4. Optimal decarbonisation policy mix

This chapter presents theoretical insights from the literature on the “optimal” decarbonisation policy mix and links these insights to the specificities of the Netherlands. It also reviews existing research to present the current state of knowledge on the design of a decarbonisation policy portfolio. It first describes the range of decarbonisation policy instruments and underlying market failures that justify government intervention. It then presents the main takeaways from an existing state-of-the-art model developed for analysing interacting market failures and complements them with additional elements that are particularly relevant in the Dutch context (international competitiveness and carbon leakage, international knowledge spillovers, innovation path dependency, business dynamics and risk-sharing).

Achieving industry decarbonisation in the Netherlands requires a diverse set of policy instruments that account for specificities of the Dutch industry, namely small open economy with an industrial specialisation in emission-intensive trade-exposed activities, organisation around industrial clusters and strong integration in the European Union, both economically and politically. Keeping up the approach combining carbon taxation and innovation support is necessary to overcome the two-pronged barrier to industry decarbonisation, namely the lack of economic incentives both for carbon emissions minimisation and for long-term investments in low-carbon technologies. In addition, implementing policies that facilitate the provision of the necessary infrastructure and preserve business dynamism is required to enable both incumbent industrial firms' decarbonisation investments and innovative incumbents to emerge in the transition to the 2050 zero-net emission economy.

4.1. The wide range of policy instruments for decarbonisation

A myriad of policy instruments promoting a sustainable transition in the industry co-exist in the Netherlands and in other countries alike (Chapter 5, the current policy package). These instruments aim at achieving industry decarbonisation through different mechanisms addressing different intermediary objectives. Examples of such instruments include renewable energy portfolio standards, e.g. required production shares from wind and solar energy; emissions pricing, e.g. taxes or cap and trade systems; performance standards, e.g. maximum emission rates for steel production; financial incentives for R&D and subsidies for demonstration and technology deployment, e.g. tax credits or investment subsidies for green hydrogen production.

Pervasive interactions exist between decarbonisation instruments and create complex interplay between incentive mechanisms. Understanding whether "the whole is more or less than the sum of its parts" (i.e. whether these multiple policy interventions work together or at cross-purposes) is necessary for ensuring the efficiency and consistency of the portfolio of policy instruments and achieving decarbonisation (Fischer and Preonas, 2010[1]). For example, a policy portfolio including emission pricing and subsidies for low-carbon technology R&D and deployment can reduce carbon emissions at a significantly lower cost than any single policy alone (Fischer and Newell, 2008[2]). By contrast, in the presence of a binding emission cap, subsidies to renewable energy do not lead to further emission reductions but instead to a decrease in the price of emissions allowances, which often benefits the most carbon-intensive energy sources (Böhringer and Rosendahl, 2010[3]). International knowledge spillovers pose further challenges for the design of an efficient domestic decarbonisation policy mix. For example, fiscal support for photovoltaic energy production in developed countries in effect subsidised Chinese solar panel manufacturers' learning-by-doing (Peters et al., 2012[4]).

Understanding the interactions between instruments requires looking at their underlying rationale and the channels through which they operate. Recent OECD work proposes a new taxonomy allowing such an analysis based on two main dimensions (Criscuolo et al., forthcoming[5]). First, one can distinguish between supply-side instruments (e.g. innovation support policies) and demand-oriented instruments (e.g. taxes on carbon content, regulatory product standards or public procurement practices). Second, among supply-side instruments, one can distinguish those that affect efficiency within firms, e.g. R&D incentives, from those that affect the allocation of production factors between firms, e.g. framework instruments such as entrepreneurship, exit, competition and trade policies.

Critically, adequate framework conditions are a necessary complement to the policy mix for a cost-efficient decarbonisation. A dynamic business environment facilitates the green transition by enabling a reallocation of production factors from inefficient firms to more efficient firms – whether large incumbents, SMEs or start-ups. While competition is key to achieve such efficiency-enhancing reallocation, anti-carbon leakage policies can help maintain a level playing field between domestic firms and firms in environmentally laxer jurisdictions, and build a stronger and broader public support to the transition. Finally, regulation should strike the balance between credibility and adaptability in order to reduce the risk of investment in the transition.

4.2. Combined decarbonisation market failures: Technology and the environment

Two key market failures hinder decarbonisation. First, carbon emissions constitute an environmental externality, as the environmental damage from carbon-intensive production processes is borne by society as a whole – current and future generations in all countries – rather than internalised by the emitting firm. Second, technological change, which drives the cost-benefit trade-off of emission abatement over time, is subject to knowledge spillovers at both local and global levels, as firms developing or adopting a new technology create benefits for others while incurring all costs. These market failures imply that the market produces too much emissions and too little technology innovation, and their existence justifies policy intervention.

In theory, one policy instrument – namely a well-designed carbon price – would suffice to incentivise private industrial firms to internalise the external cost of CO_2 emissions *if the emission externality were the only market inefficiency*. In that case, policies that come on top of an emission tax or cap-and-trade system only distort the market allocation of emission abatement and, hence, increase overall abatement costs. However, *in the presence of additional market failures*, a carbon price alone cannot correct them all at the same time. In particular, the combination of carbon emission externalities and knowledge spillovers associated with technological innovation and adoption necessitates a portfolio of policy instruments that promotes both emission abatement and the development and diffusion of low-carbon technologies.[1]

The choice of an optimal portfolio of low-carbon and technology policy instruments in the context of pollution externality and knowledge spillovers is the object of a number of studies at the nexus between innovation and environmental economics.[2] For the purpose of this report, the general lesson from this literature is twofold. First, in an optimal scenario, carbon emissions are priced at their marginal external cost, R&D is subsidised at the spill over rate, and adoption is subsidised at the rate of learning-by-doing spill over. Second, actual policy contexts are significantly more complex than canonical models acknowledge, notably due to the existence of overlapping jurisdictions, the difficulty to identify and price all relevant market failures or even list all instruments, and the political economy of pricing externalities.

4.3. A benchmark framework for analysing decarbonisation policy mix

The economic literature on environmental and technology policy offers theoretical guidance regarding the design of a decarbonisation policy mix. For theoretical insights, this section relies on a state-of-the-art framework developed for analysing interacting market failures in the US power sector in order to gain general insights into industry decarbonisation (Fischer, Preonas and Newell, 2017[6]). The next sections discuss how the specificities of the Dutch industry affect the findings of the benchmark model.

In order to analyse the cost-efficiency of policy combinations for reducing emissions, the model under consideration includes four overlapping market imperfections: 1) an environmental externality due to carbon emissions; 2) knowledge spillovers from R&D; 3) learning-by-doing; and 4) undervaluation of the benefits of energy efficiency investments. The main conclusion is that complementing emissions pricing with technology support policies can reduce the overall cost of achieving decarbonisation in the presence of technology market failures, however, overcompensating for these failures can be welfare-decreasing.

Over-ambitious policies to support the deployment of non-fossil energy may not be cost-efficient alongside emissions pricing. Indeed, emissions pricing decreases the relative price of non-fossil energy and, thus, makes large deployment subsidies for non-fossil energy unnecessary, particularly in the case of mature technologies where learning-by-doing spillovers are relatively small. By contrast, strongly correcting market failures arising from R&D spillovers is typically a cost-efficient complement to emissions pricing to achieve significant emission reductions.[3]

In the case of the Dutch industry, a "simple" policy mix of domestic emission pricing and technology support is likely not sufficient because of the specific characteristics of the Netherlands, namely a small open economy with an industrial sector largely specialised in the production of carbon-intensive tradeable products. Therefore, the next sections discuss three key elements in the Dutch context:

- Carbon leakage and international competitiveness (OECD, 2020[7]).
- Cross-sector (Dechezleprêtre et al., 2013), cross-TRL (technology-readiness level)[4] stage (Popp, Hascic and Medhi, 2011[8])and cross-jurisdiction knowledge spillovers (Dechezleprêtre, Martin and Mohnen, 2017[9]), and path dependency (Aghion et al., 2016[10]).

In addition, the design of instruments is important for the efficiency of decarbonisation. Two further factors are discussed below:

- the role of business dynamics for innovation, including the provision of "green skills" and
- uncertainty and imperfect commitment, which call for risk-sharing and signalling.

Further factors potentially affect the decarbonisation policy mix but fall beyond the scope of this report, focused on the manufacturing sector: technical factors related to energy supply, such as intermittency of renewable or grid matters; strategic and resilience-related factors such as energy supply diversification.

Finally, the considered framework offers insights into Scope 1 and Scope 2 emissions, namely direct emissions and indirect emissions associated with the production of purchased electricity, heat and steam. It does not tackle Scope 3 emissions, namely other indirect emissions associated with the extraction and production of purchased materials, fuels, and services, including transport in vehicles not owned or controlled by the reporting entity, outsourced activities, waste disposal, etc. Reduction of Scope 3 emissions is discussed in the sections on recycling and bio-based materials in Chapter 7 on emerging technologies.

4.4. International competitiveness and carbon leakage

Unilateral environmental policies may create international cost competitiveness issues.[5] As they affect the cost structure of domestic carbon-intensive industries (and potentially all along the value chain), domestic producers can be put at a cost disadvantage relative to foreign (unconstrained) producers vis-à-vis both imports and exports, which could affect investment and production location decisions in the longer run, in particular in small open economies (Chapter 8).

Specifically, tighter environmental regulation can provide incentives for firms in emission-intensive trade-exposed (EITE) industries to shift production to laxer jurisdictions – the so-called pollution haven hypothesis.[6] Such production shifting can happen through incumbent domestic firms relocating abroad and/or increasing their holdings of foreign assets (outward foreign direct investment), as well as through new firms choosing foreign locations and foreign firms reducing domestic investment (inward foreign direct investment). While available empirical evidence supports the pollution haven hypothesis, the magnitude of the effect has been found to be small – e.g. Garsous, Kozluk and Dlugosch (2020[11]).

Overall, OECD research shows that implementing more stringent environmental policies has had little aggregate effect on economic performance over the last three decades, despite achieving significant environmental benefits (OECD, 2021[12]). Yet, small average effects across the economy hide heterogeneous impacts across industries and firms. Environmental policies create winners and losers as capital and labour are reallocated from high-emission to low-emission industries and firm (OECD, 2021[12]). On one hand, more stringent environmental policies negatively affects the performance of EITE industries, at least in the short run – e.g. steel and petrochemicals, Aldy and Pizer (2015[13]) – and of the least-productive firms. On the other hand, environmental stringency positively affects the productivity of front-runner industries and firms and the exports of low-pollution industries.

Carbon leakage is a possible consequence of unilateral carbon pricing policies and the resulting disparities in the carbon price across countries, whereby part of the emissions avoided through domestic environmental regulations are shifted to other locations. Meta-estimates of the magnitude of the leakage rate (defined as the ratio of foreign increase in emissions over domestic reductions) from *ex-ante* analyses based on computable general equilibrium models lie in the 5-25% range at the aggregate level (Branger and Quirion, 2014[14]). Yet, large disparities across industries reflect differences in carbon intensity and trade exposure, with partial equilibrium showing leakage ratios of up to 30% in aluminium industries and 50% in steel industries (Demailly and Quirion, 2008[15]). Moreover, leakage is larger the smaller the economy implementing unilateral emission pricing and the more ambitious the reduction target (Böhringer, Fischer and Rosendahl, 2014[16]).

By contrast to ex-ante analyses, *ex-post* evaluations suggest that competitiveness concerns have been overstated to date (Arlinghaus, 2015[17]; Flues and Lutz, 2015[18]). These evaluations typically find only a small effect of climate policies on carbon leakage and competitiveness, especially when compared with other determinants of trade and investment location decisions (Venmans, Ellis and Nachtigall, 2020[19]). However, the small effects observed so far may be driven by the low stringency of past climate policies, which, lacking strengthening, would fall short of achieving the net-zero emission economy by 2050. Policies that are more ambitious may have greater effects if they increase the cost handicap vis a vis trading partners, in particular if EITE industries display threshold effects and non-linearities in the relationship between environmental and economic performance.

From a theoretical perspective, disparities in carbon pricing may lead to leakage through several channels (Cosbey et al., 2019[20]):

- The competitiveness channel, due to the substitution from domestic carbon-intensive goods production, changes in FDI patterns or offshoring of carbon-intensive production (“direct leakage” or “trade channel”).
- The energy market channel, due to the price effect of reduced domestic consumption of fossil fuels on the world fossil fuel market (“indirect leakage” or “international energy price channel”).[7]
- The income channel, due to changes in real exchange rates triggered by the introduction of carbon pricing, which affects the terms of trade and, therefore, global income distribution.[8]
- The technology spillovers channel (negative leakage, i.e. lower foreign emissions), due to carbon policies inducing innovation which spills over and lead to emission reductions abroad (see the section below).

Concern regarding potential competitiveness issues both undermines global decarbonisation efforts and erodes industry support for climate policy, calling for policy intervention to level the playing field (OECD, 2020[7]). Two main types of instruments can partially tackle the issue by addressing direct leakage (or competitiveness channel): border carbon adjustments (BCA) and domestic taxes and subsidies.

A BCA consists of trade measures to put products from foreign producers who operate without a carbon price on an even footing with products from domestic producers who face a carbon price – see e.g. OECD (2020[7]) or Cosbey et al. (2019[20]). For example, one version of a BCA could combine a domestic carbon price with a mechanism that sets a price at the border and an export rebate, based on the carbon content of products and the domestic carbon price, effectively only taxing emissions from domestic consumption.[9] A meta-analysis of ex-ante studies based on computable general equilibrium models suggests that a BCA would significantly reduce direct leakage (Branger and Quirion, 2014[14]). Beyond addressing the direct leakage issue, a BCA has two main advantages: 1) for countries being affected by the BCA, it changes the benefit of co-operating in climate agreements (Helm, Hepburn and Ruta, 2012[21]); and 2) it is politically acceptable in the implementing jurisdiction. However, it has two major drawbacks: 1) observing carbon content of imported products is challenging;[10] and 2) implementation must be at the level of a free trade area and faces WTO legal uncertainty.

Domestic taxes and subsidies consist in the combination of a carbon consumption tax and a carbon price, potentially including output-based rebates or other types of subsidies, such as abatement payments. In theory, such a combination can achieve the same result as a BCA (Grubb et al., 2020[22]; Pollitt, Neuhoff and Lin, 2020[23]; Böhringer, Rosendahl and Storrøsten, 2017[24]; Böhringer, Rosendahl and Storrøsten, 2019[25]). While the challenge of observing carbon content remains, the advantage of such an option is that it can be implemented unilaterally by any country within a free trade area.

When overlapping with supranational emission trading schemes, unilateral carbon pricing may have another leakage effect, referred to as the "waterbed effect". For example, in the case of the EU Emission Trading System (ETS), any unilateral emission reduction is exactly offset by an emissions increase elsewhere absent in the compensation mechanism: the "waterbed effect" is 100%. Compensation mechanisms, such as the newly-implemented EU ETS Market Stability Reserve, "puncture" the waterbed by cancelling a fraction of surplus allowances so that unilateral action can achieve emission reductions overall instead of just leading to leakage within the system. While the effect of such compensation mechanisms remains debated, overlapping unilateral policies can be designed to limit the waterbed effect – e.g. Perino, Ritz and Benthem (2019[26]) or Böhringer and Fischer (2020[27]).

4.5. Cross-sector, cross-country and cross-TRL knowledge spill over and path dependency

Green and low-carbon knowledge spills over, in particular: 1) across sectors (Dechezleprêtre et al., 2013); 2) across countries (Dechezleprêtre, Martin and Mohnen, 2017[9]), as domestic technology investments decrease the global price of renewables (Fischer, Greaker and Rosendahl, 2018[28]);[11] and 3) across different stages of the innovation and adoption process or TRLs (Popp, Hascic and Medhi, 2011[8]). From an efficiency perspective, this suggests that knowledge spillovers should be tackled at the largest possible level of (supranational) government.

Technological knowledge spills over across different stages of the innovation and adoption process (i.e. across different TRLs), implying that instruments favouring innovation have an effect on adoption. However, innovation does not necessarily fully translate into adoption even though it removes technological barriers (Popp, Hascic and Medhi, 2011[8]), which raises the issue of absorptive capacity (Aghion and Jaravel, 2015[29]) and of financing and risk sharing (Section 4.7). The necessary co-ordination arising from the complexity of technological spill-over patterns is an argument for resorting to green industrial policy (Criscuolo et al., forthcoming[5]).

The stock of local knowledge affects geographical spillovers: a firm is more likely to innovate in clean technologies if its "inventors" are located in countries where other firms have been undertaking more clean innovations (Aghion et al., 2016[10]). The effect of the local knowledge stock is likely to be magnified by trade, as the exposure of domestic firms to foreign exporters' technology promotes further innovation (Aghion et al., 2019[30]).

Technological change is characterised by path dependency, i.e. persistence of technological change along well-defined pathways. Technology regimes are an assemblage of technological artefacts, institutions and regulations, so change tends to be cumulative and competing regimes rarely emerge (Berkhout, 2002[31]). Such path dependency can lead to inefficient lock-in, as learning-by-doing and increasing returns to scale lead to systematic exclusion of competing and possibly superior technologies (Arthur, 1989[32]). It can also lead to institutional entrapment, that is, embedded institutional, political and economic commitments to a particular technology (Walker, 2000[33]).

Path dependency is a key issue for decarbonisation, as dirty innovation is more likely at firms that already performed dirty innovation (Aghion et al., 2016[10]). The presence of an environmental externality implies inefficiently high innovation in dirty technologies in the decentralised equilibrium, calling for governments to "re-direct" innovation and restore the social optimum based on a mix of innovation subsidy and emission pricing (Acemoglu et al., 2012[34]).[12]

An important policy consequence is the risk involved with privileging specific technologies to achieve decarbonisation. However, promising the technologies, path dependency implies the existence of a trade-off between focusing exclusively on these technologies and maintaining a diverse range of options to preserve reversibility. While preserving reversibility is costly, especially for a small economy like the Netherlands, articulating a hybrid strategy of relying on co-ordinated supranational R&D effort, e.g. at the European Union level, while supporting the deployment of a broader range of technologies, is a potential strategy.

Moreover, if the only rationale for green innovation is emission reduction, one may wonder whether the government of a small open economy with important absorptive capability should have its own R&D and innovation programs at all, or rather promote technology diffusion (i.e. focus on end of TRL stages) and rely on international (in particular European) R&D subsidy initiatives. If another rationale is technological leadership, an option is investing a few selected technologies, if possible, in co-ordination with European countries, and absorbing the rest.

4.6. Business dynamics

Decarbonisation policy instruments aim at affecting the structure of the economy and, therefore, interact with business dynamics and the level of competition. In general, horizontal instruments intended for the green transition that affect firms across the board are not detrimental to competition; on the contrary, they can contribute to fostering business dynamics to the extent that they promote innovation. By contrast, targeted instruments – either technology-specific or location-specific – may give an advantage to specific firms over others if badly designed and create barriers to firm entry and exit; ultimately, this may slow down innovation and decarbonisation.

Encouraging the entry of new, innovative firms and the exit of less productive firms is thus key and complementary to decarbonisation incentives. Start-ups are often the vehicle through which radical innovations enter the market, while older incumbent firms often focus on incremental changes to established technologies. Lack of business dynamism may prevent low-carbon innovations from overtaking fossil fuel-based incumbents and secure market shares, even if they are more efficient.

Distinguishing instruments that affect firm performance ("within instruments") from those that affect the allocation of production factors between firms ("between instruments") is key for understanding innovation dynamics. On one hand, "within" instruments such as R&D tax credits and subsidies help to address the under-provision of investment in low-carbon technologies by internalising knowledge externalities. On the other hand, "between" instruments promoting the reallocation of production factors from old to young firms with a superior technology can be a major driver of aggregate productivity, including carbon efficiency (Aghion and Howitt, 1992[35]). By enabling entrants and small firms to compete and eventually challenge large incumbents, promoting reallocation can have an indirect positive effect on both challengers' and incumbents' incentives to innovate, in particular in low-carbon technologies.

In addition, the knowledge spill-over theory of entrepreneurship suggests that, by promoting the spin-off of existing but not commercialised environmental knowledge from incumbent firms, between instruments support growth within entrepreneurial firms in the low-carbon energy transition (Malen and Marcus, 2017[36]; Colombelli and Quatraro, 2019[37]).

Green skills –defined as those “needed by the workforce, in all sectors and at all levels, in order to help the adaptation of products, services and processes to the changes due to climate change and to environmental requirements and regulations” (OECD, 2014[38]) – are a necessary complement to green supply-push policies. Green support programs have been shown to be more effective in geographic areas where green skills are more prevalent (Chen et al., 2020[39]).

4.7. Risk sharing and signalling

Investment risks related to decarbonisation are relatively large. Financing costs are typically larger for low-carbon technologies, as these are often more capital-intensive than high-carbon ones, for which the main costs are fuels (Steckel and Jakob, 2018[40]; Schmidt, 2014[41]; Hirth and Steckel, 2016[42]). Moreover, uncertainty is significant regarding which low-carbon technologies will emerge.

Green risk sharing, or green de-risking, decreases the risk of low-carbon investments, thereby lowering the financing costs of emission abatement and promoting decarbonisation (Steckel and Jakob, 2018[40]).[13] Risk sharing transfers parts of the expenses associated with the realisation of a negative event away from the investors to other parties, typically the public sector, e.g. risk insurance, contracts for difference or guarantees provided by development banks. Government-sponsored green venture capital funds and government funds of green funds also contribute to sharing the risk of low-carbon investments.

In addition, the risk of low-carbon investments also comprises the uncertainty stemming from the regulatory environment over the run of projects, which dampen decarbonisation (Popp, Newell and Jaffe, 2010[43]). Volatile emission prices also weaken low-carbon investment (Flues and van Dender, 2020[44]). Policy instruments that stabilise the price of carbon or signal the government’s long-term commitment to a pre-determined price path, possibly set by law, also improve the risk-return profile of investments in low-carbon technologies.

4.8. Value chain emissions

Focusing on direct emissions only offers a partial picture when it comes to industry decarbonisation. Indirect emissions from the generation of purchased energy (Scope 2) and those associated with the extraction and production of purchased materials, fuels, services, (outsourced activities including transport, waste disposal, etc.) and use of sold products (Scope 3) are typically large in the industry, and larger than direct (Scope 1) emissions (Hertwich and Wood, 2018[45]). Therefore, constantly addressing carbon emissions along the entire value chain is necessary.

Long-term carbon neutrality implies a quasi-fully circular economy. For the industry, neutrality raises the issue of end-of-life emissions of sold products. The combination of designing products in order to minimise end-of-life emissions and recycling industrial waste, offers a way forward for the industry, which heavily hinges on the use of synthetic and bio-based feedstock.

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Notes

[1] Jaffe et al. (2005[46]) for a discussion on the combined technology and environmental market failures and Goulder and Parry (2008[47]) for a general discussion of instrument choice in environmental policy.

[2] For example Braathen (2007[54]), Fischer and Newell (2008[2]), Fischer (2010[48]), Böhringer and Rosendahl (2010[3]), Fischer and Preonas (2010[1]) and Fischer, Preonas and Newell (2017[6]).

[3] Imperfections in demand for energy efficiency investments have important effects on the optimal policy mix, as they make policies that lower energy prices, such as deployment subsidies, less desirable. While this conclusion from the model under consideration is based on household behaviour regarding energy efficiency, and even if the industry is usually assumed to be more energy-efficient, it remains relevant for the purpose of this project as there exist negative abatement opportunities in the Dutch industry (PBL, 2018[55]).

[4] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf.

[5] Unilateral emission pricing also creates efficiency issues, as abating emissions in a cost-efficient way requires one and only one price for carbon globally (Chapter 8).

[6] By contrast, the Porter hypothesis suggests that stringent environmental regulations stimulate productivity growth via efficiency improvements and innovations aimed at avoiding the policy-induced cost of polluting. Empirical studies point to the validity of the Porter hypothesis for the most productive firms (Albrizio, Kozluk and Zipperer, 2017[49]).

[7] The energy market channel is both quantitatively important (Branger and Quirion, 2014[50]) and the most difficult to address without global carbon pricing. However, it is likely to be limited for the Dutch economy, as it represents only a small share of world GDP and energy consumption.

[8] The income channel also leads to domestic reallocation from energy-intensive sectors to the others: as the competitiveness of the energy-intensive sector deteriorates, the relative competitiveness of the other sectors improves.

[9] Analogue to the implementation of value added taxes for traded products.

[10] Solution to this challenge include proposals for a “voluntary individual adjustment mechanism” allowing producers to demonstrate that their actual carbon intensity lies below a given default value (Mehling and Ritz, 2020[51]).

[11] International technology spill over may mitigate the negative impact of carbon leakage on global emissions. The spill over of policy-induced energy-saving technological innovation in the home region to the foreign region may offset carbon leakage by improving the efficiency of foreign firms (Gerlagh and Kuik, 2014[52]). However, this mechanism is of a lower-order for small open economies, as their effect on the global stock of knowledge is likely to remain small.

[12] Consistent with the argument in previous sections, relying on emission pricing alone to direct technological change has a large welfare cost in the transition (Acemoglu et al., 2016[53]).

[13] As private investment decisions are made based on the risk-return profile of investment opportunities, decarbonisation policies can either increase the return on low-carbon investments through environmental and technology policy instruments or decrease the downside risk of low-carbon investments.

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