Climate Change: The Cost of Transition

We have integrated the available industry-level climate change transition research from multiple sources and included climate change transition as the fourth long-lasting trend in Mira ABM, along with automation, ageing population and globalisation/trade conflicts.*

The transition of our economy in response to the climate change has begun in the earnest and is likely to continue in the years to come. The ultimate physical impact of climate change is arguably still uncertain, not least because it depends on the speed and extent of the policy reaction of major countries. Yet, there are energy transition facts that are already having significant impact on global supply chains, economic development and consequently, on asset pricing. Most importantly, these transition facts ***will continue*** to have impact on asset pricing in the foreseeable future, which qualifies climate change as the fourth long-lasting trend included in Mira ABM – our strategic asset management platform, along with ageing population, automation, and globalisation/trade conflicts.

Attempts to account for climate change in asset pricing so far have been focused on top-down macroeconomic analysis. Such analysis often misses the complexity of the underlying supply chain shifts. At the same time, there are detailed industry-specific studies covering climate change; however, they are fragmented and focused on individual industries. In this report, LINKS have tried to combine the body of knowledge on climate change from multiple industries into a single supply chain picture and draw conclusions with respect to asset prices.

*) Download LINKS Mira Agent Based Model (ABM): a class of models for simulating the interactions of organizations or groups with a view to assessing their effects on the system as a whole:
https://linksanalytics.com/request-trial

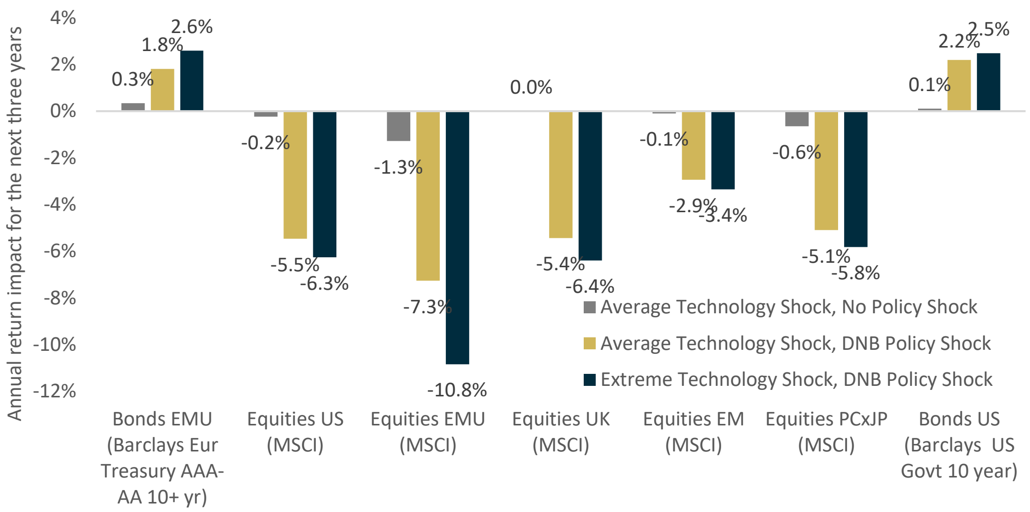
There are significant challenges in integrating analyses and thoughts across multiple industries and regions. Regulation and policy direction differences, disagreements in technology, approach and even conflicting pricing information for similar products (e.g. batteries) suggest that the results should be viewed as a direction and scale indication rather than precise forecast. We believe that the conclusions and calculations give a fair indication of the direction and scale of the impacts of climate change transition across industries and asset classes.

The energy transition scenarios introduced in this issue of Risk Wire broadly follow the scenario definitions of the De Nederlandsche Bank (Vermeulen, et al., 2018) (we will refer to this report as the DNB report) at least in the definition of extreme stress scenarios; however, they differ from the DNB scenarios both in terms of calculation methodology and areas of application in two important ways:

- **Coverage of less extreme outcomes:** while DNB covers severe yet plausible scenarios that have low probability of occurring, we additionally propose “average” scenarios that in our assessment are likely to occur. This underlines the importance of treating energy transition as a **long-lasting trend** rather than an **extreme scenario**.
- **Bottom-up business-driven methodology:** we look at the industry-level consequences of technological shocks, including the possible substitution effects, impacts on margins of various industries experiencing shifting business models. This yields a picture that diverges somewhat from the CO_2-centric top-down analysis, as it is explained in the Approach section.

Our findings suggest that most equity indices already experience a performance headwind of between -0.2% and -1.3% annually (Figure 1). The annual “cost” of transition may accelerate significantly to high a single-digit level if the DNB policy shock of sharply higher emission pricing is applied.

Figure 1: Climate transition scenario impact on various asset classes. Source: LINKS Mira ABM



There are major impact differences across regions and asset classes, which means that conclusions with respect to portfolios are best handled directly in Mira ABM.

Assumptions and Approach

A number of modelling choices have been made due to the nature of the climate change risk:

Choice 1: All impact has been assessed and implemented as a **long-lasting trend** rather than a **short-term stress scenario**. Mira ABM implementation of climate change risks can be used to assess the impact of more or less accellerated transition path. Short-term stress scenarios in our framework are temporary in nature, with the structure of economic relationships and business models returning to normal following a stress period, which makes them inappropriate for assessing climate change transition effects.

Choice 2: A broad technological impact on supply chains has been considered, rather than CO_2 or greenhouse gas (GHG) emissions alone. To illustrate the importance of this, for instance, the automotive industry (including its supply chain) emits average level of GHG compared to other industries, which is reflected in average losses in the DNB report. However, the product of the automotive industry (a car) is responsible for a large part of GHG emissions and is subject to tightening regulations and the most seismic technological shift in the last 100 years. Moreover, changing fuel source of the vehicle fleet has major repercussions for the utilities, energy, petrochemicals and plastics industries. These effects would be missed, were we to focus only on GHG emissions of the industry.

Choice 3: This study begins at the industry level and is then aggregated to arrive at asset class return estimates. We find top-down (macroeconomic) modelling of climate change challenging, since by default climate change transition assumes a degree of disruption that renders historical relationships unstable. The relationship between oil price, GDP growth rate and CO_2 pricing, for instance, is very likely to break down quickly and even reverse as more alternative energy sources become available.

Our approach begins at the industry level of GICS (Global Industry Classification Standards)[1], whereby each of the 63 industries is assessed with respect to:

- Current greenhouse gas emissions (GHG) of the production process, including the supply chain impact
- The industry's main product's GHG emissions and current/expected regulations
- Available commercially viable technological alternatives for the industry
- Implication for the industry's profitability, assuming a minimal, average and extreme pace of transition

We use industry-specific research and regulatory sources to identify key trends, technologies and challenges. Most significant assumptions by industry are sourced from external sources and referenced accordingly. Regulatory, taxation and technological shifts are then assessed to estimate the impact of three different paces of transition (minimal, average and extreme) on:

- stranded assets, i.e. book value write-offs
- earnings given the new technologies and business models
- sustainable returns-on-equity (ROE's) going forward

[1] GICS has been elected as the classification standard here as opposed to NACE used in Mira ABM in order to remain relevant to the equity market, as GICS is specifically developed for equity markets and ignores non-listed industries.

The resulting ROE impacts are then aggregated by region and industry to arrive at regional ROE's. The changes in ROE's are used then in Mira ABM pricing module to assess the impact on regional equities.

We also assess the direct impact on all industries of $100 CO_2 emission price, which is the focus of the **policy shock** scenario in the DNB report. Since the distribution of CO_2 emissions by industry is very uneven, most of the stress is on the Utilities sector. In our view, a scenario which wipes out ALL the book value of the power generation companies and renders them bankrupt is borderline implausible[2], so we have limited CO_2 price "tax" for utility companies at $60 per ton, which is the level at which most of the profits disappear, without causing financial distress.

Scenario Definition

As in the DNB study, we have implemented both policy shock and technology shock dimensions of a scenario. However, there are three sub-categories ("minimal", "moderate" and "extreme") in the technology shock dimension, with the "moderate (normal or average)" sub-categories reflecting a non-extreme, most likely scenario (Figure 2).

Figure 2: Scenario definition, LINKS Mira ABM

	No CO2 price increase	CO2 price $100 ($60 for utilities)
Minimal	Minimal change in technology and policy, airline fuel taxation of 10%, introduction of 6% VAT on air tickets, electric car fleet of 24%, wind/solar generation-22% in the mix.	Minimal change in technology and policy, airline fuel taxation of 10%, introduction of 6% VAT on air tickets, electric car fleet of 24%, wind/solar generation-22% in the mix. CO2 prices increase to $100
Moderate	Normal change in technology and policy, airline fuel taxation of 25%, introduction of 10% VAT on air tickets, electric car fleet of 27%, wind/solar generation-25% in the mix.	Normal change in technology and policy, airline fuel taxation of 25%, introduction of 10% VAT on air tickets, electric car fleet of 27%, wind/solar generation-25% in the mix. CO2 prices increase to $100
Extreme	Extreme change in technology and policy, airline fuel taxation of 25%, introduction of 20% VAT on air tickets, electric car fleet of 84%, wind/solar generation-60% in the mix.	Extreme change in technology and policy, airline fuel taxation of 25%, introduction of 20% VAT on air tickets, electric car fleet of 84%, wind/solar generation-60% in the mix. CO2 prices increase to $100

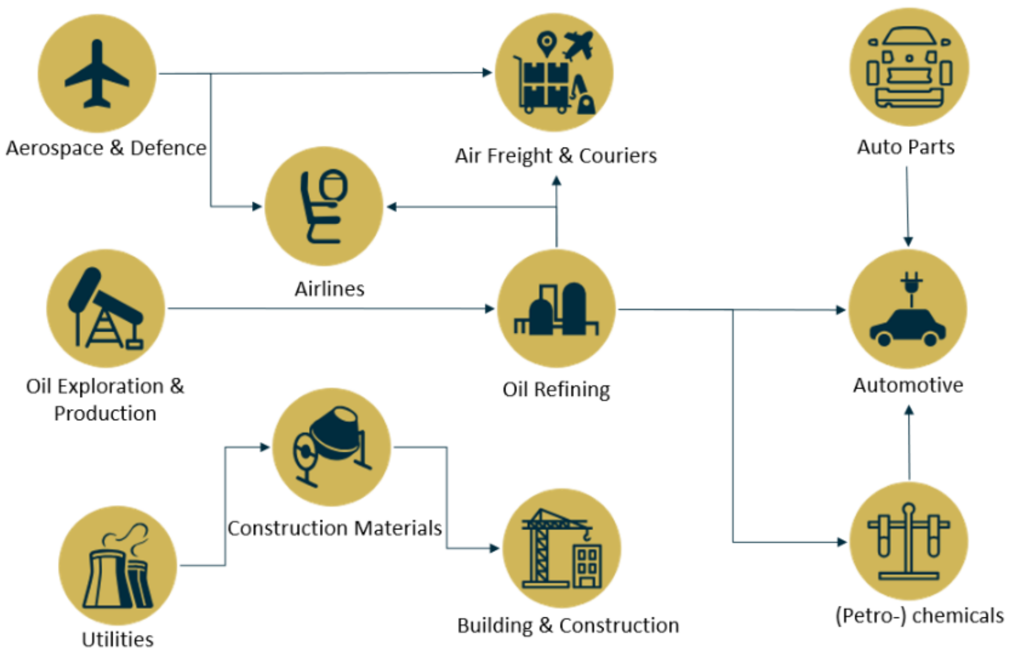
It should be noted that the DNB study proposes a scenario of no-technology and no-policy shock, i.e. the "do nothing" scenario, which is defined as the increasing anxiety in the markets due to pending physical/regulatory effects of climate change and across-the-board risk premium increase. Since varying degrees of "anxiety" scenarios can be easily simulated in Mira ABM without specific climate change reference, we do not include this scenario in the report.

[2] Arguably, it is also unfair to place the burden of all transition on utility companies, as the rest of the economy is the beneficiary of power generation.

Changes in Supply Chains

Although most industries do emit GHG and need to react one way or another, there are the "usual suspect" industries that are in the focal point of climate change transition, broadly: power generation, mining, energy, transport. Most studies focus on technologies available in these industries[3]. It is important, however, to consider the complete supply chains and their relationships as well: if for instance, the automotive industry shifts from internal combustion engines to the electric drive train, the impact will be felt by the automotive components, utilities, oil and other industries (Figure 3).

Figure 3: Industries at the centre of climate change transition



In the following sections we briefly describe the ongoing regulatory and technological disruptions. It is best to consult the relevant studies referenced in each section for a more detailed discussion of industry-specific dynamics. The specific assumptions for each industry are presented in the Appendix.

Aerospace & Defence

The civil aircraft industry does not produce much GHG in the production phase, however, just like with the automotive industry, its end product is responsible for significant year-on-year increases in emissions due to the rapid growth in air traffic (Murphey, 2016).

Policy alternatives considered in the industry include:

- Introduction of VAT for air travel (currently exempt): we assume a VAT introduction range of 6% to 20%

[3] See for instance (Berg, Clapp, Lannoo, & Peters, 2018) or (Enkvist & Naucler, 2009) for detailed coverage of most exposed industries

- Aviation fuel taxation: we assume a range of 10% - 100% tax (see the Appendix for detailed assumptions by scenario).

Technological alternatives here are still nascent; all-electric-aircraft are in the design phase globally and the battery technology is still not sufficiently advanced to produce aircraft with over 100 passenger capacity and over 1500 nautical mile range (typical short-haul standard aircraft).

Increases in taxation and aviation fuel cost, however, will disproportionately impact the short-haul flights, particularly the point-to-point traffic of low-cost airlines. There are fewer alternatives to long-haul travel (trains/cars) and the margins in long-haul travel are higher. Low-cost airlines are the major consumers of single-isle aircraft, which make up about 75% of delivered aircraft, though only about 56% of profits. The resulting impact on earnings and book value of the aerospace & defence industry as a whole, also considering a proportion of defence business that will not be affected, is in the range of -2% to -56%, with the moderate case of -34%.

Air Freight & Logistics

Higher prices for short-haul traffic particularly will impact the total volume of air freight as well as costs. Volume impact in air freight, considering the long-haul vs. short-haul split, is estimated at -5% and -42%. It is assumed that the companies in air freight will manage to pass costs on to clients, as their service is consolidated and the demand is relatively inelastic due to the significance of the delivery timing in the supply chain.

Airlines

Conventional "hub-and-spoke" airlines, such as KLM or British Airways, have average Returns on Equity of 10%, whereas low-cost "point-to-point" carriers such as Easyjet or Ryanair, deliver ROEs of 16% on the average (source: Bloomberg industry pages). The combined airline industry ROE is between the two levels. As the policy shift towards taxation of air travel is disproportionately negative for low-cost carriers, the resulting industry ROEs will converge with the traditional airline ROE's, closer to 10%.

Automotive Industry

Although the production process of automobiles is not particularly GHG intensive, the end products – cars and trucks, are responsible for the sigificant proportion of global emissions and are fully regulated. Currently, the automotive industry is still on an unsustainable path towards meeting the CO_2 emission reduction goals. Fleet average emissions should decline by 5.5% through 2021 in order to comply with the regulation. Yet, the regulatory bodies are likely to further cut the average allowed emissions; down to 80-90 g/km from the current fleet averages of 120 g/km (Tietge, 2018).

Technological possibilities of internal combustion engines have already been largely exhausted. There are two avenues car manufacturers can pursue to comply with the new regulations[4]:

- Vehicle weight reduction technologies[5]

[4] The emission cheating avenue, as the experience of Volkswagen showed, is prohibitively expensive in the long run

- Electrification of the drive train[6]

Both approaches are expensive and result in lower margins in the short run, but the electrification of drive train (producing fully electric vehicles) poses additional long-term conerns:

- A large part of the costs of electric drive train is in the battery, which is driven by material costs, such as lithium and cobalt (van der Slot, Thomas, Pfelffer, & Baum, 2016). Although the prices have been falling, significant risks exist in thin markets and high volatility of these raw materials.
- While internal combustion engines were mostly produced by the car manufacturers, who captured the profit margins, batteries are mostly produced by electronics suppliers, such as Panasonic and Samsung, who will capture the value. This creates a long-term ROE implications for the vehicle manufacturers.

We consider a range of electrification of the drive train between 24% of the fleet by 2025 in the moderate case and no weight reduction to 84% electrification in the extreme case, combined with weight reduction of 14% (extreme case quoted by the McKinsey study - (Heuss, Muller, van Sintern, Starke, & Tschiesner , 2012)). Comparing the costs of the electric drive train with the conventional ICE drive train was carried out based on estimates from (Kochhan, et al., 2017). The impact on long-term ROEs of car manufacturers is between -1.7% and continuous losses in the extreme case.

Automotive Components

As automotive components are part of the same supply chain as car manufacturers, they will face the same reality of transitioning technology, obsolete assets and the need to compete for the limited spending power of car manufacturers.

We assume that 50% of costs of transition are absorbed by the auto component manufacturers. The resulting ROE impacts are at least -4.3% and as high as all the profits in the extreme scenario.

Oil, Gas & Consumables

Increasing electrification of transport is likely to have proportional impact on demand for oil. As diesel and petrol are the most valueable output components of oil refining (cracking), contributing on average about 80-90% of the value, the falling demand for these products is likely to shrink the exploration & production and refining volume.

We assume no change in profitability of the remaining business, however, there will be substantial “stranded” assets, proportionate to the electrification of drive train: from 12% to 42% in the extreme.

[5] See (Cabrera Serrenho, Norman, & Allwood, 2017) and (Heuss, Muller, van Sintern, Starke, & Tschiesner , 2012) for weight reduction economics

[6] For more on electrification of drive train, please consult (Un-Noor, Padmanaban, Mihet-Popa , Mollah, & Hossain , 2017) or (van der Slot, Thomas, Pfelffer, & Baum, 2016)

(Petro-) Chemicals

In tandem with falling refining volumes of crude oil, the petrochemicals industry will face shortage of its main feedstock: naphtha. Naphtha is a source for most plastics, with the only other large-scale alternative – ethane viable mostly in the United States.

In our scenarios, global naphtha production volumes fall proportionately with oil refining volumes, between 24% and 84%. This creates a price impact in-line with inverse price elasticity: prices likely to increase between 50% and 170%. For the sake of simplicity, we assume that the petrochemicals industry fully absorbs this cost and does not pass it to the other industries, as analysis of increasing plastic prices would require a very broad study into a large variety of industries. It can be argued that most industries could absorb higher plastics prices and switch to alternatives already available. However, the system-wide effect of this is relatively small and probably can be ignored.

Additional technological shocks are likely to be posed by regulation to limit GHG emission specifically in the petrochemicals industry, particularly, carbon capture and storage (CCS) and shift from coal to natural gas (IEA, 2018). However, as most of these technologies relate to power generation, they are separately treated in the utilities industry.

Electric Utilities

At 2733 t/$M the electric power generation is the industry that contributes the greatest amount of CO_2 emission per $1 mln. of revenue by a large margin (Frankel, 2015). Not surprisingly, the industry ends up bearing the brunt of penalty costs in most research. Clearly, there are significant technological and policy hurdles and opportunities:

- transition to solar and wind power generation,
- carbon capture and storage technologies,
- increasing share of renewable energy causing net intermittence and increasing net balancing costs

By 2017 the share of renewables in the European generation mix was nearly 30%, including 11.2% wind and 3.7% solar (Sakhel, Buck, & Graichen, 2018). We are assuming that the current level of ~ 15% of wind and solar combined capacity transitions to from 22% (moderate case) to 60% (extreme case). The resulting generation cost increase range[7] from Eur 1 per MWh to Eur 6 per MWh is argueably not too large compared to the average wholesale cost of power.

A more significant cost is added to the system due to the intermittent nature of solar and wind power. In contrast with generation costs, the system balancing and back-up costs increase as the weight of renewable energy increases. Total added cost is in the range of Eur 7 to 17 per MWh, calculated along the lines of (Delarue & Van Hertem , 2016). The combined additional power generation cost is between +16% and +46% of the wholesale price.

In the past we have seen solar and wind energy capacity actually pushing wholesale prices down. While it is true that higher proportion of renewable energy has driven European wholesale prices down, it is largely an effect of marginal pricing: as marginal prices of wind/solar are virtually zero

[7] Although we derive full generation cost difference from the most recent study from the US Energy Information Agency (EIA, 2019), it could be argued that this cost difference may further fall due to larger scale. However, the difference is also impacted by availability of coal in various locations, e.g. Germany.

(no fuel used), the market prices power at a low level when there is ample source. However, grid operators and/or utility companies have had to subsidise the balancing costs for when there is no renewable power available – a situation that is not sustainable in the long run.

Furthermore, carbon capture and storage may be considered as an alternative to renewables. We have chosen not to second-guess the viability of either set of technologies. Should CCS be cost-competitive with renewable energy, it will be applied as and when required. In that case, renewable costs are a good approximation for CCS technology. As power production costs increase, we assume that the power generation companies will absorb half of the new cost, with the remainder picked up by consumers and the government.

The Policy Shock: CO_2 Pricing

Alongside the industry-specific scenarios we also assess the impact of a broad increase in CO_2 emission trading price, applied across all geographies, in line with the DNB study. We use CO_2 emission per $million revenue data supplied by MSCI (Frankel, 2015) to estimate total CO_2 emissions by regional indices. Then we allocate emissions to industries proportionate with their revenues and industry-specific emission intensity, captured by transition vulnerability factors in the DNB study.

The resulting total emissions priced at $100 are compared with the current price of the emissions and the difference is used as additional earnings impact by industry. Note, that calculated this way, the utility industry becomes loss-making. While this is possible for a short period of time, it is not plausible that the industry will continue to exist in the long run without generating profits. Since we approach climate change scenarios as a long lasting trend rather than a temporary shock, we limit the CO_2 price for the utilities sector at $60 – a level, which consumes most but not all of the profits of the industry. The underlying rationale for this assumption is that government subsidies or additional taxes will inevitably be used to compensate the difference.

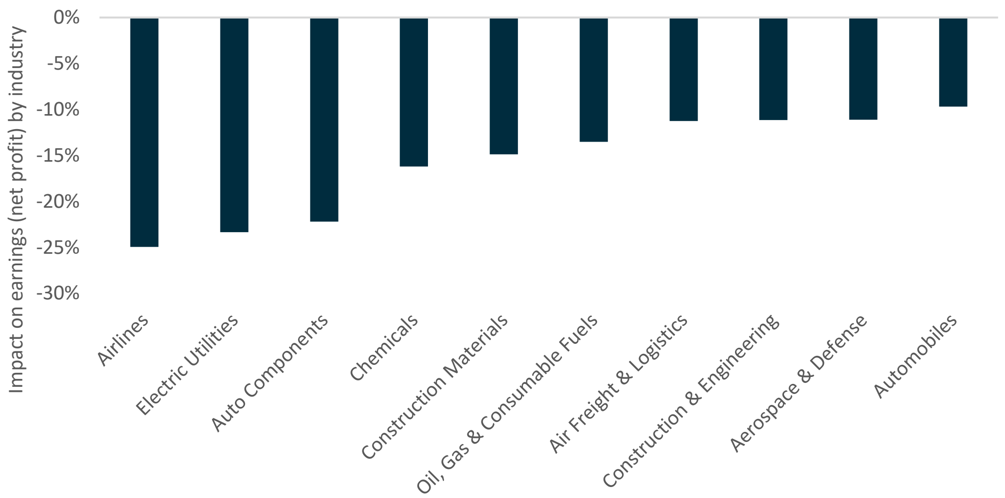
Results and Conclusions

Long-term implications for investment portfolios may vary greatly due to regional, industry and asset class specific differences. At the time of publication of this report, the **Climate change** long-lasting trend has been integrated with **Mira ABM** (Agent Based Model) World View, which enables users to estimate the impact of climate change transition scenarios on their specific portfolios. In this note we draw some general conclusions with respect to the direction and scale of the impact on major asset classes.

The moderate scenario impact is manageable. As a major part of global output is generated in the services sector, at least as far as the tradeable universe is concerned, the earnings impact of transition scenarios is not drastic, in the range of 0.2% - 1.3% (Figure 1) annually for the first three years. That is not to say that there will not be industries that struggle in terms of impact on earnings (Figure 4). To be clear, the average or moderate scenario is not extreme, i.e. it is sensible to build such a decrease in earnings into expectations in any case.

The impact of broad CO_2 price hike (the DNB policy scenario) for all industries is more severe. Simply because such a policy affects all the industries, the combined effect is larger for the whole index – a **5-6%** annual headwind in terms of return in the first five years (see Figure 1). It is important to take this in the context: the DNB describes this scenario extreme, yet plausible. To begin with, power generation companies will have to operate while continuously generating losses, which is not quite possible. Furthermore, enforcement of such a policy would be difficult, as most companies operate outside the radar of EU Emissions Trading Scheme, which was designed for heavy energy using installations only. Finally, such a policy would need to be applied globally, including US, China and other markets.

Figure 4: Impact of moderate scenario on earnings of selected industries, source: LINKS calculations



Distributional effects of climate-change transition are significant. Policy and technology shifts trigger wealth re-distribution from public (electric utilities) to private equity (wind/solar), from incumbent (Ford, GM) to newcomer companies (Tesla), between various consumer income (low- to high-income) and regional (DM to EM) groups etc. These shifts inevitably create winners and losers. A diversified broad investment portfolio is likely to post the headline results presented earlier, however, more focused investment portfolio will post a significantly different performance.

Finally, there are several important considerations that are not included in these results. First, the results are not meant to capture the cost of "arresting" global warming. Only policies currently in place or under consideration are taken into account, without regard to whether these are sufficient to meet any physical climate change goals. Secondly, more long-term and less immediate drivers of sustainable development, such as recycling and waste disposal, are not evaluated in terms of the impact on returns, yet they may pose additional costs and opportunities for various industries.

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APPENDIX: Significant industry-specific assumption and settings

Industry	Minimal	Moderate	Extreme
Aerospace & Defence	VAT on air tickets: 6% Aircraft fuel tax: 10% Short-haul traffic decline: 6%	VAT on air tickets: 10% Aircraft fuel tax: 25% Short-haul traffic decline: 33%	VAT on air tickets: 20% Aircraft fuel tax: 100% Short-haul traffic decline: 100%
Airlines	Low-cost ROE: 16% Traditional ROE: 10% Low-cost volume decline: -22%	Low-cost ROE: 16% Traditional ROE: 10% Low-cost volume decline: -49%	Low-cost ROE: 16% Traditional ROE: 10% Low-cost volume decline: -100%
Air Freight & Couriers	Volume impact of fuel/VAT: -5%	Volume impact of fuel/VAT: -11%	Volume impact of fuel/VAT: -42%
Automotive	Vehicle weight reduction: 0% Electric cars % of fleet: 24% Battery price: 180 EUR/kwh Total extra cost per vehicle: EUR 4700	Vehicle weight reduction: -5% Electric cars % of fleet: 27% Battery price: 200 EUR/kwh Total extra cost per vehicle: EUR 5500	Vehicle weight reduction: -14% Electric cars % of fleet: 84% Battery price: 220 EUR/kwh Total extra cost per vehicle: EUR 6300
Auto Parts	Cost absorbtion by component makers: 50%	Cost absorbtion by component makers: 50%	Cost absorbtion by component makers: 50%
Oil Refining	Demand for diesel & petrol: 24% Average oil/gas split: 50%	Demand for diesel & petrol: 27% Average oil/gas split: 50%	Demand for diesel & petrol: 84% Average oil/gas split: 50%
Oil Exploration & Production	Demand for crude oil down: 24%	Demand for crude oil down: 27%	Demand for crude oil down: 84%
(Petro-) chemicals	Availability of naphtha: -24% Ethylene/naphtha spread: 60% Price impact: +50%	Availability of naphtha: -27% Ethylene/naphtha spread: 60% Price impact: +54%	Availability of naphtha: -84% Ethylene/naphtha spread: 60% Price impact: +168%
Utilities	Coal generation ($/MWh): 46.3 Solar/wind (mostly onshore): 60/55.9 Additional ren. capacity: 20% Total cost intermittence & distribution (EUR/MWh): 7 Total cost combined: 8 Absorbtion of cost, utilities: 50%	Coal generation ($/MWh): 46.3 Solar/wind (mostly onshore): 60/55.9 Additional ren. capacity: 23% Total cost intermittence & distribution (EUR/MWh): 11.5 Total cost combined: 13 Absorbtion of cost, utilities: 50%	Coal generation ($/MWh): 46.3 Solar/wind (mostly onshore): 60/55.9 Additional ren. capacity: 48% Total cost intermittence & distribution (EUR/MWh): 17 Total cost combined: 23 Absorbtion of cost, utilities: 100%

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