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UK Business Competitiveness and the Role of Carbon Pricing

An assessment of the determinants of business competitiveness and the role of carbon pricing policy in the UK

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Executive Summary

In the context of major changes to UK policy, it is important to understand competitiveness, a crucial determinant of the UK's ability to generate employment, economic growth and government revenue. The UK's exit from the EU may affect sectors' access to markets and inputs, and legislation on net zero emissions will require additional decarbonisation effort which could increase sectors' operational costs and change consumer demand. These policy changes are likely to impact UK competitiveness relative to international businesses. Competitive sectors can make significant contributions to the UK's overall economic welfare by providing employment, growth and government revenue. In contrast, if UK sectors lose competitiveness relative to international competitors, there could be significant economic, social and political implications.

In particular, Net Zero objectives may present challenges for UK business competitiveness, yet it is important to understand whether and how these could make UK sectors market leaders in a global low-carbon economy. To achieve the UK's legislated net zero target, carbon pricing policy may need to become more ambitious and the level of support provided to industry through free allocation could be reduced. Higher carbon prices may present challenges for UK business competitiveness, but also opportunities. Carbon pricing creates incentives for low-carbon technology innovation and adoption. Therefore, it can help advance the competitiveness of UK firms and make them market leaders in a global low-carbon economy. Understanding competitiveness under carbon pricing enables policymakers to design policies that mitigate the downside risks and capture upside opportunities.

Competitiveness – defined as the capacity and ability of a firm or sector to gain and maintain a profitable, sustainable market share relative to rivals – needs to be understood holistically to understand the role of carbon pricing. Traditional carbon leakage assessments, such as those used by the EU or California, allow for a high-level assessment across a large number of sectors of emissions intensity and trade exposure in order to understand just one element of the role of carbon pricing in impacting firm competitiveness. However, they fail to account for the magnitude of carbon cost shocks, competitive dynamics, abatement opportunities and options for sectoral conduct to capture upside opportunities from carbon pricing. As a result, such leakage assessments can be considered, at best, a partial indicator of sectoral competitiveness under carbon pricing.

Given that competitiveness is a multifaceted concept driven by many factors, this report develops a comprehensive and practical framework to help understand it. There are three main components to the framework, as shown in Figure 1:

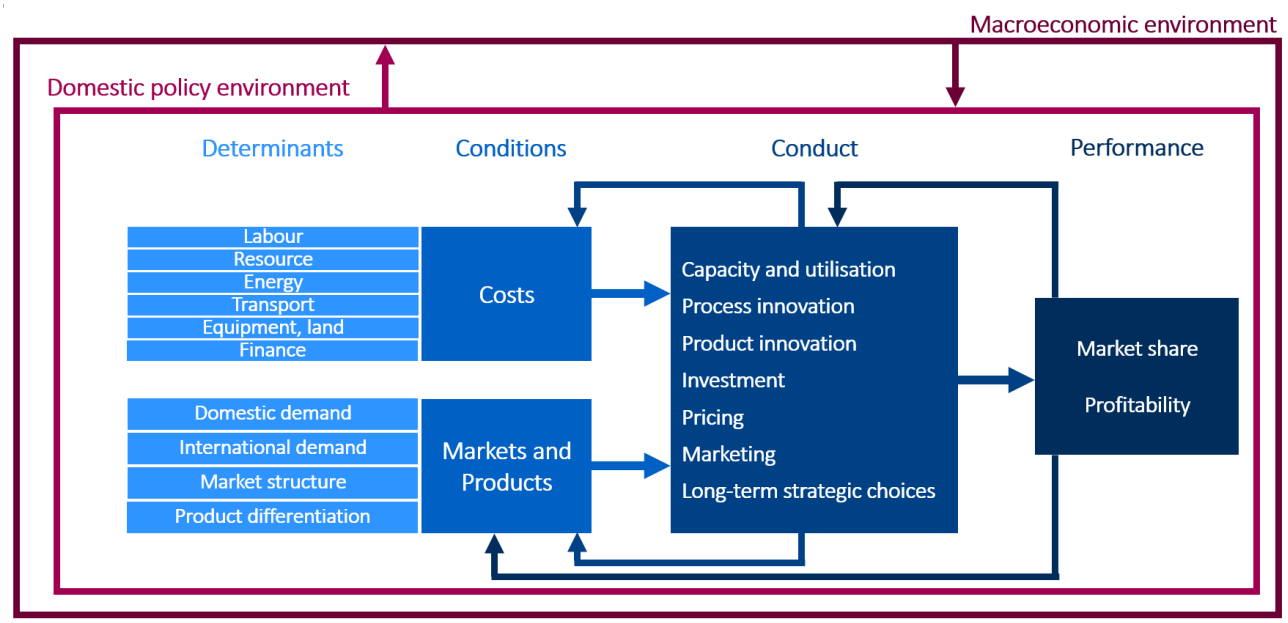
- **Conditions** form the basis for establishing a sector's competitive edge and inform opportunities and constraints for its conduct, categorised into costs, and markets and products.
- **Conduct** covers the actions that a firm can take in the market, underpinned by its strategy and managerial and organisation ability.
- Both ultimately affect a sector's competitive performance, measured by market share and profitability over time.

The framework recognises that the relationship between these components is not exclusively one-way. As firms assess their performance and make conduct choices, these feed back into conditions and again to performance. Increases in market share and/or profitability could give the firm the ability to modify its pricing strategy, innovate, or develop economies of scale. Decreases in these could motivate the firm to change its conduct choices in other ways.

The broader macroeconomic and policy environments are also important elements of competitiveness as they can impact conditions, influence conduct and drive performance. A recessionary macroeconomic environment can imply a reduction in domestic demand, whereas high inflation can imply an increase in input costs. Labour laws can influence the cost of labour along with its productivity by modifying the flexibility with which firms can lay off workers, hire new workers, and provide training. Economic business cycles also influence firms' conduct choices, as high uncertainty or fears of a recession may lead to reduced investment. Regulatory stability reduces policy uncertainty and expands the investment time horizon of firms, allowing for more strategic conduct decisions.

In operationalising the framework, archetypes focus an analysis on the conditions and conduct choices that are most relevant to the sector or firm. This report builds on Porter's competitive strategies concept and classifies sectors as quality archetypes or price archetypes. Firms that compete on quality provide a product that has a characteristic in addition to those of competitors which increases consumers' willingness to pay. This then allows for a higher price on the product, without losing market share to competitors. On the other hand, firms that compete on price offer products that are similar across firms, and therefore will lose market share if they price above competitors. As a result, they attempt to reduce price (and costs) as much as possible.

Figure 1: Determinants, conditions and conduct form the basis for a firm or sector's competitive performance.



The framework is able to highlight the role of carbon pricing in determining competitiveness through the instrument's impact on conditions, as governed by the archetype, and conduct which then affect performance. It shows how a carbon cost changes the conditions and how innovation in abatement technologies, pricing strategy, and other forms of conduct can affect overall competitiveness. Generally, downside risks of carbon

pricing materialise first through conditions, then conduct, before impacting performance. This negative impact is covered in the literature on carbon leakage, which highlights short- and long-term channels for reduced competitiveness. But such downside risks occur only when conduct is constrained – for example, because the lack of abatement opportunities limits process innovations. Furthermore, for sectors that are price archetypes, low-cost pass-through capacity limits pricing options. The framework captures these nuances, showing how sectors can change conduct in relation to carbon pricing to exploit upside opportunities and reduce downside risks and gain a competitive edge.

In the context of carbon pricing, the framework can thus help policymakers understand:

- The relative role of carbon pricing in a sector compared with other competitiveness drivers
- If a sector is at genuine risk of negative competitiveness impacts from carbon pricing and of carbon leakage
- Where a sector has agency to respond to carbon costs, either through abatement or cost pass-through
- How carbon pricing can lead to sectoral innovation and help improve competitiveness in the context of a net zero industrial strategy
- The increased demand for a product arising from carbon pricing
- And the types of policy support necessary to help UK businesses capture upside opportunities and mitigate downside risks

The framework can be applied by policymakers as a tool to assess the competitiveness of UK sectors and the role of carbon pricing with the guidance of the step process. The framework aims to be a practical tool that can assess the competitiveness of UK sectors and provide an understanding of the role of carbon pricing. This report provides a detailed step process in order to complete such an analysis. This process covers a series of tasks that gather the necessary data, calculate metrics and present the method for assessing competitiveness. The impact of carbon pricing is presented as part of the process, but other policy changes could be analysed, such as changes in labour market policies.

Contents

1. Introduction

Multiple important changes in the UK policy environment are likely to affect the competitiveness of UK firms within and across sectors. The UK's exit from the EU may affect sectors' access to markets and inputs, among other factors; legislation on Net Zero emissions (UK Government, 2019) could increase sectors' operational costs and change consumer demand; and the Industrial Strategy (UK Government, 2017) may drive more innovation activity in industrial sectors. All these policy changes are likely to impact UK competitiveness relative to international peers.

Competitiveness is crucial for the UK to generate employment, economic growth and government revenue. A UK sector that competes with international rivals needs to be competitive to sell its products and services at a profitable rate over time. Competitive sectors can make significant contributions to the UK's overall economic welfare by providing employment, growth and government revenue. In contrast, if UK sectors lose competitiveness relative to international peers, there could be significant economic, social and political implications.

This report develops a comprehensive and applicable framework for policymakers to analyse the current competitiveness of a sector and impacts of potential policy changes such as carbon pricing. A comprehensive framework of general competitiveness of UK firms should capture all factors relevant for a sector's competitiveness. It should also allow policymakers to apply the framework to any given sector to assess its competitiveness and analyse the role of carbon pricing. The framework presented in this report is embedded in the literature on competitiveness. This literature has either developed conceptual theoretical frameworks or assesses competitiveness using metrics, but rarely have these two aspects been analysed together. These two strands of the literature are developed to offer an applicable framework, with theoretical grounding, that details how firms face conditions and choices of conduct to advance their performance, embedded in the domestic and macroeconomic environment.

This framework is particularly relevant in the context of increasing, but not yet harmonised, global ambition in climate policy, as the number of jurisdictions with carbon pricing increase but remain incomplete. There are 56 carbon pricing schemes implemented at the regional, national and subnational level (World Bank, 2019a). Prices in existing carbon pricing systems vary from US$1 to US$127/tCO2e (£1–95/tCO2e). However, many key UK trading partners, such as Brazil or Turkey, have no carbon pricing scheme in place today. And while China is implementing a national emissions trading system (ETS), resulting carbon prices are expected to be low and industrial emissions will not be priced in the near term (World Bank Group, 2019).

The UK's existing climate policy suite includes carbon pricing across industry, electricity generation and intra-EEA (European Economic Area) aviation, and an increase in scope and ambition in light of net zero objectives could increase asymmetry in carbon pricing with trading partners. The UK currently prices emissions in industry, electricity and intra-EEA aviation as part of the EU ETS and charges a Climate Change Levy (CCL) on selected fossil fuels. It also applies the Carbon Price Support (CPS) – effectively a carbon tax on electricity – which results in a higher carbon price than for EU competitors. The UK's recent policy changes could further extend the carbon pricing gap to other jurisdictions: its legally binding target to reach net zero emissions by

2050 may increase carbon prices substantially; and its departure from the EU implies that carbon prices can depart from EU ETS levels (Vivid Economics, 2019).

This report analyses the role of carbon pricing in competitiveness by using the framework to advance traditional carbon leakage assessments and offer a holistic understanding of carbon pricing impacts. Existing carbon leakage assessments, such as those used by the EU and California, allow for a high-level analysis of emissions intensity and trade exposure across a large number of sectors. However, they fail to account for the magnitude of carbon cost shocks, competitive dynamics and options for sectoral conduct. This report provides a more holistic understanding of the downside risks and upside opportunities of carbon pricing for UK firms. It establishes the role of carbon pricing through its initial and dynamic impact on conditions and the options of conduct a sector faces to advance its competitiveness.

This report forms the basis for an extensive and practical stepwise application. It includes a stepwise process for policymakers to follow in performing the analysis of a given UK sector, from scoping to conclusion. This forms the basis for a broader, more detailed application of this framework across policymakers to analyse the competitiveness of UK sectors and the role of carbon pricing.

The remainder of this report is structured as follows:

- Section 2 discusses the existing literature on competitiveness and carbon pricing
- Section 3 presents the general framework of competitiveness
- Section 4 analyses the role of carbon pricing within the framework
- Section 5 provides stepwise instructions for applying the framework
- Section 6 concludes

2. Literature Review

Competitiveness is an intensely debated concept, illustrated by the lack of consensus on a definition or framework. Nevertheless, to inform our own definition, important insights into what competitiveness is can be gained from the literature on the definitions of competitiveness.

This literature review presents existing work on definitions, determinants and frameworks of competitiveness, as well as the theoretical and empirical role of carbon pricing, to inform the framework in Sections 3 and 4. It identifies the definitions, determinants and frameworks that are most appropriate to include into the comprehensive and applicable framework in Section 3. It also presents the theoretical role of carbon pricing in competitiveness and discusses the empirical evidence from existing policies. This provides the foundations for developing the role of carbon pricing within the competitiveness framework in Section 4.

This report focuses on competitiveness at the firm and sectoral level because national competitiveness masks heterogeneity between sectors and firms (Krugman, 1994).[3],[4] Competitiveness can be defined at different levels:

- Traditional studies of competitiveness at the micro-level build on existing theories of the firm and more directly describe the concept. Firms compete with similar firms in a given sector on their relative competitiveness, not on a national aggregate (Krugman, 1994). Hence, sector- and firm-level competitiveness are the focus of this report.
- Macro-level applications have originated from, and are widely used by, governments, but have faced criticism. National-level metrics that rely on aggregate measures of competitiveness obscure heterogeneity across firms and may inaccurately describe the economy and misdirect policy (Dosi, Grazzi, & Moschella, 2013).
- The relevance of the micro-foundations of competitiveness is further demonstrated in macro-level definitions. They often rely on firm-level indicators to build macro-level indicators (Altomonte, Aquilante, & Ottaviano, 2012; Porter & Ketels, 2003).

The remainder of this section offers a review of the literature on competitiveness generally, and then reviews the literature on the impact of carbon pricing on competitiveness.

[3] A firm can be defined as an organisation comprising a number of individuals bound by employment contracts with a central contracting authority. Firms came to exist because they produced more efficiently than individual and family producers (Grant, 2010). Coase posits that transaction costs from operating in markets are reduced in firms, whereas Tirole and Holmstrom explain it as the better management of incomplete contracts (Coase, 1937; Holmstrom & Tirole, 1989).

[4] The definition and framework aim to apply to all sectors of the economy. However, some specific sectors divert so substantially from usual competition that it might be difficult to apply the framework to them. For example, some software services operate on almost no marginal costs and sell at a loss or monetise data. These firms represent only a small part of the economy and the framework should be applicable to the large remainder of the economy.

2.1 Competitiveness

2.1.1 Definitions

Most of the literature defines competitiveness as the capacity to sell in markets and gain market share. Definitions going back to the 1980s have specifically highlighted the capacity to sell products and services of superior quality and lower costs as characteristics of competitiveness, emphasising product differentiation and quality alongside cost and price factors (Buckley, Pass, & Prescott, 1988). Often implicitly, the market is assumed to be both domestic and international. Other definitions, such as that of the European Management Forum of 1984, directly refer to the price and non-price qualities of products in establishing market superiority (Ambastha & Momaya, 2004; Buckley et al., 1988).

A sole focus on market shares neglects the role of profitability[5] and long-term aspect of competitiveness. Firms can increase their market share by selling at zero or negative profits for a short period of time, although this may not be sustainable. Therefore, a long-term understanding of competitiveness should include considerations of sustainable profits (Peneder et al., 2017). This is particularly relevant when analysing the impact of long-term policy or industrial changes, as opposed to short-term shocks, as the latter may be subject to business cycle effects.[6] For example, an analysis of carbon pricing could show a short-term negative impact on competitiveness. However, employing a definition of competitiveness which considers the long term can show potential benefits to competitiveness that can arise from innovation, strategic decisions by management and cost reductions (Buckley et al., 1988, p. 198).

Some literature defines competitiveness through productivity, but this fails to provide a complete and logical understanding of the concept. Productivity here is defined as the amount of output per unit of input. For example, Porter & Ketels (2003) define competitiveness as productivity, and the World Bank (2017, p. 64) defines competitiveness as achieving market share through improved productivity. Because productivity is a determinant of competitiveness, it would be inconsistent to then claim productivity is competitiveness. Productivity is also difficult to compare across industries and countries because they face different production functions and exchange rate effects (Cattell, Flanagan, & Jewell, 2004). The World Economic Forum previously used a productivity-based competitiveness index but switched to the wider Global Competitiveness Index to address such shortcomings (Sala-i-Martin & Artadi, 2004). In empirical studies, productivity is often used as a metric for competitiveness, but this is complemented by other indicators such as market share, profitability, or plant exit (Martin, Muûls, de Preux, & Wagner, 2014).

2.1.2 Determinants

The literature has identified an extensive list of factors that influence competitiveness. Table 1 provides a summary of determinants of competitiveness commonly identified in the literature. Most sources focus on analysing the role of a specific determinant in the performance of firms, without connecting them to a framework or studying their interactions. The table describes the direct impact that these determinants

[5] Profitability can be best measured by returns to investment or profit margins.
[6] The long term is defined as per traditional economics literature: where all inputs of production are variable(Varian, 2010).

have on components of competitiveness, and not on competitiveness itself. The latter will be discussed in the framework section.

Table 1: The literature identifies various determinants of competitiveness

Determinants	Role in competitiveness	Selection of key sources
Labour market efficiency	Matches jobs to workers with the right skill sets, increasing productivity of employee and employer, which reduces costs of production.	Bassanini, Nunziata, & Venn, 2009; Mortensen & Pissarides, 1994
Labour education and training	Increases skills of workforce, improving productivity, which reduces costs of production.	Acemoglu, 2009; Barro & Lee, 2013
Accumulation of capital assets	Influences firm productivity and can replace labour, both of which reduce costs.	Solow, 1956
Ease of access to energy, material, and resources	Ease of access reduces transportation and administrative costs of resource use, reducing overall costs.	Baldwin & Ito, 2011
Number of competitors	Increased competitors reduces ability to price highly, which can limit financial capacity to innovate, but simultaneously increase the incentive to do so.	Blundell, Griffiths, & Van Reenen, 1999; Schumpeter, 1934
Consumer market size	Increases in consumer market size allow for economies of scale, thereby reducing costs.	Rivera-Batiz & Romer, 1990
Existence of market exit and entry barriers	Existence of market barriers increases pricing ability of the firm; removing them increases the number of competitors.	Bartelsman, Scarpetta, & Schivardi, 2005
Openness to trade	Increases both number of competitors and size of consumer market.	Melitz, 2003
Exchange rate volatility	Reduces the incentive to invest for firms exposed to exchange rate volatility because they sell and buy in international markets or	Aghion, Bacchetta, & Banerjee, 2004

	have large amounts of debt in foreign currencies.	
Interest rate increases	Increases cost of borrowing, which reduces incentive to make investments.	Fischer, 1993
Inflation volatility/ deflation	Volatile inflation creates uncertainty about future prices and the lack of predictability makes long-term investments riskier. Deflation or near-zero inflation increases real value of debt, which increases real interest rates and may discourage investment and reduce consumer demand.	Fischer, 1993
Regulation stability	A stable policy environment reduces uncertainty about the future and expands firms' time horizon, allowing for better strategic decisions that impact competitiveness.	Aisen & Veiga, 2013; Alesina, Ozler, Roubini, & Swagel, 1996
Strong public institutions and rule of law	Formal and informal constraints, and associated enforcement mechanisms, imposed by public institutions reduce uncertainty in firms' economic activities, increasing incentives for investments.	Acemoglu, 2009; Banerjee & Iyer, 2005
Public finance	High public debt financed by taxes can introduce market distortions; debt financed by government borrowing can lead to high interest rates and crowding-out of private investment.	Fischer, 1993; Krugman, 1988; Pindyck & Solimano, 1993
Good physical infrastructure	Connects economic agents, reduces transaction costs, and facilitates flow of information and integration of markets into global value chains, thereby reducing costs.	Aschauer, 1989; Straub, 2008
Good technological infrastructure	Effects similar to good physical infrastructure (above).	Franklin, Stam, & Clayton, 2009
Access to financing from effective institution	Access to financial capital at appropriate rates incentivises investments.	King & Levine, 1993; Tobin, 1984

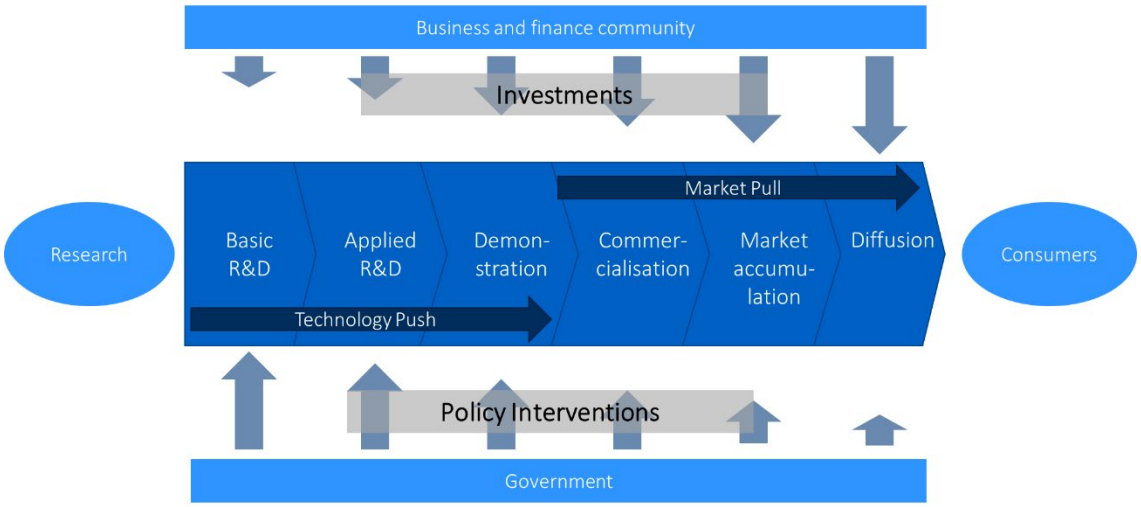
Healthy workforce	Increases productivity of workers.	Bloom & Canning, 2000
Innovation	Reduces production cost by improving production process. Increases pricing ability or demand by improving or distinguishing product sold (expanded further below).	Fagerberg, 2006
Agglomeration and clusters of industry	Increases demand and supply markets, reduces resources transport costs, increases availability of skilled labour, and creates technology and innovation spillovers.	Duranton & Puga, 2004; Marshall, 1890

The remainder of this section provides additional detail on innovation as a key factor for competitiveness in in general; Section 2.2 elaborates on its particular role under carbon pricing.

Innovation

Innovation comprises a multi-stage process to translate a new idea or invention into a technology or product that creates value. Innovation can be considered as a multi-stage process: from research and development (R&D) to demonstration, commercialisation, market accumulation and diffusion (Grubb, 2004).Investment emphasis changes along this innovation chain, as demonstrated in Figure 2. At the start of the process, the focus should be on the development of technology through R&D funding – 'technology-push' – in which the government has a greater role. Towards the end of the process, economic incentives and returns to investors play a bigger role in supporting innovation – 'market-pull' – in which the private sector participates more. Policies such as carbon pricing are market-pull measures since they increase the returns from low-carbon technologies to investors.

Figure 2 Innovation is made up of various steps, which require different policy interventions. Source: Stern (2007) based on Grubb (2004).



The literature on economic growth has identified innovation as a key driver of competitiveness. Innovation in the field of economics was first identified as a driver of economic growth. It started with Schumpeter's (1911) recognition of entrepreneurship and innovation as forces for creative destruction and technological change. Solow (1956) and Swan (1956) built on existing models of economic growth by including a variable for technology, but assumed that technological change happened exogenously. Romer (1990) challenged this model as one of the main creators of innovation-based growth theory, which assumes that technological change is determined endogenously in economic growth models.

More recently, innovation has been applied to competitiveness in the fields of business and microeconomics as embodying the dynamic potential for future competitiveness. Including innovation in competitiveness frameworks allows for a long-term understanding of markets and of outcomes of dynamic interaction (Fagerberg, 2006).

Various types of innovation have been identified and are not limited to technological progress. Process innovation improves production processes and optimises resource use, reducing the costs and allowing for greater price competition (OECD & Eurostat, 2018). The assembly line production of Ford's Model T in 1913 is a historic example (Wilson & McKinlay, 2010). Product innovation involves differentiating a firm's products or services from others in the market (OECD & Eurostat, 2018). This type of innovation may also result in new consumer markets if the product is substantially different. Tesla's entry into the electric vehicle market with a high-end vehicle is an example (Chen & Perez, 2018). Both types of innovation affect competitiveness, albeit through different channels.

2.1.3 Archetypes

The relative role of each determinant in overall competitiveness is specific to the sector or firm and archetypes can help to focus analysis. Firms and sectors are heterogeneous in the relevance of specific determinants, as they may face different costs, pricing abilities and market structures. Exploiting these differences and categorising firms or sectors according to certain rules enables a more focused and streamlined analysis of competitiveness and understanding of the relationships between determinants.

An example of such classification is Porter's division of firms according to two mutually exclusive competitive strategies: cost and differentiation. Porter's generic strategies identify two ways that firms can achieve a higher rate of profit compared with a

rival. Either they supply the same product at a lower cost, or they supply a different product at a higher price (Porter, 1985). Which strategy a firm pursues depends on factors that are internal and external to the firm, the classification of which is further detailed in Section 3.3. According to Porter, these two strategies are mutually exclusive, and a firm which is 'stuck in the middle is almost guaranteed low profitability' (Porter, 1985, p. 42).

This designation of cost and differentiation strategies as mutually exclusive has received criticism in the literature, with researchers pointing out that successful firms often pursue both strategies simultaneously. Researchers have claimed that firms that retain flexibility in their strategy are better able to respond to changes in market conditions (Miller, 1992). The ability to overcome the 'dilemma of the opposites' is the mark of the most successful companies, according to Baden-Fuller and Stopford (1992).

Alternatives to Porter's competitive strategies include divisions according to capital or labour intensity and according to R&D intensity, but these offer little insight into a firm's competitiveness behaviour beyond their area of focus. Categorising sectors according to whether they are capital- or labour-intensive refers primarily to the production method they use. It is useful to understand which inputs are more important to a firm, but it cannot give much insight into what sort of strategies or actions a firm can undertake to become competitive beyond changing those two inputs. Sectors can also be classified according to the level and type of innovations they undertake (Galindo-rueda & Verger, 2016; Pavitt, 1984). Although this gives an insight into innovation processes that are specific to a firm, it provides limited information on the possible actions a firm can take beyond innovating.

Therefore, Porter's classification is the most relevant as it informs which determinants could be more important to a firm according to its competitive strategy. This classification is useful in understanding which determinants matter more for each firm, according to its competitive strategy. It then allows for a greater understanding of possible actions firms can take to improve their competitiveness. It does not limit the analysis to a specific determinant of competitiveness, unlike the alternatives above; instead it allows for a broad prioritisation of determinants.

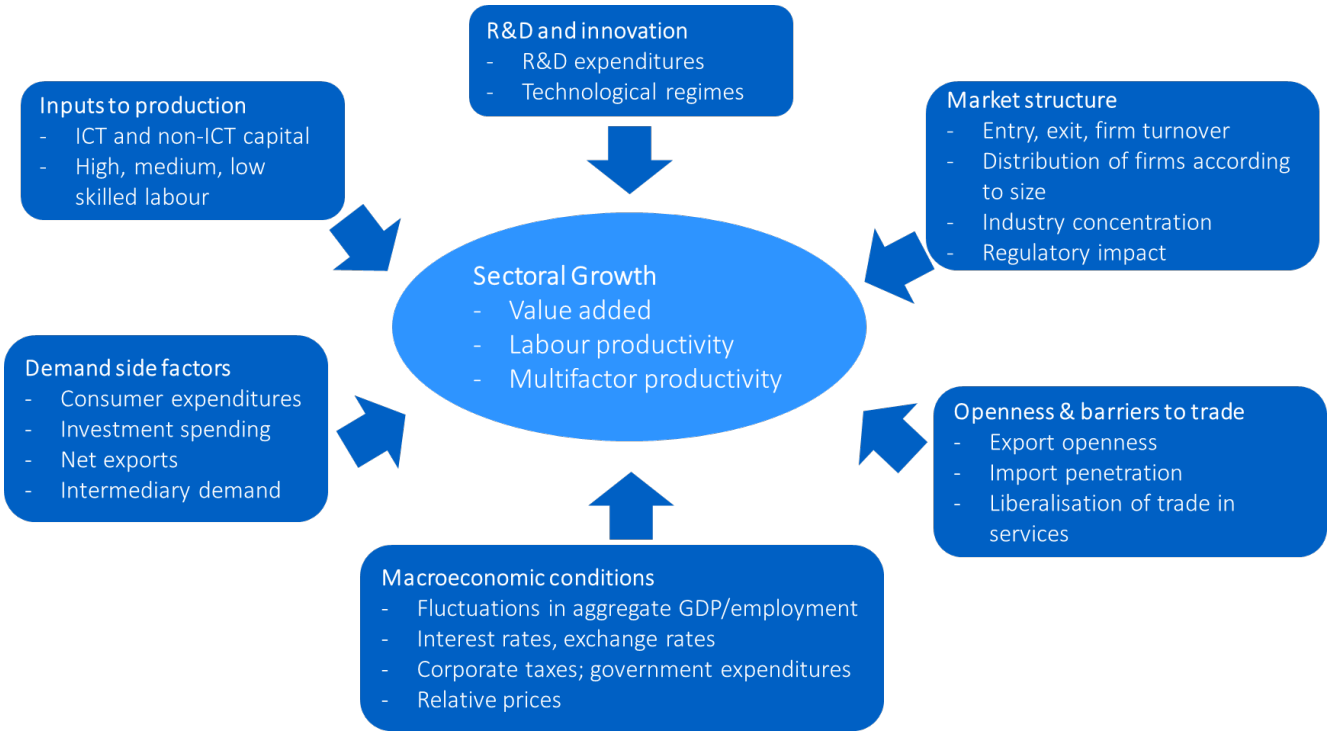
A branch of the literature has also attempted to attribute Porter's strategies to sectors empirically. Aiginger's empirical research (2001) is the best known work in establishing whether European industries compete on quality or price, equivalent to Porter's cost and differentiation strategies.

2.1.4 Frameworks

There are few comprehensive frameworks on determinants and drivers of competitiveness. Some existing frameworks are conceptual and abstract models. In contrast, aggregated indices are easier to apply but hinder the understanding of interactions and dynamic effects around competitiveness.

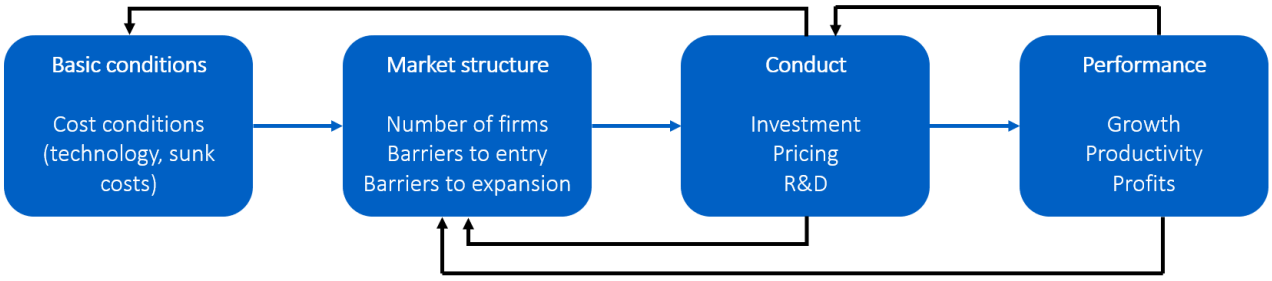
Conceptual models of competitiveness aim to establish the major determinants and their patterns and how they relate to competitiveness. One of the most comprehensive frameworks to date is by Peneder (2009). It organises determinants of competitiveness across six groups: macroeconomic conditions, demand-side factors, inputs to production, R&D and innovation, market structure, and openness and barriers to trade. These six dimensions and their sub-categories are individually analysed as drivers of competitiveness. Figure 3 illustrates the framework. However, it does not capture dynamic elements.

Figure 3: Peneder's framework identifies six determinants. Source: Peneder (2009).



The Structure–Conduct–Performance (SCP) model shows the dynamic relationship between competitiveness and market structure. The traditional SCP model is a framework extensively used in industrial organisation economics. It illustrates how a sector's market structure determines the type of competition and the performance of firms. Peneder expands on the one-way causation link between market structure and firm performance and adds feedback links to show how a firm's performance can affect market structure (see Figure 4). For example, firms can erect barriers to market entry through marketing and change the market structure (Peneder, 2009). This framework has been used by governments to understand markets and anti-competitive behaviour, and has also been used as an analytical tool by firms to understand how to compete in markets (Porter, 1980). The age and widespread use of this framework is an indicator of its strength and applicability to business strategy.

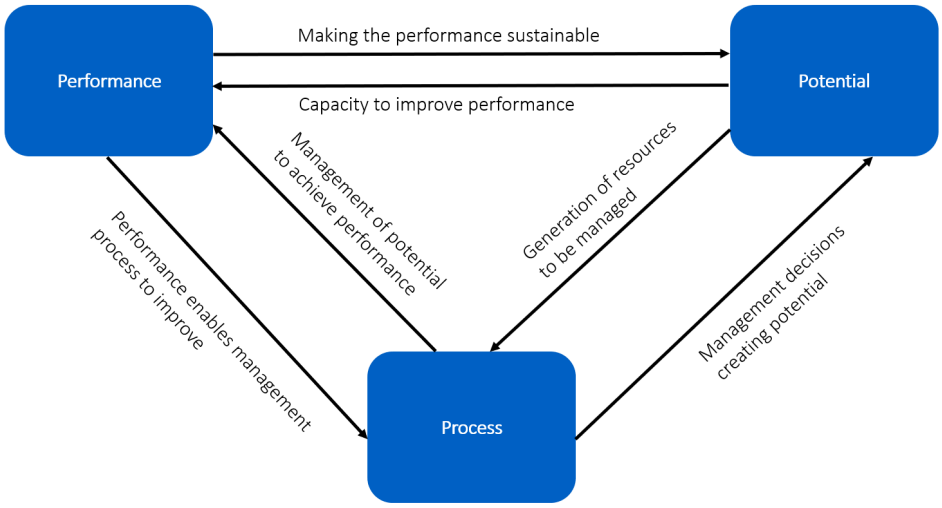
Figure 4: The Structure-Conduct-Performance model emphasises dynamic aspects. Source: Peneder (2009).



A different conceptual framework is the '3 Ps' of competitiveness model. It describes competitiveness as a dynamic and ongoing process with three stages: performance is the outcome of the process; potential is the inputs into the operation; and process is the management of the operation. For a static indicator of competitiveness, the performance stage is enough. For a greater understanding of future competitiveness and the ability to sustain it, Buckley et al. (1988) argue the potential and process stages must also be

analysed. This model is influenced by external factors such as market structure, regulation and macroeconomic conditions. Figure 5 illustrates the overall structure of the framework. Because of the model's emphasis on potential and process – two harder-to-quantify aspects of competitiveness – it is less applicable to empirical work and more suited as a conceptual model to understand competitiveness.

Figure 5: Performance, potential and process are all interlinked in the 3Ps model. Source: Buckley et al (1988).



Other frameworks move away from conceptual relationships and use aggregated indices, which fail to explain the interactions between different determinants. Competitiveness indices aggregate various micro- and macro-level determinants according to certain defined weightings. The Global Competitiveness Index of the World Economic Forum (Sala-i-Martin & Artadi, 2004) includes 12 pillars of competitiveness, aggregated according to the country's development stage. Another example is the IMD's (2016) World Competitiveness Index, which includes 340 criteria along with four main competitiveness factors.[7] Using indices to understand competitiveness involves a choice as how to weight determinants and does not account for interactions. This results in an arbitrary judgement since these relationships are not well studied. Additionally, aggregating various determinants of competitiveness does not allow us to study how these determinants interact with one another.

2.1.5 Performance metrics

The literature employs a variety of metrics for competitiveness, each with its advantages and disadvantages. The practice in empirical literature has been to analyse competitiveness impacts using a combination of metrics. This aligns with the literature on definitions of competitiveness explored above, which highlights the need to supplement single measures of competitiveness. For example, market shares can be combined with a measure of profitability to capture a holistic and long-term view of competitiveness. Table 2 displays metrics frequently used in the empirical literature, along with their advantages and disadvantages.

[7] The factors are economic performance, government efficiency, business efficiency and infrastructure. The criteria stem from business surveys.

Table 2: The literature has used various metrics for competitiveness, each with advantages and disadvantages

Metrics	Advantages	Disadvantages	Source
Profit (profitability or profit margin)	• Metric is easy to calculate and data is readily available • Captures cost and revenue aspects of competitiveness • Easy to compare across countries	• Difficult to compare across different sectors • Firms selling different types of products or in different markets	Abrell, Zachmann, & Ndoye, 2011; Commins, Lyons, Schiffbauer, & Tol, 2011; Dechezleprêtre, Nachtigall, & Venmans, 2018; Demailly & Quirion, 2008; Reinaud, 2008
Market share (in physical or monetary terms)	Metric is easy to calculate and expresses role in different markets	• If the market is regionally bounded, high market share may not be an indicator of competitiveness but of a small market with few firms • Firms can have high sales but make zero or negative profits • Cross-market comparison difficult if market structures differ significantly	Peneder et al., 2017
Productivity (total factor productivity, labour, capital)	Reflects efficiency of firm in transforming inputs into outputs	• Measurement is difficult • Cross-industry and -country comparisons are complex because variations in production functions and exchange rates affect productivity	Commins et al., 2011; Jaraite & Di Maria, 2012; Klemetsen, Rosendahl, & Jakobsen, 2016; Marin, Marino, & Pellegrin, 2018

Employment	Sustained growth in employment may reflect sustained growth in value added and productivity	• Employment is an input into production, not a direct indication of competitiveness – firms may have low competitiveness and high employment if labour laws are inflexible	Abrell et al., 2011; Commins et al., 2011; Dechezleprêtre et al., 2018; Flues & Lutz, 2015; Marin et al., 2018; Martin, de Preux, & Wagner, 2014; Wagner & Petrick, 2014
Export share/ net imports	Reflects competitiveness because exporting firms do not have a home advantage	• Firms can be large exporters but make zero or negative profits if their costs are high or prices low • Cross-market comparisons are difficult if market structures differ significantly • Exports are high by default for products with global value chains	Boutabba & Lardic, 2017; Branger, Quirion, & Chevallier, 2017; Flues & Lutz, 2015; Wagner & Petrick, 2014
Turnover	Displays capacity to sell in market	• Misses the cost component of competitiveness – firm may have high turnover but high costs, and therefore low competitiveness	Chan, Li, & Zhang, 2013; Flues & Lutz, 2015; Marin et al., 2018; Wagner & Petrick, 2014

Robust competitiveness assessments rely on a mix of quantitative and qualitative metrics. The nature of frameworks and the limitations of metrics inevitably require the use of qualitative appraisals. These can include interviews with industry stakeholders and surveys of firms. Comprehensive analyses of competitiveness in the literature often include consultations with key stakeholders (Sala-i-Martin & Artadi, 2004).

2.2 Competitiveness and the role of carbon pricing

Carbon pricing is globally on the rise as jurisdictions take action to reduce their emissions through market instruments, but incomplete coverage can present risks to the competitiveness of UK firms and sectors if policy is not designed appropriately. There are currently 56 carbon pricing policies implemented or scheduled for implementation at the regional, national and subnational level (World Bank Group, 2019). However, many trading partners of the UK, such as the US, China, Brazil and Turkey have no national carbon pricing scheme in place today.[8] The UK's recent policy changes could further extend the carbon pricing gap to other jurisdictions: its aim to reach Net Zero by 2050 could lead to increases from current carbon prices; and its departure from the EU means carbon prices may depart from the EU ETS level (Vivid Economics, 2019). This suggests that carbon pricing plays an important role in UK competitiveness in some sectors.

This section reviews literature on the role of carbon pricing in impacting competitiveness. It first examines the literature on the key theoretical channels before offering a synthesis of literature on the empirical evidence.

2.2.1 Theoretical role in competitiveness

Carbon pricing is a key tool to achieve Net Zero cost-effectively and it can impact competitiveness both negatively and positively. Carbon pricing can play a central role in achieving UK's Net Zero target cost-effectively. A robust carbon price is important for facilitating switching to lower-carbon production, and for intermediate and final consumers to create a viable long-term business case for large-scale investments in lower-carbon processes, materials and efficient use.[9] However, carbon pricing may also affect competitiveness, and policymakers should design appropriate policy responses accordingly. Carbon pricing can provide downside risks and upside opportunities for a firm's competitiveness:

- **Downside risk**: Carbon pricing can increase a firm's production costs directly through carbon compliance costs, and indirectly through higher input costs or short-term abatement costs.
- **Upside opportunity**: Carbon pricing can spur innovation, increase business sustainability and productivity, and create demand for low-carbon products in the medium and long term.

Carbon pricing will likely need to be complemented by other policy measures to achieve the rate of decarbonisation required for Net Zero. Carbon pricing solves the problem of greenhouse gas emissions being unpriced and of polluters not bearing the cost of their emissions. However, other issues associated with low-carbon innovation and technological development, such as spillovers and barriers to uptake, are more effectively addressed with policies such as R&D support and innovation clusters.

[8] While China is implementing an ETS, resulting carbon prices are expected to be low and industrial emissions not to be covered.
[9] The deep decarbonisation required for net zero faces a variety of barriers, including non-price barriers. Carbon pricing alone is insufficient to overcome these and should be one element within a broader policy suite (Vivid Economics, 2019).

There is general agreement in the theoretical literature that carbon pricing can increase production costs relative to uncovered jurisdictions and result in carbon leakage. The theory of negative competitiveness impacts of carbon pricing is well established in the academic literature (Branger et al., 2017). If a firm in one jurisdiction has to pay for its emissions or purchase carbon-priced inputs, its production costs increase relative to competitors in other jurisdictions. This might reduce its market share and increase the market share of its competitors. Not all negative competitiveness impacts count as carbon leakage, and Box 1 explains the differences between general competitiveness impacts and carbon leakage. Carbon leakage can occur through a reduction of output in the short term, or a reduction in investment in the long term (Vivid Economics, 2015).[10]

Box 1: Competitiveness and carbon leakage

Carbon pricing can cause competitiveness impacts but not all competitiveness impacts count as carbon leakage (Vivid Economics, 2015):

Carbon pricing can increase a firm's production costs. If a firm is not able to abate or pass through costs, its competitiveness relative to rival firms may be affected.

This competitiveness impact is carbon leakage only if all three conditions are fulfilled:

1. **Carbon pricing is asymmetric – i.e. the firm's competitors do not face a similarly ambitious carbon price.** For example, currently under the EU ETS, if UK production shifts to the EU27 as a result of carbon pricing, this suggests that UK firms have faced a competitiveness impact but this is not carbon leakage.

2. **Emissions shift to a region with less ambitious carbon pricing.** Carbon leakage occurs if emissions, along with production and employment, decrease in the covered region and increase in the uncovered region. If carbon pricing reduces a sector's output because its goods become more expensive, and the production is not taken up by international firms, it is not carbon leakage.

3. **Production shifts to a firm with higher emissions intensity.** If production moves to a firm with lower emissions intensity and emissions decrease as a result, it is not carbon leakage.

Carbon pricing can also have positive effects on competitiveness. Carbon leakage covers only negative impacts.

Policymakers might still be interested in negative competitiveness impacts that are not carbon leakage. If production and employment shift as a result of carbon pricing, it may still be a political concern.

Carbon leakage risk is particularly high for emissions-intensive and trade-exposed (EITE) sectors. The literature generally agrees that the impact of carbon pricing on competitiveness varies by sector (Aldy & Pizer, 2015; Branger & Quirion, 2013). Sectors that exhibit high emissions intensity and high trade exposure are most likely to be at risk of carbon leakage (Dechezleprêtre & Sato, 2017).[11] Their high emissions intensity implies that carbon costs as a share of the production value are substantial. High trade exposure

[10] The third theoretical channel, a change in international fuel prices, is less relevant for the UK.
[11] 'EITE sectors' also includes sectors that exhibit low trade exposure, such as cement.

is a proxy for a limited possibility to pass through costs to consumers, as competitors with a lower or no carbon price could offer a similar good at a lower price.

The ability to conduct cost pass-through is determined by a variety of factors for which trade intensity is only a proxy. Determining the ability to pass through costs is complex. Trade intensity has been used as a proxy because it is easy to calculate with publicly available data. However, cost pass-through depends on a variety of factors such as industry structure, size of the firms, transportation costs, capacity utilisation and policy environment (CPLC, 2019). Furthermore, cost pass-through capacity varies over time and space and is fundamentally dynamic in nature (Reinaud, 2008). Box 2 summarises current approaches and measurement challenges.

Box 2: Carbon leakage risk drivers and associated measurement challenges

The literature identifies two main considerations for assessment of sectoral leakage risk:

1. Carbon cost impact: the impact that carbon pricing has on a firm or sector; and

2. Carbon cost pass-through capacity: whether a firm has the capacity to pass through carbon costs to consumers without loss of market share or profit margin.

However, each of these channels is difficult to observe in practice given data limitations, and is therefore often estimated through use of a proxy:

1. Carbon cost impact can be measured by volume of emissions created per unit of output, revenue, value added and profit. While this is often quite easy to capture, for some sectors or processes emissions data may be challenging to gather. Proxies to capture carbon cost increase include energy cost shares and, for indirect costs increases, electricity intensity.

2. Measure cost pass-through capacity is more challenging. A wide range of factors can be important include market power, elasticities of demand, the elasticity of domestic supply, and elasticities of foreign supply. However, these are difficult to observe or measure, and policymakers have tended to approximate through measurable drivers – most notably measures of trade intensity, which is a poor proxy for cost-pass through capacity (Martin et al., 2014).

Leakage risk is also driven by abatement potential and carbon price differentials between countries, but these have not been used in practice to quantitatively measure risk levels:

1. Abatement potential and cost can influence investment decisions and leakage. If a firm can reduce emissions at low cost it will be able to cost-effectively reduce the carbon cost it faces, thus reducing the risk of leakage. However, this can vary significantly by firm or by sector.

2. As carbon leakage is driven by carbon price differentials, competing countries introducing carbon pricing policies of equivalent stringency should lessen the risk of leakage. However, prices can change quickly, making this a challenging metric to obtain on an ongoing basis.

However, carbon pricing can also induce innovation and increase competitiveness in the medium and long term, as formulated in the Porter hypothesis. Porter & van der Linde (1995) famously expressed the idea that 'strict but flexible environmental regulation', such as carbon pricing, can induce innovation that not only improves environmental performance, but also partially or fully offsets the initial costs of the regulation in the long term. This process happens in two steps: in the first, well-designed environmental regulation incentivises innovation;[12] in the second, the benefits from this innovation offset the costs of complying with the regulation.

The Porter hypothesis rests on the underlying assumptions that firms do not always act as profit-maximisers and that markets are not operating optimally. If firms are making profit-maximising decisions and markets operate optimally, the firms would undertake any profit-improving innovations without the need for regulation. The literature broadly identifies two reasons why the real world departs from this (Ambec, Cohen, Elgie, & Lanoie, 2013). The first observes that firm choices are driven by managers, who may suffer from behavioural biases. These include present bias, which prevents managers from undertaking investments that are profitable in the future but costly now; loss aversion, which deters costly and risky changes; and bounded rationality, whereby reasoning shortcuts, like habits, hinder new routines (Aghion, Dewatripont, & Rey, 1997; Ambec & Barla, 2002; Kennedy, 1994). The second reason is the existence of market failures: because of technological spillovers, firms underinvest in innovation. Theoretical research shows that regulation can move an industry to an equilibrium with higher investments in R&D (Mohr & Saha, 2008). With imperfect competition, Simpson and Bradford show that regulation can give an advantage to firms that become greener before their competitors (1996). Ambec and Barla emphasise that asymmetric information creates a market for environmentally poor products due to a lack of information about environmental quality, highlighting the need for signalling such as environmental standards (2007).

Empirical research on the Porter hypothesis generally finds a positive impact of environmental regulation on innovation, but the research is less clear on the impact on business performance. Jaffe and Palmer find that pollution abatement costs positively impact R&D expenditures (1997). This is supported by research examining the link between regulation and successful environmental patent applications (Lee, Veloso, & David, 2011; Popp, 2003, 2006). On the impact of regulation on productivity, the Jaffe et al. review of the evidence finds mostly negative impacts, but more recent studies contradict this (Jaffe, Peterson, Portney, & Stavins, 1995; Alpay, Buccola, & Kerkvliet, 2002) . Ambec et al. emphasise that in estimating this relationship, dynamic dimensions and long-term impacts must be accounted for using lags (2013). Comparing Lanoie et al. (2011) and Lanoie et al. (2008), the former finds a negative impact on business performance using a static econometric model, whereas the latter finds a positive impact using lags of three of four years.

The theoretical literature does not offer a consistent view on whether downside risks or upside opportunities overcome each other to ultimately impact competitiveness. Downside risks and upside opportunities are well established in economic theory. They can both occur simultaneously, but their size can vary. It is an empirical question if carbon pricing impacts a firm or sector's competitiveness positively or negatively (Branger et al., 2017). Dechezleprêtre & Sato (2017) conducted a

[12] Porter and van der Linde identify five channels through which this happens: signalling companies about resource inefficiencies and potential technological improvements; raising corporate awareness of environmental impacts; reducing uncertainty of value of investments; creating external pressure – an important component of the innovation process; and levelling the transition playing field between regulated companies.

comprehensive assessment of the empirical literature and concluded that while general environmental regulation has occasionally had an impact on trade flows, these impacts were small and concentrated in only a few sectors. The next section presents empirical research on the effect of carbon pricing on carbon leakage, innovation and overall competitiveness.

2.2.2 Empirical evidence

This section discusses the empirical evidence on carbon pricing and competitiveness generally and for the UK. Annex B presents further case studies for the EU ETS, California's ETS and New Zealand's ETS.

There is limited research on the UK individually because the UK's main carbon pricing policy is at the EU level. The UK's main carbon pricing policy has been the EU ETS and most empirical literature has focused on the impacts on the EU as a whole. In those studies, the impact on UK firms could be concealed by an EU average. There is a limited number of studies that look at UK firms under the EU ETS separately. Some studies look at the UK's CCL. The impacts of the CPS on emissions have been assessed (Abrell, Kosch, & Rausch, 2019), but not yet the impact on competitiveness. There is also no separate study on the effect on innovation in the UK, but the study on patents in the EU ETS below includes the UK.

While limited, the available research finds no evidence that carbon pricing has negatively affected the competitiveness of UK firms. Dechezleprêtre et al (2018) investigate the competitiveness impacts of Phase I and II of the EU ETS on UK firms separately. They find no negative impact on revenues, fixed assets or employment, and even find a positive effect on profits. The findings also qualify the study by Oberndorfer, Alexeeva-Talebi, & Löschel (2010), who find low cost pass-through rates for UK industries as an indicator of potential carbon leakage risk. Martin, de Preux, & Wagner (2014) estimate the impact of the CCL on UK manufacturing and find no impact on employment, gross output, productivity or plant exit.

For other countries under the EU ETS, there is little to no ex post empirical evidence of carbon leakage, suggesting minimal negative competitiveness impacts of carbon pricing to date. The empirical literature has focused on the effects of carbon pricing on output, revenue, profits and employment in EITE industries. The large majority finds no or only insignificant effects from carbon pricing. Some studies find minimal effects on a small group of sectors, but no sector is regularly found to be negatively affected (CPLC, 2019; Vivid Economics, 2015). Annex A provides a comprehensive summary of ex post carbon leakage assessment.

Some literature does find a causal link between carbon pricing and innovation, although the arising abatement investment is insufficient for the rapid decarbonisation needed for a net zero future aligned with the global emissions abatement commitments of the Paris Agreement. Using patents as a proxy for innovation,[13] Calel & Dechezleprêtre (2016) find an increase of up to 10% in low-carbon patenting by firms covered by the EU ETS. They also find an increase of up to 1% in patents in other technologies, suggesting that carbon pricing can unlock a broader innovation environment. A report by the Carbon Pricing Leadership Coalition similarly highlights the innovation and investment that can arise from carbon pricing (Carbon Pricing

[13] Innovation is generally difficult to measure; patents and R&D expenditures are the most established proxies (Energy Systems Catapult, 2019).

Leadership Coalition, 2017). Sato et al. (n.d.) suggests that low-carbon investments were made in addition to regular investment, but the levels triggered are not sufficient for the rapid decarbonisation needed. There is limited evidence from other regions; Cui, Zhang, & Zheng (2018) find indicative evidence for increased patent application under China's regional ETS pilots. Nevertheless, evidence is expected to broaden with wider coverage and higher carbon prices in the future.

The lack of evidence on carbon leakage can be explained by low carbon prices and leakage mitigation policies, and does not rule out carbon leakage in the future. Carbon prices have remained well below £20/tCO2 in many jurisdictions around the world until recently (ICAP, 2018), which reduces the impact on production costs.[14] EU ETS prices have increased steeply over the past year, but their impact on competitiveness has not yet been assessed. Furthermore, most schemes offer free allowances or rebates to emitters, reducing average carbon costs further. The empirical literature does not conclude that carbon pricing would never have negative impacts on competitiveness, only that under current policies carbon leakage has not yet occurred. Future increases in ambition relative to trading partners and the exhaustion of low-cost abatement opportunities can increase the risk of carbon leakage. For example, reaching net zero emissions in the UK could require much higher carbon prices than present today (Burke, Byrnes, & Fankhauser, 2019).

The empirical literature on the effects of carbon pricing is constrained by data availability and methodological challenges. Most jurisdictions with carbon pricing schemes experienced low carbon prices until recently (World Bank Group, 2019). A lack of impact on competitiveness can stem from the lack of substantial carbon prices, successful leakage mitigation policies or a change in firm behaviour. Furthermore, some of the theoretical risks and opportunities occur only in the long term and cannot be studied with recently introduced schemes. Methodological challenges in distinguishing the effect of carbon pricing from other trends in the economy further complicate the analysis. The following studies represent the most recent and state-of-the-art research, but some long-term effects of carbon pricing remain unknown to date.

Studies suggest that determinants other than carbon pricing have so far been more important for competitiveness. Most studies in the current environment of low carbon prices conclude that carbon costs are an unimportant relative to other determinants of competitiveness. Oikonomou, Patel, & Worrell (2006) find that tariffs, labour productivity, transportation costs and exchange rates are more important for a firm's production decision. Ederington & Minier (2005) find that EITE sectors are also capital-intensive, which makes them less likely to relocate due to carbon costs and more likely to remain in capital-abundant countries. Nevertheless, the investigation of carbon leakage remains a focus of the academic research and the political debate (Branger et al., 2017).

2.3 Conclusions from the literature

There is no universally accepted definition of competitiveness in the literature, but a combination of sustainable market share and profitability seem to capture the relevant elements of competitiveness. Much of the literature defines competitiveness as the ability to sell in markets and gain market share. However, some researchers argue that

[14] The Swedish carbon tax is substantially higher than this range. However, sectors that are likely to experience competitiveness impacts from carbon pricing either receive rebates or are covered by the EU ETS (Energy Systems Catapult, 2018).

a definition of competitiveness focused solely on market share overlooks the long-term capacity to retain profits, which should be included. Although, in the past, competitiveness has been defined as productivity, the literature has stressed that productivity is a determinant of competitiveness, not a definition of it. An assessment of these arguments suggests that a definition of competitiveness should include market share and profitability in the long term.

The literature presents various determinants of competitiveness and emphasises the role of each determinant of competitiveness being sector-specific and ultimately an empirical question. This list includes conditions that firms face in terms of inputs and markets, choices firms make (such as innovating and erecting market barriers), and broader business environment factors (such as inflation and physical infrastructure). Which determinants matter more for competitiveness depends on the characteristics of the sector. For example, the impact of a factor such as labour market efficiency depends on whether production in a sector is labour-intensive and whether the sector's market competes on costs.

Frameworks like the conceptual 3Ps model, Peneder's six determinants models, and aggregate indices list determinants of competitiveness but fail to explain the relationship between these. Conceptual frameworks such as those of Peneder (2009) and Buckley et al. (1988) give an overview of the components of competitiveness, but lack a structure that explains the relationships between different determinants and competitiveness. Additionally, they are rarely applied in practice in order to analyse the competitiveness of a given sector. Indices of competitiveness lack the theory to explain how determinants affect competitiveness, weighting them arbitrarily. Although they give information about current competitiveness, they are less applicable in analysing the drivers of competitiveness.

Our framework therefore builds on the modified Structure–Conduct–Performance model, which highlights the role of a firm's actions in mediating competitiveness. The Structure–Conduct–Performance framework has academic foundations in industrial organisation theory and is used by governments and firms. It provides a more comprehensive understanding of competitiveness by emphasising the dynamic aspects of competitiveness and by structuring the relationship between determinants.

Using categories to prioritise determinants is a useful way to streamline an analysis of competitiveness, and Porter's competitive strategy division is the most relevant. The role of determinants is specific to a firm or sector. However, it can be effective to classify firms and sectors according to specific rules in order to prioritise the analysis of the most important determinants. Various classifications exist in the literature, according to production method and innovation intensity, for example. Porter's classification according to competitive strategy is most suited to this analysis.

The theory about carbon pricing and its impacts on competitiveness not only refers to the downside risks, but also highlights the importance of analysing upside opportunities. Carbon pricing can initially increase production costs, thus reducing competitiveness. The impact will vary across sectors, but those with high emissions intensity and trade exposure are at greater risk. However, this can then incentivise the firm to react in order to mitigate or eliminate competitiveness impacts – through innovation for example. This capacity complements traditional emissions intensity and trade exposure analyses, and should be part of a competitiveness framework.

The empirical literature on the impact of carbon pricing finds initial support for the Porter hypothesis and no evidence of negative competitiveness impacts in the past, although results are constrained by methodological challenges. The empirical literature finds no consistently negative impacts of carbon pricing on competitiveness in the past. It does find increased patenting from carbon pricing, suggesting firms respond to an initial cost shock by undertaking innovation. Difficulties in this empirical work arise from methodological issues such as a lack of data and confounding effects from other determinants of competitiveness. Challenges also emerge from low-carbon prices, policy responses to address competitiveness concerns, and from the relatively recent introduction of carbon pricing which restricts the study of long-term impacts. The reviewed literature cannot predict competitiveness impacts in the future; higher carbon prices in the future could lead to both more innovation and higher carbon leakage if policy responses are not designed appropriately.

3. Conceptual Framework

This section presents the holistic framework of business competitiveness which builds on, but remains embedded in, the literature and is applicable by policymakers. The framework captures both conditions that sectors face and actions that they can take, incorporating firm managerial decisions into the understanding of competitiveness determinants. It includes feedback loops to capture the dynamic aspect of firm behaviour and competitiveness. The framework can be applied by policymakers to better understand competitiveness and is accompanied by detailed step-by-step instructions for application in Section 5.

In the context of carbon pricing, this framework builds on traditional carbon leakage assessments as it captures both exposure to impacts and capacity to act. Section 4 presents the role of carbon pricing within this framework. It integrates upside opportunities, and the potential for improving business competitiveness in response to, or in anticipation of, negative shocks. The framework employs metrics used in carbon leakage assessments, but takes a longer-term view by recognising the firm's ability to react strategically and maintain or improve their competitiveness. It can also guide policymakers in considering complementary policies that reduce downside risks and enhance upside opportunities.

The remainder of this section is structured as follows:

- Section 3.1 defines competitiveness
- Section 3.2 presents the framework, details its components, and discusses how they are interlinked
- Section 3.3 introduces archetypes that prioritise certain elements of the framework for a given sector

3.1 Definition

Business competitiveness is defined in this report as:

"The capacity and ability of a firm or sector to gain and maintain a profitable, sustainable market share relative to rivals in domestic and international markets.'"

This definition of business competitiveness is based on the analysis of literature and stakeholder feedback. It captures:[15]

- **The differences between a positive competitive environment and a firm's ability to take advantage of this.** Capacity refers to favourable market, macroeconomic and policy conditions that create the potential for a firm or sector to gain or maintain a profitable market share. Ability refers to a firm or sector's managerial capability to act upon these conditions.

[15] Annex F provides a list of stakeholders consulted for this report.

- **The dynamics of competitiveness over time, rather than a static view which looks only at current market share or profitability.** Focusing statically, at one point in time, overlooks the capacity to sustain positive, or overcome negative, periods. For example, analysing only one year of profit and market share could misrepresent a firm's actual condition if the year chosen is an exception to the firm's general trend. Firms may take certain actions, such as innovation or relocation, that could have negative impacts in the short term but positive impacts in the longer term.

- **Market share and profitability over time as the relevant performance metrics.** The literature review concluded that using dual indicators of competitiveness, market share and profitability over time captures the most relevant facets of competitiveness. A sole focus on market share overlooks the fact that firms could reduce their profitability to crowd out competitors, for example by lowering prices. The definition does not emphasise notions of competitiveness that the literature deems insufficient, such as productivity, since these capture only a limited part of competitiveness determinants.

- **The relative nature of competitiveness, whereby sectoral competitiveness cannot be assessed in isolation or in absolute terms.** Competitiveness is by nature a relative concept. A firm or sector's competitiveness can be assessed only by benchmarking it against rivals in domestic and international markets.

3.2 Framework and components

This section arranges conditions and conduct into an analytical framework using a modified Structure–Conduct–Performance model. The framework links how conditions and conduct affect a firm's competitiveness over time. It is a modified version of a Peneder's (2009) competitiveness model[16] and is presented in Figure 6. It is based on the competitiveness components discussed in the literature review and draws them logically together. The three main components are as follows:[17]

- **Conditions** form the basis for establishing a sector's competitive edge and inform opportunities and constraints for its conduct, categorised into costs, and markets and products.

- **Conduct** covers the actions that a firm can take in the market, underpinned by a firm's strategy and managerial and organisational ability.

- Both ultimately affect a sector's performance, measured by market share and profitability over time.

The remainder of this sections details the components individually and how they interact in static and dynamic ways, and presents appropriate metrics – market share and profitability – to assess them.

[16] Peneder's model distinguishes between basic conditions and market structure. This framework sees components like market concentration or elasticity of demand on the same level as other basic conditions. Basic conditions and market structure are combined into *Conditions* and then classified into *Costs* and *Market and Products.*

[17] The determinants discussed in the literature review are elements of conditions and conduct.

The framework uses insights from the literature to identify determinants that influence competitiveness through conditions, conduct and the broader environment, as shown in Figure 6 below, and to identify relevant metrics. Table 1 of the literature review identifies various determinants, ranging from more firm-focused factors, such as input costs, access and quality, to broader environmental factors such as inflation and infrastructure. This section structures determinants of competitiveness and offers the most relevant metrics to assess them. Finally, it discusses the role of the macroeconomic and policy environment as overarching factors influencing competitiveness.

While the measurement of some conditions and conducts can be straightforward with quantitative metrics, others are more challenging and require qualitative assessments. Some conditions and conduct options can be measured with metrics that are relatively easy to calculate based on public data, especially cost conditions. Other factors rely on a mixture of qualitative assessments and quantitative approximations.

Multiple metrics are presented for specific cases of conditions and conduct, as explained below, to obtain a better understanding of certain determinants. For example, the labour cost determinants include both unit labour costs along with productivity and share of skilled labour. Analysing the impact of a higher minimum wage on competitiveness, the first metric would capture increased labour costs, but the second and third metrics could capture an improvement in labour productivity and hence decreased costs.

3.2.1 Conditions

Conditions form the basis for establishing a sector's competitive performance and inform opportunities and constraints for its conduct. The conditions can be categorised into costs, and markets and products. Costs relate to a firm or sector's expenditure to produce a good or service. Markets and products capture factors such as demand, markets structures and product differentiation. Table 3 presents the conditions, divided into various sub-categories, and gives a definition and link to competitiveness.

Underlying drivers like complex supply chains and clusters can impact multiple conditions simultaneously. Many modern sectors operate with complex supply chains. This allows them to improve efficiency upstream and produce goods at lower cost and bring them to the market faster. Local clusters can facilitate this process within a small regional scope. Complex supply chains and clusters can be underlying drivers of multiple conditions (Duranton & Kerr, 2018).

Table 3 lists the conditions and provides a description and potential metrics.

3.2.2 Conduct

Conduct covers the actions that a firm can take in the market, underpinned by its strategy and managerial and organisation ability. Conduct choices represent how firms act and react in response to changes in conditions and performance (Mason, 1939; Phillips, 1976). They are simultaneously constrained by the firm's conditions while having an impact on them (Peneder, 2009).

Conduct can be assessed through a combination of quantitative and qualitative metrics. Managerial decisions and the strategic vision of firms, in particular, can be assessed only qualitatively as they are by nature more descriptive. Some types of conduct

benefit from a mixed quantitative and qualitative assessment. For example, pricing strategies, for which price elasticities of consumer demand can be estimated, can be supplemented with qualitative assessment from consumer surveys. Other types of conduct that benefit from using both types of metrics include market power, innovation, and marketing and branding.

A qualitative assessment of conduct could include various methods. Semi-structured interviews or focus groups could be held with key stakeholders of the sector being analysed. Document analysis could also be undertaken, covering industry, company and bank reports. Table 4 presents conduct determinants, their impact on competitiveness, and metrics to measure this impact.

Table 3: Definitions and metrics for the conditions of competitiveness, grouped into categories

Category	Determinant	Definition and role in competitiveness	Metrics
Costs	Labour	Direct and indirect payments to employees in total or per unit of output. They are influenced by labour productivity and labour laws.	Labour costs per unit of output, labour productivity, share of skilled labour (McKenzie & Brackfield, 2008)
	Resources	Costs of raw materials in total or per unit of output. They are partly determined by the location and ownership of inputs.	Raw material costs per unit of output
	Energy	Costs of fuels, including electricity, in total or per unit of output. They are determined by international prices, domestic market structure and regulation, and production processes within the firm.	Energy costs per unit of output
	Transport	Cost of transport to consumers per unit of output. They are impacted by the distance to consumer markets and weight and volume of goods.	Cost of transport to consumer per unit of output, weight to value ratio
	Equipment and land	Equipment costs include fixed and one-time expenses for machinery, construction and other equipment used for production. Land costs encompass fixed and one-time expenses for land without any constructed assets.	Cost of capital per unit of output, depreciation rates, land to gross value added (GVA) ratio (Peneder, 2009)
	Finance	Costs that stem from borrowing money. Financing costs directly affect firms' profit but can also constrain their ability to make investments that could improve competitiveness.	Weighted average cost of capital per unit of output

Markets and products	Domestic demand	Share of domestic market at a given price for a sector's goods. Demand is a key basis for the level of production and profitability, and its growth supports the development of economies of scale (Nakao, 1980).	Volume of domestic market, share of domestic market, apparent domestic demand,[18] elasticity of demand
	International demand	Share of international market at a given price for a sector's goods. Market access decides if a firm can benefit from international demand (Nakao, 1980).	Exports intensity, share of international market, elasticity of demand, revealed comparative advantage, Grubel-Lloyd index, tariff and non-tariff measures (Peneder, 2009)
	Market structure	Structure of the market a firm competes in, defined by the market concentration, entry barriers and firm age and size. A less competitive market can increase a firm's profit in the short term, but might reduce competitiveness in the long term (Tirole, 1988).	Hirschman-Herfindahl index, mark-up, entry and exit over time, number of firms (Cavalleri et al., 2019)

[18] A proxy for domestic consumption, calculated as production plus imports minus exports of the product.

Table 4: Definitions and metrics for conduct

Conduct	Definition and role in competitiveness	Metrics
Capacity and utilisation	Ratio of actual level of output to sustainable maximum level of output, i.e. utilisation to capacity (Corrado & Mattey, 1997). Firms can adjust their production capacity and capacity utilisation to reduce their costs. For example, firms could increase their utilisation to match their capacity instead of buying newer equipment, reducing costs of expenditures.	Capacity, utilisation rate (Christiano, 1981)
Process innovation	Development of new or significant improvement in existing production or delivery method (Cohen & Klepper, 1996). Firms can undergo process innovations to reduce costs relative to competitors. For example, a firm could improve its production methods and fuel use to lower impact from an increase in oil prices.	Number of patents, R&D expenditure (OECD & Eurostat, 2018), qualitative assessment
Investment	Investment in capital assets, equipment and land (Driver, Temple, & Urga, 2005). Firms can invest in new capital that is more efficient to reduce operating costs relative to competitors. For example, in response to an increase in the minimum wage, a firm could replace labour with new capital.	Investment intensity (Kotsina & Hazak, 2012); gross/net investment
Long-term strategic choices	Strategic choices include mergers and changes in location. For example, in response to higher energy costs from trade barriers, firms can merge with competitors in a way that reduces costs, by developing economies of scale and reallocating production (Roller, Stennek, & Verboven, 2006).	Qualitative assessment
Pricing	Pricing strategies can grant access to different consumer groups, superiority over competitors, and increased profitability (Waldman & Johnson, 2007). For example, a firm could decide to not pass a cost increase in raw materials on to consumers to maintain market share.	Cost pass-through estimates, elasticity estimates; qualitative assessment

Product innovation	Development of a new product, or significant improvements to existing one (Cohen & Klepper, 1996). Firms can undergo product innovations to increase the quality of their product, to serve different consumer preferences, or to create a new product market. For example, in response to a fall in demand, product innovation would differentiate offerings from other firms.	Number of patents, R&D expenditure, product quality (OECD, 2018); qualitative assessment
Marketing and branding	Firms can use marketing to increase demand by promoting knowledge of the firm or its products. It can also create brand loyalty which creates a barrier to competition. After an opening to international competitors, firms could increase their marketing budget to promote demand and deter competitors.	Marketing expenditures (Graham & Frankenberger, 2000); qualitative assessment
Long-term strategic choices	Firms can use mergers and change of location to alter market structure and access different consumer markets (Roller et al., 2006).	Qualitative assessment

3.2.3 Performance

Competitive performance, the outcome of interest, is measured using profitability and market share. As per the definition, the measurement of these two metrics should be over time and judged relative to competitors.

The options to compute market share and profitability are detailed in Table 5. The choice between these will be subject to data availability. Market shares can be calculated for output or for sales, at the global or regional level. Profitability metrics are ratios, making them useful for comparison across companies. There are margin ratios, which detail the company's ability to convert sales into profits at different degrees of measurement, and a return on assets ratio, which represents a company's ability to generate returns on investment in assets.[19]

Table 5: Formulas for calculating market share and profitability

Market share	Profitability
$\text{Share of global output} = \frac{\text{Output of UK sector}}{\text{Global output}}$	$\text{Gross profit margin} = \frac{\text{Gross profit}}{\text{Revenue}}$
$\text{Share of regional output} = \frac{\text{Output of UK secto}}{\text{regional output}}$	$\text{Operating profit margin} = \frac{\text{Operating profit}}{\text{Revenue}}$
$\text{Share of global sales} = \frac{\text{Sales of UK sector}}{\text{Global sales}}$	$\text{EBITDA margin} = \frac{\text{EBITDA}}{\text{Revenue}}$
$\text{Share of regional sales} = \frac{\text{Sales of UK sector}}{\text{Regional sales}}$	$\text{Net profit margin} = \frac{\text{Net profit}}{\text{Revenue}}$
	$\text{Return on assets} = \frac{\text{Net income or net profit}}{\text{Average total assets}}$

Note: EBITDA, earnings, before interest, tax, depreciation and amortisation.

3.2.4 Interactions

A firm's conditions influence its conduct choices which in turn affect performance. Costs impact the profitability of a firm, but not directly. The firm always makes a choice with respect to its conduct which mediates the relationship between conditions and performance. For example, high costs can reduce profitability, but the firm is continuously

[19] This report has chosen to focus on return on assets, as opposed to return on equity, as the latter gives profitability from the investor's point of view. Different indicators have different advantages and disadvantages, and data availability might affect the selection.

making choices regarding the way it sells its products and places itself in the market. It can choose to increase prices, which can offset the increase in costs in the profitability metric.

The relationship between these components is not exclusively one-way since firms will assess their performance and make conduct choices that then feed back into conditions and performance. Firms continually evaluate their performance. Increases in market share and/or profitability could give the firm the ability to modify its pricing strategy, innovate, or develop economies of scale. Decreases in these could motivate the firm to change its conduct choices in other ways.

Conduct choices can affect conditions. For example, the decision to undertake a merger will affect the market structure, and the choice to invest in process innovation will change the burden of certain costs. This will again feed back into performance through conduct choices.

Certain conduct options will have a greater impact on some conditions than on others. Cost conditions are affected by conduct choices of capacity and utilisation, process innovation, capital investment and long-term strategic choices. In contrast, product and market conditions are affected by pricing strategies, product innovation, marketing, and long-term strategic choices.

These interactions will also depend on the timeframe of the analysis, which is why it is important to consider conditions, conduct and performance components in the long term. Some conditions may change more flexibly and quicker than others in response to changes in conduct choice and macroeconomic and policy environment, depending on sector, country and firm characteristics. For example, how quickly labour costs can change from a long-term strategic decision to reduce the workforce will depend on the labour market flexibility in the country and sector of interest. Innovation may increase costs and reduce competitiveness in the short term, but reduce costs and improve competitiveness in the long term. Furthermore, reducing capital investment decreases costs in the short term, but might be costly in the long term.

3.2.5 Environment

The broader environment can impact competitiveness through various channels, as identified in the literature. A recessionary macroeconomic environment can imply a reduction in domestic demand, whereas high inflation can imply that input costs increase. High-interest environments affect the cost of finance, and exchange rate volatility can impact companies that have foreign debt or that buy and sell in international markets.[20] Economic business cycles also influence firms' conduct choices, as high uncertainty or fears of a recession may lead to reduced investment. Regulatory stability reduces policy uncertainty and expands the time horizon of firms, allowing for more strategic conduct decisions. A strong rule of law gives firms confidence in the safety of their assets, which can incentivise conduct decisions like investment and innovation.

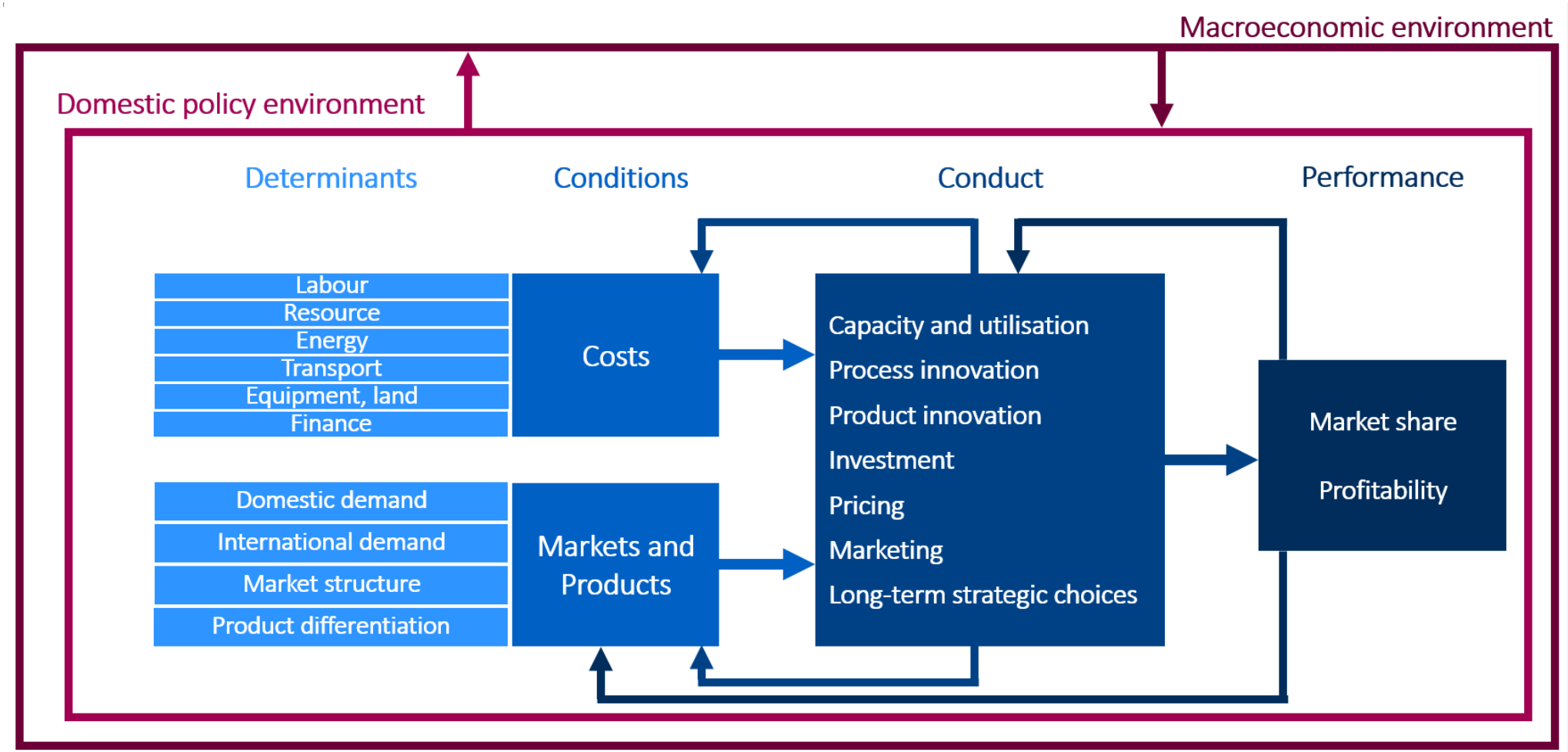
[20] A high-interest environment is defined in this report as the risk-free rate of interest set by the Central Bank being higher than the historic average for a prolonged period of time.

The domestic policy environment[21] affects sectoral competitiveness in distinct ways, although this impact is not always easy to predict.[22] The ways in which the domestic policy environment can affect conditions, conduct, and the performance of firms are numerous. For example, labour laws can influence the productivity of workers by changing the flexibility with which firms can lay off workers, setting minimum wages, and providing training for workers. Another example could be how trade policy can reduce the investment firms make if there is uncertainty around it, or how it can limit the capacity for firms to increase market share by erecting trade barriers. Additionally, competition regulation can influence the long-term strategic choices firm make, for example by defining the ability to conduct mergers.

Policy and macroeconomic environments also interact with each other. A recession could affect a government's spending ability, for example. Conversely, a change in domestic policy could alter the macroeconomic environment. For example, lax fiscal or monetary policy could lead to an inflationary domestic macroeconomic environment, reducing sectoral competitiveness. Even though sectors have no direct control over the macroeconomic environment and policy, both can affect their competitiveness.

[21] Sectors that trade internationally will be impacted by the policies in those countries (e.g. standards). However, the framework captures this element through the international demand determinant. The framework references the domestic policy environment explicitly in order to remain tractable.
[22] Domestic policy includes regulatory costs not captured in specific conditions. Taxes such as corporate taxes, along with general business subsidies, are captured in the policy environment, whereas labour taxes and energy subsidies are captured in the condition component.

Figure 6: Conditions, conduct and performance interact in a firm's competitiveness



While the framework offers a holistic understanding of competitiveness, it is necessary to focus on certain elements to facilitate its use as a tool. The next section defines archetypes as a way to differentiate how sectors compete and to focus on certain elements of the framework.

3.3 Sector archetypes

Archetypes provide criteria with which the researcher can systematically focus an analysis of competitiveness on the conditions and conduct choices that are most relevant to the sector studied, reducing time and effort. Archetypes effectively act as criteria through which an analysis of competitiveness can be prioritised. This gives the researcher flexibility to perform a more condensed analysis if time-constrained by focusing on the most important components, while also permitting a more comprehensive analysis.

Based on the literature review, this report adapts Porter's two strategies of competition and Aiginger's empirical classification into more flexible archetypes. Porter's strategies are relevant in understanding both conditions that are the most important to certain firms and the conducts they should perform, but they are inflexible in their characterisation of these strategies as mutually exclusive. Aiginger's (2001) empirical classification has three categories, with an intermediate competitive strategy. To allow for greater flexibility, the framework similarly employs three categories; these are not used as blunt selectors of components, but as mechanisms to prioritise them in an analysis, and we have therefore termed them as archetypes.

As per Aiginger, archetypes are separated into price, quality and intermediate competition, corresponding with Porter's cost and differentiation strategies. Firms that compete on quality provide a product that has an additional characteristic compared with competitors and which consumers value. This then allows for a higher price on the product, without losing market share to competitors. On the other hand, firms that compete on price produce similar products to competitors but attempt to reduce price, and therefore costs, as much as possible. Firms that do not correspond to either of these provide a product where both price and quality are important for the consumer, and therefore belong to the intermediate competition archetype.

Depending on a firm's competitive archetype, certain components and conduct choices will matter more than others. All determinants and conducts still play a role in a firm or sector's competitiveness, but with varying degrees of importance.

Cost conditions are more relevant for price archetypes. For the sectors that compete mostly on price; there is typically little opportunity or demand to differentiate a product in exchange for a higher price. Therefore, the cost determinants are more important in a sector's competitiveness than the market and product determinants. Such sectors will focus on conduct choices that reduce cost.

Market and product conditions are more important for quality archetypes. For sectors that compete mostly on quality, consumers are typically willing to pay a higher price for a different product that provides more value to them. Therefore, markets and product determinants are more important in a sector's competitiveness than the cost

determinants.[23] They will act to increase consumers' willingness to pay, and focus on product differentiation and marketing.

For intermediate archetypes, both cost and market and product conditions are significant. Sectors in the intermediate archetype face consumers who evaluate both the price and quality of a product relative to competitors. For these sectors, it is therefore important to act on product differentiation and marketing alongside reducing or matching the price (and therefore costs) of competitors.

Sectoral conduct typically depends on archetypes. For a quality archetype, even if its cost conditions are impacted negatively, it might still make conduct choices that affect markets and product determinants, because the minimisation of costs is not as relevant in its sector. For example, if a producer of battery dividers, a product that competes on quality, is faced with increased costs, it could choose to act on its pricing strategy and pass on costs, rather than prioritising decreasing cost burdens through reduced production. For intermediate archetypes, unlike quality or price archetypes, all conduct choices are relevant.

Conduct impacts performance by defining the price at which products are sold, influencing the demand for the products and the costs of production. A firm can influence its profitability and market share by changing these three factors. An archetype describes which of these factors are targeted: a quality archetype is more likely to increase prices or aim to capture more demand (for example, through advertising) rather than reduce costs. An archetype's conduct can then affect both market share and/or profitability.

The framework uses empirical evidence to classify sectors as price, quality or intermediate archetypes. Aiginger builds three indicators of quality, two of which are relevant to this report's archetypes. The first is the unit value of exports, calculated by dividing the nominal value of exports by their physical volume. The higher the unit value, the higher the willingness to pay of consumers. The second is revealed quality elasticity, in which sectors with high prices and high quantities sold are classified as quality competitors, as their products must have certain characteristics that increase consumer willingness to pay. It is attributed to sectors if high (low) unit values in exports correspond to high (low) exported quantities relative to important quantities within a sector. Table 9 in Annex C presents a list of sectors and their attributed archetypes, based on Aiginger's research (2001).

[23] A price archetype does not imply that firms cannot compete on quality. There is just less opportunity to do so and costs are the main factor of competitiveness. Similarly, overall costs do matter for quality archetypes as well – just to a lesser extent than for a price or intermediate archetype.

4. Role of Carbon Pricing within the Framework

This section explains the role of carbon pricing within the conceptual framework, and how this builds on traditional assessments of carbon leakage.24 This analysis builds on the theoretical base of carbon leakage by analysing changes in conduct, drawing on the EU's qualitative carbon leakage assessment (European Commission, 2018). It offers a holistic understanding of the role of carbon pricing to help policymakers appreciate its role in driving competitive benefits.

Carbon pricing affects firms' competitiveness through its impact on conditions and conduct, which translates into changes in market share and profitability. This section analyses the channels through which carbon pricing affects competitiveness using the framework to understand the direction and magnitude of carbon pricing impact. It studies how the carbon cost changes the conditions and how innovation in abatement technologies, pricing, and other forms of conduct can affect the overall impact on competitiveness.

4.1 Carbon pricing impacts

The impacts of carbon pricing will vary according to how the policy is designed, with free allocation typically significantly reducing cost impacts on EITE industries in ETSs. Carbon pricing impacts will depend on the design of the policy. In addition to the direct level of the carbon price, other aspects of design may affect the effective price faced, such as exemptions, rebates and free allocation of allowances. Policies like border carbon adjustments and increased global coordination efforts on carbon pricing can reduce asymmetry in carbon price exposure compared with international peers.

The analysis of carbon pricing design in this framework is embedded in, but also deviates from, traditional carbon leakage assessments in order to offer a more holistic perspective of the competitiveness impacts of carbon pricing. Governments of mature carbon markets such as the EU or California use simple proxy metrics of emissions and trade intensity to allow for a high-level assessment across a large number of sectors (Vivid Economics, 2015).These metrics, as discussed in the literature review, fail to account for the magnitude of carbon cost shocks and competitive dynamics. Neither do they take upside opportunities into account, and so do not offer a holistic understanding of possible competitive gains from carbon pricing.

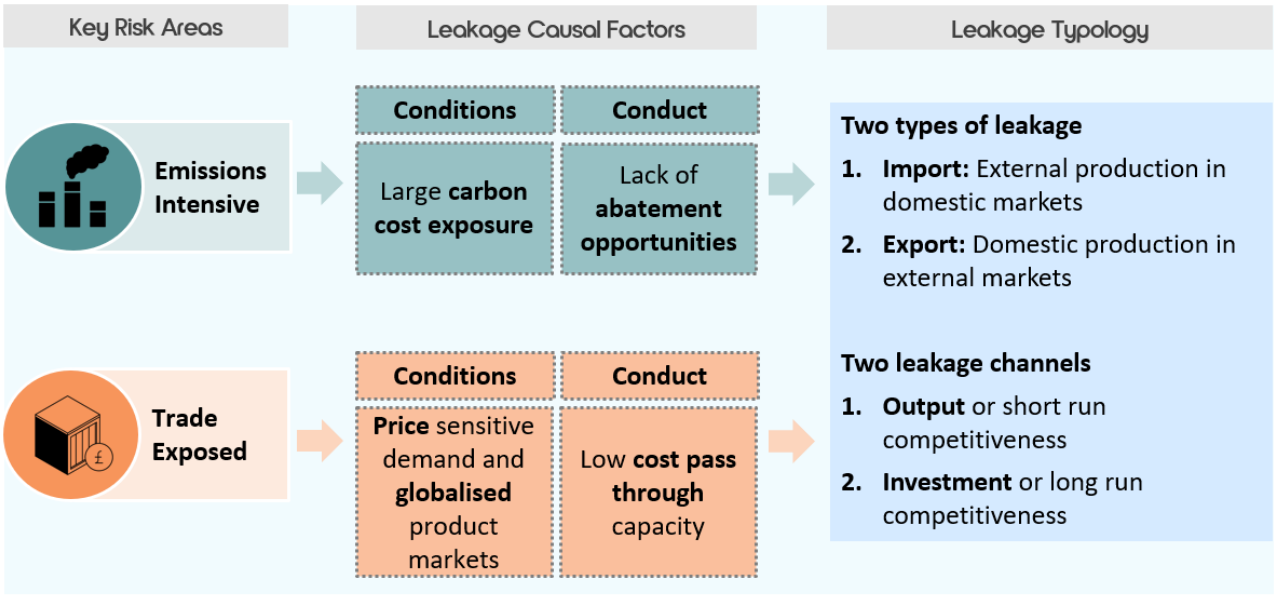
Generally, downside risks of carbon pricing materialise first through conditions, then conduct, and can result in import and export leakage through the output and investment channels. Figure 7 illustrates the causal chain of downside risk from carbon pricing within the framework. Carbon pricing first affects conditions. But downside risks occur only when conduct is constrained – for example, because the lack of abatement opportunities limits process innovations and low cost pass-through capacity limits pricing options. As a result, the sector has to reduce output or margins. The former can result in

[24] Carbon pricing is one policy that affects competitiveness, but policymakers will also be able to analyse the impact of other policies using the conceptual framework.

output leakage; the latter can result in investment leakage in the long term if the lack of financial resources constrains the ability to invest (CPLC, 2019).

Sectors can change conduct in response to carbon pricing to exploit upside opportunities and gain a competitive edge. Carbon pricing can positively impact the conditions firms face. It can also incentivise conduct that reduces the carbon pricing burdens, and even advances them against their international rivals (Energy Systems Catapult, 2019). It is important to note the need for a long-term perspective in this analysis. Initially, the impact on conditions and conduct may be negative, but, with time, markets and firms adjust such that the negative impacts become positive.

Figure 7: The downside risks of carbon pricing are embedded in traditional carbon leakage theory

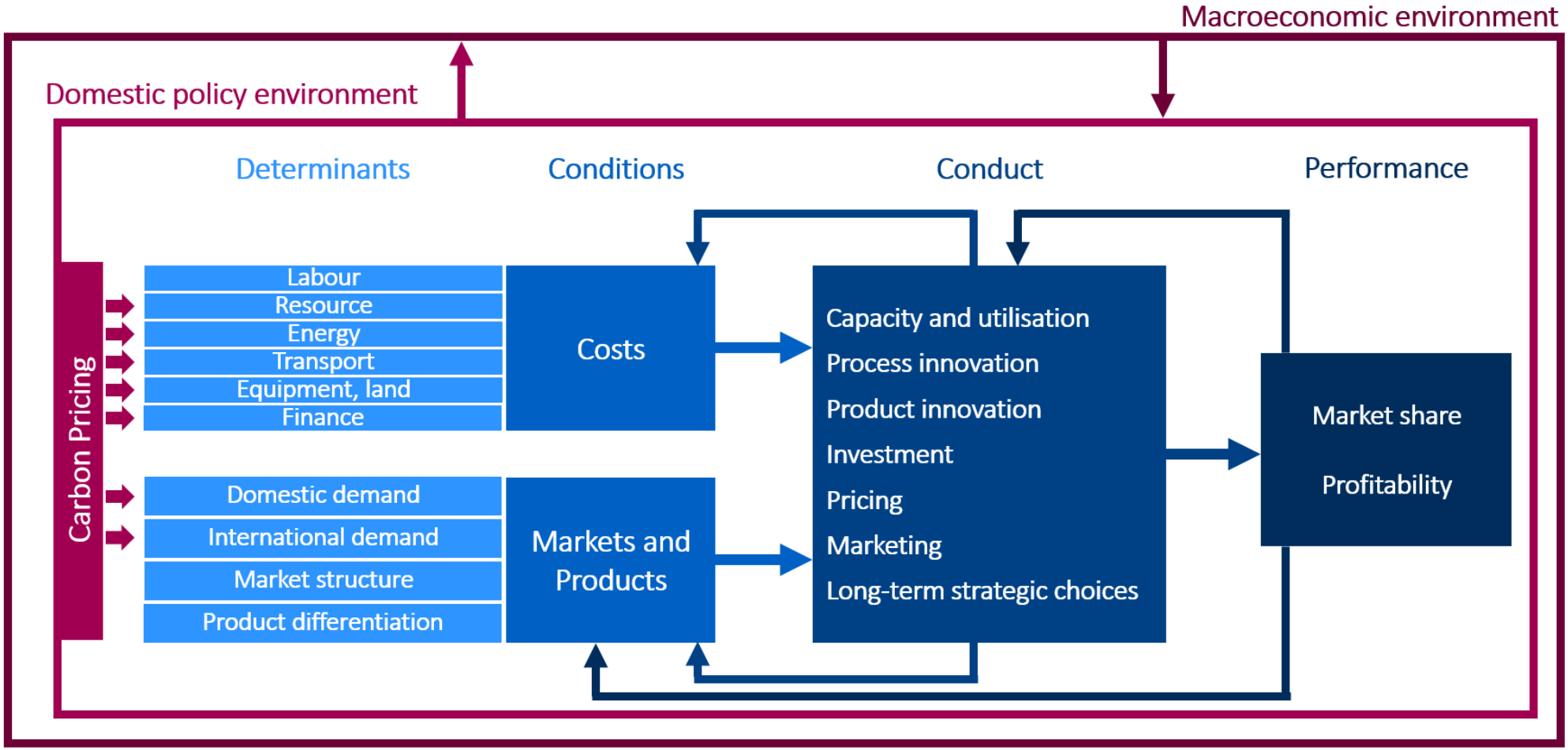


Carbon pricing can increase the demand for the products of specific firms, expanding or opening new consumer markets or bases. The imposition of a carbon price incentivises firms to move away from polluting inputs and methods. Firms that produce more energy-efficient and less-polluting inputs and production tools may therefore gain from higher demand for their products. For example, energy producers under carbon pricing are incentivised to increase the share of renewable energy in their mix. This will therefore increase demand for producers of renewable energy equipment, such as wind turbine and photovoltaic panel producers. Another channel is how producers of greener production inputs may see their demand increase. For example, steel makers may increase their purchases of recycled steel as a production input and reduce iron ore, as the processing of recycled steel is less emissions-intensive.

Carbon pricing can also motivate firms to change their conduct in a way that is beneficial to their overall performance. It can encourage firms to innovate, either in their production methods to reduce carbon costs, or in their product offering to gain additional demand. Firms can also invest in newer capital, upgrading their production tools into more carbon-efficient ones in a way that may reduce overall costs. Carbon pricing can also motivate a marketing strategy that focuses on green aspects of products, which can then increase demand.

Figure 8 illustrates the changes from carbon pricing within the general competitiveness framework.

Figure 8: Carbon pricing can affect firm performance through conditions and conduct



4.2 Conditions

Sectors can experience the effects of carbon pricing through different channels, although the overall impact on conditions will usually be ambiguous in the long run. They will have to buy allowances or pay a tax for their emissions from owned or controlled sources, captured by increased resource costs. They may experience indirect impacts from higher input costs. This is because input suppliers, such as energy, raw materials and equipment suppliers, also face costs from carbon pricing that they may pass through to their consumers. Finally, carbon pricing may change the demand for certain products. For example, producers of electric arc furnaces may face higher demand from steel producers that want to reduce emissions.

This section focuses on the impact on conditions, in the absence of conduct choices and taking other policies as given. Table 6 explains the impact on conditions. It analyses the theoretical impact before any conduct choices are made. For example, carbon pricing can increase the price a sector pays per unit of resources. Overall effects on competitiveness might be ambiguous or positive if the sector increases investment – however, this is part of the analysis of conduct in the section below.

Table 6: The initial impact of carbon pricing is on conditions

Category	Determinant	Explanation	Metrics
Costs	Labour	Labour costs are unlikely to be affected by carbon pricing because they are not linked to fossil fuel use.	N/A
	Resource	Resource costs could increase as a result of carbon pricing. If the raw materials used by a supplier release emissions in their production or extraction, carbon pricing will increase their production costs and potentially prices.	Change in resource costs due to carbon pricing, using emissions intensity. Estimation might require assumption on cost pass-through.
	Energy	Energy costs can increase if coal, gas, oil or other emissions-intensive fuels are used for electricity production and their prices have increased from the carbon pricing policy (Grover, Shreedhar, & Zenghelis, 2016). If the sector itself is covered by carbon pricing, the increased costs come from complying with the policy.	Change in energy costs due to carbon pricing, using emissions intensity. Estimation might require cost pass-through assumptions taken from the literature.
	Transport	The costs of transport can increase if fuels covered under carbon pricing are	Change in transport costs due to carbon pricing, using emissions

		used in transportation of inputs to product markets.	intensity. Estimation might require assumptions on cost pass-through.
	Equipment and land	Equipment costs can increase if production of equipment itself is affected by carbon pricing and costs are passed through. Land costs may be impacted through land sector emissions pricing.	Qualitatively
	Finance	The costs of finance can be impacted if carbon pricing shifts reduce returns to emissions-intensive assets and lead to asset-stranding risk.	Quantitatively[25] and qualitatively
Markets and products	Domestic demand	Downstream sectors can change their demand if covered by a carbon price. For example, electricity producers may change their demand away from coal to wind turbines as they seek to reduce the carbon price they face.	Price elasticity in consumer markets; qualitatively
	International demand		
	Market structure	Carbon pricing does not change market structures directly in the conditions, but a change in conduct and performance can affect them; for example, firms with green upside can begin to raise barriers to entry over time.	N/A
	Product differentiation	Product differentiation will not be affected by carbon pricing directly, but firms' conduct in response to the policy change can lead to it.	N/A

Note: Direction of initial impact is in the absence of conduct and presents theoretical channels. In practice, impacts might be small and very indirect for many sectors.

[25] For example, based on the UNPRI Inevitable Policy Response forecasts.

4.3 Conduct

Firms can reduce the initial impact of carbon pricing arising from increased production costs by making certain conduct choices, and some responses may increase competitive performance. For example, they can increase their capacity utilisation to increase output per input or increase prices to pass costs through to their consumers. They can also invest in process innovation to reduce costs, or in product innovation to differentiate their offering from the market and gain greater market share. These conduct choices can recoup some or all of the negative cost impacts of carbon pricing, and even increase competitiveness. This is embedded in Porter's hypothesis of carbon pricing spurring innovation.

Negative competitiveness impacts may emerge where sectors can neither conduct abatement nor pass through costs. If conduct choices are limited, sectors cannot mitigate or outweigh the carbon pricing impact on conditions. As discussed in the literature review, many sectors are not constrained, and have the capacity to reduce emissions intensity through innovation and at least partially pass through costs.

Table 7 summarises firm conduct choices in response the impacts from carbon pricing on conditions.

Table 7: Firms have many options as to how to conduct themselves in response to carbon pricing

Determinant	Potential firm responses to carbon pricing	Time horizon of conduct	Metrics
Capacity and utilisation	Firms can adjust their production capacity and capacity utilisation to reduce the costs of inputs negatively impacted by carbon pricing. If firms reduce their production under the conditions defined in Box 1, this qualifies as carbon leakage through the output channel.	Capacity: short term Utilisation: long term	Capacity, utilisation rate
Process innovation	Carbon pricing may incentivise process innovation. This could involve improving the efficiency of production processes or using inputs that are less emissions-intensive. This innovation in production processes and inputs can increase costs in the short term but reduce costs and improve competitiveness in the long term (Martin, Muuls, & Wagner, 2011).	Long term	Change in R&D expenditures, change in number of patents; qualitative

Investment	Firms can invest in more efficient, lower-emissions equipment or transportation methods as a response to carbon pricing impacts. Firms are incentivised to reduce the quantity of emissions-intensive capital. Carbon pricing can also increase investments by guaranteeing a business case for low-carbon technologies – for example, for a wind turbine manufacturer. If firms reduce their investment under the conditions defined in Box 1, this qualifies as carbon leakage through the investment channel. The current level of emissions intensity and an estimation of this using best available technologies can approximate abatement options. Stable profit margins can give an indication of the ability of a firm to undergo long-term investments.	Short term	Change in investment per unit of output; difference between current emissions intensity and under best available technologies; Costs of versus return on investment
Long-term strategic choices	Firms could change their production location in order to avoid or eliminate the impact of carbon pricing on their costs. Alternatively, firms could merge with rivals in order to access less emissions-intensive processes or technologies, reduce competition and increase cost pass-through capacity (Fikru & Gautier, 2017).	Long term	Qualitatively
Pricing	In response to carbon pricing and changes in competitiveness, firms can change their pricing strategy. The ability to increase prices is measured by cost pass-through rates, which measures to what extent firms can pass carbon costs to consumers (Ganapati, Shapiro, & Walker, 2019). If the cost-pass-through capacity is low, firms could not pass through cost increases to maintain market share at the expense of profit margins.	Short term	Cost pass-through; trade intensity as proxy; qualitatively

	Trends in output prices in comparison to production costs including carbon costs and market concentration can help understand cost pass-through ability.		
Product innovation	Firms can undertake product innovation in response to carbon pricing. If the initial impacts are negative, firms may be able to mitigate these by improving existing products or creating new ones. This would allow them to charge higher prices and thus reduce the cost impact on profits. Firms that produce low-carbon goods experience increased certainty in future returns which can trigger additional effort in innovation.	Long term	Change in R&D expenditures, change in number of patents; qualitatively
Marketing	Possible role of marketing green products to consumers as demand changes to more sustainable choices.	Long term	Qualitatively

4.4 Performance

Carbon pricing can impact competitive performance, depending on its effect on conditions and the firm's conduct. Firms that are unable to make conduct choices that mitigate negative impacts from carbon pricing may see their profitability or market share decrease. Firms that can fully mitigate and compensate for negative impacts, along with those that face only positive impacts (such as demand increases), may see their profitability and market share increase.

The conduct choices that firms make to mitigate the impact on competitive performance act through different channels. Examples include the following:

- A firm can increase the price of its product, fully or partially passing costs from carbon pricing through to consumers. The effect on performance would depend on consumers' price elasticity of demand. If it is inelastic, an increase in price would not reduce demand substantially and profitability could increase.
- A firm could reduce this cost impact by innovating its process. If innovation reduces the energy used in production, and thereby the costs of energy per unit of output, then profitability increases.
- It could also innovate and differentiate its product to increase demand. This would increase both profitability and market share.

- It could relocate production to a jurisdiction where costs of inputs and/or regulation are lower. This could restore competitiveness and profitability.

Conduct choices can also go beyond mitigating negative impacts of carbon pricing and improve competitive performance by capturing upside opportunities. Business competitiveness can increase above its pre-carbon pricing levels if very productive conduct choices are made. For example, if a firm undertakes process innovation in order to reduce energy costs, and the innovation is so successful that energy costs decrease to levels lower than those prior to the introduction of the carbon price, then competitive performance may improve relative to international rivals.

The conceptual framework can be applied as a practical tool to understand the competitiveness of a UK sector. Sections 3 and 4 have provided a conceptual framework of competitiveness and the role of carbon pricing. Section 5 illustrates the practical application of the framework by presenting stepwise instructions to apply the conceptual framework.

As a result of problems with traditional carbon leakage metrics, significant cost pass-through rates have been observed in industrial sectors identified as at risk of leakage, leading to windfall profits. While cost pass-through rates vary between sectors, it is generally agreed that there is at least some pass-through of carbon costs in the most emissions-intensive sectors. Minimum cost pass-through rates range from 0% for fertilisers to 60% for iron and steel, and above 100% for refined products (European Commission, 2015). If firms receive free allowances and are able to pass through costs, they may be able to generate windfall profits.

This points to the need to understand leakage risk and the role of carbon pricing embedded within the broader competitiveness framework. This analysis builds on the theoretical base of carbon leakage by analysing changes in conduct, drawing on the EU's qualitative carbon leakage assessment (European Commission, 2018). It offers a holistic understanding of the role of carbon pricing to help policymakers appreciate its role in driving competitive benefits.

Box 3 illustrates the role of the sector archetypes in focusing on the framework components for battery separators under carbon pricing.

Box 3: Carbon pricing and competitiveness considerations for battery separators

Battery separators are a highly engineered, plastic material critical to the functioning of a battery as they separate the positive and negative electrodes. The two electrodes create a short if they come into contact, causing the battery to fail. The separators are a highly engineered polyethylene-based product for both lead-acid and lithium-ion batteries. Emissions from battery separator manufacturing come primarily from the use of fossil-fuel-fired boilers. They are used for steam during the production process to remove the solvent from the final product, to operate the emission control systems, and to recycle and separate inputs.

When Oregon considered introducing a carbon pricing scheme, it needed to understand whether battery separator manufacturers were EITE. The state includes facilities potentially covered under the carbon price and which are leading global suppliers of battery separators. Much of their production is also for the domestic market, where the facilities in Oregon compete with those in Tennessee

and Indiana – states without carbon pricing. The sector has also recently experienced significant competition from China, South Korea, Thailand and India.

While industry stakeholders thus suggested that the sector had low cost pass-through capacity and was at risk of leakage, there are mitigating factors to this claim. While the sector faced a challenging domestic and international environment, carbon cost exposure is low due to low emissions intensity: battery separators are a high-value product and carbon costs would represent a small proportion of overall costs. Moreover, the sector is within the quality archetype for competition: markets and product determinants are more important than the cost determinants and firms build relationships with customers and differentiate products to increase willingness to pay. Thus, while regulations ultimately offered blanket protection to all manufacturing sectors as EITE, analysis suggested further research was necessary to understand the nature and extent of carbon leakage risks for this sector (Vivid Economics, 2018).

5. Framework Application

This section sets out how the conceptual framework can be applied. The framework aims to be a practical tool that can be used in assessing the understanding of the competitiveness of UK sectors. This section provides instructions to perform such an analysis, from scoping to conclusion. It lists the tasks to be performed, providing advice and suggestions at every step. Section 5.1 presents the step process.

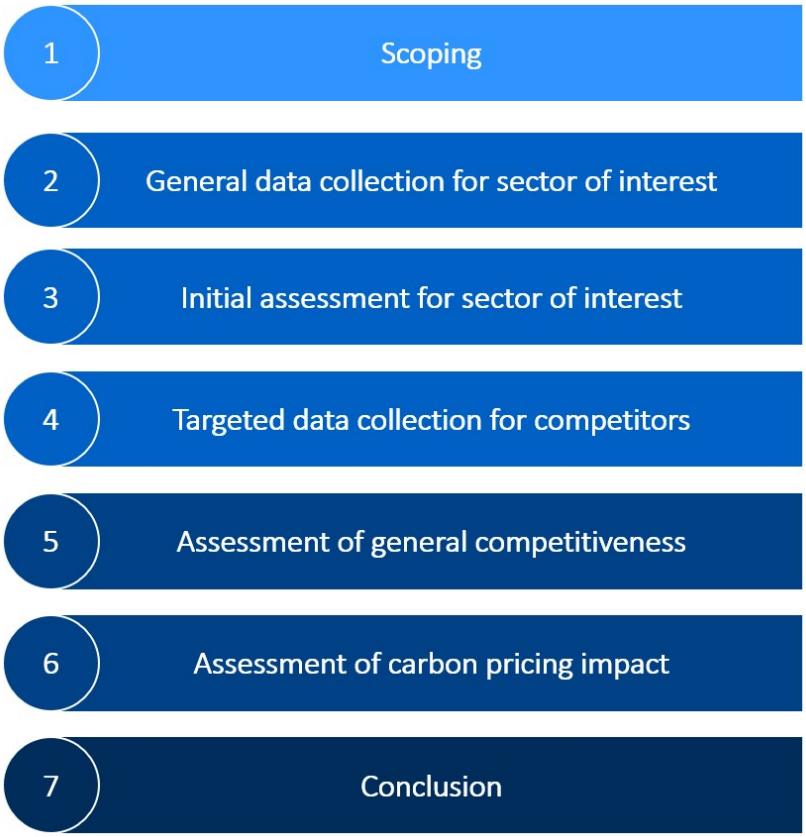
5.1 Step process

This step process applies the framework of the previous section as a tool to assess competitiveness and the role of carbon pricing in it. It expands the framework beyond being a theoretical model that conceptually explains competitiveness to a tool that can be used to analyse competitiveness of UK sectors. The step process describes a series of tasks that gather the necessary data, calculate metrics, and present the methods for assessing competitiveness.

The approach provides an understanding of a firm or sector's competitiveness, a comparison with competitors, and a method for understanding the impact of policy changes. In this section, the impact of carbon pricing is presented as part of the process, but other policy changes could be analysed, such as changes in labour market policies. The application of the framework allows for the design of policies that mitigate downside risks and facilitate upside opportunities more effectively, by understanding the channels through which these shocks affect competitiveness.

The step process also provides guidance on the conduct of research and analysis, and the final output can vary in its structure. The step process guides policymakers on the application of the framework and sets out a logical method to conduct the work. The final output, such as a brief on the sector's competitiveness, can follow a different structure. Figure 9 provides an overview of the seven steps described in this section.

Figure 9: The application follows a seven-step process



Data and information constraints can be a significant challenge and the researcher may not be able to access all required components. Data and information are unlikely to be available for all elements of the framework and all geographies analysed, particularly for small and emerging industries. Primary data collection such as stakeholder interviews can fill some of these gaps. Researchers should aim to obtain information on the prioritised elements of the framework and make assumptions when gaps remain despite thorough research and primary data collection.

5.1.1 Step 1: Scoping

Step 1 determines which economic activities, markets and competitors are within the scope of sector analysis. At the end of this step, the sector will have been classified according to SIC 3 and SIC 4 levels, and attributed to an archetype. The main competitors and product substitutes will also have been identified.

Step 1.1: Sector classification at SIC level 3

Classify the sector at SIC level 3 to define which economic activities are within the analysis and which are excluded. Consistency in sector scope is particularly important for the comparison of cost components across competitors. For qualitative metrics, the strict inclusion and exclusion of certain activities is less important, and many industry reports and studies in the academic literature will not make this distinction.

Step 1.2: Identify key sub-sectors at SIC level 4

Identify whether separate analysis for sub-sectors is required. Altomonte and Bekes (2016) find large within-sector differences in production. For some sectors, the SIC 3 level is sufficient because sub-sectors have similar production processes and competitiveness dynamics. For example, the production of cement does not require a separate analysis at

the sub-sector level. In contrast, the production of basic precious and other non-ferrous metals (SIC 24.4) includes distinct sub-sectors like aluminium (SIC 24.42) and lead, zinc and tin (SIC 24.43), and therefore requires a separate analysis. A rapid assessment of secondary literature forms the base of this decision.

Step 1.3: Archetype classification

Classify each sector according to archetypes set out in Annex C. The archetypes constitute an important part of the competitiveness as discussed in Section 3.3. They help to understand the type of competition sectors face, and allow for the prioritisation of important determinants in Step 3. If the archetype is expected to vary between sub-sectors, the revealed quality elasticity for each sub-sector can be calculated using UN Comtrade data.

Step 1.4: Determine geographical scope of the market

Determine whether the sector's market is global or more bounded. The relative nature of competitiveness requires a definition of the market in which a UK sector competes. The market scope is global for the large majority of sectors. However, high transportation costs for heavy goods, or language barriers for services, among others, can bound the geographical scope of a market. A rapid assessment of secondary literature and qualitative data collection with primary stakeholders form the base of this assessment.

Step 1.5: Identify main competitors

Identify the two to three main competitors of the UK sector. Any data and information compiled for the UK sector is meaningful only in comparison with international rivals. The focus on two to three main competitors strikes a balance between an informative assessment and a reasonable effort. Main competitors can be the biggest export countries, the largest importers of the product into the UK, or countries that export to the same destination the UK sector does. A rapid assessment of secondary literature and qualitative data collection with key stakeholders form the base of this assessment. UN Comtrade data can be used to inform the assessment based on trade flows into export destinations.

Step 1.6: Examine whether other sectors need to be included

Examine whether substitutes of the sector's product need to be included in the analysis. A UK sector might not only compete with rivals that produce a similar good in other countries. For example, glass, plastics and paper may all compete in the packaging market. A rapid assessment of secondary literature and qualitative data collection with key stakeholders form the base of this assessment. If other sectors are identified, they should be included as competitors throughout the rest of the analysis.

5.1.2 Step 2: General data collection for UK sector

Step 2 collects all the relevant data and information from primary and secondary sources for the UK sector. This step aims to collect all necessary data and information for the UK sector in order to analyse conditions, conduct and performance. The data gathered includes quantitative data for the sector in question, qualitative data, data on carbon pricing, and interviews with sector stakeholders. The information is then used to further prioritise conditions and conduct. The data collection for main competitors is performed at a later stage to avoid elaborate research for negligible factors.

Step 2.1: Collect secondary quantitative data for the UK sector

Collect secondary quantitative data on the required components of the framework. Many components of the framework rely primarily or partly on quantitative data. This can be obtained from national statistical offices, international databases, academic literature, government reports and grey literature.

The following components of the framework rely primarily on quantitative data for the assessment:

- **Conditions**: Costs relating to labour, resources, energy, transport, equipment and land, and finance
- **Conduct**: Capacity and utilisation, investment
- **Performance**: Market share, profitability

The following components of the framework rely partly on quantitative data for the assessment:

- **Conditions**: Domestic demand, international demand, market structure
- **Conduct**: Process innovation, pricing, product innovation

Step 2.2: Gather secondary qualitative information for the UK sector

Collect secondary qualitative information on the required components of the framework. Qualitative information on the framework components complements the quantitative data for certain components. It allows for a more nuanced understanding of the determinants of competitiveness and possible conduct choices. For other components, qualitative information is the only source to understand their role in the sector's competitiveness. It can be obtained from qualitative data collection with key stakeholders, academic literature, government reports and grey literature. Bank, consultancy, industry and company reports are likely to be a major source of information.

The following components of the framework rely primarily on qualitative information for the assessment:

- **Conduct**: Marketing and branding, long-term strategic choices
- **Macroeconomic and policy environment**

The following components of the framework rely partly on qualitative data for the assessment:

- **Conditions**: Domestic demand, international demand, market structure
- **Conduct**: Process innovation, pricing, product innovation

Step 2.3: Collect secondary data and information on carbon pricing for UK sector

Collect secondary data and information on carbon pricing that affects the UK sector. This part of the data collection forms the basis of the analysis of the role of carbon pricing. It is necessary to understand this existing burden in order to assess the impact of carbon pricing on competitiveness. Existing schemes in the UK include the CCL, the CPS and the

EU ETS. Forecasts or assumptions on future carbon pricing schemes might also be used depending on the focus of the assessment. The data and information can be obtained from national statistical offices, international databases, academic literature, government legislation and reports, and grey literature.

The following data and information should be collected:

- **Conditions**: Explicit (market) carbon price, allocation mechanism and rebates (and other secondary policies that might reduce the initial carbon cost shock), emissions intensity, upstream and downstream emissions
- **Conduct**: Main abatement options, secondary literature on previous cost pass-through capacity under carbon pricing (if available)
- **Performance**: Secondary literature on previous impact of carbon pricing on market share and profitability (if available)

Step 2.4: Collect primary information through interviews

Conduct interviews to close potential gaps on framework components. The previous steps of data collection might not be sufficient to understand all components of the framework. Some of the qualitative conduct components in particular may be difficult to assess through secondary data. Semi-structured interviews with industry representatives can fill some of the potential gaps. Conclusions from industry interviews should take the incentives to provide correct information into account. Expert interviews can further supplement the evidence base.

5.1.3 Step 3: Initial assessment for UK sector

Step 3 assesses the conditions and conduct to gain a first understanding of the sector and to prioritise components for the assessment against key competitors in Step 4. This section draws together quantitative data and qualitative information on the UK sector from Step 2 to derive primary findings. It employs the data from Step 2 and calculates the metrics on the conditions and conduct. It also prioritises conditions and conduct through the archetypes and the importance of determinants.

Step 3.1: Draw together data and information on UK sector

Use data and information to derive first findings on conditions of the UK sector. The collection of secondary quantitative data and qualitative and primary information allows for a first understanding of the UK sector. The collected evidence can be used to fill condition components of the framework. This allows first findings on the characteristics of the UK sector to be derived.

Step 3.2: Prioritise components

Use the archetypes and collected evidence to prioritise framework components. Conditions should be focused according to the archetypes. This reduces the amount of data-gathering and calculations for international competitors. The archetypes determine if ‘costs’ or ‘market and products’, or both, should be prioritised. Table 9 in Annex C can be used for the SIC 3 level. If the initial analysis concludes that sub-sectors vary substantially, archetypes can be calculated with trade data.

5.1.4 Step 4: Targeted data collection for competitors

Step 4 collects the data and information on the prioritised components for main competitors. It uses secondary sources for the main competitors identified in Step 1. Only data collection on the conditions and conduct prioritised in Step 3 as well as on performance is necessary. This step prepares for the comparison of the UK sector against its competitors in Step 5.

Step 4.1: Collect secondary quantitative data for competitors

This step repeats Step 2.1 for prioritised components and performance for main competitors.

Step 4.2: Gather secondary qualitative information for competitors

This step repeats Step 2.2 for prioritised components for main competitors.

Step 4.3: Collect secondary data and information on carbon pricing for competitors

This step repeats Step 2.3 for prioritised components for main competitors.

5.1.5 Step 5: Assessment of general competitiveness

Step 5 assesses the general competitiveness of a UK sector by comparing it against key competitors. It involves the calculation of performance metrics for the sector in question and its competitors, followed by a comparison of performance, conditions and conduct metrics.

Step 5.1: Calculate performance metrics

Calculate how the UK sector and its main competitors have been performing over time. This step provides an understanding of the outcome of current competitiveness for the UK sector and its main competitors. The calculation of market share and profitability[26] gives an indication of current competitiveness. The following steps help to understand the reasons for these results.

Step 5.2: Draw together data and information on competitors

Use data and information to fill in the prioritised framework components for competitors. The collection of secondary quantitative data and qualitative information allows for an understanding of the main competitors. The collected evidence can be used to fill each prioritised component of the framework.

Step 5.3: Benchmark UK sector against competitors

Benchmark the results on conditions, conduct and performance of the UK sector against its competitors. Use the analysis in Steps 3 and 5.2 to compare the competitiveness of the UK sector with its key peers. Include factors that overlap between different components, such as cluster effects, supply chains and market trends. Account for the macroeconomic and policy environment in this benchmarking assessment.

[26] This can often be an empirically challenging task, given data difficulties and the fact that company accounts often cover activities that span several products/markets, commercial sensitivities, etc.

5.1.6 Step 6: The role of carbon pricing in competitiveness

Step 6 focuses on the role of carbon pricing in a sector's competitiveness. It analyses the downsides and upsides on conditions and conduct. The following step involves an assessment of likely conduct options to mitigate negative impacts, based on metrics and archetype. Finally, the impact of carbon pricing on the sector of interest is compared with key competitors.

Step 6.1: Assess if any of the conditions can generally be affected by carbon pricing in the sector

Assess if the sector's conditions can be expected to face downside risks or upside opportunities in line with the framework. The sector can expect:

Downside risks, if:

- Costs are expected to increase by at least 5% according to the EU Phase 3 carbon cost criteria[27]
- Markets are expected to be affected by downstream demand destruction. For example, producers of coal plant turbines or diesel engines might face a substantial decrease in demand if coal generation or road transport face a carbon price. This analysis is qualitative, based on the secondary literature

Upside opportunity, if:

- Markets are expected to be affected by increased downstream demand. For example, producers of wind turbines or vehicle batteries might face a substantial increase in demand if coal generation or road transport face a carbon price. This analysis is qualitative, based on the secondary literature previously collected

If there are no downside risks identified, skip Steps 6.2 and 6.3. If there are no upside opportunities identified, skip Steps 6.4 and 6.5. If neither downside risks nor upside opportunities are identified, proceed with Step 7 directly.

Step 6.2: Assess downside carbon pricing on prioritised conditions, taking into account allocation and rebate mechanisms.

Calculate the cost increase through carbon pricing through an assumed average carbon price (taking allocation and rebates into account), emissions intensity and an assumption on cost pass-through. Average carbon price calculations are presented in Annex E:

- **Energy costs:** For fossil fuels, multiply the use of each fossil fuel per unit of output with its emissions intensity and the average carbon price. For electricity, multiply the use of electricity per unit of output with the average carbon intensity of the grid and the average carbon price. A 100% cost pass-through for fossil fuels and electricity provides a realistic assumption and an upper-bound cost estimate.
- **Transport costs:** Determine the emissions intensity per mile travelled by an average for the vehicles used (LDV, HDV, ships, aeroplanes). Obtain the average miles travelled per unit of output from secondary literature. Multiply these by the

[27] Sum of direct and indirect cost increase divided by GVA is at least 5%. The assumption on the carbon price should be consistent with the analysis after.
https://ec.europa.eu/clima/policies/ets/allowances/leakage_en

average carbon price. A 100% cost pass-through provides a realistic assumption and an upper-bound cost estimate.

- **Resource costs:** The impact of carbon pricing on resource costs is more indirect than for transport and energy. Determine two or three resources that are most important for resource costs and that have high emissions intensity. Multiply their emissions intensity with the average carbon price. A lower cost pass-through provides a more realistic assumption; a 100% cost pass-through can provide an upper-bound cost estimate.
- **Equipment and land costs:** Use secondary literature to indicate whether equipment and land costs could increase from carbon or other emissions pricing. The effect is likely to be indirect and might be negligible.
- **Cost of finance**: Carbon policy costs leading to increased risk of asset-stranding suggest that financing costs could rise also. Use secondary literature to determine the nature of risks.

Determine the impact on domestic and international demand:

- **Domestic demand:** A price elasticity from secondary literature can be combined with an estimated or guessed price shock on the sector's product to approximate impacts on demand. Alternatively, secondary literature can be used to assess qualitatively how sensitive the sector's market is to price shocks.
- **International demand:** If key markets are affected by carbon pricing, repeat the steps of the analysis as above in domestic demand.

Step 6.3: Assess the downside impact of prioritised conduct

Analyse the capacity to pass through the cost increase to consumers. Sector-specific estimations of cost pass-through can give an indication. However, for many sectors these estimates tend to vary substantially and have limited explanatory power. Alternatively, an analysis of the market structure and profit margins can help to understand cost pass-through capacity qualitatively. The European Commission (2018) qualitative assessment provides a good framework for this assessment.

Step 6.4: Assess upside effect of current or future carbon pricing on prioritised conditions

Determine the impact on domestic and international demand:

- **Domestic demand:** A price elasticity from secondary literature can be combined with an estimated or guessed price shock on the sector's product to approximate impacts on demand. Alternatively, secondary literature can be used to assess qualitatively how sensitive the sector's market is to price shocks.
- **International demand:** If key markets are affected by carbon pricing, repeat the steps of the analysis as above in domestic demand.

Step 6.5: Assess the upside impact of prioritised conduct

Analyse the capacity for investment and innovation based on historical data:

- **Process and product innovation:** Analyse two to three main abatement options. Identify barriers to innovation and what role carbon pricing plays in overcoming them. Use historical data from within the sector or from an analogous sector in response to a carbon policy/regulation if available. Draw comparisons pre- and post-carbon policy/regulation between the change in R&D expenditure and/or the change in number of patents. Careful consideration should be applied as these are not perfect proxies for innovation but the best currently available.
- **Investment:** Use historical data from within the sector or from an analogous sector to determine the capital available and/or the ability of a sector to make investments as a proxy to measure the relative impact of cost pressures that enable innovation. This can be done by measuring the change in investment per unit of output in response to a carbon policy/regulation. Alternatively, benchmark the best available technologies/processes for a given sector and compare the best sector's costs versus return on investment with the firm being assessed.
- **Long-term strategic choices:** Qualitatively determine from within the sector or from an analogous sector in response to carbon policy/regulation the impact on long-term strategic choices.

Step 6.6: Benchmark the UK sector's competitiveness under carbon pricing against competitors

Benchmark the results on conditions, conduct and performance of the UK sector against its competitors. Compare results of Steps 6.3–6.5 between the UK sector and main competitors. Provide the outlook of expected future development in carbon pricing.

5.1.7 Step 7: Conclusion

Conclude the analysis by drawing the insights together and taking future changes into account. This step builds on Steps 5 and 6 to conclude the assessment of competitiveness of the UK sector and the role carbon pricing plays. It should holistically account for all prioritised components of the framework. It should make limitations of the analysis transparent and provide an outlook on future changes to competitiveness. A summary of this step-by-step process is provided in Annex D.

6. Conclusion

Major changes in UK policies are likely to affect the competitiveness of UK firms, and policymakers need a tool to assess these changes. Multiple changes in UK policies are likely to affect many or all UK sectors and their competitiveness: The UK's exit from the EU can affect sectors' access to markets and inputs, among others; legislation on net zero emissions can increase sectors' operational costs, change consumer demand and will require substantial changes in production processes; and the Industrial Strategy (UK Government, 2017) can incentivise innovation activity in industrial sectors. All these policy changes are likely to impact the competitiveness of UK businesses relative to international peers. It is crucial for UK policymakers to understand the competitiveness of sectors in light of these policy changes.

This report builds a comprehensive and applicable framework for assessing UK business competitiveness by advancing the existing literature and discussing the framework with experts and UK government stakeholders. The existing literature includes conceptual frameworks that are difficult to apply and competitiveness assessments that are not grounded in theory. This work combines the existing literature with a comprehensive and applicable framework of competitiveness. It defines competitiveness as the capacity and ability of a firm or sector to gain and maintain a profitable, sustainable market share relative to rivals in domestic and international markets. The resulting framework has been discussed with departmental representatives, academics and internal experts from Vivid Economics and Energy Systems Catapult.

The framework shows how sectors face conditions and conduct themselves based on these conditions and the domestic policy and macroeconomic environment in order to improve performance. Conditions form the basis for establishing a sector's competitive edge and inform opportunities and constraints for its conduct, categorised into costs, and markets and products. Conduct covers the actions that a firm can take in the market, underpinned by its strategy and managerial and organisational ability. This ultimately affects the sector's performance, measured by market share and profitability over time. The framework is dynamic and its components are intertwined and have feedback loops. Finally, conditions, conduct and performance are embedded in the macroeconomic and policy environment.

Carbon pricing is a necessary instrument for industrial decarbonisation and can play an important role in making UK firms market leaders in a global low-carbon economy. Carbon pricing puts a price on emissions that cause large losses to the world economy, and is therefore a necessary instrument for any climate policy suite. Under net zero, carbon prices are expected to increase and the level of free allowances under an ETS will have to change with a shrinking cap. This could cause negative impacts for UK firms. However, carbon pricing also creates incentives for low-carbon technology innovation and adoption. It can help advance competitiveness of UK firms and make them market leaders in a global low-carbon economy. Understanding competitiveness under carbon pricing enables policymakers to design policies that mitigate the downside risks and facilitate upside opportunities.

This report analyses the role of carbon pricing in competitiveness by advancing traditional carbon leakage assessments within the framework. Existing carbon leakage assessments such as by the EU or California allow for a high-level assessment across a large number of sectors but fail to account for the magnitude of carbon cost

shocks, competitive dynamics and the options of conduct. This report provides a more holistic understanding of the downside risks and upside opportunities of carbon pricing for UK firms. It analyses carbon pricing through its initial impact on conditions and the options of conduct a sector can take to advance its competitiveness. It helps policymakers to understand risks and opportunities that stem from increased carbon pricing and decarbonisation in the next decades on the way to net zero and to formulate adequate policy responses.

This report forms the basis for an extensive application by providing stepwise instructions. The framework is expected to be used extensively across government in the future and aims to be a practical tool to study the competitiveness of UK firms. This report includes a stepwise process for policymakers to perform the analysis of a given UK sector from scoping to conclusion. It also includes further guidance on elements necessary for a detailed sector analysis. This forms the basis to apply the framework widely across government in order to analyse the competitiveness of UK sectors and the role of carbon pricing.

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Annex A: Empirical carbon leakage evidence

Table 8 summarises the empirical evidence on carbon leakage under carbon pricing schemes.

Table 8: There is no evidence of strong carbon leakage under the EU ETS

Sector	Author	Scope	Strong evidence of leakage
Iron and steel	Boutabba and Lardic (2017)	Phases I and II and part of Phase II of the EU ETS; 2005-15	No
	Branger, Quirion, and Chevallier (2017)	Phases I and II of the EU ETS; 2005-12	No
	Chan, Li, and Zhang (2013)	EU ETS before and after implementation; 2001-09	No
	Bruyn, Markowska, and Nelissen (2010)	EU ETS; 2005-09	No
	Ellerman, et al. (2010)	Phase I of the EU ETS	No
Cement	Boutabba and Lardic (2017)	Phases I and II and part of Phase II of the EU ETS; 2005-15	No
	Branger, Quirion, and Chevallier (2017)	Phases I and II of the EU ETS; 2005-12	No
	Chan, Li, and Zhang (2013)	EU ETS before and after implementation; 2001-09	No
	Ellerman, et al (2010)	Phase I of the EU ETS	No
Glass	Oberndorfer, Alexeeva-Talebi, and Loschel (2010)	EU ETS on prices in UK manufacturing;	Low-cost pass-through indicates some

		2001-07; selected products only	effect on competitiveness
Pulp and paper	Abrell, Zachmann, and Ndoye (2011)	EU ETS; 2005-08	No
	Anger and Oberndorfer (2008)	EU ETS on competitiveness in Germany	No
	Yu (2013)	EU ETS on competitiveness in Sweden; 2004-06	No
Chemicals	Bruyn, Markowska, and Nelissen (2010)	EU ETS; 2005-09	No
	Oberndorfer, Alexeeva-Talebi, and Loschel (2010)	EU ETS on prices in UK manufacturing; 2001-07; selected products only	No
	Yu (2011)	EU ETS on competitiveness in Sweden; 2004-06	No
All	Dong, Dai, Zhang, Zhang, & Long (2019)	China ETS pilots on GDPI 2006-2015	No

Annex B: Literature on international examples

This section presents three mature carbon markets and their experience of competitiveness in detail. The international analysis includes the EU ETS, the Californian ETS and New Zealand's ETS, covering their design, their policies to mitigate carbon leakage, and empirical evidence on competitiveness impacts.

EU ETS

The EU ETS is Europe's carbon pricing flagship for electricity, industry and aviation, but it has suffered from low allowance prices in the past. The EU established its ETS in 2005, and today it covers most greenhouse gases in electricity, industry and intra-EEA aviation. Allowance prices have remained below £10/tCO2e for most of Phase III (2013–20), failing to trigger substantial emissions reductions beyond business-as-usual (Marcu et al., 2019). Prices being low is due to too many allowances and the parallel rise in renewable energy. Prices have increased recently, partly due to the announcement to remove excess allowances in Phase IV (2021–30) through the Market Stability Reserve. The EU is currently discussing the implementation of a net zero target which would also affect the EU ETS (European Commission, 2019).[28]

The EU ETS uses benchmarked free allowances for industry to mitigate competitiveness impacts, and some member states offer additional indirect cost compensation. Industry emitters receive free allowances based on an ex ante carbon leakage risk assessment, sector-specific benchmarks, and their historical emissions. Phase IV will retain this fixed sector benchmark approach but intends to update the benchmarks more frequently (The European Parliament and Council, 2018). In addition, many member states provide indirect cost compensation for electro-intensive sectors (see, for example, BEIS, 2018). The EU is currently debating the implementation of a border carbon adjustments for EITE industry instead or in addition to free allowances (European Commission, 2019).

The empirical literature does not find negative impacts of the EU ETS on competitiveness, and in fact finds some evidence of a positive impact on innovation and fixed-asset formation. The most comprehensive analysis by Dechezleprêtre et al (2018) finds no negative competitiveness impacts for firms in France, the Netherlands, Norway and the UK between 2005 and 2012. Instead, the comparison between regulated and unregulated firms shows an increase in profits and fixed-asset formation. The lack of carbon leakage is echoed in the recent paper by Naegele & Zaklan (2019), who find no impacts on trade flows. Some papers find negative impacts (such as Boutabba & Lardic, 2017), but they tend to be minor effects and constitute only a small part of the literature. The absence of negative competitiveness impacts may be attributed to high cost pass-through, low carbon prices, increased R&D activity (Calel & Dechezleprêtre, 2016) and leakage mitigation policies (Joltreau & Sommerfeld, 2018; SEO Economisch Onderzoek, 2017). These empirical studies of the EU ETS highlight how understanding the market

[28] The EU uses the term 'climate neutrality' for net zero.

structure matters for competitiveness appraisal, and emphasise how policy design can reduce the negative impacts of carbon pricing.

EU ETS experience has shown that the policy of substantial free allowances comes at various costs, including delayed decarbonisation, and the net zero target will not allow current levels of emissions to be maintained. Free allowances have reduced compliance costs for EU industries and mitigated some competitiveness impacts. However, the policy also comes at certain costs. Dechezleprêtre et al (2018) find that installations with over-allocation did not reduce their emissions under the EU ETS. Other side effects include less closure or replacement of inefficient plants (Verde, Graf, & Jong, 2019), excess output (Branger et al., 2015), and lower cost pass-through (Neuhoff & Ritz, 2019). Furthermore, free allowances generally reduce the revenues available for other policy objectives, such as household compensation or green investment support (World Bank, 2019b). However, a rapidly declining emissions cap under a UK and/or EU ETS will naturally reduce the role of free allowances and shift the focus to other leakage mitigation policies.

Californian ETS

California's ETS covers industry, electricity and transport as part of a larger policy suite. Launched in 2013 and covers industry and electricity, its remit was expanded to transport fuels in 2015 (CARB, 2017). However, the ETS cap effectively functions as a backstop for multiple overlapping climate policies, and the impact of the ETS on emissions reductions may be limited (Near Zero, 2017). As a result, allowance prices have remained below £15 /tCO2e (ICAP, 2018). The scheme has also been linked with Quebec since the end of 2014. The next compliance period in 2021 will introduce changes to the supply adjustment mechanism and offset rules (ICAP, 2019b).

California uses output-based allocation to mitigate carbon leakage and carbon border adjustments for electricity. Industry emitters receive allowances based on their ex ante carbon leakage risk[29] and a sector benchmark, similar to the EU. However, the number of allowances depends on their current level of output rather than their historical output. This approach is called output-based allocation. Special rules apply to providers of electricity and natural gas. In addition to the free allowances, California has implemented carbon border adjustments for electricity. Electricity importers are required to hold allowances and electricity exporters do not have to surrender allowances (CARB, 2011).

There is no available empirical assessment of competitiveness impacts and the evidence is limited to ex ante estimations. To date, there is no ex post study on carbon leakage available, but only ex ante analysis studies of potential carbon leakage. This approach uses models to simulate competitiveness impacts at an assumed price (Vivid Economics, 2015). Ex ante assessments include the work by Gray, Linn, and Morgenstern (2016), who project substantial output loss for heavy industry. Cullenward (2014) estimates substantial carbon leakage risk in the electricity sector, and Hamilton, Ligion, Shafran, & Villas-Boas (2016) find similar results for food-processing. One of the reasons why ex ante studies of California find negative impacts, unlike ex post empirical analysis of the EU ETS, may be due to characteristics of ex ante modelling. For example, policy measures that are effective in addressing leakage, such as free allowances, are not modelled well in ex ante studies. Another reason may be the generally low carbon prices

[29] However, recent changes in legislation will provide the same level of support irrespective of the leakage risk category after 2020 (CARB, 2019).

(Vivid Economics, 2015). In addition, the Carbon Pricing Leadership Coalition has identified how carbon pricing is only one of many factors that influence competitiveness and investment choices (CPLC, 2019).

New Zealand ETS

New Zealand's ETS covers around half of the country's emissions and is the only ETS to cover forestry, although generous offset rules have weakened allowance prices substantially. The ETS covers forestry, electricity, industry and waste, accounting for approximately 51% of emissions (ICAP, 2019a). Coverage has increased over time and the country is currently debating the inclusion of agriculture, which has only reporting obligations at the moment. Prices have remained below £15/tCO2e in the past, and below £5/tCO2e between 2012 and 2016 (ICAP, 2018). Emitters were able to use international offsets generously to fulfil their compliance obligation, which weakened the allowance price substantially (New Zealand Productivity Commission, 2018).

New Zealand uses output-based allocation to mitigate carbon leakage risk. EITE sectors receive free allowances based on their emissions intensity, sector benchmarks and current level of output. The forestry sector received one-off free allowances at the launch of the scheme. The country is currently developing an auctioning mechanism (ICAP, 2019a).

Similar to California, there is no empirical assessment of competitiveness impacts, and only ex ante research is available. To date, there is no published ex post evaluation of competitiveness impacts from the New Zealand ETS. There are a few ex ante modelling studies available: the New Zealand Institute of Economic Research (2016) projects no negative impacts on the trade balance from an increase in carbon pricing ambition; a previous analysis with a different model estimates a reduction in national welfare if New Zealand were to introduce unilateral carbon pricing (NZIER and Infometrics, 2009). Nevertheless, none of these simulations has yet been verified by empirical evidence, and they generally rely heavily on model structure and assumptions.

Annex C: Sector archetypes

Table 9 assigns an archetype to each economic activity based on the importance of quality competition.

Table 9: Each economic activity is assigned an archetype

NACE 1.1	Economic activity	Archetype
1550	Dairy products; ice cream	Quality
1590	Beverages	Quality
1600	Tobacco products	Quality
1720	Textile weaving	Quality
1760	Knitted and crocheted fabrics	Quality
1820	Other wearing apparel and accessories	Quality
1910	Tanning and dressing of leather	Quality
1920	Luggage, handbags, saddlery and harness	Quality
1930	Footwear	Quality
2420	Pesticides, other agro-chemical products	Quality
2430	Paints, coatings, printing ink	Quality
2440	Pharmaceuticals	Quality
2460	Other chemical products	Quality
2820	Tanks, reservoirs, central heating radiators and boilers	Quality
2920	Other general-purpose machinery	Quality
2930	Agricultural and forestry machinery	Quality

2940	Machine-tools	Quality
2950	Other special purpose machinery	Quality
3120	Electricity distribution and control apparatus	Quality
3220	TV, and radio transmitters, apparatus for line telephony	Quality
3310	Medical equipment	Quality
3320	Instruments for measuring, checking, testing, navigating	Quality
3340	Optical instruments and photographic equipment	Quality
3350	Watches and clocks	Quality
3410	Motor vehicles	Quality
3420	Bodies for motor vehicles, trailers	Quality
3430	Parts and accessories for motor vehicles	Quality
3520	Railway locomotives and rolling stock	Quality
3530	Aircraft and spacecraft	Quality
3620	Jewellery and related articles	Quality
3650	Games and toys	Quality
1530	Fruits and vegetables	Price
1540	Vegetable and animal oils and fats	Price
1740	Made-up textile articles	Price
2010	Sawmilling, planning and impregnation of wood	Price
2020	Panels and boards of wood	Price

2040	Wooden containers	Price
2050	Other products of wood	Price
2110	Pulp, paper and paperboard	Price
2120	Articles of paper and paperboard	Price
2210	Publishing	Price
2410	Basic chemicals	Price
2510	Rubber products	Price
2610	Glass and glass products	Price
2640	Bricks, tiles and construction products	Price
2650	Cement, lime and plaster	Price
2660	Articles of concrete, plaster and cement	Price
2670	Cutting, shaping, finishing of stone	Price
2680	Other non-metallic mineral products	Price
2710	Basic iron and steel, ferro-alloys (ECSC)	Price
2720	Tubes	Price
2740	Basic precious and non-ferrous metals	Price
2830	Steam generators	Price
2870	Other fabricated metal products	Price
2960	Weapons and ammunition	Price
2970	Domestic appliances n. e. c.	Price

3110	Electric motors, generators and transformers	Price
3130	Isolated wire and cable	Price
3140	Accumulators, primary cells and primary batteries	Price
3230	TV, radio and recording apparatus	Price
3540	Motorcycles and bicycles	Price
3660	Miscellaneous manufacturing n. e. c.	Price
1510	Meat products	Intermediate
1520	Fish and fish products	Intermediate
1560	Grain mill products and starches	Intermediate
1570	Prepared animal feeds	Intermediate
1580	Other food products	Intermediate
1710	Textile fibres	Intermediate
1750	Other textiles	Intermediate
1770	Knitted and crocheted articles	Intermediate
1810	Leather clothes	Intermediate
1830	Dressing and dyeing of fur; articles of fur	Intermediate
2030	Builders’ carpentry and joinery	Intermediate
2220	Printing	Intermediate
2300	Coke, refined petroleum and nuclear fuel	Intermediate
2450	Detergents, cleaning and polishing, perfumes	Intermediate

2470	Man-made fibres	Intermediate
2520	Plastic products	Intermediate
2620	Ceramic goods	Intermediate
2630	Ceramic tiles and flags	Intermediate
2730	Other first processing of iron and steel	Intermediate
2810	Structural metal products	Intermediate
2860	Cutlery, tools and general hardware	Intermediate
2910	Machinery for production, use of mech. power	Intermediate
3000	Office machinery and computers	Intermediate
3150	Lighting equipment and electric lamps	Intermediate
3160	Electrical equipment n. e. c.	Intermediate
3210	Electronic valves and tubes, other electronic comp.	Intermediate
3510	Ships and boats	Intermediate
3550	Other transport equipment n. e. c.	Intermediate
3610	Furniture	Intermediate
3630	Musical instruments	Intermediate
3640	Sports goods	Intermediate

Note: Archetype based on estimated revealed quality elasticity (RQE) in Aiginger (2001): low RQE = Price archetype; medium RQE = Intermediate archeypte; high RQE = Quality archetype.

Annex D: Summary step process

Table 10 provides a summary of the step process.

Table 10: Summary

Step	Task	Sources
1	Scoping	
1.1	Sector classification at SIC level 3	-
1.2	Identify relevant sub-sectors at SIC level 4	ONS, industry reports
1.3	Archetype classification	Annex of Phase 1 report. UN Comtrade for sub-sector calculation
1.4	Determine geographical scope of the market	Industry, company or bank reports; academic literature, Competition and Markets Authority reporting
1.5	Identify main competitors	Industry, company or bank reports; academic literature; UN Comtrade for export market
1.6	Examine if other sectors need to be included	Industry, company or bank reports; academic literature
2	General data collection for UK sector	
2.1	Collect secondary quantitative data for the UK sector	National statistical offices, international databases Industry, company or bank reports; academic literature; government and NGO reports
2.2	Gather secondary qualitative information for the UK sector	Industry, company or bank reports; academic literature; government and NGO reports

2.3	Collect secondary data and information on carbon pricing for UK sector	National statistical offices, international databases Industry, company or bank reports; academic literature; government and NGO reports
2.4	Collect primary information through interviews	Semi-structured interviews with industry representatives; expert interviews if necessary
3	Initial assessment for UK sector	
3.1	Draw together data and information on UK sector	Data collection
3.2	Prioritise components	Archetypes
4	Targeted data collection for competitors	
4.1	Collect secondary quantitative data for competitors	National statistical offices, international databases Industry, company or bank reports; academic literature; government and NGO reports
4.2	Gather secondary qualitative information for competitors	Industry, company or bank reports; academic literature; government and NGO reports
4.3	Collect secondary data and information on carbon pricing for competitors	National statistical offices, international databases Industry, company or bank reports; academic literature; government and NGO reports
5	Assessment of general competitiveness	
5.1	Calculate performance metrics.	Data collection
5.2	Draw together data and information on competitors	Data collection

5.3	Benchmark UK sector against competitors	Metrics
6	The role of carbon pricing in competitiveness	
6.1	Assess if any of the conditions can generally be affected by carbon pricing in the sector	Data collection
6.2	Assess downside carbon pricing on prioritised conditions, taking into account allocation and rebate mechanisms	Data collection
6.3	Assess the downside impact on prioritised conduct	Data collection, assessment of general competitiveness
6.4	Assess upside effect of current or future carbon pricing on prioritised conditions	Data collection
6.5	Assess the upside impact of prioritised conduct	Data collection, assessment of general competitiveness
6.6	Benchmark the UK sector's competitiveness under carbon pricing against competitors	Metrics
7	Conclusion	

Annex E: Calculations for average carbon prices

Output-based allocation

For jurisdictions that calculate product benchmarks as a function of the average emissions intensity of facilities producing the same product, the average carbon price facing different products will be the same across products.

The generalised formula to calculate average carbon price:

$$\text{Average price} = \left(\frac{\text{average incremental cost (£)}}{\text{average emissions (tCO2e)}}\right)$$

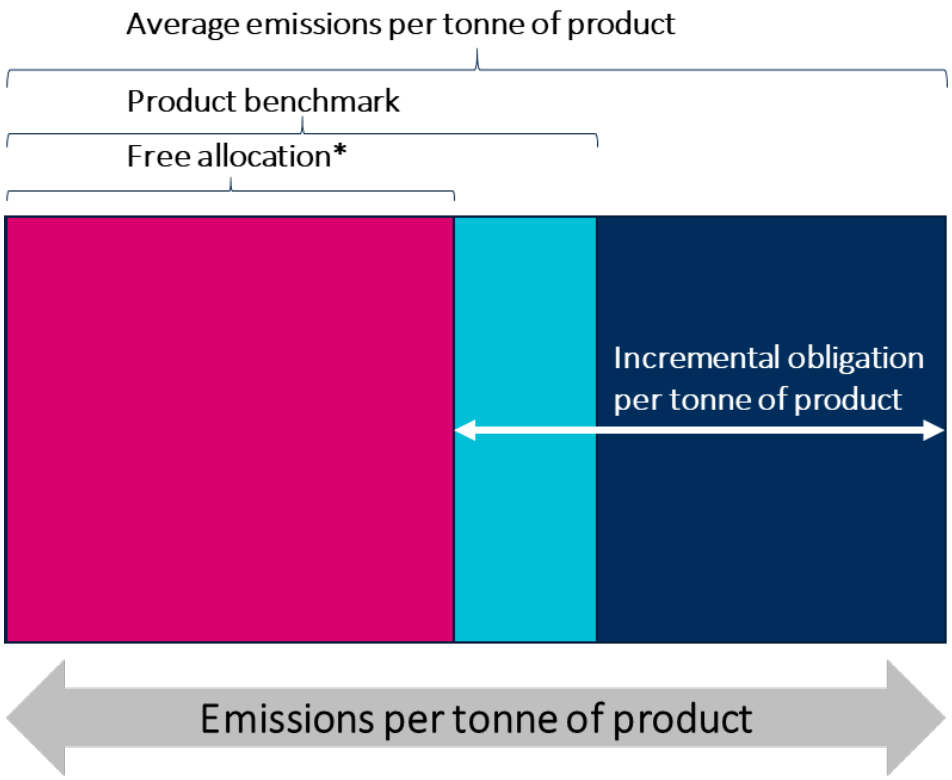
Where average incremental cost is:

Incremental cost = Incremental obligation × explicit carbon price

= (Actual emissions - free allocation) × explicit carbon price

= (Average emissions intensity -
(product benchmark × adjustment factor)) × explicit carbon price

Figure 10: Benchmarking and incremental obligation under output-based allocation



Note: *Free allocation often determined by multiplying product benchmarks by an adjustment factor that declines over time to provide a temporal abatement incentive.

Fixed sector benchmarking allocation

This calculation approach differs from output-based allocation as free allocation does not vary per tonne of annual production, but is fixed at historical levels which decline at pre-determined set rates.

The general approach to calculating average carbon prices for this methodology is as follows:

- First, collect annual production data for each relevant Prodcom code.
- Then take as a reference activity level the highest median annual production data.
- From this, calculate free allocation for every year using the other inputs into the allocation formula (e.g. the carbon leakage factor and product benchmarks).[30]
- This free allocation in the base year is then used to calculate the free allocation in the current year by multiplying the base year value by the current year's cross-sectoral correction factor (which takes into account the annual cap reduction under the EU ETS).
- Then calculate actual emissions from relevant products using data on the average emissions intensity for each product in the EU (based on previous analysis or secondary literature) and data on the production at the Prodcom code level 6.
- Due to precise emissions intensity values being unavailable, sensitivities on the average emission intensity are performed. There are high and low sensitivities. The range is created based on average of percentage change in emissions intensity for float glass, clinker, basic iron and steel, which are the emissions intensities available for the EU. No sensitivities in the values were made for geography.

This can then be used along with the free allocation to calculate the average carbon cost by identifying the incremental obligation per tonne of product in each year according to the formula for average price above.

Grandfathered allocation

To calculate the allocation provided to these firms, first the average emissions over this period as provided by firm-level data must be calculated. Emissions data for each year is needed to allow for a calculation of the shortfall of allowances in each year, and then hence the average carbon price.

[30] Other inputs obtained from EU policy documents.

Annex F: Stakeholder list

A workshop with government participants discussed the framework and collated feedback. It included representatives from the following organisations:

- Department for Business, Energy and Industrial Strategy (BEIS)
- Devolved Administrations: The Governments of Scotland, Wales and Northern Ireland
- HM Treasury
- The Committee on Climate Change

The framework has been further discussed with and reviewed by internal experts from Vivid Economics and Energy Systems Catapult, and by Misato Sato from the LSE Grantham Research Institute on Climate Change and the Environment.

Company profile

Vivid Economics is a leading strategic economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

We are a premier consultant in the policy-commerce interface and resource- and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world. The success we bring to our clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.

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