EEIST

IMPACTS OF TRANSITION CASE STUDIES

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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.

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Contributors

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CASE STUDY:

Modelling Labour Market Transitions: The case of productivity shifts in Brazil

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Policy question: How would occupation-level unemployment be affected by growth paths with different drivers and emissions outcomes in Brazil?

Region: Brazil

Methods: A data-driven occupational mobility network combined with an agent-based model.

Key finding(s): The number of occupations facing higher unemployment due to limited mobility is lower in a manufacturing-driven (i.e. lower emissions) growth path (21 per cent of occupations) than in an agriculture-driven (i.e. higher emissions) growth path (49 per cent). So, more effort towards increasing productivity in manufacturing is both better aligned with the country's NDC targets and results in fewer labour market frictions.

Engagement: This case study emerged from a collaboration between the authors and the Brazil office of the World Bank. The data on labour movement, scenarios of interest and the CGE model they were developed with came from the World Bank team. The findings and framing were developed by the authors with input from the World Bank. In future work, this case study will be further developed with the World Bank, both in methodological terms, but also on refining the policy implications. Input from the Brazilian government will also be sought, via the EEIST community of practice in Brazil, to explore additional scenarios that may be of interest.

Summary: The authors combine macro-economic model outputs with a dynamic labour market simulation to study how, within a context of green transitions, productivity shifts in different sectors and regions may affect occupation-level unemployment in Brazil. Specifically, the study combines a data-driven occupational mobility network with an agent-based labour market model to account for limited mobility and second order frictions in the labour market. With this approach, they discuss how changes in labour demand affect occupations depending on how much mobility may be expected to and from other occupations. They find that increased productivity in manufacturing results in fewer labour market frictions than increased productivity in agriculture.

Introduction

Brazil is one of the major greenhouse gas emitters in the world,[186] with most emissions linked to agriculture, directly and indirectly as demand for agricultural land still drives deforestation (Ferreira Filho and Hanusch, 2022).[187] In 2021, emissions from land use change and forests accounted for over 49 per cent of the total, with emissions from agriculture almost 25 per cent.[188]

In 2020, Brazil updated its Nationally Determined Contribution (NDC) with a new intermediate target[189] and, compared to 2005 levels, wants to lower its emissions by 37 per cent in 2025 and by 43 per cent in 2030, with a long-term goal of carbon neutrality by 2060. Gurgel, Paltsev and Breviglieri (2019)[190] argue that the 2030 NDC goal could be achieved mostly through reducing deforestation and changes to agricultural practices. In the long-term, Soterroni et al. (2022)[191] argue that halting deforestation and promoting restoration will be critical to achieving net zero.

While Brazil's Forest Code is a key command-and-control policy for preserving and restoring native vegetation - and, therefore, reducing emissions - its stringency and sustained enforcement are subject to economic pressures. On the one hand, Brazil's highly competitive agriculture is still land-hungry. On the other hand, the restriction of land supply may cause welfare losses from lower agricultural employment and higher food prices (Ferreira Filho and Hanusch, 2022).

Within this context, Ferreira Filho and Hanusch (2022) consider different growth paths and how they would impact deforestation and emissions in Brazil. The authors show that transitioning to a manufacturing or services productivity growth model could reduce emissions and deforestation significantly while sustaining long-term GDP growth, with manufacturing having the biggest emissions savings. Conversely, agricultural productivity growth leads to higher emissions and can lead to both an increase and a decrease in deforestation depending on whether the productivity growth happens in the Amazon or elsewhere respectively (see Ferreira Filho and Hanusch, 2022, for more details).

In both cases, as productivity grows, the relative demand for labour in different occupations would likely shift, potentially requiring workers to switch occupations. Several economic models, including IO and CGE models, estimate the changes in labour demand of different industries during a transition. However, these estimates often do not account for labour market frictions that limit workers' mobility between jobs. Recent studies argue that limited labour mobility needs to be taken into account – generally, and when modelling the post-carbon transition[192] – as in reality some workers may find it harder, or even impossible, to switch into certain occupations and may face higher unemployment rates as a result. Similarly, firms may face more skill shortages and unfilled vacancies in occupations that grow during the transition.

The labour market model

To account for the labour market structure and frictions that can limit worker mobility, in this case-study we model occupation-level labour market dynamics using the data-driven occupational mobility network model developed by Del Rio-Chanona, Mealy, Beguerisse-Díaz, Lafond and Farmer.[193]

We begin by constructing our empirical occupational mobility network[194] (Figure 64) using the RAIS dataset (Relação Anual de Informações Sociais), which contains data on all worker-job-firm combinations of contracts active in Brazil at some point during each year, from 2011 to 2019. The resulting network consists of 2,591 nodes – representing six-digit occupations[195] – and an edge between two nodes reflects the probability that a worker will transition from one occupation to another, as recorded in RAIS.

[186] UNEP, UNEP Copenhagen Climate Centre (UNEP-CCC). Emissions Gap Report 2021. https://www.unep.org/resources/emissions-gap-report-2021.

[187] Ferreira Filho, J. and Hanusch, M. (2022). A Macroeconomic Perspective of Deforestation in Brazil's Legal Amazon. Policy Research Working Papers; 10162. World Bank. https://openknowledge.worldbank.org/handle/10986/38253.

[188] SEEG (Greenhouse Gas Emission and Removal Estimating System). Based on total emissions - CO2e(t) GWP-AR5.

[189] Although with a different baseline, making the target less, rather than more, ambitious in practice (UNEP, UNEP-CCC, Emissions Gap Report 2021).

[190] Gurgel, A. et al. (2019). The Impacts of the Brazilian NDC and their Contribution to the Paris Agreement on Climate Change. Environment and Development Economics, 24(4): 395-412.

[191] Soterroni, A. et al. (2022). Nature-Based Solutions are Critical for Putting Brazil on Track Towards Net Zero. Preprints 2022, 2022110054.

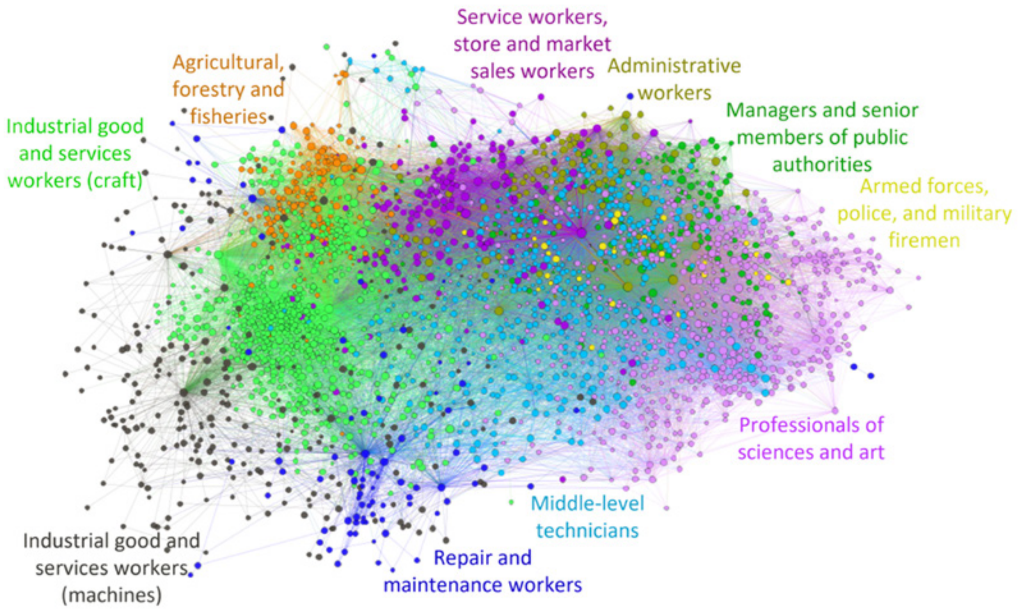
[192] Castellanos, K. and Heutel, G. (2019). Unemployment, Labour Mobility and Climate Policy. National Bureau of Economic Research. https://doi.org/10.3386/w25797

[193] del Rio-Chanona, M.R. et al. (2021). Occupational Mobility and Automation: A Data-Driven Network Model. Journal of the Royal Society Interface. https://doi.org/10.1098/rsif.2020.0898

[194] Mealy, P. et al. (2018). What You Do At Work Matters: New Lenses On Labour. SSRN Electronic Journal, Apr 2018.

[195] Every occupation is classified according to the Brazilian 2002 CBO (Classificação Brasileira de Ocupações) system. This is a nested classification, where each detailed occupation has a six-digit code. Occupations that share the same first digits can be grouped together. In this case study, we also use the three-digit and one-digit occupation codes. There are 2,591 six-digit occupations in our case study, which can be grouped into 196 three-digit occupations, or ten one-digit occupations. For example, six-digit code 913110 refers to Maintenance mechanics for mining equipment; this six-digit occupations is included in the three-digit code 913, which refers to all Maintenance mechanics for heavy machinery and agricultural equipment; the one-digit code 9 refers to all Repair and maintenance workers.

Figure 64: Occupational mobility network. Every node is a six-digit occupation, and wider edges between occupations signify more occupational mobility. Occupations are coloured by their one-digit level occupation (see labels), and sized by the log of total employment of the respective occupation.



Then we turn to an agent-based labour market model that comprises the number of workers employed, unemployed[196] and vacancies open in each occupation at each time step. Workers apply for jobs in accordance with the limitations given by the occupational mobility network; that is, they can only apply to vacancies in occupations that they are linked to in the occupational mobility network (their neighbouring occupations). Workers are fired and vacancies are opened via two processes; a random process and a state-dependent process which responds to the difference between the occupation-specific realised demand (i.e. employment plus vacancies) and the target demand of each scenario. If the realised demand is lower (or higher) than the target demand in the scenario, more vacancies are opened in that occupation and fewer workers fired (or vacancies are closed and more workers are fired).

Brazil's structural change to green growth

We use the product-level labour demand estimates from Ferreira Filho and Hanusch (2022) to simulate occupation-level labour demand and, with our labour market model, study occupation-level unemployment under the mobility frictions given by the occupational mobility network.

Policy scenarios

To investigate how structural change to growth may affect workers in different occupations, we apply two different policy scenarios from Ferreira Filho and Hanusch (2022): a boost to productivity in manufacturing and a boost to productivity in agriculture in Brazil, compared to a baseline that assumes no productivity change. Both of these lead to GDP growth, but agricultural productivity growth would lead to more greenhouse gas emissions.[197] Ferreira Filho and Hanusch (2022) find with their TERM-BR CGE model that a nationwide permanent annual increase of total factor productivity (TFP) of 0.5 per cent in manufacturing leads to a cumulative 3.9 per cent higher GDP over 12 years, 0.8 million hectares less deforestation, and over 67,833 kT less CO_2 emissions in Brazil compared to the baseline scenario. Vice versa, an 0.5 per cent permanent annual increase in agricultural TFP in Brazil would lead to a cumulative 1.8 per cent higher GDP, 0.3 million hectares less deforestation, but 18,221 kT more CO_2 emissions over the same period.

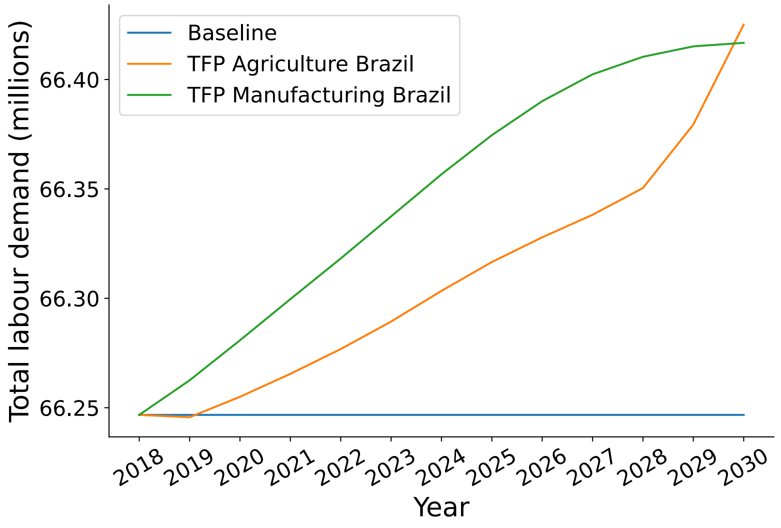
Projected labour demand by occupation

We translate the labour demand changes per commodity to labour demand change per occupation using 2018 RAIS data on industry-occupation composition. As our agent-based labour market does not model population growth, we renormalise the population growth from the labour demand projections by keeping the total labour demand constant in the baseline. We keep the variation in total labour demand for each productivity increase in relation to the baseline. In Figure 65, we show the adjusted total labour demand for the baseline and scenarios.

[196] An unemployed worker counts as unemployed in the occupation in which they were most recently employed.

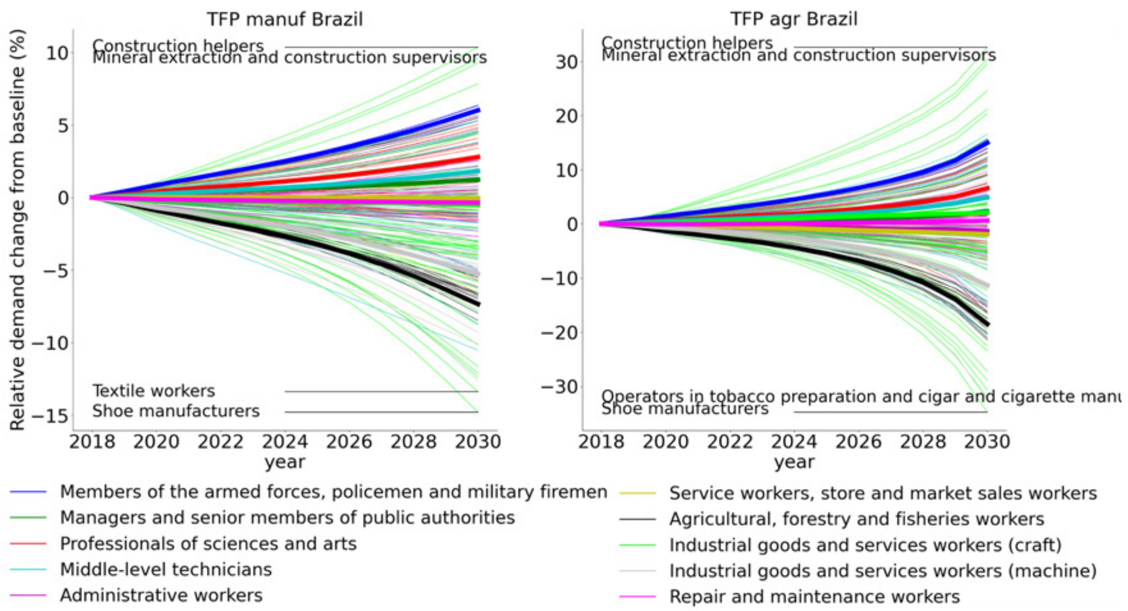
[197] Compared to agriculture, manufacturing is comparably less emissions-intensive due to Brazil's relatively clean power mix (see Ferreira-Filho and Hanusch, 2022).

Figure 65: Total labour demand for each scenario with the total labour demand for the baseline scenario kept constant from 2018 to 2030.



When we disaggregate labour demand by occupation, we find that in both scenarios demand for agricultural workers decreases, and demand for workers in public services and education increases (see Figure 66). The agriculture TFP growth scenario leads to much more occupational relative demand changes with respect to the baseline than the manufacturing TFP growth scenario: at the three-digit level, the groups of occupations with the largest growth (decline) in demand experience a +10 per cent (-15 per cent) change in the manufacturing TFP growth scenario, and +33 per cent (-35 per cent) change in the agriculture TFP growth scenario. Nonetheless, both scenarios see a decline in demand for agricultural workers and some manufacturing occupations compared to the baseline, whereas service workers and construction occupations experience a demand increase.

Figure 66: Employment demand per occupation compared to the baseline for the scenario with TFP growth in manufacturing (left), and with TFP growth in agriculture (right). The bold lines represent the average of occupations grouped by their one-digit level (see legend). The thin lines are occupations grouped at the three-digit level, coloured by their one-digit classification. The top and bottom two three-digit occupations by impact are labelled.



A boost of a sector's TFP implies less labour demand is required for the same output, but general equilibrium effects may cancel this out and increase a sector's labour demand. A productivity increase makes it cheaper to produce a certain product, which can lead to a lower equilibrium price. If demand remains relatively stable despite a lower price, employment needs to decline in order for supply to meet demand. If, however, a lower price increases demand a lot, more workers are required. This may explain part of the difference in the trajectories of demand for occupations in Figure 66.

The demand decline in both scenarios for Agricultural workers may thus be explained as follows. An agriculture productivity increase leads to more output with the same number of workers. This can result in higher wages for its workers and/or lower prices for agricultural products. In this case the demand increase due to lower prices is not enough to counterbalance productivity growth. As a result, demand for workers declines. For the other scenario, an increase in manufacturing productivity may lead to lower prices and higher wages in manufacturing. Wage increases are not restricted to manufacturing but also (partly) affect agriculture due to labour competition pressures. Higher wages in this case are not compensated by more demand as workers receive higher wages, and demand for workers in the agricultural sector declines.

Results

We ran the agent-based labour market model for the agriculture TFP scenario, for the manufacturing TFP scenario, and for the baseline, using the occupational mobility network and, as a comparison, a completely connected frictionless network, in which workers can switch between all occupations without any friction. In Figure 67, for each TFP shock we plot the (percentage) change in labour demand in 2030[198] (in relation to the baseline scenario) against the average (percentage-point) unemployment rate change from 2018 to 2030, also in relation to the baseline scenario. We do so using both the occupational mobility network and the frictionless network.

Using the frictionless network, the changes in labour demand have a similar impact on the unemployment rate for all occupations – around 0.13 percentage points lower than the baseline for the manufacturing TFP scenario and 0.08 percentage points lower for the agriculture scenario. This decrease in the unemployment rate is due to an overall increase in demand for the two TFP scenarios relative to the baseline (see Figure 65); there are more jobs available in the two scenarios and since unemployed workers are free to apply to any open vacancy in any occupation, they would do so until the vacancies opened due to the extra demand are filled. The small variations we see for occupations that have the same demand change in 2030 compared to the baseline are due to the different profiles of this demand change throughout the scenario from 2018 until 2030. This is what would happen if there were no labour market frictions.

When we consider a more realistic labour market structure by using the occupational mobility network, in both scenarios we see a negative correlation between changes in unemployment and worker demand, as we would expect; in general, an increase in labour demand relative to the baseline results in a decrease in the unemployment rate. We can also see that once we allow for mobility frictions, most of the occupations experience a smaller decrease – or even an increase – in the unemployment rate, and occupations that have a similar change in labour demand can see quite different changes to the unemployment rate. That is, the occupational mobility network shows how labour market frictions hinder some of the employment benefits workers would experience in a frictionless network.

In the top panel of Figure 67, we see the results for the TFP agriculture scenario. We can clearly see that network effects impact the unemployment rate of occupations with a similar change in labour demand quite differently. For example, agriculture managers and tree growers see a similar decrease in demand of 20 per cent and 21 per cent respectively, but agriculture managers have an increase in the unemployment rate of 0.24 percentage points, much lower than the increase of over 0.57 percentage points faced by tree growers. One cause of this difference is that the neighbours of tree growers face a greater decrease in demand than agriculture managers, so when the demand shock happens, there are fewer opportunities for tree growers to find employment in neighbouring occupations.

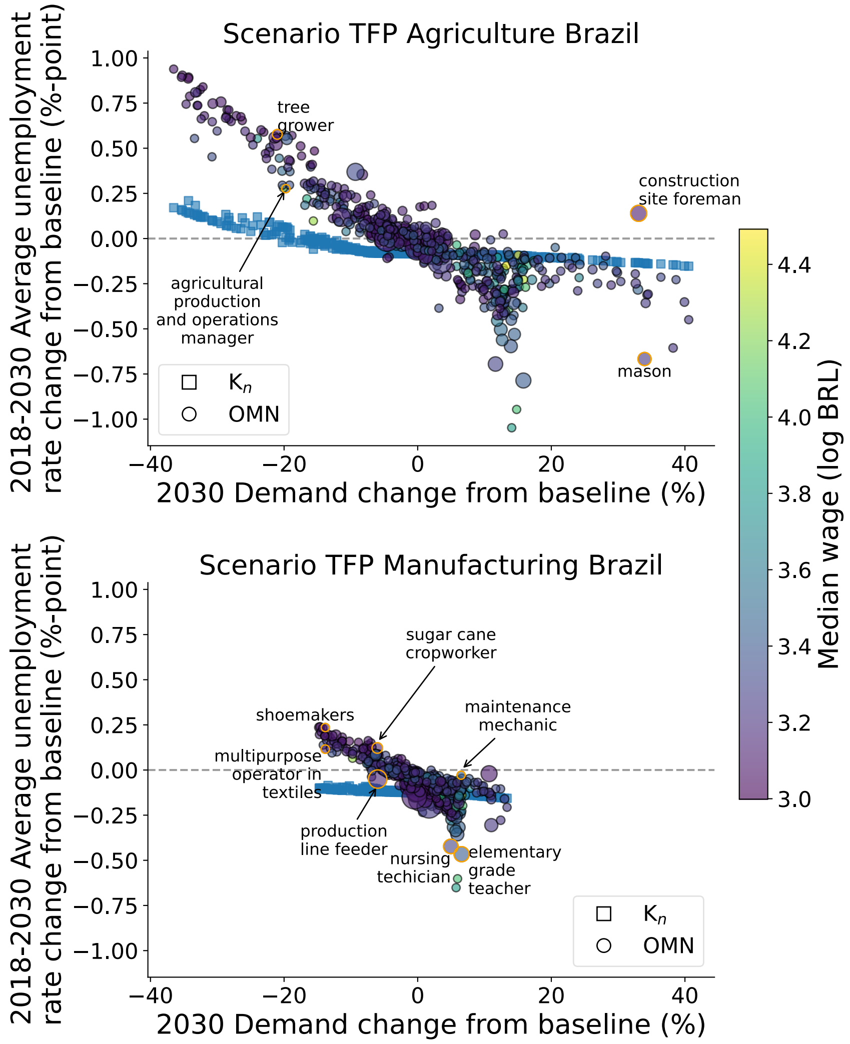
Similarly, both construction site foremen and masons experience an increase in demand relative to the baseline of around 34 per cent. Construction site foremen have more neighbours than masons, but more neighbours can mean that there is more competition for new jobs created by a demand shock, and hence the unemployment rate increases despite an increase in demand, as seen in Figure 67 for construction site foremen but not for masons. These nuanced secondary effects highlight the benefits of considering the occupational mobility network over the frictionless network.

[198] The actual demand change from 2018 to 2030 for each scenario agrees with the demand change in 2030 relative to the baseline almost entirely, with small variations.

Under the TFP manufacturing scenario, we also see the network effects. Shoemakers and multipurpose operators in the textile industry both feel about a 14 per cent decrease in labour demand, but have different unemployment outcomes. Similarly, elementary teachers and maintenance mechanics have an increase in labour demand of around 6 per cent, but elementary teachers see one of the largest declines in the unemployment rate compared to the baseline. In both of these pairs, the occupation that is better off compared to the baseline is the occupation with more neighbours.

We can also identify vulnerable occupations – i.e. those that will experience the greatest increase in the unemployment rate, compared to the baseline in 2030. At the four-digit occupation-level, which contains 621 occupations, vulnerable occupations in both scenarios include civil construction assistants, masonry structural workers, weaving machine operators and agricultural workers in oil-seed crops. Cigarette and tobacco processors are also vulnerable in the agriculture scenario while occupations in the shoe-making sector (handmade shoe and leather goods workers, and shoe-dressing preparatory workers) are at risk of increased unemployment in the manufacturing scenario. These vulnerable occupations would be good targets for re-skilling programmes to mitigate the labour market impacts of a green transition pathway.

Figure 67: Average percentage-point change in the unemployment rate from 2018-2030 for each occupation with at least 1,000 employees in 2018 for TFP Agr Brazil (top), and TFP Manuf Brazil (bottom) compared to the baseline scenario, against percentage change in demand for each scenario in 2030 compared to the baseline. The circles are the model output using the occupational mobility network (OMN) and the squares using the frictionless network (Kn). The size of each circle is proportional to employment in 2018 and the colour represents the log of the median monthly wage in BRL in 2018.



Discussion

Comparing the labour market effects in the TFP manufacturing and TFP agriculture scenarios, we see that the absolute changes in labour demand are lower in the TFP manufacturing shock. More importantly, in the TFP manufacturing scenario the number of occupations facing more unemployment (than in the baseline) due to difficulties in switching between occupations is lower (21 per cent) than in the TFP agriculture scenario (49 per cent). In other words, our results suggest that, overall, the changes in labour demand resulting from a sustained increase in manufacturing productivity allow more negatively affected workers to move from occupations with decreased demand than in the agriculture scenario. This is largely due to the difference in magnitude of the occupation-level labour market demand changes in each scenario, and also influenced by how adaptive workers are. Moreover, as mentioned above, while emissions in the TFP manufacturing scenario are lower than in the baseline, they are higher than the baseline in the TFP agriculture scenario. This indicates that increased attention to manufacturing productivity growth can help align Brazil with its NDC targets and grow the number of jobs, as well as affect fewer occupations negatively.

The network in our model is impacted by several factors such as differences in the skillsets needed or geographical constraints, but it is important to note that we do not address geography explicitly in this case-study. Instead, we assume that there is one job market for all workers to apply to jobs within, and while geographical constraints are implicit in the occupational mobility network (as occupations that are geographically concentrated will be more connected to one another), we cannot consider the role of geography separately from other effects such as skillsets, wage differences, racial and gender biases, etc. As relocation of workers is an important consideration for the CGE scenarios, adding geography into the model is an important direction for future work.

Another consideration for future research is to couple the labour market model with the model we use for demand – in this case the CGE and land-use model. At present, the CGE model is run independently of the labour market model and so the labour market frictions that slow down labour reallocation are not taken into account in subsequent time steps. A coupling of the two models will be able to show how much labour market frictions might slow down, or enable, the transition to net zero. Allowing for more realistic out-of-equilibrium behaviour in the macroeconomic model would be another route for future research.

The set of occupations we use in our analysis is constant; the model only deals with occupations that already exist, specifically within the 2002 CBO occupation classification system. The data we use also works within this classification system and so research into the creation of new jobs is another interesting future research question.

Finally, the RAIS data we use to calculate the occupational mobility network only captures the formal labour force, which in Brazil amounts to around 67 per cent of the total.[199] This should be taken into account when interpreting these results, and in future work we can reconcile the RAIS data with informal labour force data, such as using data from PNAD household survey.

In this case study, we combine scenarios proposed by Ferreira-Filho and Hanusch (2022) to investigate the impacts of total factor productivity increases on Brazil's economy with a more realistic labour market model to show the occupation-level impacts of these scenarios on unemployment. However, this modelling approach could also be used to inform many other aspects of low-carbon transition policies. For example, the occupation-specific labour market implications of increasing the speed of a net zero transition can be investigated. Similarly, our modelling approach could inform policymakers on the labour market implications of different technology choices, and the reskilling required for the different transition options.

[199] Ulyssea, G. (2018). Firms, Informality and Development. The American Economic Review 108.8 https://doi.org/10.1257/aer.20141745

CASE STUDY:

China and the Social Consequences of the Coal Transition

ALEX CLARK (UNIVERSITY OF OXFORD) AND WEIRONG ZHANG (NORTH CHINA ELECTRIC POWER UNIVERSITY)

Policy question: What are the fiscal and employment effects of phasing out coal power in China?

Region: China

Method: Microsimulation.

Key finding(s): Under a baseline scenario consistent with China's carbon neutrality goal, employment supported by coal declines from 2.7 million in 2021 to 1.4 million in 2035, and 94,000 in 2050. The annual rate of tax revenue loss rises to over 10 per cent by the 2040s. However, given the current levels of subsidies, coal is likely to already be a net fiscal drain. China's major coal-producing areas, such as Inner Mongolia, will face significant challenges unless they successfully diversify.

Engagement: The development of this case study benefited from collaboration with the Carbon Tracker Initiative and researchers from the North China Electric Power University, and was completed with the support of the International Institute for Applied Systems Analysis (IIASA). In coordination with the British Embassy in Beijing, it was disseminated widely to an audience in China comprising a number of other embassies, foundations, international organisations, civil society actors and government officials.

Summary: The authors use a dynamic simulation to consider how phasing out coal – a technology choice – can affect employment and tax revenues from the coal sector over time and across space. They use asset-level data in a micro-level dynamic simulation of the coal sector that has higher resolution than that implied by the regional aggregation often needed in macro modelling, while overcoming the lack of high-quality micro data required to run empirically robust network models.

Introduction

China faces an unprecedented structural challenge in phasing out the use of coal in its domestic economy. China's coal consumption, at some four billion tonnes annually, is four times more than that of the second-largest consumer, India, and underpins most of its electricity generation and heavy industrial production. If China achieves its long-term target of carbon neutrality by 2060, coal's role as an energy source will diminish to a fraction of its current level in the coming decades. Achieving this requires widescale deployment of a combination of renewables, electrification, synthetic hydrogen-based fuels, energy efficiency measures, and, most likely, carbon capture and storage coupled with other carbon-removal technologies.

These structural and technological shifts will have profound consequences for the composition of China's economy at all levels. Researchers and policymakers need to be able to analyse in detail how these changes will play out over space and time across the coal value chain as well as the wider economy. In designing policies to manage the socioeconomic and distributive impact of these changes, two key aspects stand out: the effect of coal power phase-out on employment in the coal sector, and the impact on tax revenue from the sector.

In their study Estimating the Employment and Fiscal Consequences of Thermal Coal Phase-Out in China, Clark and Zhang (2022)[200] set out to answer these closely related questions. Due to data limitations at the time of writing, their study focuses on thermal coal (for electricity generation) only, which accounts for roughly half of China's total coal consumption.[201]

Approaches to modelling structural change

Traditionally, a structural economic change of this nature and its effects on jobs and tax revenues would be analysed through the lens of equilibrium-based macroeconomic modelling based on detailed input-output tables describing production-consumption networks.[202] These models are designed to capture substitution effects across industries in response to changes in prices and demand and to incorporate rates of technological change, but do not generally capture the dynamics of specific sectors at a high level of granularity. They rely on a significant degree of regional aggregation and a number of quantitative assumptions that are not necessarily accurate and are hard to validate in data-poor contexts subject to command-and-control policies and heavily regulated markets, like China (e.g. on price elasticities, demand growth, price formation, etc). More recent approaches use network analysis to understand how labour markets adapt to changes at the micro level – but the corresponding models rely on detailed, high-quality micro-level data such as linked employer-employee datasets.[203 204]

In China's case, the data required to run empirically robust network models is largely unavailable to researchers outside the Chinese government. Furthermore, most conventional economic models are incapable of ingesting micro-level data without some form of aggregation, producing relatively low-resolution results. Therefore, macro modelling is not sensible and network modelling is not feasible.

Model design, dynamics and limitations

Given these constraints, rather than predicting what the most likely pathway might be, this study uses a micro-simulation approach to model the dynamics in the coal sector system. The study estimates the magnitude and distribution and of jobs and tax revenues generated by the thermal coal sector (both geographically and across value chains and enterprises), and how these change over time.

Using asset-level datasets of China's coal power plants and coal mines, supplemented by a range of independently sourced data points and assumptions on employment in coal transport, plant utilisation rates, tax rates and productivity improvements, the coal sector is modelled independently from other sectors and taking the final demand for coal as determined exogenously as a function of China's climate policy.

[200] Clark, A. and Zhang, W. (2022). Estimating the Employment and Fiscal Consequences of Thermal Coal Phase-Out in China. Energies (Basel), 15(3): 800. doi:10.3390/en15030800.

[201] Most of China's coal consumption for purposes other than electricity generation is used to generate heat, largely for industrial processes such as steel and cement production, with a small and shrinking proportion still being used for domestic heating. At the time this study was undertaken, data availability limited the scope to thermal power only. The Spatial Finance Initiative at Oxford University has since published asset-level datasets for the steel and cement sectors that may facilitate an expansion of this model to cover a much greater share of China's total coal consumption.

[202] Mercure, J-F. et al. (2018). Macroeconomic Impact of Stranded Fossil Fuel Assets. Nature Climate Change, 8(7): 588-593. doi:10.1038/s41558-018-0182-1.

[203] del Rio-Chanona, R. M. et al. (2020). Supply and Demand Shocks in the COVID-19 Pandemic: An Industry and Occupation Perspective. Oxford Review of Economic Policy. doi:10.1093/oxrep/graa033.

[204] Mealy, P. (2018). Know What? New Lenses on Productive Knowledge Shed Light on Long Run Development, Structural Change, Job Switching and the Transition to the Green Economy. In J. D. Farmer & C. Hepburn (Eds.).

The demand-driven model is built from the bottom up, incorporating location-specific data on individual thermal coal plants in China, and linking these to provincial coal-mining capacity. Employment and tax revenue calculations are overlaid on this network and evolve over time, based on changes in the activity of coal plants. Differences in coal type, and the physical distance between mines and plants, is also accounted for, allowing a coal transportation layer to be added to the analysis. For aforementioned data quality reasons, plants are not linked to specific mines in this iteration of the model, although as researchers develop a greater understanding of the determinants of mine-plant relationships (e.g. distance, transportation cost, shared mine and plant ownership), this could be incorporated in a straightforward manner.

Consistent with the risk-opportunity analysis framework developed in Mercure et al. (2020),[205] the model is designed to handle non-marginal changes, while remaining – in this iteration – agnostic on substitution and price effects resulting from changes in demand. This is not to say that these effects are not relevant to the Chinese case, but rather to reserve judgement in the face of the reality of heavily regulated markets, as well as fundamental uncertainty on price formation, elasticities and the details of coal supply contracts. As information availability improves, this model can certainly be improved to reflect greater knowledge on these critically important dynamics.

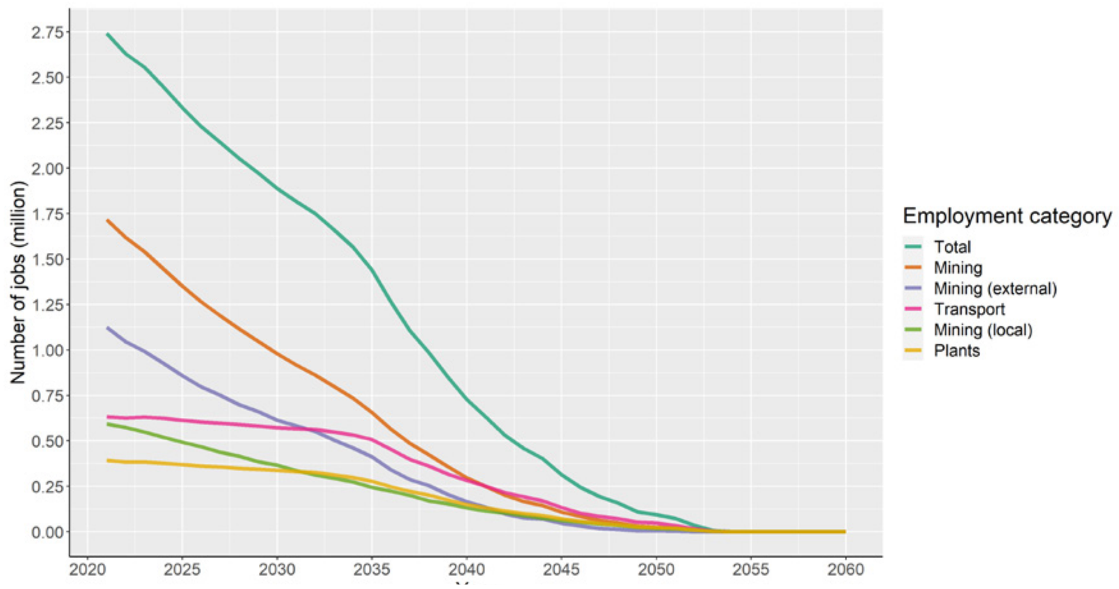
Results

We model a baseline scenario as one in which existing plants operate as planned for their 30-year lifetimes and are then retired; all currently approved plants are built (while those which are currently planned but not approved are not built); and the mining industry does not have an alternative source of demand for thermal coal.[206] These conditions result in a phase-out of coal power by the mid-2050s. Any retiring coal plants are replaced not with new coal power but with lower-cost sources of clean power.

The model is run for four other scenarios: a No Transition (NT) scenario (in which all planned plants are built and operate for their full lifetimes, regardless of approval status); and three additional scenarios reflecting more ambitious climate policies, calibrated to approximately match the coal capacity trajectories modelled by He et al. (2020).[207] The R scenario reflects greater competition from low-cost renewables, and the C50 and C80 scenarios require 50 per cent and 80 per cent reductions in emissions from coal-fired power by 2030 relative to 2015, respectively. Progressively stricter scenarios entail a greater short-term drop in coal capacity and a more rapid phase-out of the remaining fleet.

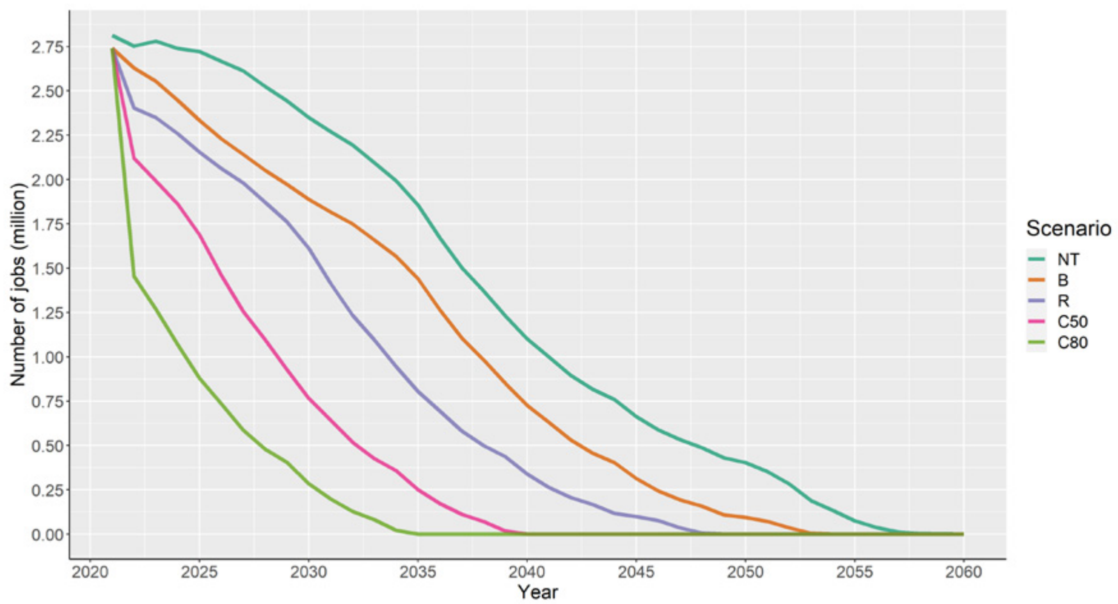
In the baseline scenario, a continuation of historical labour productivity growth trends in the coal mining sector implies jobs will be lost to efficiency in the medium term. Employment supported by thermal coal consumption declines from 2.7 million in 2021, to 1.4 million in 2035 and 94,000 in 2050. Total mining jobs are separated into those generated by coal consumption in the same province where the coal is mined ('local') and coal consumption in other provinces ('external'). Across both categories, the number of coal miners alone facing redundancy even without any changes to the existing policy baseline is projected to exceed 1.1 million by 2025 (see Figure 68).

Figure 68: Employment in thermal coal mining, power, and transport sectors under baseline scenario, 2021–2060.



As Figure 69 shows, the R scenario's impact on total employment is limited until the late 2020s, but its marginal impact over the baseline widens to 630,000 jobs in 2035, before narrowing again – with much larger gaps for C50 and C80. Conversely, a NT scenario would only protect 500,000 employees from redundancy by 2030 and employment would still fall 40 per cent by 2040, and 85 per cent by 2050.

Figure 69: Employment in the thermal coal mining, power and transport sectors under five coal phase-out scenarios, 2021-2060.



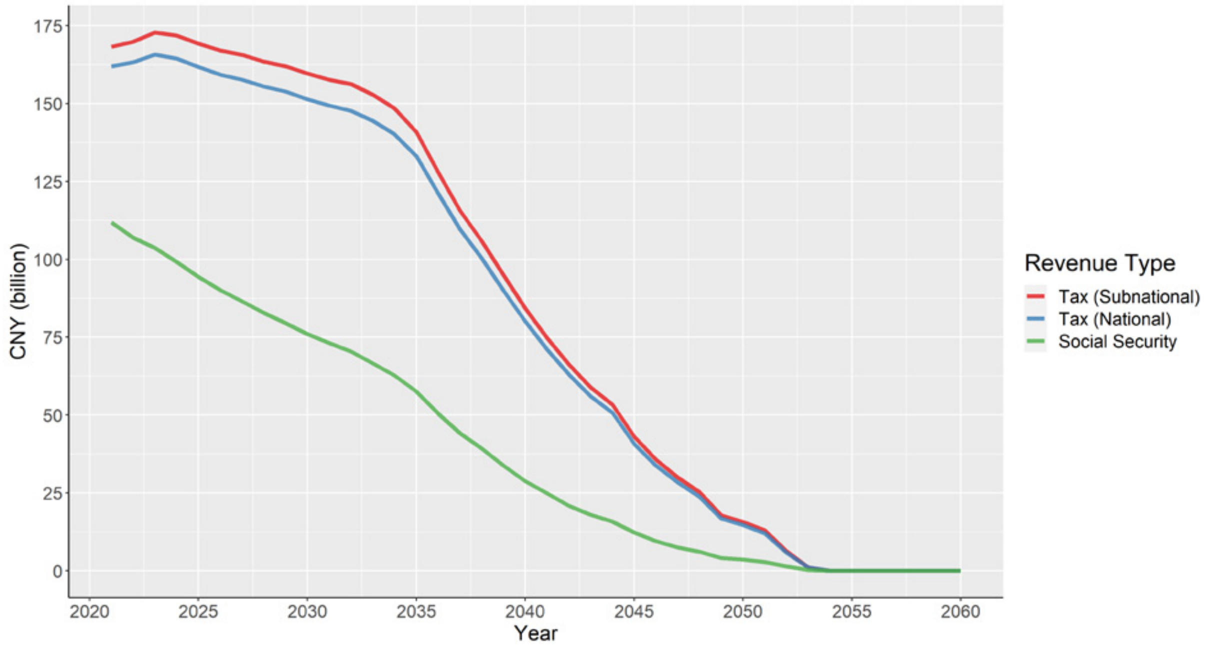
[205] Mercure, J-F. et al. (2020). Risk-Opportunity Analysis for Transformative Policy Design and Appraisal. Global Environmental Change 70: 102359.

[206] It is possible but unlikely that large-scale alternative uses for thermal coal will be found within China, assuming it continues to export only a modest share of its total coal production. This may lead to the outright closure of mines producing thermal coal exclusively, particularly those supplying specific plants. However, while many coal mines produce either thermal or coking (metallurgical) coal, some mines produce both types and may be less affected by a phase-out of thermal coal only. It remains to be seen whether China's demand for coking coal will decline at a similar rate to thermal coal or whether decarbonisation of industrial coal use will be delayed in comparison.

[207] He, G. et al. (2020). Rapid Cost Decrease of Renewables and Storage Accelerates the Decarbonization of China's power system. Nature Communications, 11(1): 1-9.

The contribution of thermal coal to tax revenues in the same scenario totals approximately CNY 300 billion annually from 2021-2030 (with an additional CNY 110 billion in social security contributions), peaking in 2023 at CNY 340 billion (see Figure 3). With total subsidies, not including greenhouse gas externalities or fully including local pollution externalities, likely to be at around CNY 480 billion annually (based on a detailed survey of the available literature on direct and indirect subsidies across the value chain modelled in the study), the thermal coal sector considered on its own is likely to already be a net fiscal drain on China's public finances.

Figure 70: Breakdown of tax (national and subnational) and social security revenues generated by thermal coal sector, 2021-2060, baseline scenario.



As coal plants begin to retire in larger numbers in the mid-2030s, fiscal revenues fall rapidly, with the annual rate of tax revenue loss rising from 1 per cent through the 2020s, to over 10 per cent by the 2040s. As assumptions for China's future policy on coal becomes stricter, losses in jobs and tax revenues are brought forward in time. Under an admittedly unlikely policy of no transition at all, in which all currently planned coal plants are built, these losses are delayed but not ultimately prevented.

Tax revenues track total coal consumption, such that the B and NT scenario see revenues peak in 2023 (CNY 339 billion) and 2027 (CYN 399 billion) respectively. The tax base remains stable up to 2030 even under the R scenario, falling by just 17 per cent through the 2020s and declining rapidly thereafter. The C50 and C80 scenarios see a similar rate of decline but brought forward 10-11 years and 15-16 years compared to the baseline, respectively. This reflects the capital intensity of the tax base: tax revenue declines are driven almost entirely by capacity retirement.

Assessing these results at the provincial level suggests that the coal-producing areas responsible for the vast majority of production, namely Inner Mongolia, Shanxi, Shaanxi and Xinjiang, will face significant challenges in managing the localised effects of expected job losses and redirecting labour supply to other productive uses. With industries dependent on coal exports, these provinces are relatively labour-efficient, but their high level of exposure to declining coal demand implies a rapid collapse in tax revenues to their respective provincial government in the 2030s unless they successfully diversify.

At the company level, coal demand from the 'Big Five' state-owned power companies supports 40 per cent of national jobs and tax revenues from thermal coal in 2021. The jobs supported by the 10 largest firms' activities nationwide – with one exception – will fall by roughly 70-85 per cent by the early 2040s, while tax revenue generated by each firm's coal consumption will fall by roughly 45-70 per cent.

Policy conclusions

This work yields at least two major policy conclusions, to be refined and tested in future research. First, millions of jobs in China's thermal coal sector are at risk in the coming decades, but failing to adopt decarbonisation policies will likely have a limited impact on the magnitude and distribution of jobs lost because most of these losses are driven by consolidation and automation. Only the most aggressive decarbonisation policy scenarios (C50 and C80) result in a significant increase in job losses, particularly in the 2020s. The prospect of large-scale job losses in the coal sector is therefore an important policy consideration, but not in itself a reason to delay low-carbon transition measures, especially in the context of expanded employment in other sectors, and cost savings resulting from a rapid transition.[208] The case study Unstoppable renewables and marginal pricing in China, India and Brazil finds that a scenario in which the transition to clean power is accelerated has more positive outcomes for employment and GDP in China than a scenario in which the transition to clean power is delayed.

Second, losses in tax revenues from declining coal sector activities are not a reason to delay the transition either, because they are very likely to be more than offset by the savings made by reducing subsidies paid to the sector, even without considering greenhouse gas externalities. However, wide variations in the net short- and long-term net fiscal impact on individual provinces make a strong case for redistributive measures to be taken by the national government. Any net fiscal savings from phasing out coal in less-exposed provinces could be used to temporarily replace losses felt by more-exposed provinces as they reposition and/or diversify their tax base, easing their path through the transition.

Looking ahead: the usefulness of a bottom-up lens

The plant-specific analysis allows the user to identify the ultimate (demand-side) drivers of employment and tax revenues from the coal sector at a high level of granularity both in terms of location and asset ownership. Accounting for flows of coal across provincial borders also allows for analysis of how demand in one province can support employment and tax revenue in another.

The model also allows for many different types of demand-side and supply-side policy to be evaluated, based on their impact on demand from individual plants or supply from individual mines. Scenarios for future coal demand can be calibrated in a number of ways, either by adjusting the lifetime of each coal plant/mine and its utilisation/production rate directly, or by simulating the effect of provincial or national policies to control emissions from the coal power sector or coal production (which, for example, may target less-efficient plants first). Similarly, the underlying assumptions and calculations for estimating employment and tax revenues associated with coal mining, transportation and use can be easily adjusted in response to new or updated information on various aspects of the coal sector value chain.

While the existing model covers only coal use in the power sector, it can also be expanded to include coal use in heavy industry (primarily for steel and cement manufacturing) and the underlying modelling approach can also be expanded to other parts of the energy sector, including non-coal power generation, and to oil and gas extraction and use (although in the latter case, there is a much greater international dimension).

This model is relatively simple in its construction and logic, and does not examine how declines in employment and tax revenues in the coal sector might be offset by gains due to substitution away from coal towards other energy sources. These questions are perhaps better answered by other modelling approaches using network analysis and input-output tables, but the microsimulation approach employed here can either be integrated into these complementary approaches or used as a means of comparing results and calibrating the dynamics of responses to external stimuli.

For example, this modelling approach can be used to identify how 'optimal' pathways for coal phase-out identified through macroeconomic modelling (e.g. based on least-cost power generation) might diverge from the results of the top-down policies that continue to play a major role in determining coal demand in China. It could also be used in dialogue with results from other models to identify where results might be unrealistic or imply unprecedented changes to the composition of the coal sector in different provinces and regions across China. Last but not least, the high-resolution nature of the analysis can also help to anticipate sources of political, economic or other resistance to change, based on vulnerable locations, entrenched interests, political-economic incentives or other factors.

[208] See Way, R. et al. (2022). Empirically Grounded Technology Forecasts and the Energy Transition. Joule, 6(9): 2057-2082. doi.https://doi.org/10.1016/j.joule.2022.08.009.

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