EXECUTIVE SUMMARY

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NEW ECONOMIC MODELS OF ENERGY INNOVATION AND TRANSITION:

ADDRESSING NEW QUESTIONS AND PROVIDING BETTER ANSWERS

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This document presents the executive summary and policy highlights sections of the 'New economic models of energy innovation and transition: Addressing new questions and providing better answers' report, produced by the EEIST project.

To view other parts of the full report, including modelling case studies on the global energy transition, the power and industrial sectors, transport, agriculture, impacts of the transition, national decarbonisation plans and finance, go to https://eeist.co.uk/eeist-reports/new-economic-models-of-energy-innovation-and-transition/

About

The Economics of Energy Innovation and System Transition (EEIST) project develops cutting-edge energy innovation analysis to support government decision making around low-carbon innovation and technological change.

By engaging with policymakers and stakeholders in Brazil, China, India, the UK and the EU, the project aims to contribute to the economic development of emerging nations and support sustainable development globally.

Led by the University of Exeter, EEIST brings together an international team of world-leading research institutions across Brazil, China, India, the UK and the EU.

The consortium of institutions are UK: University of Exeter, University of Oxford, University of Cambridge, University College London, Anglia Ruskin University, Cambridge Econometrics, Climate Strategies, India: The Energy and Resources Institute, World Resources Institute, China: Tsinghua University, Energy Research Institute, Brazil: Federal University of Rio de Janeiro, University of Brasilia, Universidade Estadual de Campinas (UNICAMP) EU: Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna.

Contributors

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Executive summary

This report represents a major effort to demonstrate the value of new economic modelling to policy questions relevant to the low-carbon transition. Through 15 real-world, global, regional and national case studies, developed in partnership with policy stakeholders, the report demonstrates how new economic modelling approaches can deliver crucial insights for decision makers. It also provides guidance on how to evaluate and choose between different modelling approaches and how to support their use.

A new generation of economic models is needed to inform successful policymaking on the energy transition. Most of the models used by governments are based on the assumption of equilibrium, in which, without external shocks, the economy is stable and the actors in it have no reason to change their strategies. This can be a suitable modelling approach for some policy questions. However, where the dynamical processes of moving between states are important, these models are not appropriate. Decarbonisation requires system transitions in each of the emitting sectors of the economy – situations in which many actors have strong reasons to change their strategies, new technologies emerge and the structure of markets changes. While equilibrium models remain valuable – for example for answering questions such as 'what could a net-zero economy look like?' – disequilibrium models are important as a complementary tool, particularly for answering questions such as 'how do we get there?'.

New models can help identify policies that will drive cost-effective decarbonisation. In general, models that simulate the processes of change in the economy arrive at different answers to policy questions compared to models that calculate and compare states of the economy at specific points in time. The case studies in this report present a range of new models and reveal a set of key findings on four types of policy questions. These are underpinned by the use of different methods, focusing on different countries: Brazil, China, India, and the UK. Table A summarises the key findings and further examples are given in the policy highlights section that follows this executive summary.

Table A: Policy questions addressed and key findings in this report

Policy questions	Key findings
Development direction: Should we decarbonise? How much will it cost? What will be the macroeconomic impacts?	• Multiple case studies, for different countries and using a range of methods, all find that decarbonisation is likely to provide net job creation and, depending on the specific economic structures of the geographies of interest, may lead to economic growth overall. • A faster transition than currently envisaged is preferable. • There may be negative impacts or costs under certain transition scenarios and we can identify the specific periods, sectors or occupations where these might be, as well as connections to other development objectives.
Technology choices: Which technologies should we focus on? What will be the sectoral impacts?	• Policymakers should minimise barriers to zero-emission technologies whose performance improves, and costs reduce, with greater deployment. These include solar, wind, electrolysers and batteries. Policymakers should shape markets to be conducive to faster innovation and growth in these technologies. • Different countries will have different technologies to focus on, depending on their current situation. • Transitioning away from fossil-fuel technologies can have predictable and manageable impacts, depending on the nature of the transition.
Policy choices: Which policies are best to support our goals?	• Investing in zero-emission technologies tends to be more effective than putting a price on fossil fuels for achieving emissions reductions and innovation in key energy technologies. • Regulation can be highly effective as a means to reallocate investment towards zero-emission technologies, accelerating their improvement and cost reduction. • Technology mandates or government procurement are effective policies to kickstart an industry and can make other policies more effective. • Carbon pricing can be helpful when used as part of a package of policies (more so when implemented as a tax than as a cap-and-trade scheme). • Timing of policy support is key, with late support increasing the chances of unwanted lock-in. • Policy support can often be revenue or fiscal-neutral.
Policy design: How should we design this policy?	• Subsidies or taxes may be particularly effective when they are set at a level that makes a zero-emission technology cost-competitive with fossil fuels. • Regulations may be more effective when they mandate uptake of a zero-emission technology than when they require increasing efficiency of fossil fuels (though both together may be best). • Emissions trading schemes need to be designed to avoid introducing a brake on emissions reductions when quick progress outstrips adjustments in permit supply.

New models can provide broader insights into low-carbon transitions. Beyond choosing a technology mix, or policies for the deployment of clean technologies, the new generation of models can also provide insights into wider societal, environmental and macroeconomic aspects of the transition. They can help to address questions such as where jobs will be gained and lost, where skill gaps in the workforce may arise, how the transition may affect the balance of trade and how tax revenues from fossil fuels could be replaced.

A new generation of models is becoming available. The case studies use a variety of modelling approaches, including: (i) data analysis approaches such as systems mapping and economic complexity; (ii) macroeconomic models such as the Energy-Environment-Economy Macro-Econometric Model (E3ME) and its evolutionary sector-specific extensions; (iii) detailed economic System Dynamics models; (iv) empirically validated agent-based models; and (v) extended energy system models. This plurality is important to ensure we do not rely on one type of modelling. What these approaches have in common is that they assume the economy is in a state of change and they simulate processes of change so that these can be understood and influenced by policy. These approaches are also underpinned by a commitment to bottom-up, structurally realistic, empirically validated economic modelling; these are delivering on the promise these methods made when they first emerged, sometimes 20 or 30 years ago.

Through this diversity of methods and policy questions, two methodological lessons emerge. First, there is enormous value in academics, analysts and policymakers working together to simultaneously co-develop suitable models and analyse real policy questions; this mode of working repeatedly delivers value and improved capacity to use new economic modelling. Second, the value of detailed policy analysis and appraisal is clear, with decision makers demanding comprehensive representation of policies and their implementation in models.

There is great potential for further improvement in economic modelling. This can come from progress of three kinds:

1. Learning what works in practice: As more applications of these new modelling approaches are completed, rich learning will be developed on what works best and how analysts and decision makers can best use these methods and build capacity.
2. Developing powerful thinking tools: The use of new economic models will support, and be supported by, the further development of economic theory on processes of innovation and structural change, from the 'Ten Principles for Policymaking in the Energy Transition' we outlined in our previous report, to the rules of thumb we can use to think about technology and economic systems, such as feedbacks, exponential change and tipping points.
3. Increasing innovation and transparency: As demand grows for new economic modelling, we expect to see new methodological innovations appearing. Transparency and clarity in model development and use will also improve, supporting wider use of the new approaches and faster innovation in their development.

Governments and international organisations can accelerate the emergence and development of these new modelling approaches. Governments are the largest customers of policy analysis; by procuring and funding the development of new models, they can stimulate the investment of time and intellectual capital by the academic community into these new approaches. Governments can improve their own institutional capability to take advantage of the new generation of models by training their officials in disequilibrium model development and complementary analytical techniques such as system mapping and risk-opportunity analysis.

The primary audience for this report encompasses the many analysts, modellers, researchers and academics conducting research within and for governments, multilateral organisations and the private sector on the energy transition and energy and climate policy. Policy teams and decision makers will also find value in this report, as it summarises the key findings of new economic modelling and helps readers understand why different types of analysis provide different insights.

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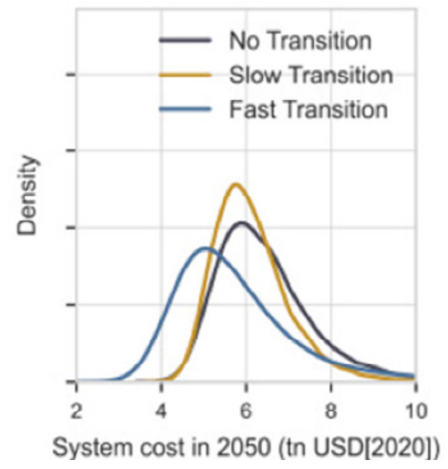
Policy highlights

Here, we present a selection of policy findings from the case studies in this report. The purpose of this section is not to provide a summary, but to give some examples that illustrate the potential of new economic models to address new questions and provide better answers to the policy problems of energy innovation and transition. Readers can refer to the case studies to find more detail on the methods, results, limitations and policy implications of each of these pieces of analysis.

The pace of the transition

The case study Empirically Grounded Energy Technology Cost Forecasts finds that a fast transition to a zero-emission energy system (including energy use across power, transport, buildings and industry) could cost less than a slow transition, and that it could save around $12 trillion compared to business-as-usual in global aggregate terms (Figure 1). This is the opposite of the traditional view that the more emissions are to be reduced, the more costs will be incurred. The reason for this difference is that our study uses a more realistic representation of the way that the costs of clean technologies fall as their deployment rises.

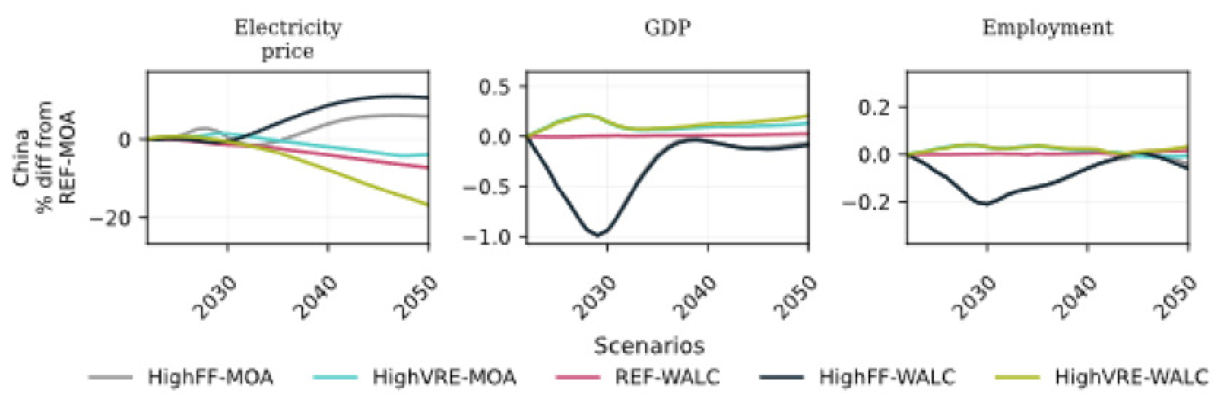
Figure 1: Forecast distributions of annual system cost in 2050.



The power sector

The case study Unstoppable Renewables and Marginal Pricing shows that choices of market design will be crucial to realising the opportunity of low-cost renewable electricity (Figure 2). While solar power with energy storage could be half the cost of coal power by 2030 in the countries we consider, the price of electricity could still be high if market prices are determined by the marginal unit of supply (likely still to be provided by fossil fuels). Alternative market designs where electricity prices reflect the weighted average levelised cost (WALC) of electricity generation could lead to lower prices, contributing to better outcomes for employment and economic growth.

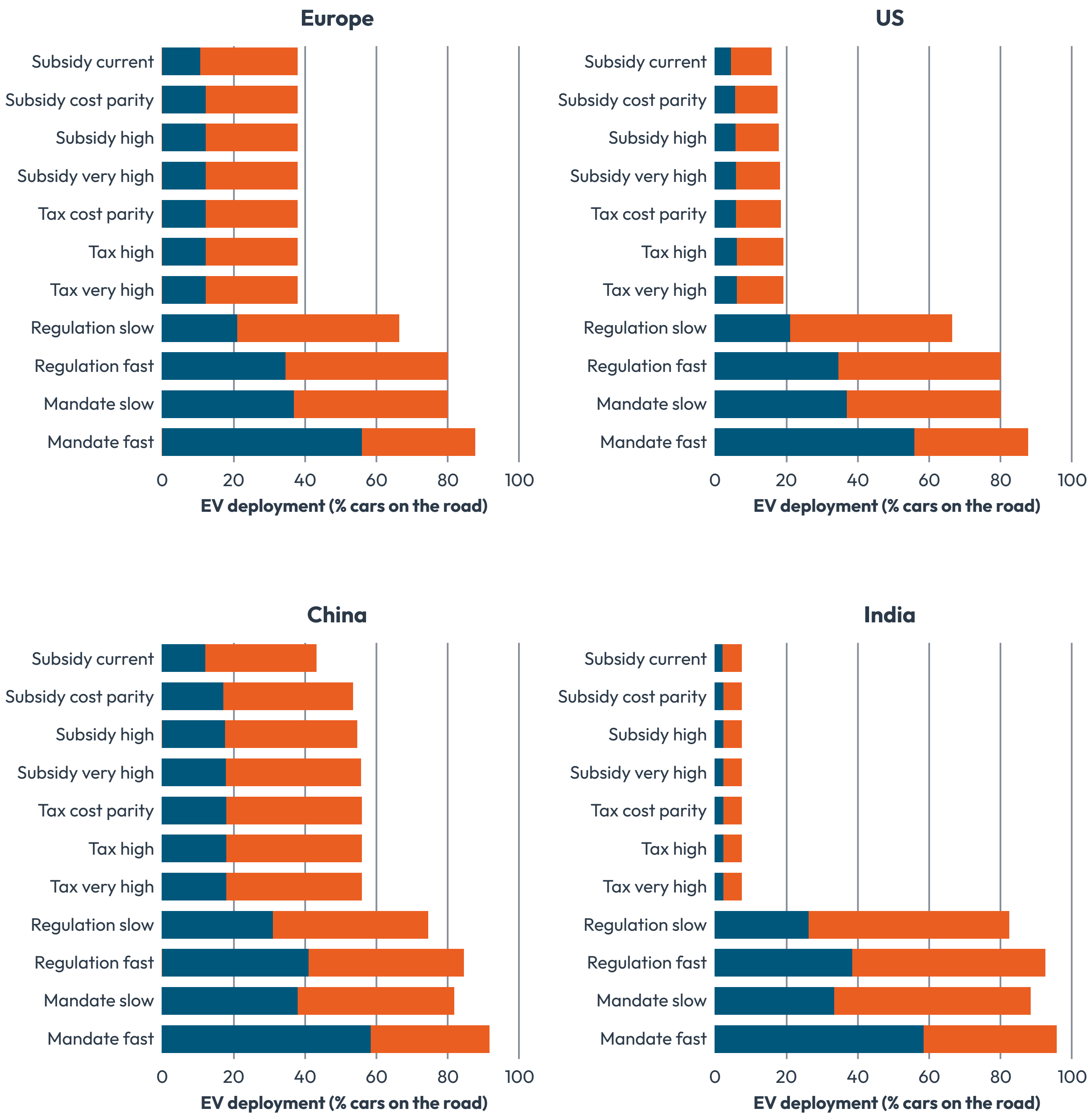
Figure 2: Comparison of electricity prices, GDP and employment, in percentage difference to the reference scenario (REF-MOA) in China. HighFF = High fossil fuels scenario; HighVRE = High variable renewables scenario; REF = Reference scenario; MOA = Merit order approach; WALC = Weighted Average Levelised Cost.



Zero-emission vehicles

The case study Activating EV Tipping Points shows how a simulation model can be used to compare policy options individually and in combination. We find that zero-emission vehicle mandates and efficiency regulations are often likely to be the most cost-effective policies for driving the transition to zero-emission vehicles, with subsidies the next best and taxes by far the least cost-effective option (Figure 3). The study also finds that policy combinations that act on both the supply and demand for zero-emission vehicles can achieve more than the sum of their parts, while other policy combinations achieve less than the sum of their parts. These findings are only possible in a model that simulates likely outcomes instead of computing 'optimal' solutions.

Figure 3: Policy incentives and EV deployment under different policy assumptions.



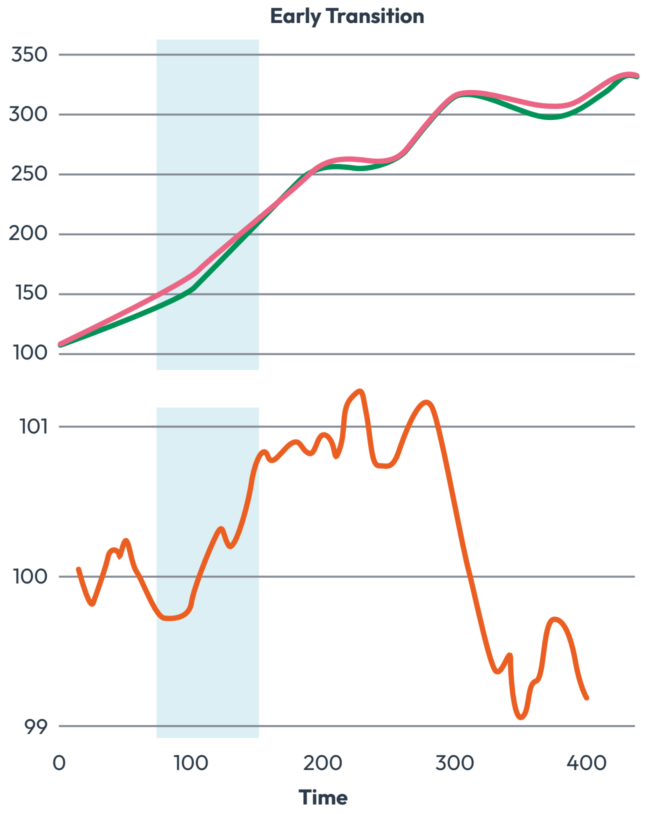
Hydrogen in power and industry

The case study Modelling Sector Coupling of Hydrogen and Ammonia in India shows the risks and opportunities arising from a policy choice about infrastructure: whether to connect hydrogen and ammonia production plants to the electricity grid, or to construct them as 'islanded' plants connected only to local industrial off-takers. The study finds that not only does the 'connected' approach result in hydrogen and ammonia produced at 10-25 per cent lower cost (Figure 4), but also reduces the need for solar and wind-generating capacity by around 200-300 GW and has significant advantages in terms of energy security and the resilience of electricity supply to weather variations, compared to the 'islanded' approach. These findings arise from the model's exploration of the dynamic interactions between the power and industrial sectors: green hydrogen and ammonia improve the efficiency of the electricity system by providing energy storage and dispatchable power; lower-cost electricity in turn enables lower-cost production of green hydrogen and ammonia. Policy choices such as how to pay for the grid connections of hydrogen plants could determine which of the alternative infrastructure configurations comes into being.

Figure 4: Levelised cost of hydrogen across scenarios.

Agriculture and land use

The case study Supporting sustainable agriculture intensification finds that, without significant policy intervention, competition between farmers for short-term profitability and market share is likely to lead to soil degradation, with serious risks to food security in the long-term. It finds that giving farmers better access to information about sustainable practices – and incentivising their uptake of new technologies – could significantly increase the chances of the agriculture system making a transition to sustainability (Figure 5). Importantly, the results suggest that policy interventions are more likely to be effective if they are introduced early in the transition; if left too late, the divergence of technological development may make it impossible to avoid a lock-in to unsustainable agricultural practices. These findings are made possible by the model's representation of farmers as economic actors with diverse resources and knowledge, acting in a context of uncertainty, whose actions influence the market and are in turn influenced by the market.



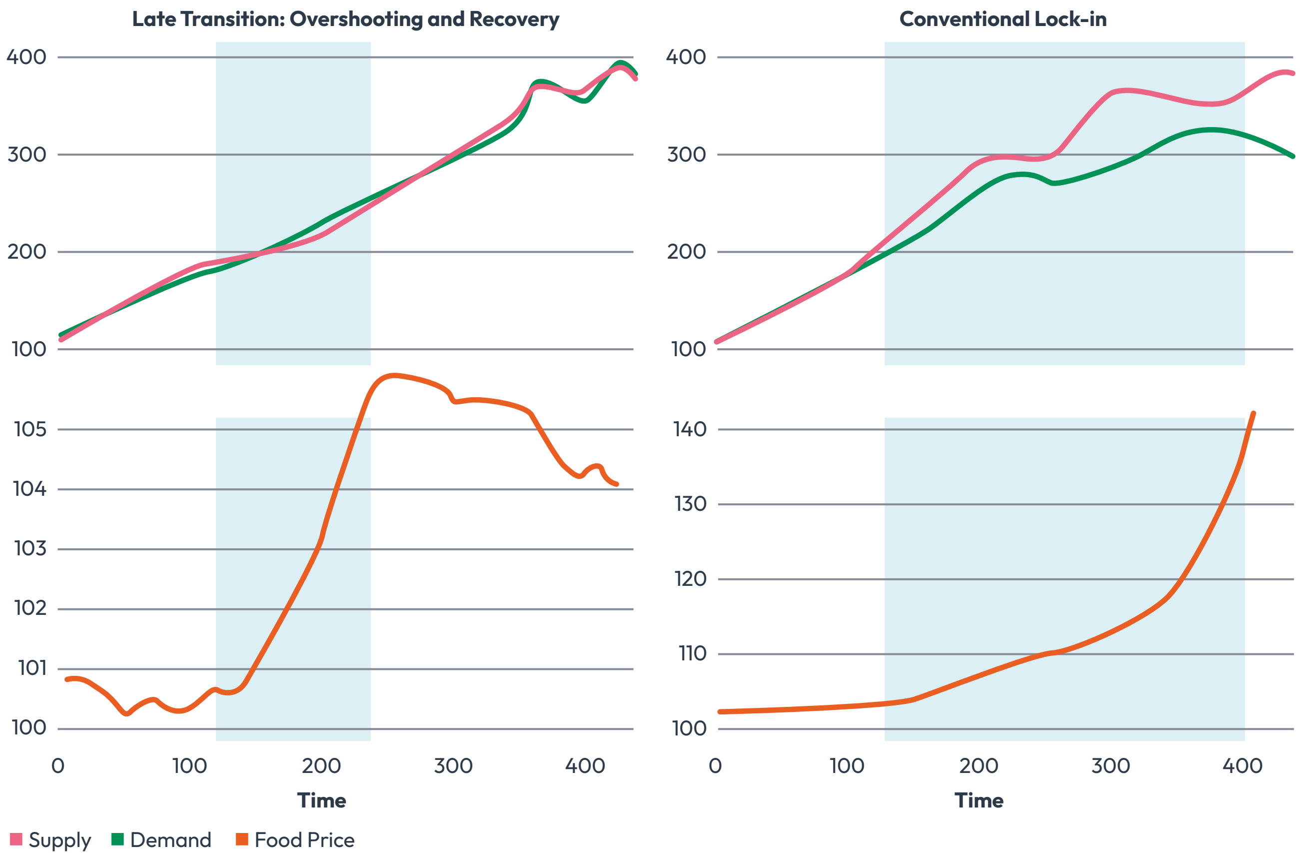


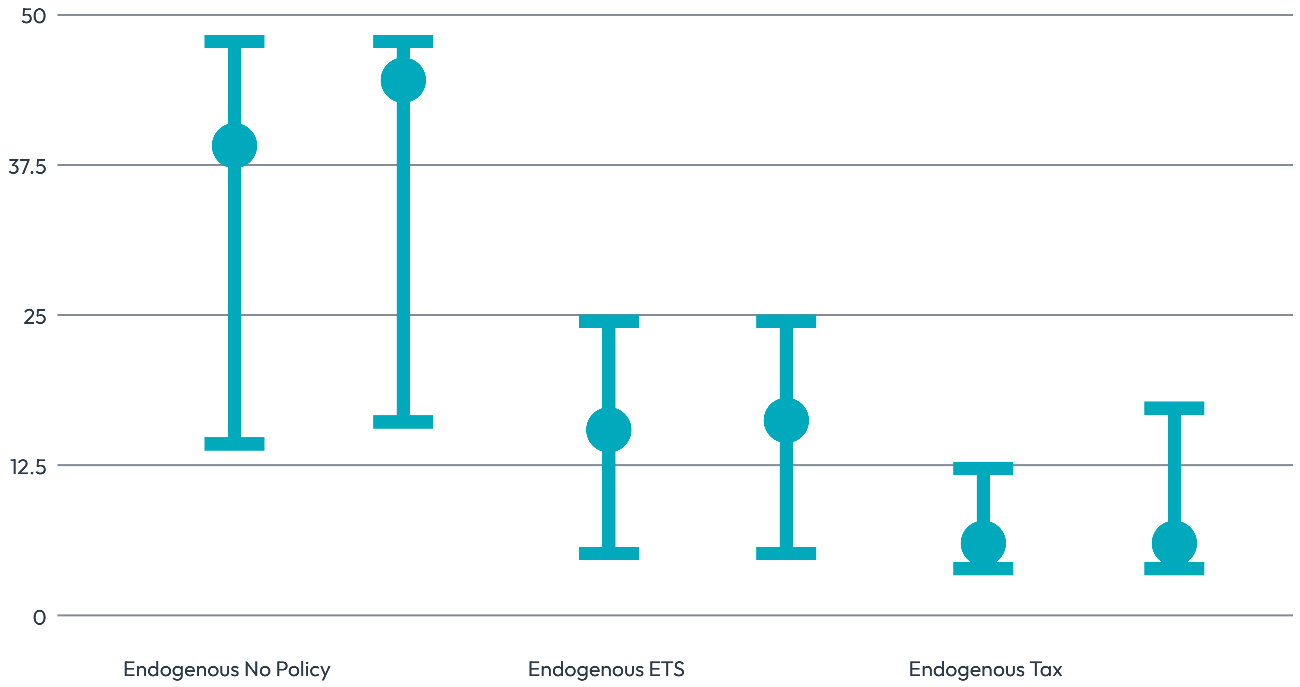
Figure 5: Three different single runs of the model, exemplifying the main types of dynamics observed in the model: rapid transition to sustainable farming, overshooting (or late transition) and conventional lock-in. For each run, the distance between total demand and supply and the food price dynamics are shown. X-axis represents time steps in model simulation, y-axis represents changes with respect to initial values (set equal to 100). Red areas correspond to periods of insufficient food.

Carbon pricing

In a previous report,[1] we noted that the traditional view that carbon pricing is the most cost-effective way to support decarbonisation depends on the assumption of equilibrium, and that this is at odds with the reality of low-carbon transitions being processes involving innovation and structural change. The case study Policy Options for Rapid, Smooth Decarbonisation and Sustainable Growth looks at carbon pricing from a global perspective. It finds that, when used alone as a policy instrument, a low level of carbon pricing is ineffective for achieving a low-carbon transition consistent with the goal of limiting temperature rise to 2°C, and that a high level of carbon pricing consistent with this goal could lead to economic instability, with a surge in unemployment, bankruptcies and recession. The study suggests that a mixture of policies including subsidies and regulation can be more effective in putting the economy on a pathway to sustainable growth.

The case study What is the Most Cost-Effective Form of Carbon Pricing? finds that, contrary to the traditional view, the two most common forms of carbon pricing – a tax and an emissions trading scheme (ETS) – are not equivalent in their cost-effectiveness. Our modelling finds that, for the same carbon price, a tax is likely to drive much faster emissions reduction than an ETS (Figure 6). The difference between these policy options also depends significantly on the structure of the markets to which they are applied. These findings are made possible by the use of models and techniques that make no assumption of equilibrium and instead explore the dynamic interactions of policies, technologies, companies and markets.

Figure 6: Time (showing min and max and mean) to reach zero emissions in the simulations (in years). The horizontal bars indicate the mean value from multiple model runs with each scenario.

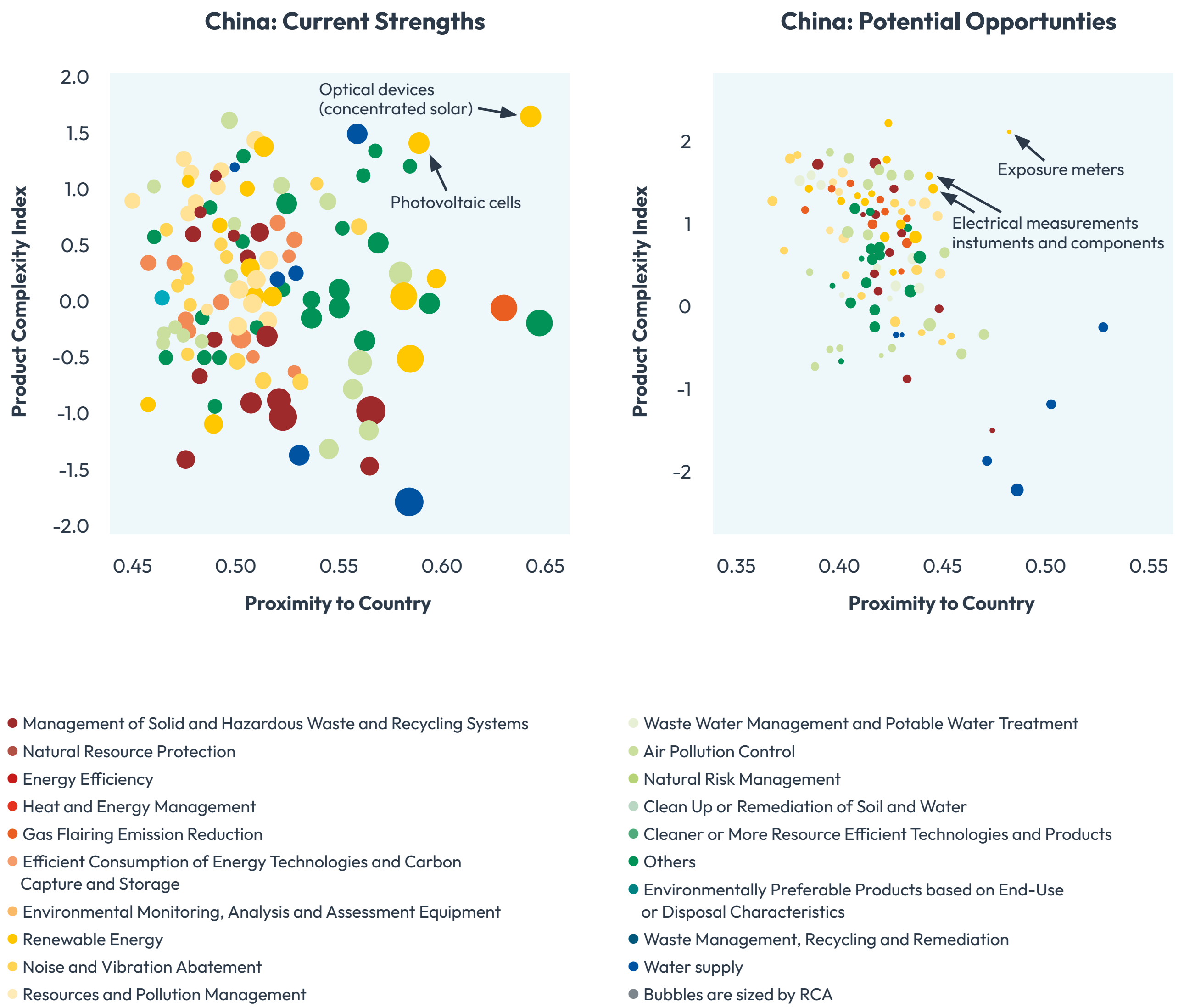


[1] Diaz-Anadon et al. (2022). Ten Principles for Policymaking in the Energy Transition: Lessons from experience.

Industrial competitiveness

The case study The Green Complexity and Competitiveness of China's Exports shows how an understanding of the network structure that relates different products in the economy to each other based on trade patterns can be used to predict new areas in which a country may be able to gain industrial competitiveness (Figure 7). We find that China's competitiveness in clean technologies exceeds its overall competitiveness in manufacturing, that it recently became competitive in exporting electric vehicles, and that areas in which it has the opportunity to increase its competitiveness include environmental monitoring technologies.

Figure 7: China's green export products divided into current strengths (left) and potential opportunities (right). Size of product circle indicates China's current revealed comparative advantage; colours represent product categories.

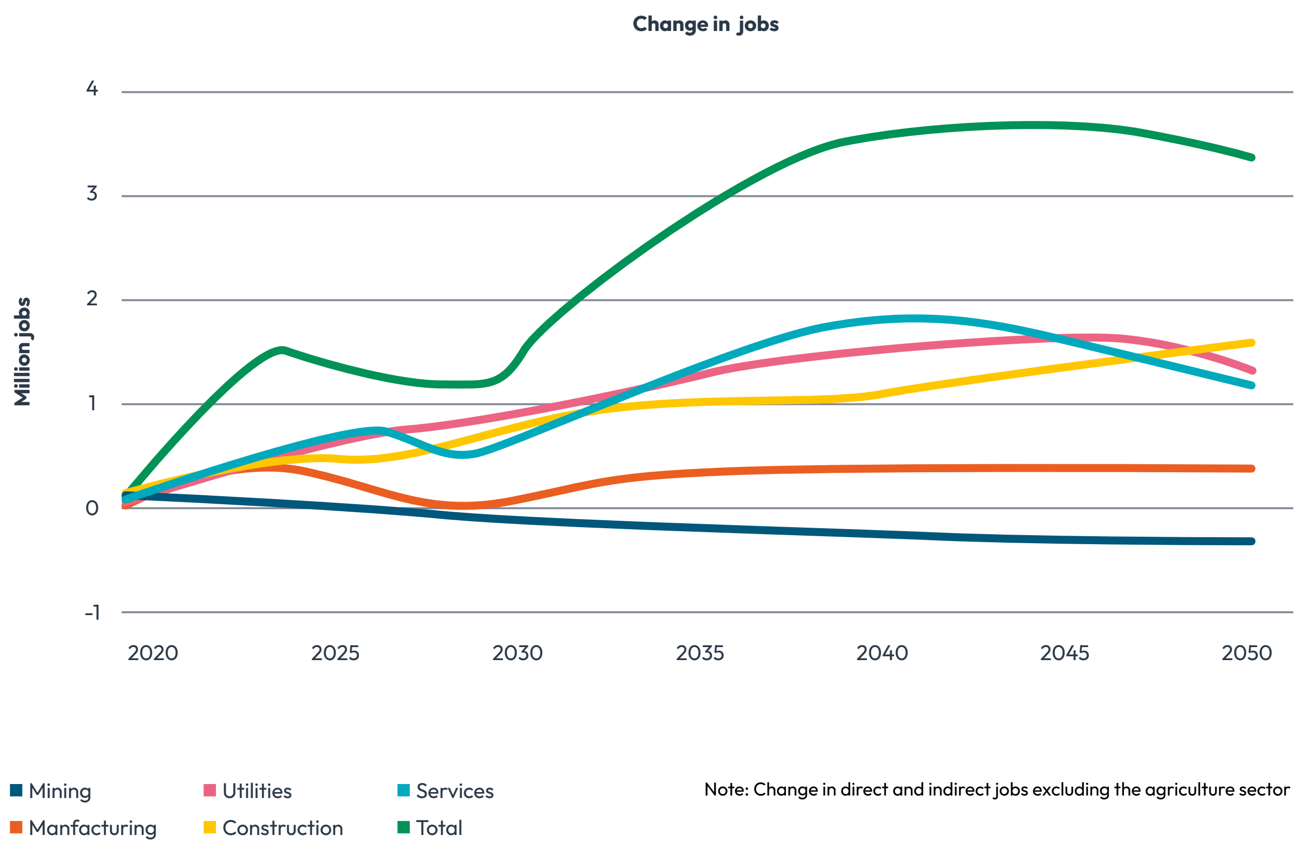


Jobs and skills

The case studies Economic Impacts of Net Zero in India and Decarbonising the Indian Economy (Figure 8), which use different modelling approaches, both find that the low-carbon transition is likely to generate additional jobs overall in India compared to a business-as-usual scenario. This finding is possible because these models do not assume that investment is optimally allocated to assets, or that people are optimally allocated to jobs, throughout the economy. Instead, the models allow for the realistic prospects of unproductive capital and unemployment. While job losses in fossil fuel sectors are likely to be substantial, these are more than offset by growth in jobs in sectors such as power generation, services and construction.

The case study Modelling Labour Market Transitions: The case of productivity shifts in Brazil considers how people's ability to move from sectors where jobs are being lost to those where they are being created will depend on their skills. Modelling the labour market with this realistic constraint provides insights into where skills gaps could be a barrier to the low-carbon transition, and where (in which sectors) unemployment is most likely to arise. The study finds that, in Brazil, the number of occupations where people could face an increased risk of unemployment due to difficulties in switching to new occupations is higher in a scenario where economic growth is driven mainly by increases in agricultural productivity than in a scenario where growth is driven mainly by manufacturing productivity. These findings could inform policies on worker retraining and economic development.

Figure 8: Macroeconomic outcomes in a long-term decarbonisation scenario, relative to the reference scenario.



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Economics of Energy Innovation and System Transition

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Find out more at:
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