to the national schemes.

Figure 29. GSCI results under IGM scenario for years 2023-2030



Source: own elaboration.

Second important conclusion stemming from figure 29 is the fact that, in spite of having a considerably more positive approach towards the biomethane deployment speed, nearly all analysed countries record a downward trend in their competitiveness score, particularly after the assumed last year of the energy crisis, 2024. Two exceptions are **Poland**, for which the successful renewable gas development trend know from France in the past has been replicated and Denmark, that under the IGM scenario exhausts its assumed generation growth potential already in 2025. This would suggest that, given the considerable significance attributed to the Es variable under this scenario, the countries largely fall short of reaching the deployment speed at which their *GSCI* score would be improving in the following years. Such conclusion would, in turn, signal that integrating into larger markets should not be perceived as a silver bullet that could assure improvements to the integrated zone's competitiveness.

Thirdly, while it could be assumed that the IGM scenario would prioritise countries with the largest biomethane generation capacity, it needs to be noted that the resultant "competitive" country group does not include the **United Kingdom**. This might be a natural consequence of the fact that many of the *GSCI*'s components are values related to the economy's size, which, given the United Kingdom's development level and gas market size, translates into relatively strict expectations towards the achieved growth rate. In addition, the expected growth in biomethane production rate until 2026 is already known and reflected in the number of agreements signed under the new support scheme, causing the country to lag behind its competitors (Hopwood, 2022). In any case it is worth reemphasizing that the contemporary understanding of competitiveness should not be associated merely with prices, as the significance of this variable may be expected to fall over time, particularly in sectors having a potentially strong detrimental impact on the environment.

Finally, the case of Italy appears to confirm the assumed impact of the Es variable variations on the overall score. Since **Italy's** expected increment in biomethane production was modelled as being quite modest, the country's competitive gap versus the "competitive" group is also expected to increase. Since, as mentioned before, the country was notoriously paying a premium for its gas supplies, it would only seem reasonable that it should seek improvements to its competitive positions through widespread application of the BiogasDoneRight initiative (Stefano Bozzetto, 2017). Such revision of the trend could perhaps be stemming from the newly available funding under the recently approved recovery and resilience plan (European Commission, 2021).

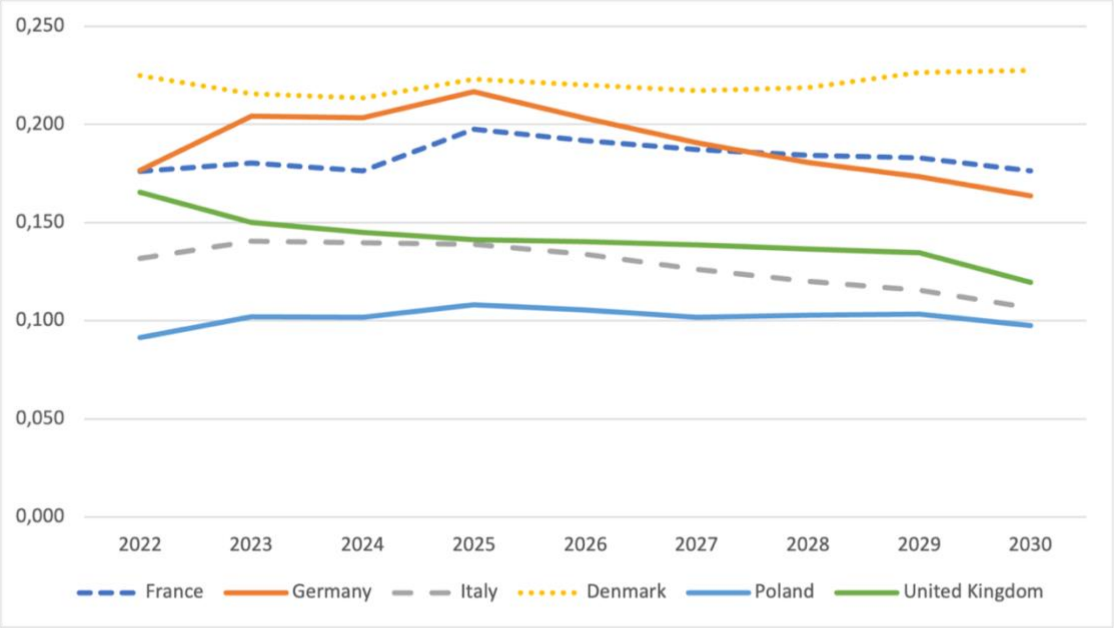
4.4.5. Results under RDM scenario

The results under the RDM scenario indicate less profound differences between the countries analysed (figure 30). As expected, regional integration of the four countries leaves the **United Kingdom and Poland** at a disadvantage for retaining national markets for renewable gases. This translates into Poland being unable to surpass Italy's score over the course of the entire forecast period and United Kingdom remaining way below the top three countries despite still being able to deliver the gas to its consumers at a considerably lower price than France or Germany.

With slightly more modest assumptions towards biomethane deployment speed, **Denmark** reaches its assumed production capacity in 2026. Nonetheless, this allows the country to retain a robust competitive position until the end of the forecast, with the runner-up countries increasingly lagging behind. This trend is likely to be a consequence of the fact that the modelled industrial consumer price in Denmark continues to fall all the way until 2030. This trend reemphasises the unique position of Denmark in Europe, as being the only producing country that, alongside a steady decline in domestic demand and growing biomethane output, can benefit from a constant supply surplus in the coming years.

Under the RDM scenario, **France** is expected to outperform **Germany** earlier than under the two other forecasts. This reconfirms that the country's biomethane capacity increase can be expected to remain robust and higher than in other countries, even if it does not allow to reach the 4 bcm target by 2030 under any scenario considered. It also deserves to be mentioned that France is able to arrive at the second highest *GSCI* score despite having one of the highest industrial gas consumer prices throughout the forecast period.

Figure 30. *GSCI* results under RDM scenario for years 2023-2030



Source: own elaboration.

Finally, it is worth to note that **Poland's** competitiveness score under the RDM scenario appears to remain largely stagnant, as could be observed in all the calculations for the period

2008-2022. This would signal that, without improved integration and increased competition, the country would likely carry forward its competitiveness score despite the extensive efforts to improve the flexibility of its national gas network and the availability of alternative sources of gas. This would seem to confirm that better integration would support competitiveness of some countries and help them overcome stagnation.

Conclusions

The application of the *GSCI* index to evaluate the national gas sector's competitiveness and its changes over time has proved to offer interesting results, both when applied to historical data and when it is based on forecasts. For historical analyses, the tool appears to rightly capture the major structural changes that lead to increased liquidity and/or increased market size. It also correctly captures periods of supply shocks and other negative changes that lead to market foreclosure or periods of extremely high prices. Although the amplitude resulting from such positive and negative changes naturally results from the weights distribution under each scenario, it needs to be emphasized, that in all cases they remain part of the result, confirming that a composite index is the proper tool to analyse competitiveness within its contemporary understanding.

The presented *GSCI* index is not free from flaws that collectively make its application challenging and time-consuming. On one hand this relates to the amount of data necessary for the calculation of some of its subcomponents, particularly since some of it can come from different sources and be displayed in different units, therefore require further processing. This is particularly the case for biomethane production details, where the data can prove to be fragmentary or biased, particularly if the countries compared apply different sustainability criteria. On the other hand, the inclusion of a qualitative component, although necessary to study the phenomenon properly, requires time-consuming analyses of the available information, the results of which may not be fully replicable by different researchers, as the process is not entirely free from subjectivity. The best solution to address this flaw is to ensure that different sources are used in the evaluation of each country's institutions, so that the resultant score reflects a balanced opinion.

Study results support answering the research questions suggested at the beginning of this chapter:

1. Does sizeable domestic natural gas production ensure a competitive advantage over countries relying predominantly on imports?

   A holistic look at the results for the entire period between 2008 and 2030 confirms **that availability of domestic production does not warrant strong competitive advantage**. This can be best observed on the example of Denmark, a net exporter until 2010, that at the same time was ranked among the least competitive over that period. By the time it has regained its exporter status, the country has managed to move to the top ranks through other means. Correspondingly, the competitive dominance of Germany up until the early days of the energy crisis signals that strong import reliance does not imply that the national gas sector is necessarily being put at a disadvantage.
2. Do direct pipeline connections to natural gas exporting countries support competitiveness of the importers when compared to countries further away from the production fields?

   GSCI scores for the period between 2008-2022 confirms that the **proximity of the producer countries does not offer any tangible competitive advantage over the countries further downstream**. This can be observed on the example of Italy – despite having direct connections to Algeria and Libya, the country was forced to pay a considerable premium for its supplies when compared to its neighbours further up north, despite them being largely reliant on imports through other countries and/or LNG. Similarly, the example of Poland shows that, despite being the first country on the import route from Russia out of the analysed group, the country was apparently forced to pay a considerable premium over other countries and the situation only started to change as alternative supply sources were established.
3. Can the development of biomethane production facilities support the sector's competitiveness despite the additional costs stemming from their subsidization?

   The question of biomethane's impact on the country's competitiveness, as measured by the *GSCI* is more difficult to answer. **The study results signal**

that the overall competitive position can either improve or deteriorate as new capacities develop. It appears that the answer to the third question depends largely on the nature of the support scheme and the extent to which it impacts consumer prices. The example of France (running a GO trading scheme) and Denmark (running competitive tenders for gas price-linked feed-in-premiums alongside a GO scheme) show that the support schemes can ensure a considerable boost to the biomethane production development pace, while keeping the costs reasonably low. Consequently, the feed-in-tariff schemes operated by the UK (between 2010 and 2021) and Italy (as of 2018 for biomethane) have proved to be burdensome and their impact on the competitiveness score can be seen as quite ambiguous.

4. Does an integrated market for biomethane support sectoral competitiveness versus the current national support schemes?
   Comparative analyses of the **results under the RDM scenario versus the two other forecasts signals that larger markets under a common set of rules do support gas sector's competitiveness**, which would be in line with the theoretical considerations. This can be observed on the example of Poland and Italy, whereby the latter is only able to retain its competitive advantage by 2030 only under the RDM scenario (i.e. when it is part of the regionally integrated market). This conclusion seems further reinforced by the fact that the gap between the *GSCI* scores of the UK and the top three integrated markets of DE, DK and FR continues to grow from the beginning of the RDM scenario forecast and that its competitive position is much closer to Italy, over which it holds a considerable advantage under the two other forecasts.

The results stemming from the application of the *GSCI* appear to confirm its usefulness for competitiveness analyses at mesoeconomic level, bearing in mind that such analysis requires an individual approach, since each sector is different. As in most other economic analyses, the results and conclusions will likely strongly depend on the assumptions made, but the scenario-based analyses should enable filtering through the results and support the selection of the most credible and balanced forecast. Further studies could explore the application of the *GSCI* to analyses covering other renewable and low-carbon gases apart from biomethane (such as synthetic methane and hydrogen). The emergence of such alternative fuels could also support analyses of how these different fuels can impact the competitiveness of the national gas sectors, depending on the volumes they are able to deliver to displace fossil gas. Such considerations and analyses will, however, only become possible after a clear set of rules is established for their production under the new EU “Gas Package” and the related secondary legislation. It also deserves to be noted that the new technologies will likely have tangible impact on the sector’s competitiveness past the 2030 forecast horizon presented in this study.

Concluding remarks

This study addresses the problem of evaluating competitiveness at mesoeconomic level on the example of the gas sector. To make such evaluation possible, a dedicated synthetic indicator reflecting the relative performance of the national gas sectors has been designed. The idea follows the approach taken by the World Economic Forum in designing the Global Competitiveness Index to evaluate the macroeconomic competitiveness of national economies. The application of the Gas Sector Competitiveness Index (*GSCI*) can support comparative analyses of different national sectors, allowing a better understanding of how they perform, particularly in face of the reinforced decarbonization efforts driven by diverging national policies.

The application of the GSCI in this study focused on the impact of decarbonization policies pursued in Europe on the competitiveness of the national gas sectors. Its design followed a review of literature on the different definitions of competitiveness that has supported the notion that contemporary understanding of the phenomenon spans beyond purely economic considerations. In particular, it spans onto positive and negative externalities that different activities may entail and suggests that these may impact the perceived quality of the products and services offered to consumers. This conclusion encouraged studying the natural gas sector in detail, since on one hand it is responsible for considerable greenhouse gas emissions but on the other hand it underpins an important share of energy consumption that cannot be easily electrified.

The study carried on to describing the process of gas market liberalization, the goal it was to achieve, and the key principles governing a contemporary market for gas. It has emphasized the importance of good governance and national markets integration that have collectively enabled many European countries to develop well-functioning and liquid markets despite being strongly reliant on gas imports. This conclusion has underlined the importance of institutions both in the process of establishing competition in the formerly monopolized sectors and into effective integration across borders that improve market functioning.

In the next step, the gas sector was analysed in the context of the ambitious decarbonization strategy pursued by the European Union. Different technologies enabling the displacement of fossil gas have been presented and discussed in the context of readiness for commercial application. This analysis has signalled that currently only biomethane production technology (i.e. gaseous fuel produced in the process of anaerobic digestion of organic waste) is available at scale. It also enables processing of waste that would otherwise be a source of greenhouse gas emissions on its own. Once identified, the technology was analysed in the context of different legislative acts that have been proposed under EU's strategy to reach carbon neutrality in the future. While the analysis has confirmed that the decarbonization potential of biomethane has been both recognized and supported under the new policies, it has also underlined that the process will require considerable investment and operational support in the future that would in turn impact the cost of gaseous fuel supply. The question remained whether better quality of supply (in terms of offering less carbon-intensive fuel mix) could offset the negative consequences of the fuel supply costs to the overall competitiveness.

The results of the study presented in chapter 4 confirm that the application of a synthetic indicator in the context of evaluating the phenomenon of competitiveness is the right approach, as it supports capturing its complex nature. The "beyond GDP" aspects of competitiveness within its contemporary definitions as described in chapter 1 require referring to qualitative parameters when performing such analyses on one hand, but at the same time emphasize the importance of the concept in the 21st century as climate policies become the top priority.

The analytical value of the *GSCI* designed in chapter 4 of this study appears to be confirmed by the consistency of the results with the theoretical considerations around competitiveness. This primarily relates to the fact that the competitiveness score calculated for the research group give no grounds to believe that large domestic production or proximity of large gas producing countries (as per research questions 1 and 2) are sufficient to warrant competitive advantage in a contemporary world. It is an important conclusion for EU's gas market, as it supports the notion that it can establish a strong competitive position despite inevitability being reliant of gas imports for years to come. It also supports the notion that the efforts to liberalize and integrate the national gas markets, as described in chapter 2, have not been done in vain.

Answer to research question 3 on the net impact of biomethane production facilities deployment on sectoral competitiveness will depend on the consumer preference and the value they will attribute to the less carbon-intensive gaseous fuel alternatives. This value will in each case be compared against the associated cost brought about by the related support scheme that will finance the scale-up of biomethane production. Since the application of the *GSCI* confirms that the interplay between the benefits of developing carbon-neutral gas production facilities and the related costs will largely depend on the design of the underlying support schemes, it is worthwhile to carefully consider the past experience in financing the RES-E generation sources that have often proved to be costly. This also appears to be confirmed by the past experience of the prime-moving countries in terms of financing biomethane technologies, such as United Kingdom and Denmark, where huge progress was achieved in terms of sustainable gas production, but at the same time the related costs have proved to be high. This experience supports the idea of establishing a more balanced approach to financing biomethane technologies, where the potential beneficiaries need to compete over the subsidies offered. Examples of such schemes, as outlined in chapter 3, include competitive tenders and tradable certificate schemes, both of which can bring more tangible effects where markets are larger and more integrated. Therefore, this conclusion further reinforces the need for stronger integration for cost-efficient decarbonization of the EU gas market.

Study results also signal that a more integrated gas market with a large number of active companies engaged in competition can be a source of advantage. This reinforces the validity of the Gas Target Model for the EU and the need to tackle barriers to economic integration also in the context of decarbonization of the economy. It can help counterbalance the additional costs brought about by the deployment of new, capital-intensive technologies such as biomethane production, thereby reducing the costs to end consumers. This suggests that further efforts to tackle barriers to establishing a fully-integrated internal market for gas would be in line with the ambitious climate targets under the broader Fit-for-55 strategy outlined in chapter 3.

Limitations to this study largely stem from the fact that the *GSCI* includes variables that cannot warrant full objectivity – this primarily relates to the qualitative components capturing the institutional setup of the given sector, but also to the fact that weights applied to the composite indices are also burdened with a degree of subjectivity. In the context of the Ins variable, the risk of impartiality was addressed through reviewing different sources and reflecting them in the score, although it can never be guaranteed that the sources used are not biased on their own. In terms of application of weights, the best approach followed in other studies using a synthetic indicator is to run sensitivity analyses and/or scenarios with an emphasis of different aspects of the synthetic measure.

Other limitation in constructing the *GSCI* and its possible expansion to other countries, is the availability of data and other information necessary to establish the necessary database. While the information around the size of the economy and the annual gas consumption level are easily available, more detailed information, such as the number of supply sources or the capacity available at interconnection points is either available for only the past few years or is not easily collectable from a single database. The problem is more pronounced, however, when it comes to gathering the information necessary to establish a ranking of institutional performance in the given year – even if multiple sources are used, none of them offer explicit analyses of the reforms that could be of interest for all the EU Member States in every edition. This makes the analyses prone to omissions, yet the only way to mitigate such risk is to refer to multiple external and impartial sources, which, in turn, makes the data collection time-consuming. Nonetheless, it needs to be emphasised that lack of a comprehensive evaluation of the national gas sectors confirms that the proposed *GSCI* addresses an existing knowledge gap. The information deficiencies will also likely diminish over time as well, since the availability of information for many countries has improved considerably since 2008 and, given the growing importance of biomethane, information on its development scale will likely be advertised by the national authorities in the future.

In terms of other research methods used, it deserves to be recognized that time-series based forecasting for the gas sectors has always been challenging, yet the recent turbulence brought about collectively by the increased emphasis on decarbonization, Covid-19 pandemic and Russia's war of aggression against Ukraine has made it very difficult and imprecise. As the situation stabilizes and the fit-for-55 legislative package takes its final shape, new models may become available to support forecasting changes to gas sector competitiveness in the future.

Furthermore, the design of the synthetic indicator in its final form entails four components that have been selected as described in chapter 4, yet it deserves to be noted that other variables can be used to characterize the different features of the gas sector. An immediate alteration could be to replace the emission savings variable with previously discarded job creation indicator, although this would naturally alter the focus of the study. Additionally, other variables could be used to reflect the flexibility offered by the natural gas infrastructure, potentially factoring in the additional elasticity that it provides to the electricity grid. While this can be seen as an external effect from the perspective of the gas sector, it reflects the additional value brought about by the gas sector in the context of decarbonizing the economy. Further studies would be required to explore how the interplay between the gas, electricity and hydrogen sectors could be measured and reflected in the national competitiveness considerations.

The practical contribution of the *GSCI* stems from the fact that it can form a useful tool to study the changing competitive position of the different countries over time. Calculations of the index can be expanded onto other EU countries as they engage in developing renewable and low carbon gas production facilities. Countries from other regions that choose to liberalize their national gas sectors going forward can also be evaluated and enable more nuanced comparisons in terms of the different legislative solutions and the impact they may have on sectoral competitiveness over time. The conclusions of this study also speak in favour of further integration of markets inside the EU, which, given the reluctance of national authorities manifested over the past and as described in chapter 2, has a value of its own.

Future studies might expand the application of the GSCI onto other, currently nascent technologies that either enable avoiding carbon emissions (such as CCS) or do not involve additional emissions over the fuel's lifecycle (such as synthetic methane from sustainably produced hydrogen). The structure of the index may also be adapted for the purpose of analysing the future hydrogen market as well, since the draft legislative documents described in chapter 3 of this study suggest that its structure will largely build on the practices known from the gas market. Third area of expansion would be to consider certain modifications of the GSCI that would enable comparisons between monopolized and liberalized gas sectors with a strong focus on their ability to decarbonize the gaseous fuel mix they offer. These modifications would need to build on different assumptions, considering that in a monopolized sector the consumer may have limited options to signal their preference, whereas institutions would be focusing on different goals in the two regimes.

Annex 1

Correlation matrix I (for G_{infr} variable)

Ic	Sc	
1.0000	0.1092	**Ic**
	1.0000	**Sc**

Source: own elaboration.

Correlation matrix II (for Ins variable)

Eceval	IEAreports	EFETreports	Sd	
1.0000	0.5962	0.4221	-0.0428	**Eceval**
	1.0000	0.2268	-0.1081	**IEAreports**
		1.0000	0.1635	**EFETreports**
			1.0000	**Sd**

Source: own elaboration.

Correlation matrix III (for GSCI)

Gp	Es	Ginfr	Ins	Jc	
1.0000	0.2002	-0.0629	0.0492	0.2002	**Gp**
	1.0000	0.1334	0.2473	1.0000	**Es**
		1.0000	-0.5560	0.1334	**Ginfr**
			1.0000	0.2473	**Ins**
				1.0000	**Jc**

Source: own elaboration.

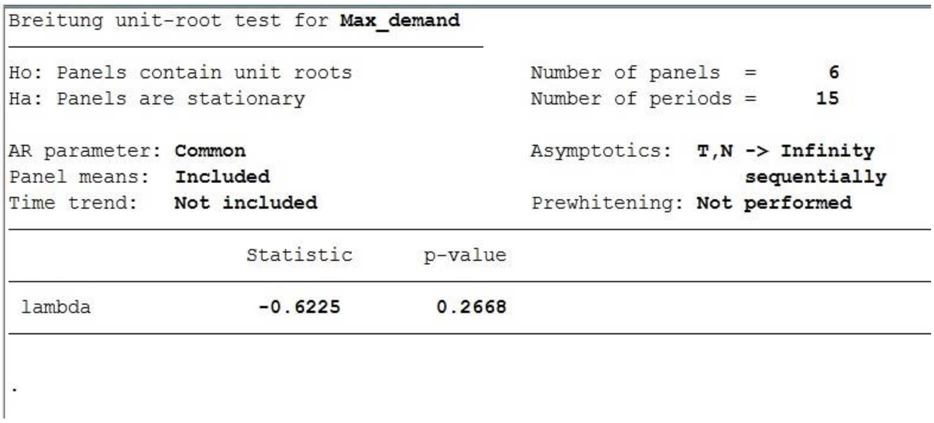
Correlation matrix IV (for GSCI)

Gp	Es	Ginfr	Ins	
1.0000	0.2002	-0.0629	0.0492	**Gp**
	1.0000	0.1334	0.2473	**Es**
		1.0000	-0.5560	**Ginfr**
			1.0000	**Ins**

Source: own elaboration.

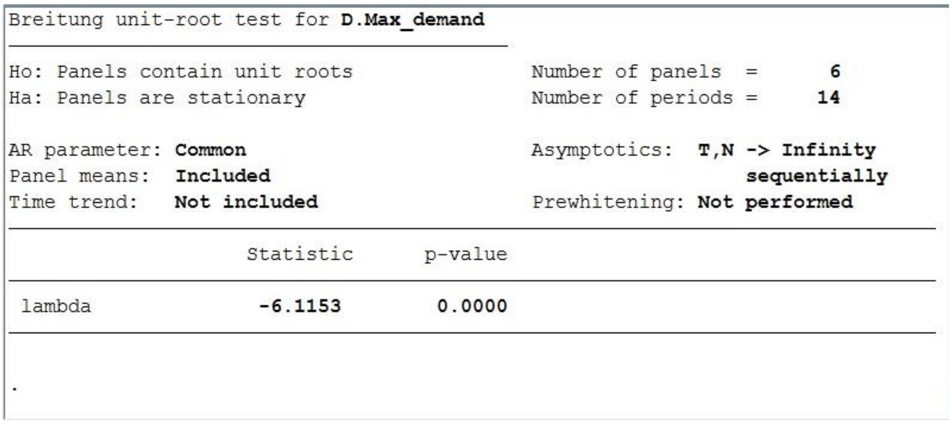
Annex 2

Breitung stationarity test for Max_demand variable



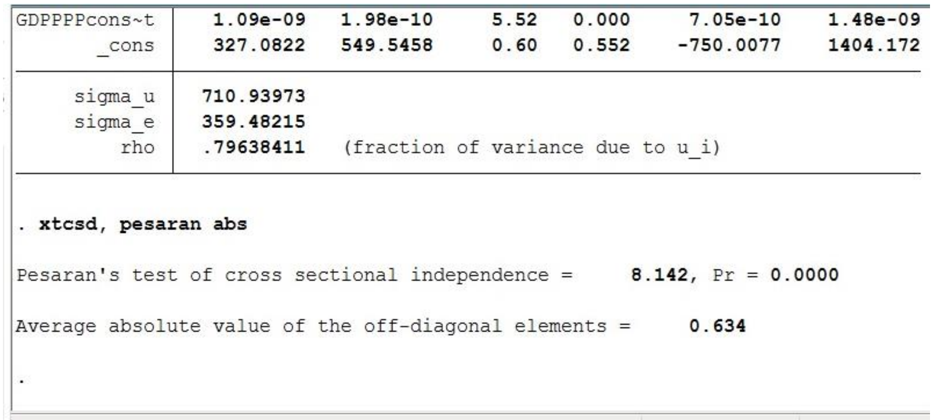
```
Breitung unit-root test for Max_demand
------------------------------------------
Ho: Panels contain unit roots              Number of panels  =      6
Ha: Panels are stationary                  Number of periods =     15

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                      sequentially
Time trend:   Not included                 Prewhitening: Not performed
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda               -0.6225        0.2668
------------------------------------------------------------------------------

.
```

Breitung stationarity test for first order differences of Max_demand variable



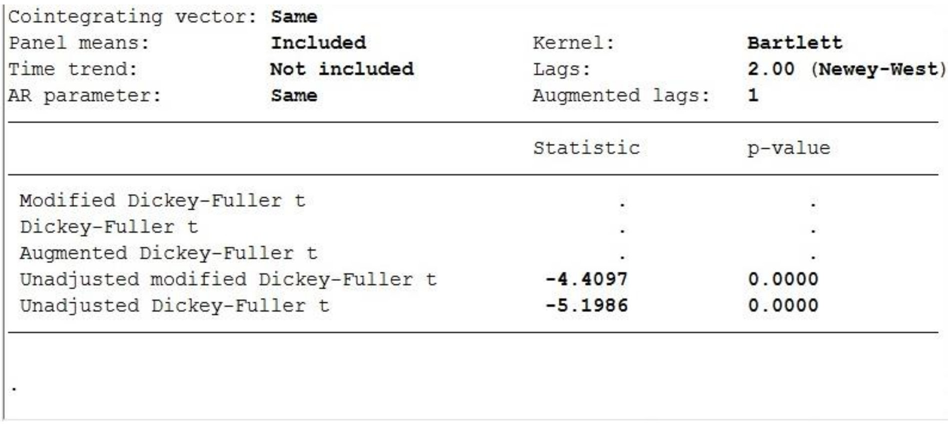
```
Breitung unit-root test for D.Max_demand
------------------------------------------
Ho: Panels contain unit roots              Number of panels  =      6
Ha: Panels are stationary                  Number of periods =     14

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                      sequentially
Time trend:   Not included                 Prewhitening: Not performed
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda               -6.1153        0.0000
------------------------------------------------------------------------------

.
```

Pesaran’s test of cross-sectoral dependence



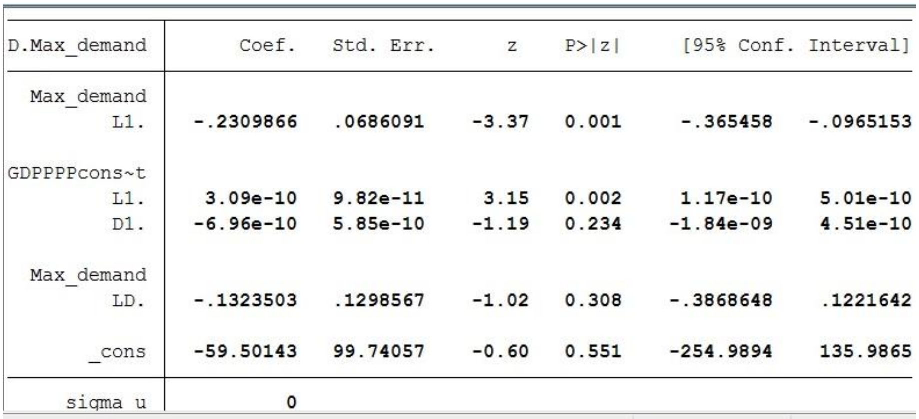
```
GDPPPPcons~t |   1.09e-09   1.98e-10     5.52   0.000     7.05e-10    1.48e-09
       _cons |   327.0822   549.5458     0.60   0.552    -750.0077    1404.172
-------------+----------------------------------------------------------------
     sigma_u |  710.93973
     sigma_e |  359.48215
         rho |  .79638411   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =     8.142, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.634

.
```

Kao cointegration test for Max_demand and GDP variables



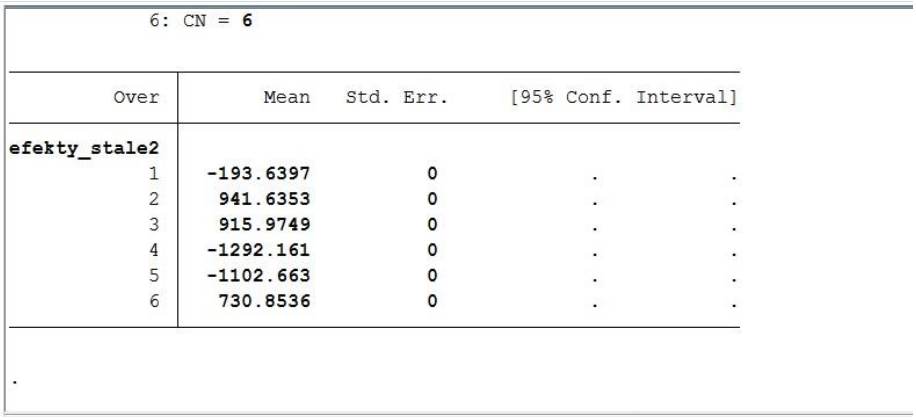
```
Cointegrating vector: Same
Panel means:          Included            Kernel:           Bartlett
Time trend:           Not included        Lags:             2.00 (Newey-West)
AR parameter:         Same                Augmented lags:   1
-----------------------------------------------------------------------------
                                          Statistic         p-value
-----------------------------------------------------------------------------
 Modified Dickey-Fuller t                         .                 .
 Dickey-Fuller t                                  .                 .
 Augmented Dickey-Fuller t                        .                 .
 Unadjusted modified Dickey-Fuller t        -4.4097            0.0000
 Unadjusted Dickey-Fuller t                 -5.1986            0.0000
-----------------------------------------------------------------------------

.
```

Final regression model for Max_demand



```
D.Max_demand |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  Max_demand |
         L1. |  -.2309866    .0686091    -3.37   0.001     -.365458   -.0965153
             |
GDPPPPcons~t |
         L1. |   3.09e-10    9.82e-11     3.15   0.002     1.17e-10    5.01e-10
         D1. |  -6.96e-10    5.85e-10    -1.19   0.234    -1.84e-09    4.51e-10
             |
  Max_demand |
         LD. |  -.1323503    .1298567    -1.02   0.308    -.3868648    .1221642
             |
       _cons |  -59.50143    99.74057    -0.60   0.551    -254.9894    135.9865
-------------+----------------------------------------------------------------
     sigma_u |          0
```

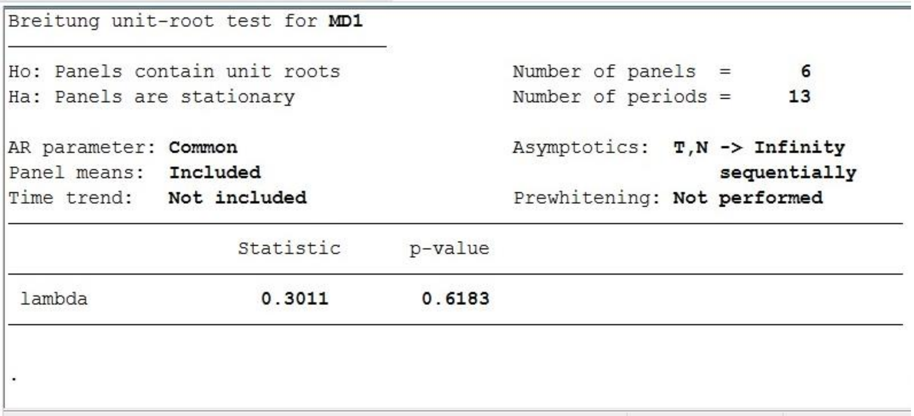
Stationary effects for Max_demand



```
            6: CN = 6

--------------------------------------------------------------
        Over |       Mean   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
efekty_stale2|
           1 |  -193.6397           0             .           .
           2 |   941.6353           0             .           .
           3 |   915.9749           0             .           .
           4 |  -1292.161           0             .           .
           5 |  -1102.663           0             .           .
           6 |   730.8536           0             .           .
--------------------------------------------------------------

.
```

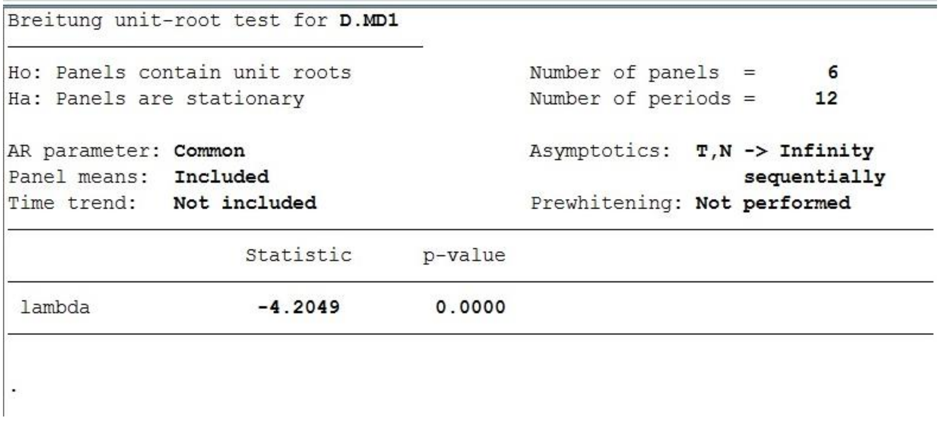
Annex 3

Breitung stationarity test for MD1 variable (MD1 = Max demand / GDP)



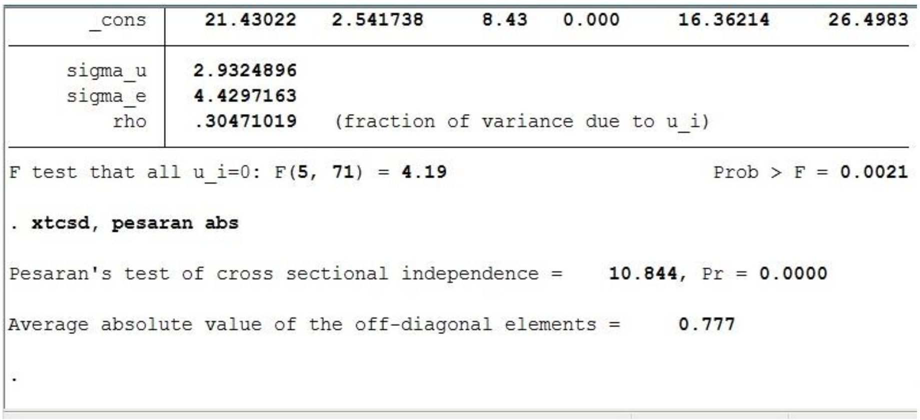
```
Breitung unit-root test for MD1
--------------------------------
Ho: Panels contain unit roots              Number of panels  =      6
Ha: Panels are stationary                  Number of periods =     13

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                      sequentially
Time trend:   Not included                 Prewhitening: Not performed
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda              0.3011        0.6183
------------------------------------------------------------------------------

.
```

Breitung stationarity test for first order differences of MD1 variable



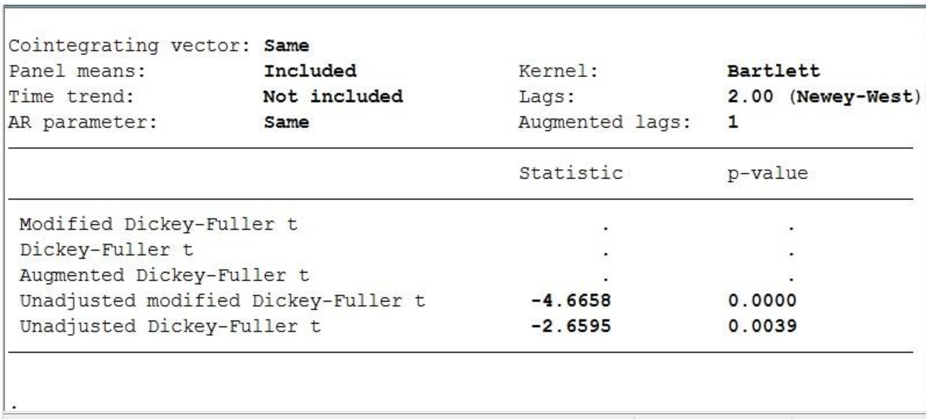
```
Breitung unit-root test for D.MD1
----------------------------------
Ho: Panels contain unit roots              Number of panels  =      6
Ha: Panels are stationary                  Number of periods =     12

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                      sequentially
Time trend:   Not included                 Prewhitening: Not performed
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda             -4.2049        0.0000
------------------------------------------------------------------------------

.
```

Pesaran’s test of cross-sectoral dependence



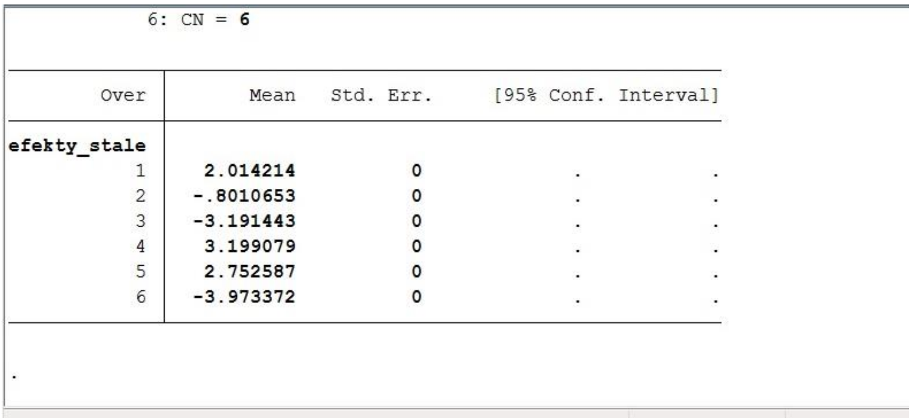
```
       _cons |   21.43022   2.541738     8.43   0.000     16.36214     26.4983
-------------+----------------------------------------------------------------
     sigma_u |  2.9324896
     sigma_e |  4.4297163
         rho |  .30471019   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(5, 71) = 4.19                       Prob > F = 0.0021

. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =    10.844, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.777

.
```

Kao cointegration test for Gp and MD1 variables



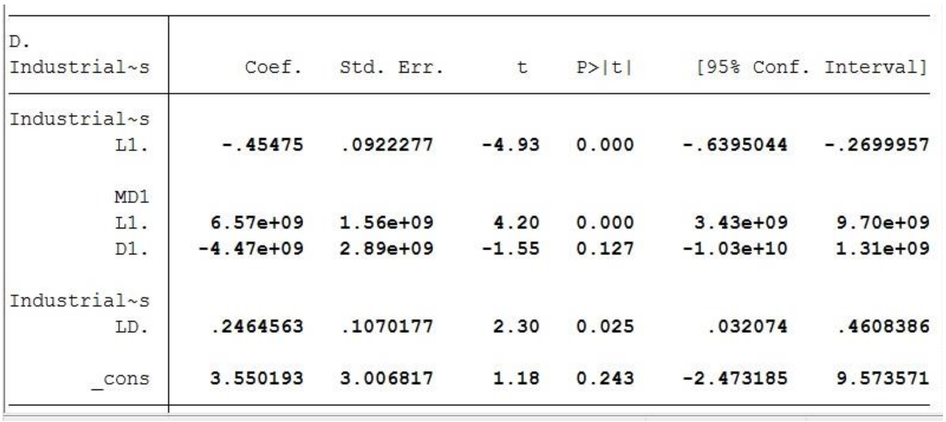
```
Cointegrating vector: Same
Panel means:          Included              Kernel:          Bartlett
Time trend:           Not included          Lags:            2.00 (Newey-West)
AR parameter:         Same                  Augmented lags:  1
------------------------------------------------------------------------------
                                            Statistic        p-value
------------------------------------------------------------------------------
 Modified Dickey-Fuller t                           .                .
 Dickey-Fuller t                                    .                .
 Augmented Dickey-Fuller t                          .                .
 Unadjusted modified Dickey-Fuller t          -4.6658           0.0000
 Unadjusted Dickey-Fuller t                   -2.6595           0.0039
------------------------------------------------------------------------------

.
```

Final regression model for Gp



```
            6: CN = 6

--------------------------------------------------------------
        Over |       Mean   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
efekty_stale |
           1 |   2.014214          0             .           .
           2 |  -.8010653          0             .           .
           3 |  -3.191443          0             .           .
           4 |   3.199079          0             .           .
           5 |   2.752587          0             .           .
           6 |  -3.973372          0             .           .
--------------------------------------------------------------

.
```

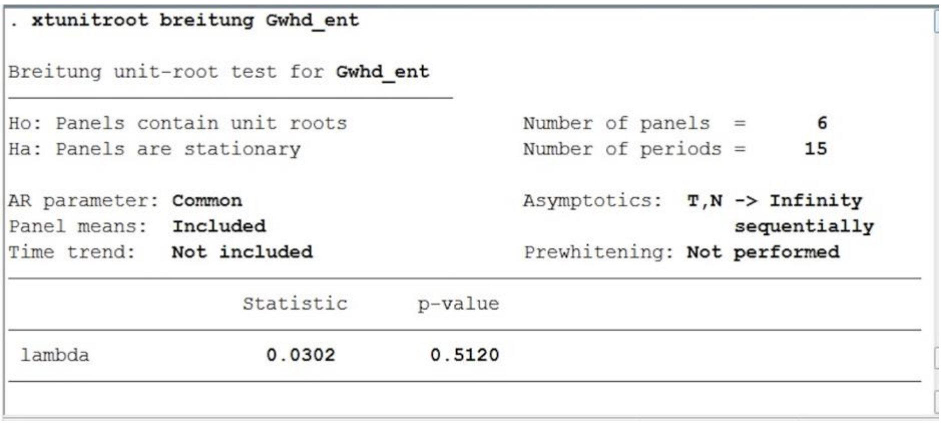
Stationary effects for Gp



```
------------------------------------------------------------------------------
D.           |
Industrial~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Industrial~s |
         L1. |    -.45475   .0922277    -4.93   0.000    -.6395044   -.2699957
             |
         MD1 |
         L1. |   6.57e+09   1.56e+09     4.20   0.000     3.43e+09    9.70e+09
         D1. |  -4.47e+09   2.89e+09    -1.55   0.127    -1.03e+10    1.31e+09
             |
Industrial~s |
         LD. |   .2464563   .1070177     2.30   0.025      .032074    .4608386
             |
       _cons |   3.550193   3.006817     1.18   0.243    -2.473185    9.573571
------------------------------------------------------------------------------
```

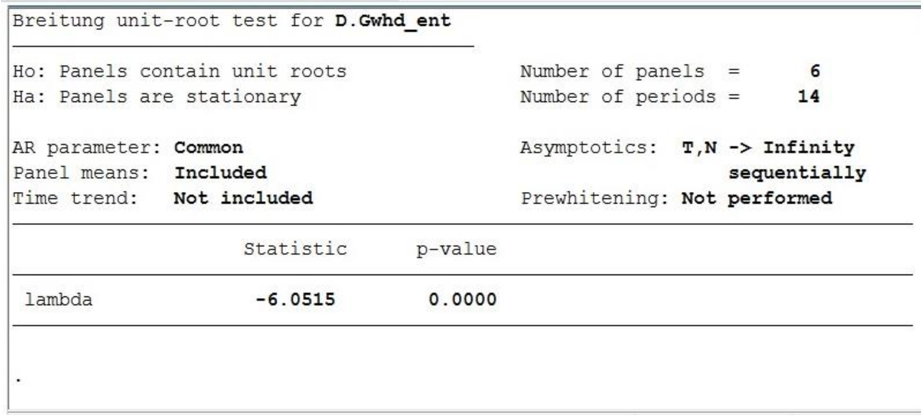
Annex 4

Breitung stationarity test for Ginfr_en variable



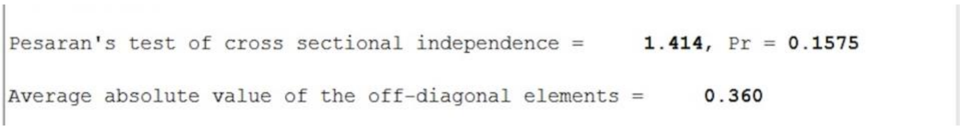
```
. xtunitroot breitung Gwhd_ent

Breitung unit-root test for Gwhd_ent
----------------------------------------
Ho: Panels contain unit roots               Number of panels  =      6
Ha: Panels are stationary                   Number of periods =     15

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included                  Prewhitening: Not performed
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda                0.0302        0.5120
------------------------------------------------------------------------------
```

Breitung stationarity test for first order differences of Ginfr_en variable



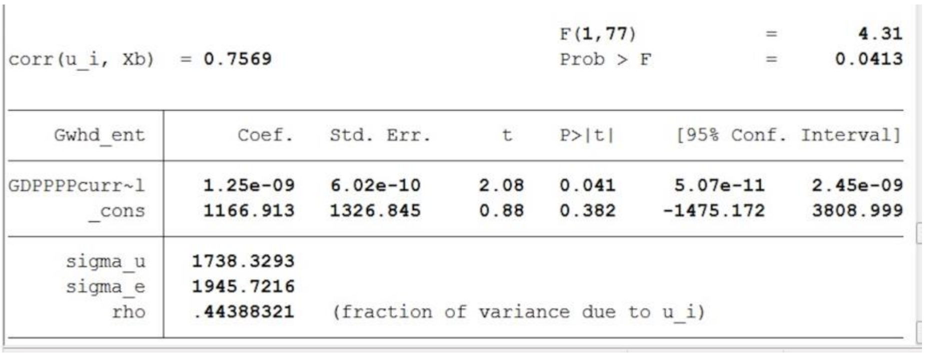
```
Breitung unit-root test for D.Gwhd_ent
----------------------------------------
Ho: Panels contain unit roots               Number of panels  =      6
Ha: Panels are stationary                   Number of periods =     14

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included                  Prewhitening: Not performed
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda               -6.0515        0.0000
------------------------------------------------------------------------------

.
```

Pesaran’s test of cross-sectoral dependence



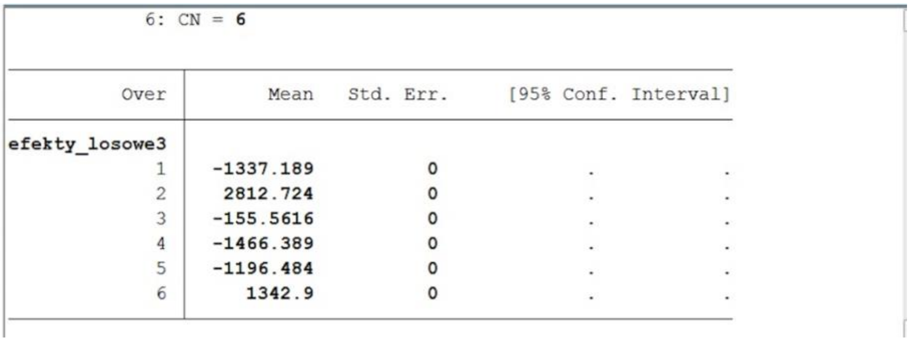
```
Pesaran's test of cross sectional independence =     1.414, Pr = 0.1575

Average absolute value of the off-diagonal elements =     0.360
```

Final regression model for Ginfr_en



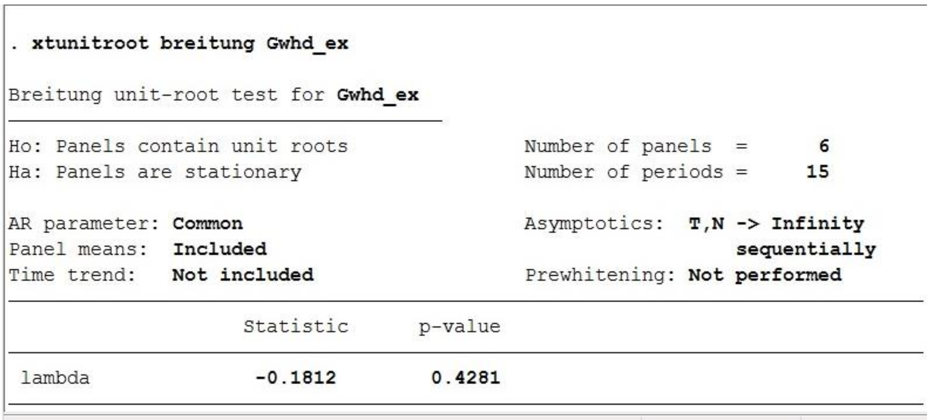
```
                                               F(1,77)           =       4.31
corr(u_i, Xb)  = 0.7569                        Prob > F          =     0.0413

------------------------------------------------------------------------------
    Gwhd_ent |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
GDPPPPcurr~l |   1.25e-09   6.02e-10     2.08   0.041     5.07e-11    2.45e-09
       _cons |   1166.913   1326.845     0.88   0.382    -1475.172    3808.999
-------------+----------------------------------------------------------------
     sigma_u |  1738.3293
     sigma_e |  1945.7216
         rho |  .44388321   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Stationary effects for Ginfr_en



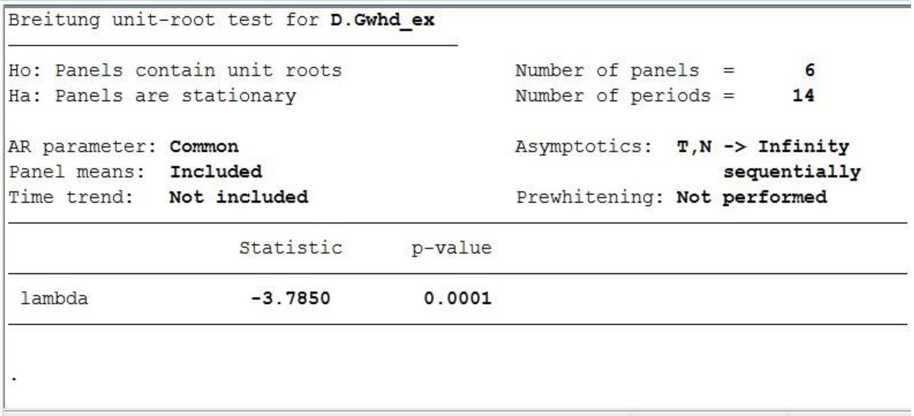
```
          6: CN = 6

          Over |       Mean   Std. Err.     [95% Conf. Interval]
---------------+------------------------------------------------
efekty_losowe3 |
             1 |  -1337.189          0             .           .
             2 |   2812.724          0             .           .
             3 |  -155.5616          0             .           .
             4 |  -1466.389          0             .           .
             5 |  -1196.484          0             .           .
             6 |     1342.9          0             .           .
---------------------------------------------------------------
```

Breitung stationarity test for first order differences of Ginfr_ex variable



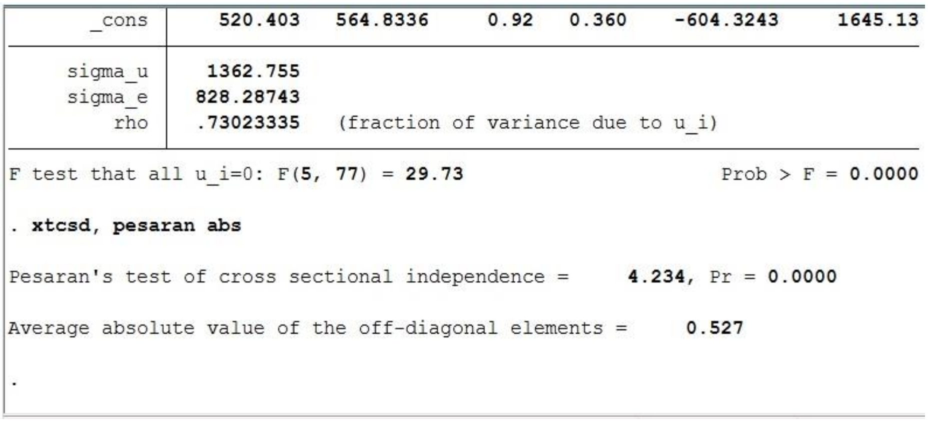
```
. xtunitroot breitung Gwhd_ex

Breitung unit-root test for Gwhd_ex
-------------------------------------
Ho: Panels contain unit roots               Number of panels  =      6
Ha: Panels are stationary                   Number of periods =     15

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                       sequentially
Time trend:   Not included                  Prewhitening: Not performed
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda              -0.1812       0.4281
------------------------------------------------------------------------------
```

Breitung stationarity test for Ginfr_ex variable’s increments



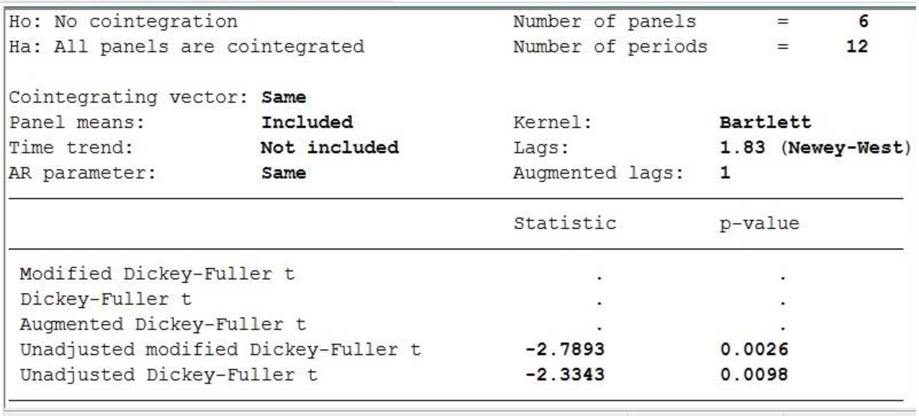
```
Breitung unit-root test for D.Gwhd_ex
-------------------------------------
Ho: Panels contain unit roots               Number of panels  =      6
Ha: Panels are stationary                   Number of periods =     14

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                       sequentially
Time trend:   Not included                  Prewhitening: Not performed
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda              -3.7850       0.0001
------------------------------------------------------------------------------

.
```

Pesaran’s test of cross-sectoral dependence



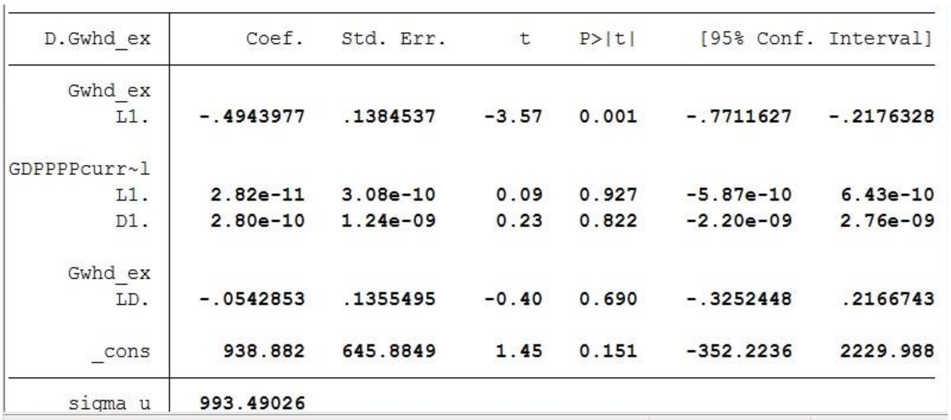
```
       _cons |    520.403   564.8336     0.92   0.360    -604.3243     1645.13
-------------+----------------------------------------------------------------
     sigma_u |   1362.755
     sigma_e |  828.28743
         rho |  .73023335   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(5, 77) = 29.73                      Prob > F = 0.0000

. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =     4.234, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.527

.
```

Kao cointegration test for Ginfr_ex and GDP variables



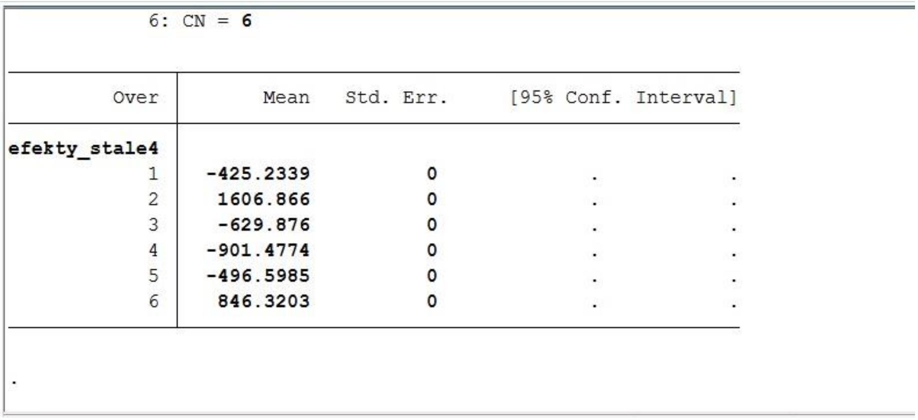
```
Ho: No cointegration                        Number of panels       =       6
Ha: All panels are cointegrated             Number of periods      =      12

Cointegrating vector: Same
Panel means:          Included              Kernel:             Bartlett
Time trend:           Not included          Lags:               1.83  (Newey-West)
AR parameter:         Same                  Augmented lags:     1

                                            Statistic           p-value

 Modified Dickey-Fuller t                           .                 .
 Dickey-Fuller t                                    .                 .
 Augmented Dickey-Fuller t                          .                 .
 Unadjusted modified Dickey-Fuller t          -2.7893            0.0026
 Unadjusted Dickey-Fuller t                   -2.3343            0.0098
```

Final regression model for Ginfr_ex



```
    D.Gwhd_ex        Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]

      Gwhd_ex
          L1.    -.4943977   .1384537    -3.57   0.001    -.7711627   -.2176328

GDPPPPcurr~l
          L1.     2.82e-11   3.08e-10     0.09   0.927    -5.87e-10    6.43e-10
          D1.     2.80e-10   1.24e-09     0.23   0.822    -2.20e-09    2.76e-09

      Gwhd_ex
          LD.    -.0542853   .1355495    -0.40   0.690    -.3252448    .2166743

        _cons      938.882   645.8849     1.45   0.151    -352.2236    2229.988

      sigma_u    993.49026
```

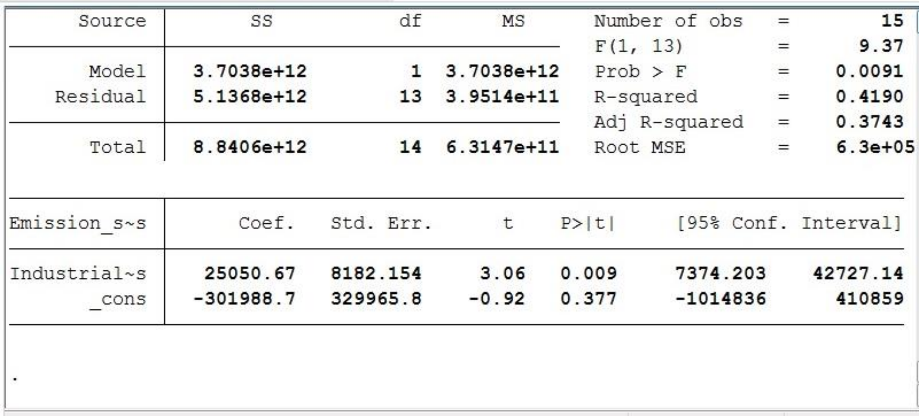
Stationary effects for Ginfr_ex



```
             6: CN = 6

         Over         Mean   Std. Err.     [95% Conf. Interval]

efekty_stale4
            1    -425.2339          0              .           .
            2     1606.866          0              .           .
            3     -629.876          0              .           .
            4    -901.4774          0              .           .
            5    -496.5985          0              .           .
            6     846.3203          0              .           .

.
```

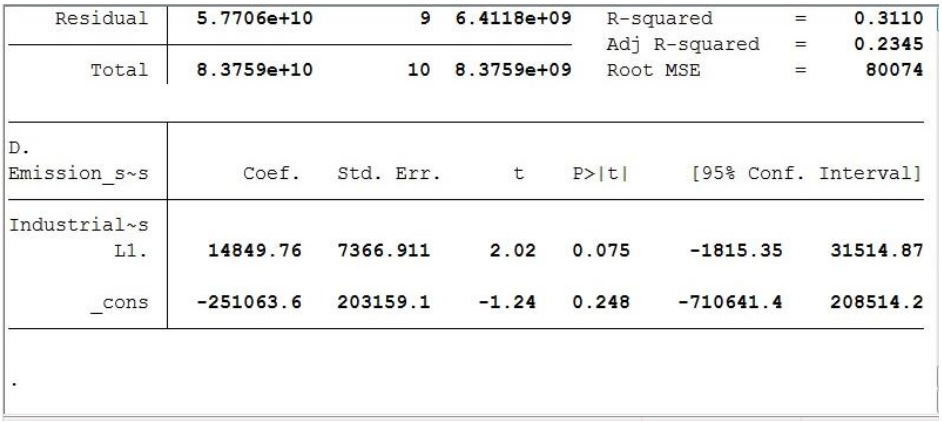
Annex 5

Linear regression for Es variable as a function of Gp for France



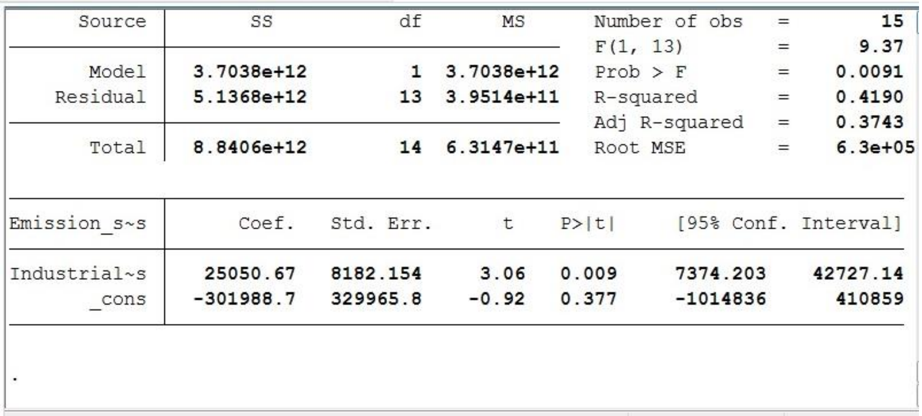
```
      Source |       SS           df       MS      Number of obs   =        15
-------------+----------------------------------   F(1, 13)        =      9.37
       Model |  3.7038e+12         1  3.7038e+12   Prob > F        =    0.0091
    Residual |  5.1368e+12        13  3.9514e+11   R-squared       =    0.4190
-------------+----------------------------------   Adj R-squared   =    0.3743
       Total |  8.8406e+12        14  6.3147e+11   Root MSE        =   6.3e+05

------------------------------------------------------------------------------
Emission_s~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Industrial~s |   25050.67   8182.154     3.06   0.009     7374.203    42727.14
       _cons |  -301988.7   329965.8    -0.92   0.377     -1014836      410859
------------------------------------------------------------------------------

.
```

Linear regression for Es variable's increments as a function of lagged Gp for Germany



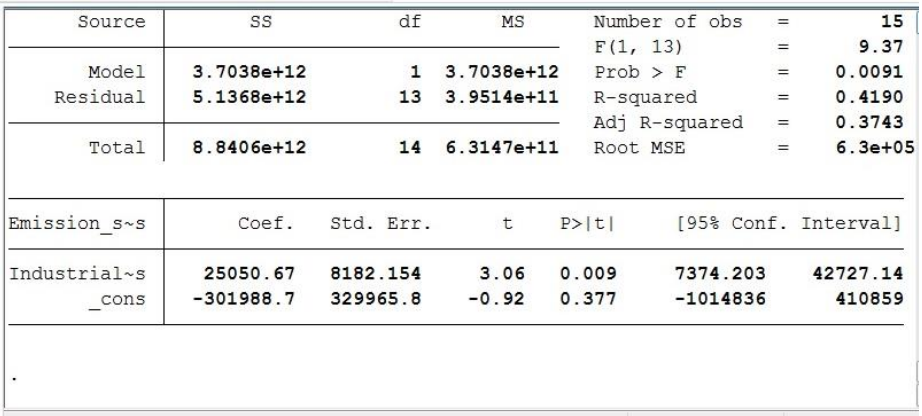
```
    Residual |  5.7706e+10         9  6.4118e+09   R-squared       =    0.3110
-------------+----------------------------------   Adj R-squared   =    0.2345
       Total |  8.3759e+10        10  8.3759e+09   Root MSE        =     80074

------------------------------------------------------------------------------
D.           |
Emission_s~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Industrial~s |
         L1. |   14849.76   7366.911     2.02   0.075     -1815.35    31514.87
             |
       _cons |  -251063.6   203159.1    -1.24   0.248    -710641.4    208514.2
------------------------------------------------------------------------------

.
```

Linear regression for Es variable as a function of Gp for Italy



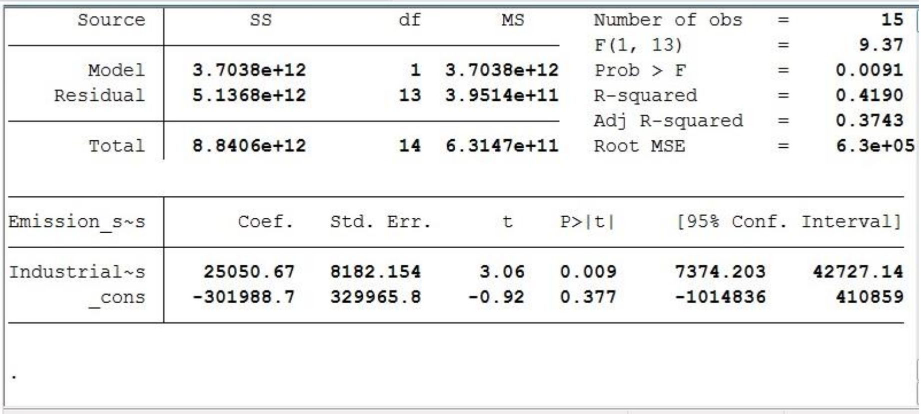
```
      Source |       SS           df       MS      Number of obs   =        15
-------------+----------------------------------   F(1, 13)        =      9.37
       Model |  3.7038e+12         1  3.7038e+12   Prob > F        =    0.0091
    Residual |  5.1368e+12        13  3.9514e+11   R-squared       =    0.4190
-------------+----------------------------------   Adj R-squared   =    0.3743
       Total |  8.8406e+12        14  6.3147e+11   Root MSE        =   6.3e+05

------------------------------------------------------------------------------
Emission_s~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Industrial~s |   25050.67   8182.154     3.06   0.009     7374.203    42727.14
       _cons |  -301988.7   329965.8    -0.92   0.377     -1014836      410859
------------------------------------------------------------------------------

.
```

Linear regression for Es variable as a function of Gp for Denmark



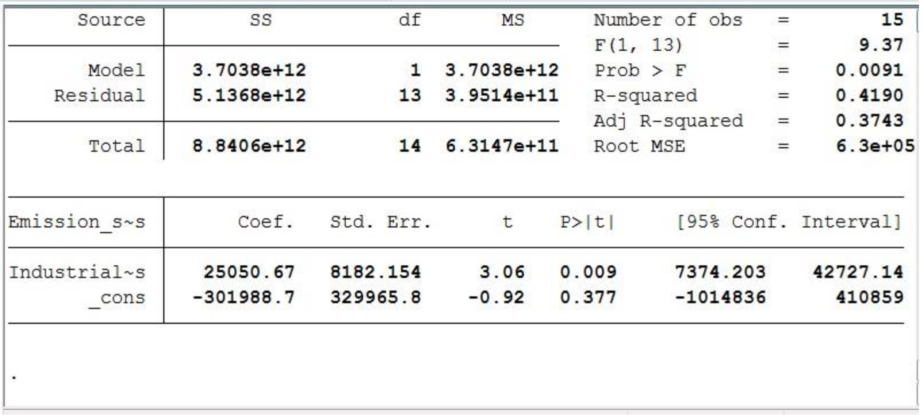
```
      Source |       SS           df       MS      Number of obs   =        15
-------------+----------------------------------   F(1, 13)        =      9.37
       Model |  3.7038e+12         1  3.7038e+12   Prob > F        =    0.0091
    Residual |  5.1368e+12        13  3.9514e+11   R-squared       =    0.4190
-------------+----------------------------------   Adj R-squared   =    0.3743
       Total |  8.8406e+12        14  6.3147e+11   Root MSE        =   6.3e+05

------------------------------------------------------------------------------
Emission_s~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Industrial~s |   25050.67   8182.154     3.06   0.009     7374.203    42727.14
       _cons |  -301988.7   329965.8    -0.92   0.377     -1014836      410859
------------------------------------------------------------------------------

.
```

Linear regression for Es variable as a function of Gp for Poland



```
      Source |       SS           df       MS      Number of obs   =        15
-------------+----------------------------------   F(1, 13)        =      9.37
       Model |  3.7038e+12         1  3.7038e+12   Prob > F        =    0.0091
    Residual |  5.1368e+12        13  3.9514e+11   R-squared       =    0.4190
-------------+----------------------------------   Adj R-squared   =    0.3743
       Total |  8.8406e+12        14  6.3147e+11   Root MSE        =   6.3e+05

------------------------------------------------------------------------------
Emission_s~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Industrial~s |   25050.67   8182.154     3.06   0.009     7374.203    42727.14
       _cons |  -301988.7   329965.8    -0.92   0.377     -1014836      410859
------------------------------------------------------------------------------

.
```

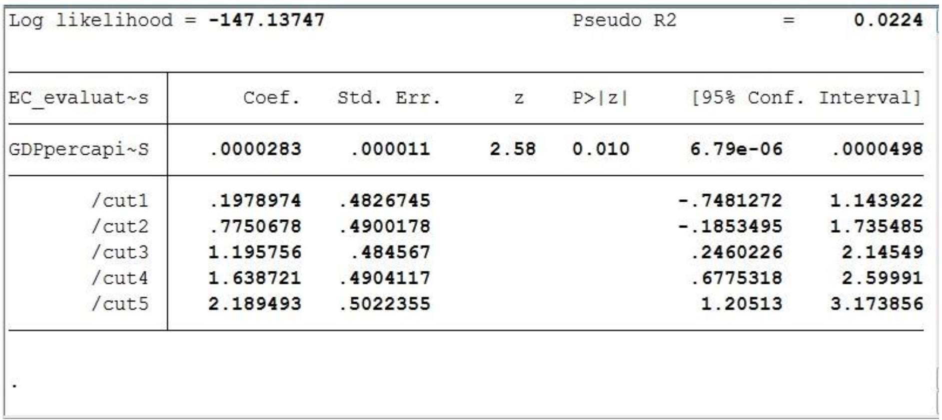
Linear regression for Es variable's increments as a function of lagged Gp for UK



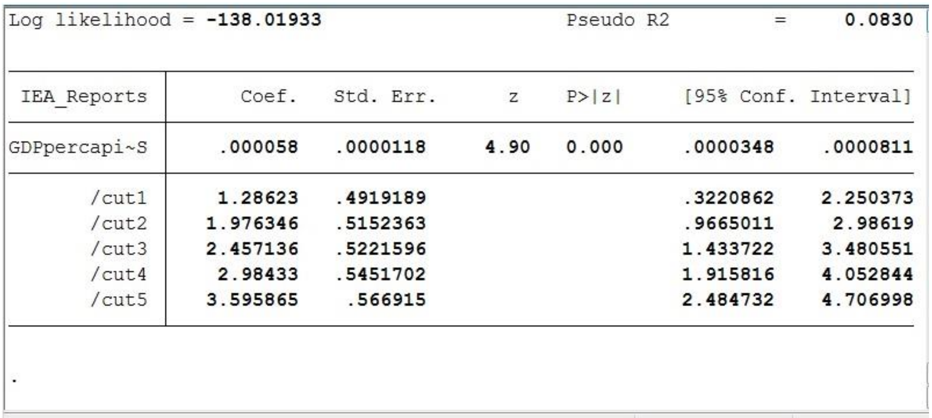
```
      Source |       SS           df       MS      Number of obs   =        15
-------------+----------------------------------   F(1, 13)        =      9.37
       Model |  3.7038e+12         1  3.7038e+12   Prob > F        =    0.0091
    Residual |  5.1368e+12        13  3.9514e+11   R-squared       =    0.4190
-------------+----------------------------------   Adj R-squared   =    0.3743
       Total |  8.8406e+12        14  6.3147e+11   Root MSE        =   6.3e+05

------------------------------------------------------------------------------
Emission_s~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Industrial~s |   25050.67   8182.154     3.06   0.009     7374.203    42727.14
       _cons |  -301988.7   329965.8    -0.92   0.377     -1014836      410859
------------------------------------------------------------------------------

.
```

Annex 6

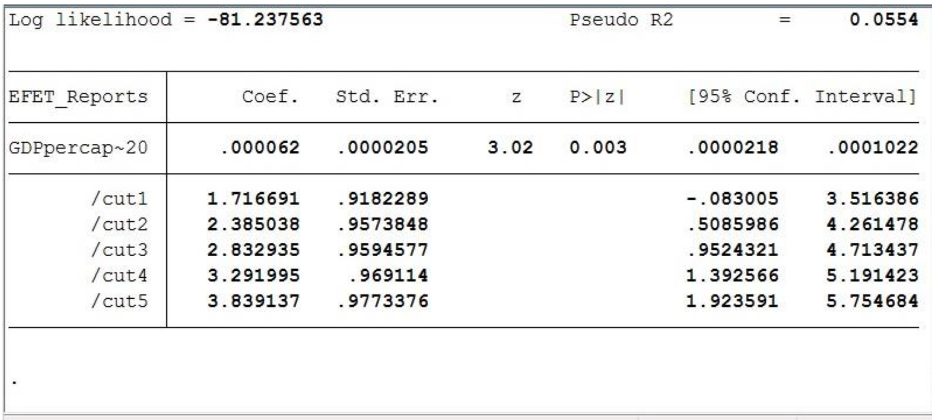
Regression results for Ins subcomponents (LcEC, LcIEA and Mp) with GDP per capita as the explanatory variable.



```
Log likelihood = -147.13747                     Pseudo R2         =     0.0224

------------------------------------------------------------------------------
EC_evaluat~s |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
GDPpercapi~S |   .0000283    .000011     2.58   0.010     6.79e-06    .0000498
-------------+----------------------------------------------------------------
       /cut1 |   .1978974   .4826745                     -.7481272    1.143922
       /cut2 |   .7750678   .4900178                     -.1853495    1.735485
       /cut3 |   1.195756    .484567                      .2460226     2.14549
       /cut4 |   1.638721   .4904117                      .6775318     2.59991
       /cut5 |   2.189493   .5022355                       1.20513    3.173856
------------------------------------------------------------------------------

.
```



```
Log likelihood = -138.01933                     Pseudo R2         =     0.0830

------------------------------------------------------------------------------
 IEA_Reports |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
GDPpercapi~S |    .000058   .0000118     4.90   0.000      .0000348    .0000811
-------------+----------------------------------------------------------------
       /cut1 |    1.28623   .4919189                      .3220862    2.250373
       /cut2 |   1.976346   .5152363                      .9665011     2.98619
       /cut3 |   2.457136   .5221596                      1.433722    3.480551
       /cut4 |    2.98433   .5451702                      1.915816    4.052844
       /cut5 |   3.595865    .566915                      2.484732    4.706998
------------------------------------------------------------------------------

.
```



```
Log likelihood = -81.237563                     Pseudo R2         =     0.0554

------------------------------------------------------------------------------
EFET_Reports |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
GDPpercap~20 |    .000062   .0000205     3.02   0.003      .0000218    .0001022
-------------+----------------------------------------------------------------
       /cut1 |   1.716691   .9182289                      -.083005    3.516386
       /cut2 |   2.385038   .9573848                      .5085986    4.261478
       /cut3 |   2.832935   .9594577                      .9524321    4.713437
       /cut4 |   3.291995    .969114                      1.392566    5.191423
       /cut5 |   3.839137   .9773376                      1.923591    5.754684
------------------------------------------------------------------------------

.
```

Bibliography

Books, Articles, Working Papers, Position Papers, Websites, Letters, Reports

Acemoglu, D., Robinson, J. A., (2012). *Why Nations Fail: The Origins of Power, Prosperity and Poverty*, 1st ed. Crown, New York.

Adamkiewicz-Drwiłło, H., (2002). *Uwarunkowania konkurencyjności przedsiębiorstwa*. PWN, Warsaw.

Agency for the Cooperation of Energy Regulators (ACER), (2013). ACER/CEER *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2012*, Ljubljana.

Agency for the Cooperation of Energy Regulators (ACER), (2014). ACER/CEER *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2013*, Ljubljana.

Agency for the Cooperation of Energy Regulators (ACER), (2016). *Implementation Monitoring Report on the Capacity Allocation Mechanisms Network Code Implementation Monitoring Report on the Capacity Allocation Mechanisms Network Code*, Ljubljana.

Agency for the Cooperation of Energy Regulators (ACER), (2021a). *ACER Report on the Implementation of the Balancing Network Code.* Ljubljana.

Agency for the Cooperation of Energy Regulators (ACER), (2021b). *ACER Balancing Monitoring Report 2019/20 Development and Analysis*. Ljubljana.

Agency for the Cooperation of Energy Regulators (ACER), (2022). *Report on Gas Storage Regulation and Indicators*. Ljubljana.

Aghion, P., Cai, J., Dewatripont, M., Du, L., Harrison, A., Legros, P., (2015). *Industrial policy and competition,* "American Economic Journal: Macroeconomics", vol. 7.

Aiginger, K., Bärenthaler-Sieber, S., Vogel, J., (2013). *Competitiveness under New Perspectives* Working Paper no 44.

Amirkhizi, T., Olczak, M., (2020). *Biomethane in the Renewable Energy Directive*. Florence School of Regulation, vol. 1.

Arapostathis, S., Pearson, P. J. G., Foxon, T. J., (2014). *UK natural gas system integration in the making,1960-2010: Complexity, transitional uncertainties and uncertain transition*. "Environmental Innovation and Societal Transition" vol. 11.

Arrow, K. J., (1972). *Gifts and exchanges. Philosophy and Public Affairs* 14.

Ascari, S., Glachant, J. M., (2011). *A Gas Target Model for the European Union: Contrasting MECOS and EURAM Proposal. Florence School of Regulation*, Florence.

Balaman, Ş. Y., (2019). "Uncertainty Issues in Biomass-Based Production Chains", in: Balaman, Ş. Y. (ed.), *Decision-Making for Biomass-Based Production Chains*. Academic Press.

Balcerowicz, Ewa., Sobolewski, M., (2005). *Competitiveness of the Polish manufacturing sector : does government policy matter?,* Center for Social and Economic Research. Warsaw.

Banet, C., (2023). *Building Europe's Hydrogen and Renewable Gas Markets*. CERRE, Brussels.

Barkema, A., Drabenstott, M., Tweeten, L., (1990). *The Competitiveness of US Agriculture in the 1990s*. Resources for the Future and National Planning Association. Washington D. C.

Barney, J., (1991). *Firm Resources and Sustained Competitive Advantage*. "Journal of Management", vol. 17 (1).

Baumann, C., Cherry, M., Chu, W., (2019). *Competitive Productivity at macro–meso–micro levels*, "Cross Cultural and Strategic Management", vol. 26 (2).

Baumann, C., Pintado, I., (2013). *Competitive Productivity - a new perspective on effective output*, "Journal of the Institute of Management Services", vol. 57 (1).

Becker, W. L., Penev, M., Braun, R. J., (2018). *Production of Synthetic Natural Gas From Carbon Dioxide and Renewably Generated Hydrogen: A Techno-Economic Analysis of a Power-to-Gas Strategy*, "Journal of Energy Resources Technology", vol. 141 (2).

Benedetti, L., Pellini, A., Giannì, M., (2021). *Biogas and biomethane in Italy. Deploying biogas and MSW-to-energy*, GSE, Rome.

Bieńkowski, W., Radło, M. J., Brada, J. C., (2008). *Growth versus Security*, Palgrave Macmillan UK, London.

Biukšāne, I., (2016). *Model of the Factors Influencing Competitiveness of the Latvian Fisheries Sector Cluster*, "Economics and Business", vol. 28.

Black, A. J., (1992). *Competition Law and British Natural Gas Regulation*, "Energy Law Journal", vol. 13 (2).

Blesh, J., Hoey, L., Jones, A. D., Friedmann, H., Perfecto, I., (2019). *Development pathways toward "zero hunger"*, "World Development", vol. 118.

Bluszcz, A., (2020). *Multidimensional comparative analysis as a tool for assessing the level of development of energy markets in selected European countries*. IOP Conference Series: Earth and Environmental Science, vol. 609 (1).

Bobba, F., Langer, W., Pous, J., (1971). *Bericht über die Wettbewerbsfähigkeit der Europäischen Gemeinschaft,* Brussels.

Bodde, D. L., (2007). "Lost in Option Space: Risk Partitioning to Guide Climate and Energy Policy", in: Sperling, D., Cannon, J. S. (eds.), *Driving Climate Change*. Academic Press, Burlington.

Boldeanu, F. T., Constantinescu, L., (2015). *The main determinants affecting economic growth,* "Bulletin of the Transilvania University of Braşov. Economic Sciences", vol. 8 (2).

Bossley, L., (1999). *Trading natural gas in the UK,* Oxford Institute for Energy Studies, Oxford.

Bouzarovski, S., Bradshaw, M., Wochnik, A., (2015). *Making territory through infrastructure: The governance of natural gas transit in Europe*, "Geoforum", vol. 64.

Bozzetto S., (2017). *The Development of Biomethane: A Sustainable Choice for the Economy and the Environment. Notes for the elaboration of a road map for the development of biogas done right and biogas refinery technologies in Italy,* Biogas Refinery Development, Padova.

Braendle, U., Mozghovyi, Y., Huryna, K., (2018). *Corporate competitiveness and sustainability risks,* „Risk Governance and Control: Financial Markets and Institutions", vol. 7 (3).

Breitung, J., (2000). "The local power of some unit root tests for panel data", in: Baltagi, B., (ed.), *Nonstationary Panels, Panel Cointegration, and Dynamic Panels, Advances in Econometrics*. JAI, Amsterdam.

Bundesnetzagentur, (2023). Marktstammdatenregister, https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht#gaserzeugung,(date of access 11. 03.2023).

Burtraw, D., Themann, M., (2018). *Pricing Carbon Effectively: Lessons from the European Emissions Trading System,* Carleton University, Ottawa.

Butnar, I., Cronin, J., Pye, S., (2020). *Review of Carbon Capture Utilisation and Carbon Capture and Storage in future EU decarbonisation scenarios,* UCL Energy Institute, London.

Cameron, A. C., Trivedi, P. K., (2005). *Microeconometrics: Methods and Applications,* Cambridge University Press, Cambridge.

Capobianco-Uriarte, M. de las M., Casado-Belmonte, M. del P., Marín-Carrillo, G. M., Terán-Yépez, E., (2019). *A Bibliometric Analysis of International Competitiveness (1983–2017),* "Sustainability", vol. 11 (7).

Checchi, A., Behrens, A., Egenhofer, C., (2009). *Long-Term Energy Security Risks for Europe: A Sector-Specific Approach*, “SSRN Electronic Journal” vol. 309.

Chikán, A., (2008). *National and firm competitiveness: a general research model. Competitiveness Review*, “International Business Journal”, vol. 18 (1/2).

Cho, D. S., (1994). *A Dynamic Approach to International Competitiveness: The Case of Korea*, “Asia Pacific Business Review” vol. 1(1).

Cho, D. S., Moon, H. C., (2000). *From Adam Smith to Michael Porter*, “Asia-Pacific Business Series”, vol. 2.

Clark, J. M., (1940). *Toward a Concept of Workable Competition*, “The American Economic Review”, vol. 30 (2).

Clingendael International Energy Programme, (2011). *CIEP Vision on the Gas Target Model*, Clingendael. The Hague.

Coase, R. H., (1937). *The Nature of the Firm*, “Economica”, vol. 4.

Commission de Regulation de l’Energie (CRE), (2022). *CRE supports the development of biomethane in France,* https://www.cre.fr/content/download/25433/file/220425_CP_Biomethane.pdf (date of access 10.02.2023).

Competition and Markets Authority (CMA), (2016). *Energy Market Investigation*. Ofgem, London.

Consorzio Italiano Biogas, (2014). *Biogas 2020 – 25.000 green jobs per l’agricolture italiana*. Paris.

Consorzio Italiano Biogas, (2017). *Biogasdoneright. Anaerobic Digestion And Soil Carbon Sequestration A Sustainable, Low Cost, Reliable And Win Win Beccs Solution*, Rome.

Costescu A, Manitsas E, Szikszai A, (2017). *State of implementation of the Third Energy Package in the gas sector.* JRC Science for Policy Report. Brussels.

Council of European Energy Regulators (CEER), (2011). *Draft Vision for a European Gas Target Model*, CEER, Brussels.

Council of European Energy Regulators (CEER), (2021). *Status Review of Renewable Support Schemes in Europe for 2018 and 2019*, CEER, Brussels.

Cournot, A. A., (1897). *Researches Into the Mathematical Principles of the Theory of Wealth,* The Macmillan Co., New York.

Couture, T. D., Cory, K., Kreycik, C., Williams, E., (2010). *A Policymaker’s Guide to Feed-in Tariff Policy Design*. National Renewable Energy Laboratory. Washington.

Cuéllar-Franca, R. M., Azapagic, A., (2015). *Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts*, “Journal of CO_2 Utilization”, vol. 9.

Dabbah, M. M., (2011). T*he Relationship Between Competition Authorities and Sector Regulators,* “The Cambridge Law Journal”, vol. 70 (1).

Dang, Q. T., Jasovska, P., Rammal, H. G., (2020*). International business-government relations: The risk management strategies of MNEs in emerging economies*, “Journal of World Business”, vol. 55 (1).

Daniel-Gromke, J., Denysenko, V., Liebetrau, J., Europe, B. I., (2019). *Biogas and biomethane in Europe. Lessons from Denmark, Germany and Italy. Ifr*i Centre for Energy. Paris.

Danish Energy Agency, (2012). *Energy Policy in Denmark*, DEA, Copenhagen.

Danø, J., (2022). *New record for biogas in the gas system in 2021*, Energinet, Copenhagen.

Das, G. G., (2017). *Food–feed–biofuel trilemma: Biotechnological innovation policy for sustainable development*, “Journal of Policy Modeling”, vol. 39 (3).

De Clara, S., Mayr, K., (2018). *The EU ETS phase IV reform: implications for system functioning and for the carbon price signal*. Oxford Institute for Energy Studies, Oxford.

de Hauteclocque, A., (2013). *Vertical de-integration and single market integration in the European Union: an incomplete transition in: Market Building through Antitrust*, Edward Elgar Publishing, Cheltenham.

Dechezleprêtre, A., Nachtigall, D., Venmans, F., (2023). *The joint impact of the European Union emissions trading system on carbon emissions and economic performance*, " Journal of Environmental Economics and Management", vol. 118.

Deniz, M., Seçkin, Ş. N., Cüreoğlu, M., (2013). *Micro-Economic Competitiveness: A Research on Manufacturing Firms Operating in TRB1 region*, "Procedia - Social and Behavioral Sciences", vol. 75.

Department for Business, Energy and Industrial Strategy (BEIS), (2021). *Final Stage IA Assessment for the Green Gas Support Scheme/Green Gas Levy*. BEIS, London.

Department of Energy and Climate Change, (2016). *Gas price elasticities: the impact of gas prices on domestic consumption – a discussion of available evidence*, London.

di Bella, G., Flanagan, M., Foda, K., Maslova, S., Pienkowski, A., Stuermer, M., Toscani, F., (2022). *Natural Gas in Europe: The Potential Impact of Disruptions to Supply*, IMF, Washington.

Diamond, J., (1997). *Guns, germs, and steel: The fates of human societies*. W. W. Norton & Company, New York.

Dignum, M., Correljé, A., Groenleer, M., Scholten, D., (2018). *Governing through visions: Evaluating the performativity of the European gas target models*, "Energy Research & Social Science", vol. 35.

Directorate General for Energy (DG Energy), (2013). *Quarterly Report: Energy on European Gas Markets*, DG Energy, Brussels.

Directorate General for Energy (DG Energy), (2014). *Quarterly Report: Energy on European Gas Markets*, DG Energy, Brussels.

Dopfer, K., Foster, J., Potts, J., (2004). *Micro-meso-macro*, "Journal of Evolutionary Economics", vol. 14 (3).

Dresch, A., Collatto, D. C., Lacerda, D. P., (2018). *Theoretical understanding between competitiveness and productivity: firm level*, "Ingeniería y competitividad", vol. 20.

Dynan, K., Sheiner, L., (2018). *GDP as a Measure of Economic Well-being*, Hutchins Center Working Paper, vol. 43, Washington.

Ebenhoch, R., Matha, D., Marathe, S., Muñoz, P. C., Molins, C., (2015). *Comparative Levelized Cost of Energy Analysis, "*Energy Procedia", vol. 80.

Ellerman, A. D., Joskow, P. L., (2008). *The European Union's Emissions Trading System in perspective*, PEW Center on Global Climate Change, Arlington.

Ellerman, A., Convery, D., de Perthuis, C., (2010). *Pricing Carbon: The European Union Emissions Trading Scheme*, Cambridge University Press, Cambridge.

Energinet, (2022). *Biomethane*, https://en.energinet.dk/gas/biomethane/ (date of access 21.01.2023).

Esser, K., Hillebrand, W., Messner, D., Meyer-Stamer, J., (1996). *Systemic Competitiveness: a new challenge for firms and for government*, "CEPAL Review", vol. 59.

Esser, K., Hillebrand, W., Messner, D., Meyer-Stamer, J., (2013). *Systemic Competitiveness: New Governance Patterns for Industrial Development*, Frank Cass & Co. Ltd. London.

European Biogas Association (EBA), European Federation of Energy Traders (EFET), The European Renewable Gas Registry (ERGaR), Eurogas, European Network of Transmission System

Operators for Gas (ENTSO-G), Gas Infrastructure Europe (GIE), (2023). *Open Joint Letter to the European Commission on the Implementation Timeline and Operational Design of the Union Database*, https://www.europeanbiogas.eu/policy/open-joint-letter-to-the-european-commission-implementation-timeline-and-operational-design-of-the-union-database/ (date of access 04.03.2023).

European Commission, (2004). European Competitiveness Report 2003, Brussels.

European Commission, (2008). *Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: Towards World-class Clusters in the European Union, Implementing the Broad-based Innovation Strategy COM (2008) 652*, Brussels.

European Commission, (2009). *Quarterly Report on European Gas Markets*. Brussels.

European Commission, (2012a). *A "Competitiveness Proofing" Toolkit for use in Impact Assessments*. Brussels.

European Commission, (2012b). *Quarterly Report on European Gas Markets*, Brussels.

European Commission, (2017). *Quarterly Report Energy on European Gas Markets*, Brussels.

European Commission, (2020a). *In focus: Renewable energy in Europe*, Brussels.

European Commission, (2020b). *Quarterly Report on European Gas Markets*, Brussels.

European Commission, (2021). *Analysis of the recovery and resilience plan of Italy*, Brussels.

European Commission, (2022a). *REPowerEU Plan*. Brussels.

European Commission, (2022b). *Commission approves modification of German scheme to support electricity production from renewable energy sources*, Brussels.

European Commission, (2023). *Biofuels – updated list of sustainable biofuel feedstocks*, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13484-Biofuels-updated-list-of-sustainable-biofuel-feedstocks_en (date of access 20.01.2023).

European Court of Auditors, (2016). *Special Report: The EU system for the certification of sustainable biofuels*. Luxembourg.

European Environment Agency (EEA), (2022). *Effort Sharing, ETS, LULUCF trends and projections in the EU-27*, https://www.eea.europa.eu/data-and-maps/figures/eu-27-effort-sharing-ets-2 (date of access 04.01.2023).

European Federation of Energy Traders (EFET), (2023). *European Gas Hub Study*, https://efet.org/home/documents?id=19 (date of access 27.02.2023).

European Hydrogen Backbone, (2022). *Country Narratives*, https://ehb.eu/page/country-specific-developments (date of access 22.01.2023).

European Network of Transmission System Operators for Gas (ENTSO-G), (2021). *Consultation response on the legislative proposal COM (2021) 557 for amending RED II*, Brussels.

European Network of Transmission System Operators for Gas (ENTSO-G), European Network of Transmission System Operators for Electricity (ENTSO-E), 2022. TYNDP 2022 Scenario Report. Brussels.

Fischer, S., (1993). *The role of macroeconomic factors in growth*, "Journal of Monetary Economics", vol. 32 (3).

Fisher, N., Nicolas R., van Wees, H., (2011). *Competition in the ancient world. Classical Press of Wales*, Swansea.

Flachsland, C., Wolff, C., Schmid, L. K., Leipprand, A., Koch, N., Kornek, U., Pahle, M., (2017). *Decarbonization and EU ETS Reform: Introducing a price floor to drive low-carbon investments*, Mercator Research Institute on Global Commons and Climate Change, Berlin.

Flanagan, R., Lu, W., Shen, L., Jewell, C., (2007). *Competitiveness in construction: a critical review of research*, "Construction Management and Economics", vol. 25 (9).

Flejterski, S., (1984). *Istota i mierzenie konkurencyjności międzynarodowej*, „Gospodarka Planowa", vol. 39 (9).

Frontier Economics, (2019). *The Value of Gas Infrastructure in a Climate-Neutral Europe. A study based on eight European countries*. London.

Gál, A. N., (2010). *Competitiveness of small and medium sized enterprises-a possible analytical framework*, "Hungarian Electronic Journal of Science", http://hej.sze.hu/eco_szer_en.html (date of access: 20.07.2021).

Garelli, S., (2002). *Competitiveness of Nations: the fundamentals*, IMD World Competitiveness Yearbook, Lausanne.

Gas For Climate, (2022). *Feasibility of REPowerEU 2030 targets, production potentials in the Member Biomethane production potentials in the EU. Gas For Climate Report*, https://gasforclimate 2050.eu/publications/ (date of access: 20.11.2022).

Giannetti, B. F., Agostinho, F., Almeida, C. M. V. B., Huisingh, D., (2015). *A review of limitations of GDP and alternative indices to monitor human wellbeing and to manage eco-system functionality*, "Journal of Clean Production", vol. 87 (1).

Giraud, G., Stahn, H., (2003*). Efficiency and imperfect competition with incomplete markets*, "Journal of Mathematical Economics", vol 39 (5-6).

Gkotsis, P., Kougias, P., Mitrakas, M., Zouboulis, A., (2023). *Biogas upgrading technologies – Recent advances in membrane-based processes*, "International Journal of Hydrogen Energy", vol. 48 (10).

Gottlieb, G., Krogulski, K., (2022). *Four Criteria for Fighting the Energy Crisis*. IMF Reional Office for Central, Eastern and Southeastern Europe. Warsaw.

Grave, K., Breitschopf B., Ordonez J., Wachsmuth J., Boeve S., Smith M., Schubert T., Friedrichsen N., Herbst A., Eckartz K., Pudlik M., Bons M., Ragwitz M., Schleich J., (2016). *Prices And Costs of EU Energy*. Ecofys Final Report, Utrecht.

Grote, D., Nunes, R., Steinborn-Cheng, W., Paletar, M., Anton, D., (2022). *Future Regulatory Decisions on Natural Gas Networks: Repurposing, Decommissioning And Reinvestments*, DNV Energy Systems Germany, Bonn.

Gustafsson, M., Anderberg, S., (2021). *Dimensions and characteristics of biogas policies – Modelling the European policy landscape*, "Renewable and Sustainable Energy Reviews", vol. 135.

Gustafsson, M., Anderberg, S., (2022). *Biogas policies and production development in Europe: a comparative analysis of eight countries*, "Biofuels", vol. 13 (8).

Haase, Nadine., (2008). *European gas market liberalisation: Are regulatory regimes moving towards convergence?*, Oxford Institute for Energy Studies, Oxford.

Hamburger, Á., (2019). I*s guarantee of origin really an effective energy policy tool in Europe? A critical approach*, "Society and Economy", vol. 41 (4).

Hamilton, W. H., (1919). *The Institutional Approach to Economic Theory*, "The American Economic Review", vol. 9 (1).

Hamilton, W. H., (1940). *The pattern of competition*, Columbia University Press, New York.

Harvey, M., (2014). *The Food-Energy-Climate Change Trilemma: Toward a Socio-Economic Analysis*, "Theory, Culture & Society", vol. 31 (5).

Hasegawa, H., (2002). *Liberalization of Gas Industries in Europe and the U.S.*, The Institute of Electrical Engineers of Japan, Tokyo.

Hayashi, M., Hughes, L., (2013). *The Fukushima nuclear accident and its effect on global energy security*, "Energy Policy", vol. 59.

Heather, P., (2015). *The evolution of European traded gas hubs*, Oxford Institute for Energy Studies, Oxford.

Heather, P., (2021). *European Traded Gas Hubs: German THE fails to impress*, Oxford Institute for Energy Studies, Oxford.

Heckscher, E., (1919). *The Effect of Foreign Trade on the Distribution of Income*, "Ekonomisk Tidskrift", vol. 2.

Heckscher, E., (1955). *Mercantilism*, George Allen and Unwin, London.

Heddenhausen, M., (2007). *Privatisation in Europe's liberalised electricity markets – the cases of United Kingdom, Sweden Germany and France*, Stiftung Wissenschaft und Politik, Berlin.

Herbes, C., Rilling, B., Ringel, M., (2021). *Policy frameworks and voluntary markets for biomethane – How do different policies influence providers' product strategies?*, "Energy Policy", vol. 153.

Hintermann, B., Ludwig, M., (2023). *Home country bias in international emissions trading: Evidence from the EU ETS*, "Resource and Energy Economics", vol. 71.

Honore, A., (2019). *Decarbonization and industrial demand for gas in Europe*, Oxford Institute for Energy Studies, Oxford.

Hopwood, L., (2022). *EIC Biomethane Study Stage 3: Market Analysis & Cost Assessment*, NNFCC, London.

Hsu, L. C., Wang, C. H., (2012). *Clarifying the Effect of Intellectual Capital on Performance: The Mediating Role of Dynamic Capability*, "British Journal of Management", vol. 23.

Huhta, K., (2021). *The Scope of State Sovereignty Under Article 194(2) TFEU and the Evolution of EU Competences In The Energy Sector*, "International & Comparative Law Quarterly", vol. 70.

Hume, D., (1742). *On the Balance of Trade, in: Essays, Moral and Political,* McMaster University Archive for the History of Economic Thought, Hamilton.

Hunt, S., Arnett, D., (2006). "Toward a General Theory of Marketing: Resource-Advantage Theory as an Extension of Alderson's Theory of Market Processes*"* in: Wooliscroft B., Tamilia R. D., Shapiro S. (eds), *A Twenty-First Century Guide to Aldersonian Marketing Thought*, Springer International Publishing, Cham.

IBISWorld, (2022). *Average closing spot prices of European Emission Allowances (EUA) from 2010 to 2021*, In Statista, https://www-1statista-1com-10npp4eukaaf8.han3.lib.uni.lodz.pl/statistics/1329581/spot-prices-european-union-emission-trading-system-allowances/ (date of access 07.01.2023).

Im, K.S., Pesaran, M., Shin, Y., (2003). *Testing for unit roots in heterogeneous panels, "*Journal of Econometrics", vol. 115 (1).

Ingram, J. C., (1973). *The Case for European Monetary Integration*, "International Finance", vol. 98.

International Energy Agency (IEA), (2009a). *Energy Policies of IEA Contries: France 2009 Review*, IEA, Paris.

International Energy Agency (IEA), (2009b). *Energy Policies of IEA Countries: Italy 2009 Review*, IEA, Paris.

International Energy Agency (IEA), (2011). *Energy Policies of IEA Countries: Poland 2011 Review*, IEA, Paris.

International Energy Agency (IEA), (2013). *Energy Policies of IEA Countries: Germany 2013 Review*, IEA, Paris.

International Energy Agency (IEA), (2015). *Energy policies of IEA Countries: France 2015 Review*, IEA, Paris.

International Energy Agency (IEA), (2019a). *Gas Market Liberalisation Reform. Key insights from international experiences and the implications for China*. Paris.

International Energy Agency (IEA), (2019b). *Energy Policies of IEA Countries: United Kingdom 2019 Review*, IEA, Paris.

International Energy Agency (IEA), (2021a). *Implementation of bioenergy in Germany – 2021 update*, IEA, Paris.

International Energy Agency (IEA), (2021b). *Energy Policy Review: European Union 2020*, IEA, Paris.

International Energy Agency (IEA), (2021c). *Energy Policies of IEA Countries: France 2021 Review*, IEA, Paris.

International Energy Agency (IEA), (2022). *Natural Gas-Fired Electricity*, IEA, Paris.

International Energy Agency, (2019c). *Gas Market Liberalisation Reform. Key insights from international experiences and the implications for China*, Paris.

Irwin, D., (2017). *Ricardo and comparative advantage at 200*, https://cepr.org/voxeu/columns/ricardo-and-comparative-advantage-200 (date of access 17.01.2021).

Ishwaran, M., King, W., Haigh, M., Lee, T., Nie, S., (2017). *International Experience of Liberalisation and Evolution of Natural Gas Markets, in: China's Gas Development Strategies*, Springer International Publishing, Cham.

Jamas, T., Pollitt, M., (2005). *Electricity Market Reform in the European Union: Review of Progress toward Liberalization & Integration*, "The Energy Journal", vol. 26.

Janda, K., Sajdikova, L., (2022). I*nstitutional Description of the European Green Deal Investment Plan Framework*, ZBW-Leibniz Information Centre for Economics, Hamburg.

Jansen, J. C., (2017). *Does the EU renewable energy sector still need a guarantees of origin market?*, "CEPS Policy Insights", vol. 7.

John, J., (2010). *The "Resource Curse": Theory and Evidence (ARI)*, "Real Instituto Elcano", vol. 172.

Joint Research Centre (JRC), (2010). *International Reference Life Cycle Data System (ILCD) Handbook general guide for life cycle assessment: detailed guidance*. Publications Office of the European Union, Brussels.

Joint Research Centre (JRC), Padella, M., O'Connell, A., Giuntoli, J., Bulgheroni, C., Edwards, R., Marelli, L., Koeble, R., (2019). *Definition of input data to assess GHG default emissions from biofuels in EU legislation: version 1d - 2019*. Publications Office of the European Union, Brussels.

Juris, A., (1998). *Market Development in the U.K. Natural Gas Industry: The Emergence of Spot, Financial and Pipeline Capacity Markets*, World Bank, Washington.

Juris, A., (1998). *Natural Gas Markets in the U.K. Competition, industry structure, and market power of the incumbent*, "Viewpoint Note", vol. 138.

Kabeyi, M. J. B., Olanrewaju, O. A., (2022). *Biogas Production and Applications in the Sustainable Energy Transition*, "*Journal of Energy*", vol. 2022.

Kancs, A., Kielyte, J., (2001). Biogas Production and Applications in the Sustainable Energy Transition, "Journal of East European Management Studies", vol. 6.

Kangle K., Kore S., Kore V., Kulkarni G., (2012). *Recent trends in anaerobic codigestion: a review*, "Universal Journal of Environmental Research and Technology", vol. 2 (4).

Kao, C., (1999). *Spurious regression and residual-based tests for cointegration in panel data*, "Journal of Econometrics", vol. 90 (1).

Kassalis, I., (2010). *Cluster-based approach: A tool to enter into the market*, in: the 6th International Scientific Conference "Business and Management 2010", Selected Papers, Vilnius Gediminas Technical University Publishing House. Vilnius.

Keynes, J. M., (1936). *The General Theory of Employment, Interest and Money*, Macmillan, London.

Khan, M. U., Lee, J. T. E., Bashir, M. A., Dissanayake, P. D., Ok, Y. S ., Tong, Y. W., Shariati, M. A., Wu, S., Ahring, B. K., (2021). C*urrent status of biogas upgrading for direct biomethane use: a review*, "Renewable and Sustainable Energy Reviews", vol. 149.

Khan, M. U., Usman, M., Ashraf, M. A., Dutta, N., Luo, G., Zhang, S., (2022). *A review of recent advancements in pretreatment techniques of lignocellulosic materials for biogas production: Opportunities and Limitations*, "Chemical Engineering Journal Advances", vol. 10.

Kirzner, I. M., (1997). *Entrepreneurial Discovery and the Competitive Market Process: An Austrian Approach*, "Journal of Economic Literature", vol. 35 (1).

Kirzner, I., (1973). *Competition and Entrepreneurship,* Liberty Fund, Indianapolis.

Knoerich, J., (2017). *How does outward foreign direct investment contribute to economic development in less advanced home countries?*, "Oxford Development Studies", vol. 45.

Krugman, P., (1994). *Competitiveness: A Dangerous Obsession*, "Foreign Affairs", vol. 73 (2).

Krugman, P., (1995). *Cycles of conventional wisdom on economic development*, "International Affairs", vol. 71.

Krugman, P., (1996a). *Pop Internationalism,* MIT Press, Cambridge.

Krugman, P., (1996b). *Making sense of the competitiveness debate*, "Oxford Review of Economic Policy", vol. 12 (3).

Kulikov, G., (2000). *Japonskij menedzhment i teorija mezhdunarodnoj konkurentosposobnosti* „Ekonomika" as cited in Kharlamova G., Vertieleva O., (2013) *International Competitiveness of Countries: Economic-Mathematical approach*, "Economics and Sociology" vol. 6 (2).

Kumar, S., Ankaram, S., (2019). "Waste-to-Energy Model Tool Presentation", in: Kumar, S., Kumar, R., Pandey, A. (eds.), *Current Developments in Biotechnology and Bioengineering,* Elsevier, Boston.

Laing, T., Sato, M., Grubb, M., Comberti, C., (2013). *Assessing the effectiveness of the EU Emissions Trading System.* Grantham Research Institute on Climate Change and the Environment, London.

Lan, T., Sher, G., Zhou, J., (2022). *The Economic Impacts on Germany of a Potential Russian Gas Shutoff,* IMF Working Papers, vol. 7.

Leamer, E. E., (1995). *The Heckscher-Ohlin Model in Theory and Practice. Princeton Studies,* "International Finance", vol. 77.

Lerche Raadal, H., Saur Modahl, I., (2022*). LCA of CCS and CCU compared with no capture: How should multi-functional systems be analysed?* E3S Web Conference 349, Stuttgart.

Levin, A., Lin, C. F., Chu, C. S., (2002). *Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties*, "Journal of Econometrics", vol. 108.

Li, X., Mulder, M., (2021). *Value of power-to-gas as a flexibility option in integrated electricity and hydrogen markets*, "Applied Energy", vol. 304.

Liptow, C., Janssen, M., Tillman, A. M., (2018). *Accounting for effects of carbon flows in LCA of biomass-based products - exploration and evaluation of a selection of existing methods,* "The International Journal of Life Cycle Assessment", vol 23 (11).

Lisowyj, M., Wright, M. M., (2020). *A review of biogas and an assessment of its economic impact and future role as a renewable energy source*, "Reviews in Chemical Engineering", vol. 36 (3).

Lont, P., (2020). *Budowa hurtowego rynku gazu ziemnego w Polsce-doświadczenia i wyzwania*, „Energetyka i Środowisko – Stan Obecny, Alternatywy, Możliwości i Zagrożenia", Lublin.

Lorin, A., (2021). *Introduction: The RED II within the Fit-for-55 Package,* Regatrace Project Report Workshop, Vilnus.

Lovegrove, K., Ngo, A., Gentilini, G., Prest, J., Urkalan, K., (2020). *Green Gas Trading-a tool for a zero emissions ACT*, ACT Environment, Planning and Sustainable Development Directorate, Canberra.

Lyons, S., Durusut, E., (2018). *Industrial Fuel Switching Market Engagement Study*, Elements Energy Limited, Cambridge.

Maarten De Vet, J., (1993). *Striving For International Competitiveness: Lessons from Electronics for Developing Countries*, "OECD Development Centre Working Papers", vol. 84.

Maltby, T., (2013). *European Union energy policy integration: A case of European Commission policy entrepreneurship and increasing supranationalism*, "Energy Policy", vol. 55.

Manyika, J., Mendonca, L., Remes, J., Klussmann, S., Dobbs, R., Karkun, K., Klinstov, V., Kuekenshoener, C., Nikomarov, M., Roxburgh, C., Schubert, J., Tacke, T., Toermanen, A., (2010). *How to compete and grow: A sector guide to policy,* McKinsey Global Institute, New York.

Marcinkowska, M., Wdowiński, P., Flejterski, S., Bukowski, S., Zygierewicz, M., (2014). *Wpływ regulacji sektora bankowego na wzrost gospodarczy-wnioski dla Polski*, „Materiały i Studia", vol. 305.

Marshall, A., (1890). *Principles of Economics,* Palgrave Macmillan UK, London.

Martin, R., (2005). *Thinking About Regional Competitiveness: Critical Issues,* Nottingham Trent University, Nottingham.

Martin, R., Sunley, P., (2008). *Slow Convergence? The New Endogenous Growth Theory and Regional Development*, "Economic Geography", vol. 74 (3).

Mathieu, C., Eyl-Mazzega, M. A., (2019). *Biogas and biomethane in Europe: Lessons from Denmark, Germant and Italy*. IFRI Centre for Energy. Paris.

Matsuyama, K., (2008). *Ricardian Trade Theory, in: The New Palgrave Dictionary of Economics*, Palgrave Macmillan UK, London.

McKelvey, R. D., Zavoina, W., (1975). *A statistical model for the analysis of ordinal level dependent variables*, "The Journal of Mathematical Sociology", vol. 4 (1).

McWilliams, B., Sgaravatti, G., Tagliapietra Simone, Zachmann, G., (2022). *A grand bargain to steer through the European Union's energy crisis*, "Bruegel Policy Contribution" vol. 14 (22).

Menanteau, P., Finon, D., Lamy, M. L., (2003). *Prices versus quantities: choosing policies for promoting the development of renewable energy*, "Energy Policy", vol. 31 (8).

Mete, G., (2020). *Energy Transitions and the Future of Gas in the EU*, Springer International Publishing, Cham.

Michalski, E., (2019). *Strategies For International Enterprise Competition*, "Zeszyty Naukowe SGGW, Polityki Europejskie, Finanse i Marketing", vol. 21 (70).

Ministere de la Transition Energetique, (2022a). *Biomethane,* Paris.

Ministere de la Transition Energetique, (2022b). *Retail Natural Gas Market,* Paris.

Mirzaee Ghazani, M., Jafari, M. A., (2021). *The efficiency of* CO_2 *market in the phase III EU ETS: analyzing in the context of a dynamic approach*, "Environmental Science and Pollution Research", vol. 28 (43).

Molle, W., (2006). *The Economics of European Integration: Theory, Practice, Policy*, Routledge, London.

Möller, M., (2012). *Incentives versus competitive balance*, “Economics Letters”, vol. 117 (2).

Momaya, K., Ambastha, A., (2005). *Technology Management and Competitiveness: Is There Any Relationship?,* “International Journal of Technology Transfer and Commercialisation”, vol. 4.

Moreno, M., Novales, A., Platania, F., (2019). *Long-term swings and seasonality in energy markets,* “European Journal of Operational Research”, vol. 279 (3).

Morrow, P. M., (2010). *Ricardian-Heckscher-Ohlin comparative advantage: Theory and evidence,* “Journal of International Economics”, vol. 82 (2).

Mosácula, C., Chaves-Ávila, J. P., Reneses, J., (2019). *Reviewing the design of natural gas network charges considering regulatory principles as guiding criteria in the context of the increasing interrelation of energy carriers*, “Energy Policy”, vol. 126.

Munoz Garcia, A., Finnerty, G., Allary, T., (2022). *EIC Biomethane Study Stage 3: Market Analysis & Cost Assessment*, NNFCC, London.

Navigant, (2019). *Job creation by scaling up renewable gas in Europe*, Navigant Netherlands B.V. Utrecht.

Negishi, T., (2001). *Developments Of International Trade Theory.* Springer, New York.

Newman, P., Vassilakis, S., (1988). *Sraffa and imperfect competition*, “Cambridge Journal of Economics”, vol.12 (1).

Noone, K. J., Ackerman, F., (2013). “Tipping Points, Uncertainty, and Precaution: Preparing for Surprise”, in: Noone, K. J., Sumaila, U. R., Diaz, R. J. (eds.), *Managing Ocean Environments in a Changing Climate*, Elsevier, Boston.

North, D. C., (1991). *Institutions*, “The Journal of Economic Perspectives”, vol. 5 (1).

North, D., (1989). *Institutions and economic growth: An historical introduction*, World Development, vol. 17 (9).

O’rourke, K. H., Prados De La Escosura, L., Daudin, G., (2008). *Trade and Empire, 1700-1870,* OFCE, Paris.

Ofgem, (2023). *Green Gas Support Scheme and Green Gas Levy: Quarterly Report* , London.

Ohlin, B., (1933). *Interregional and International Trade,* Harvard University Press, Cambridge.

Okoro, O.V., Sun, Z., (2019). *Desulphurisation of biogas: A systematic qualitative and economic-based quantitative review of alternative strategies*, “ChemEngineering”, vol. 3 (3).

Olszewska, M., (2011). *Zaufanie jako siła wspierająca działania na konkurencyjnym rynku,* “Annales. Etyka w Życiu Gospodarczym”, vol. 14 (1).

Pablo-Romero, M. del P., Sánchez-Braza, A., Salvador-Ponce, J., Sánchez-Labrador, N., (2017). “Renewable and Sustainable Energy Reviews”, vol. 73.

Pearson, P., Watson, J., (2012). *UK Energy Policy 1980-2010. A history and lessons to be learnt*, The Parliamentary Group for Energy Studies and the IET, London.

Pechstein, J., Bullerdiek, N., Kaltschmitt, M., (2020). *A “book and Claim” approach to account for sustainable aviation fuels in the EU-ETS – Development of a basic concept*, “Energy Policy”, vol. 136.

Pelka, S., de Vries, L.J., Deissenroth, M., (2019). *The Impact of Weather and of Batteries on the Investment Risk for Backup Gas Power Plants in a Largely Renewable Energy System*, 16th International Conference on the European Energy Market (EEM). IEEE. Ljubljana.

Pelkmans, J., Correia de Britto, A., (2012). *Enforcement in the EU single market*, Centre for European Policy Studies. Brussels.

Peneder, M., Barret, J., Falk, M., Loveridge, P., Matt, I., Rincon-Anzar, A., Robinson, C., Sieber, S., Silva-Porto, M., (2009). *Sectoral Growth Drivers and Competitiveness in the European Union*, Office for Official Publications of the European Communities, Luxembourg.

Perelman, M., (1995). *Retrospectives: Schumpeter, David Wells, and Creative Destruction*, "The Journal of Economic Perspectives", vol. 9 (3).

Pesaran, M. H., (2004). *General Diagnostic Tests for Cross Section Dependence in Panels*, "IZA Discussion Paper Series", vol. 1240.

Phan, C., Plouhinec, C., (2021). *Chiffres clés des énergies renouvelables Édition 2021*, Ministere de la Transition Ecologique, Paris.

Polanyi, K., (1963). *Ports of Trade in Early Societies, "*The Journal of Economic History", vol. 23 (1).

Polterovich, V., Popov, V., Tonis, A., (2010). *Resource abundance: A curse or blessing*?, "United Nations DESA Working Paper Series", vol. 93.

Porter, M., (1979). *How Competitive Forces Shape Strategy*, "Harvard Business Review", vol. 3.

Porter, M., (1990). *The Competitive Advantage of Nations*, "Harvard Business Review", vol. 3.

Porter, M., Ketels, C., (2003). *UK Competitiveness: Moving to the Next Stage,* DTI Economics Paper no. 3. Economic and Social Research Council. Swindon.

Porter, M., Stern, S., (2001). *Innovation: Location Matters*, "MIT Sloan Management Review", vol. 42.

Proietti, S., Decorte, M., Tessens, S., Fernandez, D., Repullo, F., McCarthy, P., Oriordan, B., (2020). *Mapping the state of play of renewable gases in Europe*. Regatrace Project Report on task D6.1., Brussels.

Psofogiorgos, N., Metaxas, T., (2016). *"Porter vs Krugman": History, Analysis and Critique of Regional Competitiveness*, "Journal of Economics and Political Economy", vol. 3.

Raible, M., (2013). I*ndustrial Organization theory and its contribution to decision-making in purchasing,* University of Twente, Enschede.

Ratner, M., Belkin P., Garding S. E., Welt C., (2020). *European Energy Security: Options for EU Natural Gas Diversification,* Congressional Research Service, Washington.

REDcert EU, (2021). *Scheme principles for mass balance,* REDCert GmbH, Bonn.

REDcert, (2017). *REDcert Scheme principles for mass balancing*, REDCert GmbH, Bonn.

REDcert, (2021). *Scheme principles for mass balance*, REDCert GmbH, Bonn.

Ricardo Energy & Environment, (2016). *The role of natural gas and biomethane in the transport sector,* Ricardo Energy & Environment, Harwell.

Ricardo, D., (1821). *On the Principles of Political Economy and Taxation, 3rd ed.,* McMaster University Archive for the History of Economic Thought, Hamilton.

Robb, S., (2022). *Denmark heads for 100% biomethane by 2030*, "Irish Farmers Journal", vol.12.

Rodríguez-Gómez, N., Zaccarelli, N., Bolado-Lavín, R., (2015). *Improvements in the EU gas transmission network between 2009 and 2014: grid developments and simulation assessment to test the increased ability to cope with gas crises,* Joint Research Center, Brussels.

Rodrik, D., (2002). *After Neoliberalism, What? Conference proceedings on Alternatives to Neoliberalism,* Washington.

Rogers, M., (1998). *The Definition and Measurement of Innovation*, Melbourne Institute Working Paper, no. 10/98.

Rosińska-Bukowska, M., (2012). *Rozwój globalnych sieci biznesowych jako strategia konkurencyjna korporacji transnarodowych*. Wydawnictwo Uniwersytetu Łódzkiego. Lodz.

Roszko-Wójtowicz, E., Grzelak, M., (2020). *Macroeconomic stability and the level of competitiveness in EU member states: a comparative dynamic approach*, "Oeconomia Copernicana", vol. 11.

Rubashkina, Y., Galeotti, M., Verdolini, E., Eni, F., Mattei, E., |(2014). *Environmental regulation and competitiveness: Empirical Evidence on the Porter Hypothesis from European Manufacturing Sectors*, "Energy Policy" vol. 83 (C).

Rugman, A. M., D'Cruz, J. R., (1993). *The "Double Diamond" Model of International Competitiveness: The Canadian Experience*, "Management International Review", vol. 33.

Rusu, V. D., Roman, A., (2018). *An empirical analysis of factors affecting competitiveness of C.E.E. countries*, "Economic Research-Ekonomska Istraživanja", vol. 31.

Sachs, J., Warner, A., (1995). *Natural Resource Abundance and Economic Growth*, NBER Working Paper Series, no. 5398.

Samuelson, P., (1972*). Heretical doubts about the international mechanisms*, "Journal of International Economics", vol. 2 (4).

Santiago, F., Weiss, M., (2018). *Demand-driven policy interventions to foster sustainable and inclusive industrial development in developing countries*, Inclusive and Sustainable Industrial Development Working Paper Series, no. 17.

Sarul, J., (2017). „Finansowanie innowacyjności ze środków budżetu ogólnego Unii Europejskiej", in: Jankowska, A.A., Malik, R., Wosiek, R., Domańska, A. (eds.), *Innowacyjność i Konkurencyjność Międzynarodowa. Nowe Wyzwania Dla Przedsiębiorstw i Państwa*, Oficyna Wydawnicza SGH, Warszawa.

Scarlat, N., Dallemand, J. F., (2011). *Status of the implementation of biofuels and bioenergy certification systems. Major implications, reporting constraints and implementation controls*, Publications Office of the European Union, Luxembourg.

Scherer, F., Ross, D., (1990). *Industrial Market Structure and Economic Performance*, University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference
in Entrepreneurship, Chicago.

Schmidheiny, K., (2022). *Panel Data: Fixed and Random Effects*, University of Basel, Basel.

Schumpeter, J. A., Schumpeter, E. B., (1954). *History Of Economic Analysis*, Oxford University Press. Oxford.

Schumpeter, J., (1942). *Capitalism Socialism and Democracy*, George Allen & Unwin Ltd., New York.

Schwab, K., (2013). *The Global Competitiveness Report 2013-2014*. World Economic Forum Insight Report. Geneva.

Sheng, A., Geng, X., (2012). *The new economics: Meso and Meta. World Economic Forum*, https://www.weforum.org/agenda/2012/10/the-new-economics-meso-and-meta/ (date of access 04.02.2021).

Simoglou, C. K., Biskas, P. N., (2023). *Capacity Mechanisms in Europe and the US: A Comparative Analysis and a Real-Life Application for Greece*, "Energies", vol 16 (2).

Simon, F., (2019). *Biomethane in the EU*, Euractive Special Report October 2019, Brussels.

Siudek, T., Zawojska, A., (2014). *Competitiveness in the Economic Concepts, Theories and Empirical Research*, "Oeconomia", vol. 13 (1).

Smith, A., (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations. McMaster University Archive for the History of Economic Thought*, McMaster University Archive for the History of Economic Thought, Hamilton.

Sobczak, A., Chomać-Pierzecka, E., Kokiel, A., Różycka, M., Stasiak, J., Soboń, D., (2022). *Economic Conditions of Using Biodegradable Waste for Biogas Production, Using the Example of Poland and Germany*, “Energies”, vol. 15 (14).

Sørensen, J. F. L., Jørgensen, H. P., (2022). *Rural Development Potential in the Bioeconomy in Developed Countries: The Case of Biogas Production in Denmark*, “Sustainability”, vol 14 (17).

Sprenger, R., (2007). *Trust: The Best Way To Manage,* Cyan Communications, Singapore.

Sraffa, P., (1926). *The Laws of Returns under Competitive Conditions*, “The Economic Journal”, vol. 36 (144).

Stiglitz, J. E., Fitoussi, J. P., Durand, M., (2018). *Beyond GDP Measuring What Counts For Economic And Social Performance*, OECD Publishing, Paris.

Stockler, M., Harder, B., Berman, D., Jensen, T., (2020). *Biogas production. Insights and experiences from the Danish Biogas Sector*, Food & Bio Cluster Denmark, Tjele.

Strahl, D., (1996). *Modele zarządzania bankiem (model Triada),* Wydawnictwo Akademii Ekonomicznej we Wrocławiu. Wroclaw.

Thomas, S., (2005). *The European Union Gas and Electricity Directives*. Research Institute of the University of Greenwich. Greenwich.

Tomeš, Z., Jandová, M., (2006). *Political Economy of Trade Policy*, European Trade Study Group, Dusseldorf.

Törnwall, E., Pettersson, H., Thorin, E., Schwede, S., (2017). *Post-treatment of biogas digestate – An evaluation of ammonium recovery, energy use and sanitation*, “Energy Procedia”, vol. 142.

Truby, J., Grapatin, C., Grimm-Rohn, V., Cartry, C., (2022). *The European hydrogen economy-taking stock and looking ahead. An outlook until 2030*, Deloitte Monitor, Cambridge.

Tsoulfidis, L., (2011). *Classical vs. Neoclassical Conceptions of Competition,* MPRA Paper, no. 43999.

Tupy, M., (2003). *EU Enlargement. Costs, Benefits, and Strategies for Central and Eastern European Countries*, “Policy Analysis”, vol. 489.

Tyson, L. D., (1992). *Who’s Bashing Whom? Trade Conflict in High-Technology Industries. Peterson*, Institute for International Economics. Washington.

Uhrig-Homburg, M., Wagner, M., (2008). *Derivative Instruments in the EU Emissions Trading Scheme — An Early Market Perspective*, “Energy & Environment”, vol. 19 (5).

United Nations Conference on Trade and Development (UNCTAD), (2005). *World Investment Report: Transnational corporations and the internationalization of R&D,* United Nations. New York and Geneva.

Vasconcelos, J., (2005). *Towards the internal energy market, how to bridge a regulatory gap and build a regulatory framework*, “European Review of Energy Markets”, vol. 1 (1).

Verhun, V., Pryiatelchuk, O., Zayats, O., (2020). *Competitive features of country associations based on the Global Competitiveness Index: the case of the United States – Mexico – Canada Agreement*, “Problems and Perspectives in Management”, vol. 18 (14).

Vlachou, A., Pantelias, G., (2017). *The EU’s Emissions Trading System, Part 1: Taking Stock*, “Capitalism Nature Socialism”, vol. 28 (2).

Vlados, C., Chatzinikolaou, D., (2020). *Thoughts on competitiveness and integrated industrial policy: A field of mutual convergences*, “Research in World Economy”, vol. 11 (3).

Voinescu, R., Moisoiu, C., (2015). *Competitiveness, Theoretical and Policy Approaches. Towards a More Competitive EU*, “Procedia Economics and Finance”, vol. 22.

Weresa, M. A., Kowalski, M. A., Sieńko-Kułakowska, E. B., (2017). *Rozwój klastrów i metody ewaluacji*. Oficyna Wydawnicza SGH, Warszawa.

Westerlund, J., (2005). *New Simple Tests for Panel Cointegration*, "Econometric Review", vol. 24 (3).

Wettstein, D., (1995). *Incentives and competitive allocations in exchange economies with incomplete markets*, "Journal of Mathematical Economics", vol. 24 (3).

Winship, C., Mare, R. D., (1984). *Regression Models with Ordinal Variables*, "American Sociological Review", vol. 49 (4).

Wolf, M., (2004). *Why globalization works*, Yale University Press, New Haven.

World Economic Forum, (2017). *The Global Competitiveness Report 2017-2018*, Geneva.

Yafimava, K., (2013). *EU third package for gas and the gas target model: major contentious issues inside and outside the EU*, Oxford Institute for Energy Studies, Oxford.

Yermakov, V., Sobczak, K., (2020). *Russia-Poland gas relationship: risks and uncertainties of the ever after*, Oxford Institute for Energy Studies, Oxford.

Zanni, A., (2012). *Marshall and Sraffa on Competition and Returns in Cournot*, History of Economic Ideas, vol. 20 (1).

Zhou, Y., Baldino, C., (2022*). Gas definitions for the European Union: Setting thresholds to reduce life-cycle greenhouse gas emissions*, International Council on Clean Transportation Working Paper, no. 32. Washington.

Zhou, Y., Swidler, D., Searle, S., Baldino, C., (2021). *Life-Cycle Greenhouse Gas Emissions of Biomethane and Hydrogen Pathways in the European Union*, International Council on Clean Transportation White Paper, Washington.

Zielińska-Lont, K., (2021). *Banking Union's impact on financial stability – holistic approach*. University Press, Lodz.

Zorska, A., (2017). „Umiędzynarodowienie prac B+R w korporacjach transnarodowych oraz wpływ tego procesu na innowacyjność w krajach goszczących", in: Janowska, A. A., Malik, R., Wosiek, R., Domańska, A. (eds.), *Innowacyjność i Konkurencyjność Międzynarodowa. Nowe Wyzwania Dla Przedsiębiorstw i Państwa*. Oficyna Wydawnicza SGH, Warszawa.

Żukowska, J., Pindelski, M., (2011). *Factors Determining the Competitiveness of Entities on Global Market*, Publishing House Politechnika Łódzka, Lodz.

Legal Acts, Regulations, Decisions, Proposals

Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 *on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012*, Official Journal of the European Union, L 334/1.

Commission Implementing Regulation (EU) 2022/996 of 14 June 2022 *on rules to verify sustainability and greenhouse gas emissions saving criteria and low indirect land-use change-risk criteria*, Official Journal of the European Union L 168/1.

Commission Regulation (EU) 2015/703 of 30 April 2015 *establishing a network code on interoperability and data exchange rules*, Official Journal of the European Union, L 113/13.

Commission Regulation (EU) 2017/459 of 16 March 2017 *establishing a network code on capacity allocation mechanisms in gas transmission systems and repealing Regulation (EU) No 984/2013*, Official Journal of the European Union, L 72/1.

Commission Regulation (EU) 2017/460 of 16 March 2017 *establishing a network code on harmonised transmission tariff structures for gas*, Official Journal of the European Union, L 72/29.

Commission Regulation (EU) No 176/2014 of 25 February 2014 *amending Regulation (EU) No 1031/2010 in particular to determine the volumes of greenhouse gas emission allowances to be auctioned in 2013-20*, Official Journal of the European Union L 56/11.

Commission Regulation (EU) No 312/2014 of 26 March 2014 *establishing a Network Code on Gas Balancing of Transmission Networks*, Official Journal of the European Union, L 91/15.

Commission Staff Working Document, *Accompanying document to the Report on progress in creating the internal gas and electricity market*, COM (2008) 192 final, Brussels.

Commission Staff Working Document, *Implementing the Repower EU Action Plan: Investment Needs, Hydrogen Accelerator and Achieving the Bio-Methane Targets*, , SWD(2022) 230 final, Brussels.

Commission Staff Working Document, *Technical Annex to the Communication from the Commission to the Council and the European Parliament - Report on progress in creating the internal gas and electricity market - Accompanying document to the Communication from the Commission to the Council and the European Parliament - Report on progress in creating the internal gas and electricity market*, COM(2010)84 final, SEC(2010)251 final, Brussels.

Communication from the Commission — *Guidelines on State aid for environmental protection and energy 2014-2020*, (2014/C 200/01), Official Journal of the European Union, C 200/1.

Communication from the Commission, *Guidelines On State Aid For Climate, Environmental Protection And Energy 2022*, Official Journal of the European Union, C 80/1.

Council Regulation (EU) No 904/2010 of 7 October 2010 *on administrative cooperation and combating fraud in the field of value added tax*, Official Journal of the European Union, L 268/1.

Decision (EU) 2015/1814 of the European Parliament and of the Council of 6 October 2015 *concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and amending Directive 2003/87/EC*, Official Journal of the European Union, L 264/1.

Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 *amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources*, Official Journal of the European Union, L 239/1.

Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 *on the promotion of the use of energy from renewable sources*, Official Journal of the European Union, L 328/82.

Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 *on the promotion of electricity produced from renewable energy sources in the internal electricity market, Official Journal, L 283.*

Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 *on the promotion of the use of biofuels or other renewable fuels for transport, Official Journal, L 123.*

Directive 2003/55/EC of the European Parliament and of the Council of 26 June 2003 *concerning common rules for the internal market in natural gas and repealing Directive 98/30/EC,* Official *Journal, L 176.*

Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 *establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC*, Official Journal of the European Union, L 275/32.

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 *on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*, Official Journal of the European Union, L 140/16.

Directive 2009/73/EC of the European Parliament and of the Council of 13 July *2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC,* Official Journal of the European Union, L 211/94.

Directive 98/30/EC of the European Parliament and of the Council of 22 June 1998 *concerning common rules for the internal market in natural gam,* Official Journal, *L 204.*

European Commission, *'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality,* COM (2021) 550 final, Brussels.

European Commission, *Proposal for a Council Directive restructuring the Union framework for the taxation of energy products and electricity*, COM (2021) 563 final, Brussels.

European Commission, *Proposal for a Decision of the European Parliament and of the Council amending Decision (EU) 2015/1814 as regards the amount of allowances to be placed in the market stability reserve for the Union greenhouse gas emission trading scheme until 2030*, COM (2021) 571 final, Brussels.

European Commission, *Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757,* COM (2021) 551 final, Brussels.

European Commission, *Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC as regards aviation's contribution to the Union's economy-wide emission reduction target and appropriately implementing a global market-based measure*, COM (2021) 552 final, Brussels.

European Commission, *Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652*, COM (2021) 557 final, Brussels.

European Commission, *Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency,* COM/2022/222 final, Brussels.

European Commission, *Proposal for a Directive of the European Parliament and of the Council on common rules for the internal markets in renewable and natural gases and in hydrogen*, COM/2021/803 final, Brussels.

European Commission, *Proposal for a Regulation of the European Parliament and of the Council on methane emissions reduction in the energy sector and amending Regulation (EU) 2019/942*, COM (2021) 805 final, Brussels.

European Commission, *Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement*, COM (2021) 555 final, Brussels.

European Commission, *Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport*, COM (2021) 561 final, Brussels.

European Commission, *Proposal for a Regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC*, COM/2021/562 final, Brussels.

European Commission, *Proposal for a Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism*, COM/2021/564 final, Brussels.

European Commission, *The European Green Deal,* COM (2019) 640 final, Brussels.

European Commission, *The Internal Energy Market*, COM (1988), (Commission Working Document 238), Brussels.

European Commission, *Working Document on The Internal Energy Market* COM (88) 238, final, Brussels.

Federal Energy Regulatory Commission (FERC) (1992). Order No. 636. *Pipeline Service Obligations and Revisions to Regulations Governing Self-Implementing Transportation Under Part 284 of the Commission's Regulation; Regulation of Natural Gas Pipelines after Partial Wellhead Decontrol. Docket No. PM91-11-000 and Docket No. RM87- 34-065*, 1992.

LOIS LOI no 2015-992 du 17 août 2015 *relative à la transition énergétique pour la croissance verte (1),* Journal Officiel De La République Française, DEVX1413992L.

Regulation (EC) No 1775/2005 of the European Parliament and of the Council of 28 September 2005 *on conditions for access to the natural gas transmission networks,* Official Journal of the European Union, L 289/1.

Regulation (EC) No 713/2009 of the European Parliament and of the Council of 13 July 2009 *establishing an Agency for the Cooperation of Energy Regulators*, Official Journal of the European Union, L 211/1.

Regulation (EU) No 994/2010 of the European Parliament and of the Council of 20 October 2010 *concerning measures to safeguard security of gas supply and repealing Council Directive 2004/67/EC,* Official Journal of the European Union, L 295/1.

United Nations (1998), *Kyoto Protocol to The United Nations Framework Convention on Climate Change, United Nations*, New York.

Databases

Eurostat (2008–2022) *Statistical Data Warehouse,* https://ec.europa.eu/eurostat/web/energy/database

Refinitiv Eikon (2008–2022) *Eikon Energy Commodities,* https://www.refinitiv.com/en/financial-data/commodities-data

Gas Infrastructure Europe (GIE) (2008–2022) *Aggregated Gas Storage Inventory,* https://agsi.gie.eu/

International Monetary Fund (IMF) (2008–2030) *World Economic Outlook,* https://www.imf.org/en/publications/weo

List of figures

List of Tables