European Commission

Quarterly R&I literature review 2021/Q4

Technological change and society

R&I PAPER SERIES
LITERATURE REVIEW

Research and Innovation

Technological change and society

European Commission
Directorate-General for Research and Innovation
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2022 Directorate-General for Research and Innovation EN

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INTRODUCTION

This literature review is developed by the 'Economics of R&I' team of the Chief Economist unit of DG Research and Innovation. It provides a brief summary of a selection of recent publications on R&I economics and policy. Contributors for this edition: Valentina Di Girolamo, Alessio Mitra, Océane Peiffer-Smadja, Julien Ravet (team leader).

It is easy to assume that every leap forward in technology is a leap forward in benefit, but this is not always the case.

Ancient and modern human civilizations have both benefited from and been challenged by the technological innovations, inventions and engineering applications used within societies to perform specific tasks. For societies to thrive and evolve, technological innovations have become necessary, while at the same time technologies have become shaping tools of the culture, ideals and aspirations of human societies.

We have witnessed the emergence of new technologies that do not directly answer to societal challenges, such as cryptocurrencies. While they impact our consumption and increase our ecological footprint, they seem less likely to improve our ways of living and the society as a whole.

Other **technologies**, while being able to bring huge **benefits**, such as biotechnology or robotics, could also alter our ways of living. They can increase **inequalities,** sometimes hold **ethical dilemmas** or have the potential to greatly increase our use of natural resources. On the other hand, progress achieved through the development of these technologies could add to the social good.

More generally, **how does technology and technological change impact our society?** What can we learn from the literature on how to deal with the fragile balance between risk and benefit when it comes to technological change?

TECHNOLOGICAL CHANGE AND JOBS

McGuinness, S., Pouliakas, K., & Redmond, P. (2021). Skills-displacing technological change and its impact on jobs: challenging technological alarmism?. **Economics of Innovation and New Technology**, 1-23

Messages	**1. In the EU, 16 percent of adult workers are impacted by skills-displacing technological change (SDT), with significant heterogeneity across countries. 2. Employees exposed to SDT tend to have higher levels of education, being more likely to be promoted, to work in larger organisations in roles that involve teamwork and non-routine tasks, and to face greater on-the-job training and upskilling. 3. Skills-displacing technological change (SDT) is likely to increase job-market polarization.**

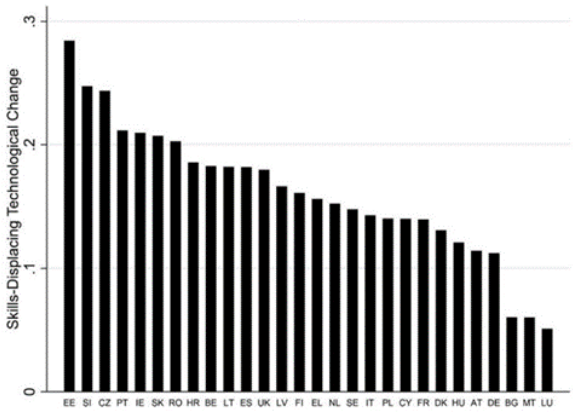
The paper identifies which workers are more affected by skills-displacing technological change (SDT), broadly defined as both new machinery and ICT systems. The authors employ individual level data from the first European Skills and Jobs Survey (ESJS), containing a representative sample of the employee workforce in all EU Member States (and UK), with information on workers' skills, tasks, workplace changes, and other relevant demographic and socioeconomic characteristics.

Cross-sectional regression analysis using OLS and probit model frameworks are employed to investigate which type of employees are more likely to be affected by skills-displacing technological change (SDT), as well as to understand what effect SDT has on the affected workers.

The authors find that around 16 percent of EU and UK employees experience SDT, and that those employees are usually higher-skilled, professional, workers employed in ICT, managerial and engineering-related occupations. Furthermore exposure to SDT is very diverse across European countries, with Estonia (28%) and Slovenia (25%) experiencing the highest rates, and Luxembourg (5%) and Malta (6%) experiencing the lowest.

The paper also demonstrates that SDT is associated with higher job-skill requirements, greater task variety within jobs, more training/upskilling, higher likelihood of being promoted, higher likelihood of working for the private sector in lager companies, and higher wages. On the other hand, individuals exposed to SDT (likely due to the faster rate of skills obsolescence) show also higher fear over losing their job.

Given these results, skills-displacing technological change (SDT) is likely to increase job-wage polarization by increasing the re-skilling opportunities of already highly skilled individuals, while leaving medium and low skilled individuals in routine jobs increasingly ill-prepared. As policy implication, the authors call for emphasizing the critical role of lifelong learning for adapting to technological innovation, instead of fearing it.

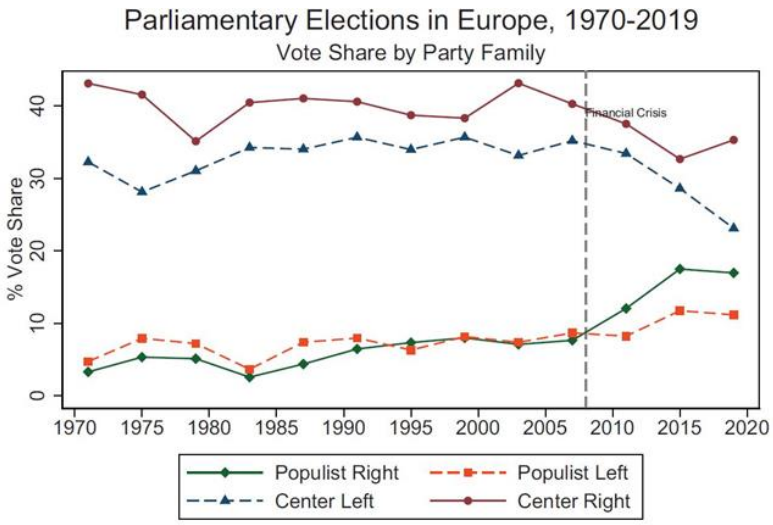


TECHNOLOGICAL CHANGE AND POLITICS

Milner, H. V. (2021). Voting for populism in Europe: globalization, technological change, and the extreme right. **Comparative Political Studies**.

Messages	**1. In Europe, technological change in the form of automation is positively related with increases in votes for extreme right parties. 2. Individual workers at risk of automation, as measured by their routine task intensity (RTI), are more likely to support right populist parties. 3. Social welfare compensation seems unable to dampen these political trends.**

The paper provides evidence on the impact of globalization and technological change on voters' political preferences in Europe. The author employs regional and individual level data for 15 European countries from 1990 to 2018.



Panel regression analysis with an instrumental variable approach is employed to investigate the impact of globalization (measured as trades) and exposure to automation (measured as routine task intensity) on likelihood of voting for extreme right wing parties.

The author finds that globalization and technological change increase the share of votes for right wing parties. It is argued that this may be a consequence of the bias of modern automation and digital technologies, which displace middle-skilled workers (that do routine and easy to automatize tasks) in both blue-collar (manufacturing) and white-collar (administrative) jobs. Such workers are a large and electorally relevant group who, by not seeing the gain of globalization and technological change, can move towards more nationalist and protectionist political ideas. Interestingly, social welfare spending does not seem to moderate the support for extremist parties.

Overall, a one standard deviation increase in import exposure (around 245 euros per worker) approximates a 1.11% increase in populist right voting. A one standard deviation increase in technological change is associated with a 0.85 percentage point increase in vote share of extremist right wing parties.

Given the presented evidence, the author highlights the political battle between "winners" and "losers" of globalization, encouraging the importance of acknowledging such trend with the objective to hamper it and safeguard European democracy.

AUTOMATION AND POPULATION AGING

Daron Acemoglu, Pascual Restrepo (2021) Demographics and Automation, **The Review of Economic Studies**, rdab031, https://doi.org/10.1093/restud/rdab031

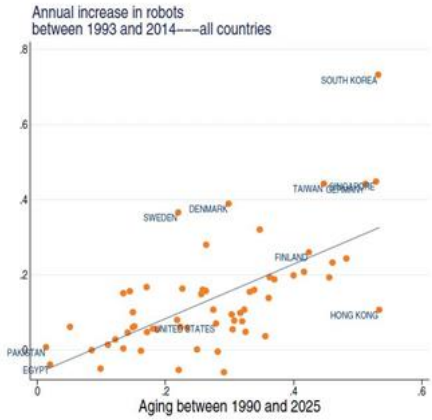
Messages	**1. Ageing leads to greater (industrial) automation, because it creates a shortage of middle-aged workers specializing in manual production tasks. 2. Countries undergoing more rapid demographic change are developing and exporting more automation technologies. 3. Ageing increases relative labour productivity and reduces the labour share in industries that have the greatest opportunities for automation.**

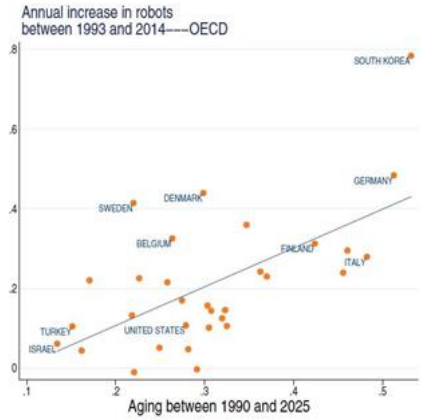
The paper gives insights on the impact that population ageing has on the development and adoption of automation technologies. The authors employ regional and country level data for 129 countries (OECD and developing nations) from 1996 to 2015.

Panel regression analysis with instrumental variable approach is employed to uncover the impact of population ageing on the use of automation in countries and industries.

The authors find that ageing is associated with the adoption of robots: a 20-percentage point increase in aging (equivalent to the difference between US and Germany) is associated with 0.16 more robots per thousand workers per year. Ageing also results in an increase in robot technologies imports: a 20-percentage point increase in ageing leads to a 64% increase in (industrial) robot imports (relative to total intermediate imports). At the same time, demographic change is also associated with higher exports of industrial robots relative to other intermediate goods: 20-percentage point increase in ageing doubles robotics exports. The same effect is found for robotics-related patents: a 20-percentage point increase in ageing leads to a 24% increase in robotics-related patents (relative to all utility patents).

It is argued that the effects of population ageing on automation technology adoption is driven by the response of firms to the relative scarcity of middle-aged workers, who typically perform manual production tasks. To confirm such hypothesis, the authors show (using US data) how jobs entailing routine tasks are predominantly performed by middle-age workers and that those industries (relying on middle-age workers) are embracing robots at a faster rate.





TECHNOLOGICAL CHANGE AND INEQUALITY

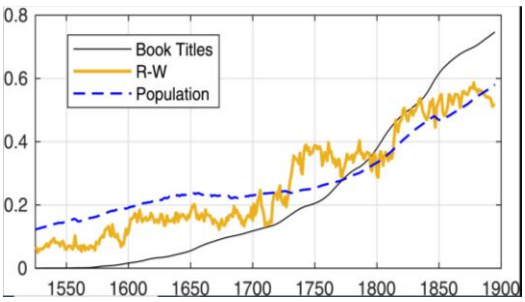
Madsena J. & Strulik H (2020). Technological change and inequality in the very long run. **European Economic Review**. *Volume 129, October 2020, 103532*

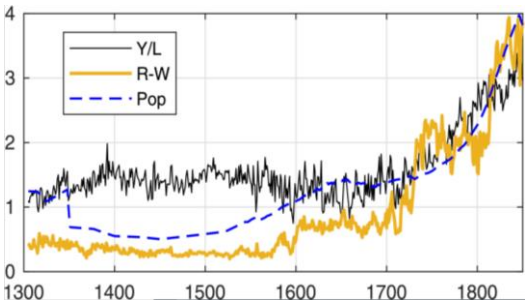
Messages	**1. Technological progress is a main driver of inequality before the onset of the fertility transition (1500-1850s), and its impact on inequality reverses after the fertility transition (1850-1980s). 2. In the very long run, technological progress initiated a fertility transition and the associated take-off of education.**

This paper investigates the impact of technological progress on the evolution of inequality before and after the fertility transition (from 1500s to 1980s as the fertility transition that took off around 1850s).

The authors set up a model of long-run development with endogenous fertility, education, and technology. The publication of new farming books and agricultural labour productivity over 1525-1895 in Britain are considered as technological progress indicators. Results on Britain are expanded to seven OECD countries considering both patents and agricultural productivity over 1800–1980s as technological progress indicators. The ratio Rent/Wage (R-W) is used as an indicator of inequality.

In the paper, several regressions are run across different periods, first for Britain only and then for a panel of OECD countries (Belgium, Denmark, France, Ireland, Spain, Britain, and the US). The model specification accounts for several control variables such as political economy





variables, manufacturing income share, parliamentary sessions, and temperature.

The authors find that technological progress is a main driver of inequality before the onset of the fertility transition (which started in the 1850s). In the key period 1700–1850 during which the R–W ratio increased the most, farming book titles explain 45.9% of the increase in the R–W ratio, while the population increase explains 22.6%, suggesting that technological progress was a major force behind increasing inequality in Britain during the same period (exacerbated by the population expansion).

Furthermore, using results on both Britain and OECD countries over 1800-1980, the authors show that inequality reaches a peak shortly after 1850s and then declines. Authors conclude that, in the very long run, technological progress induced a fertility transition, an associated take-off of education, with subsequent human capital accumulation and increasing wage.

SOCIAL IMPLICATIONS OF INNOVATION

Mao C., Koide R., Brem A., Akenji L. (2020). Technology foresight for social good: social implications of technological innovation by 2050 from a Global Expert Survey. **Technological Forecasting and social change**. Volume 153, April 2020, 119914.

Messages	**1. Technological innovation benefits society by improving communication and productivity in the supply chain. 2. But it also deepens inequality and increases the surveillance of the public. 3. Although technology provides more options for environmentally conscious choices and better infrastructure, its affordability is a concern.**

This paper investigates how technology would impact society and people's way of living between now and 2050.

This study uses an online survey of 137 authors of articles published in technology foresight-orientated scientific journals in 2018. They applied a free-text method and treated the results using quantitative cross-sectional analysis.

The respondents indicated the level of relationship of different areas with technological innovation, which is displayed in the figure. Bubbles on the right corresponds to areas that have been classified by the respondents as the most impacted by technological innovation, such as governance, cybersecurity privacy, control and surveillance. Bubbles on the left are areas considered as being less impacted by technological innovation, such as population movement or environmental degradation, but still mentioned by the respondents as being linked to technological change. The vertical axis represents the frequency these areas were mentioned by the respondents.

Authors highlight that technological innovation benefits society by improving communication and productivity in the supply chain, as well as providing more options for environmentally conscious choices and better infrastructure. However, it causes unintended consequences such as deepening inequality and increasing the surveillance of the public and its affordability is a concern.

The authors recommend to consider wellbeing as a key factor in deciding whether certain technology should be promoted to add value to the social good.

TECHNOLOGICAL CHANGE AND WORKER WELL-BEING

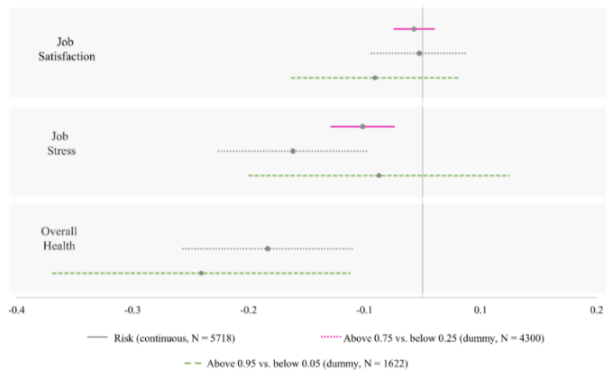
Nazareno, L., & Schiff, D. S. (2021). The impact of automation and artificial intelligence on worker well-being. **Technology in Society**, *67*, 101679.

Messages	**1. Changes in the workplace conditions resulting from the introduction of new technologies can significantly affect worker well-being. 2. Technological complementarity (i.e., the use of technology to complement workers) is not a uniform good, as it also produces negative effects on some dimensions of workers' well-being.**

The paper provides a conceptual framework accounting for the effects of automating technologies on worker well-being. The analysis focuses on the introduction of AI technologies and aims at exploring how the well-being of workers complemented by AI at work is affected.

The conceptual framework explores the effects of automation along five hypotheses: H1 - Creative freedom hypothesis capturing the positive effects that automation can produce by freeing workers from routine tasks and enabling their creativity capabilities; H2 - Cognitive overload hypothesis accounting for the stress that an excessive cognitive overload can induce on workers; H3 - Loss of meaning hypothesis referring to the potential loss of identity that workers could experience seeing the relevance of their job role significantly reduced by new technologies; H4 - Surveillance and control hypothesis capturing the potential effect that AI technologies can have on workers when used to improve monitoring mechanisms within the workplace; H5 - Job insecurity hypothesis focusing on the forward-looking effects of automation linked to workers potentially fearing abrupt job changes, eventually resulting in job displacement.

To disentangle the aforementioned mechanisms, the paper uses data from the General Social Survey (GSS) over the period 2002-2018. The empirical strategy consists in regressing different well-being measures (such as job satisfaction, stress at work, overall health) on automation risk. The model specifications are gradually enriched with additional covariates and account for automation risk variation overtime.



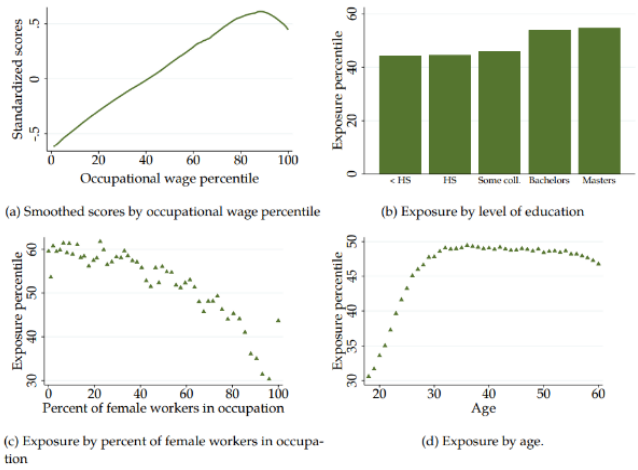
The paper's main contribution is to provide empirical evidence showing that technological complementarity is not uniformly positive. The results suggest that automating technologies affect workers well-being in terms of job stress and overall health dimensions, especially in those jobs where workers face higher levels of automation risk. The effects on job satisfaction are instead ambiguous. From a policy perspective, the evidence suggests caution when assessing the effect of automating technologies on the job market, calling for increasing the attention to the often neglected effects on worker well-being.

AI AND HIGH-SKILLED WORKERS

Webb, M. (2020). The impact of artificial intelligence on the labour market.

Messages	**1. New technologies create winners and losers in the labour market, inducing changes in relative demand for labour. 2. AI exposure is highest for high-skilled occupations and affects different types of workers compared to software and robots.**

The paper aims at estimating the relationship between the extent to which an occupation's task can be replaced by technology and changes in demand for that specific occupation. The author develops a static task-based model in which the economy produces a unique final good via a CES production function, and provides a new empirical measure of automation exposure to assess how the adoption of particular technologies affects labour demand dynamics.



(a) Smoothed scores by occupational wage percentile

(b) Exposure by level of education

(c) Exposure by percent of female workers in occupation

(d) Exposure by age.

Figure 7: **Exposure to AI by demographic group**

The analysis focuses on three types of substitutive technologies, namely robots, software and AI. The measure of automation exposure is developed by quantifying the overlap between text of patents and the text of job description. Information on patents are retrieved from Google Patents Public Data, provided by IFI CLAIMS Patent Services; whereas data on job descriptions are collected using the O*NET database of occupations and tasks. To measure the relationship between automation exposure and labour demand, data on changes in wages and employment from the US Census 1960-2000 and from the ACS 2000-2018 are used.

The results from the empirical analyses suggest that exposure to robot technology negatively affects within-industry employment shares and wages at the 25th to the 75th percentile, with an estimated decline between 9% and 18%, and 8% and 14%, respectively. Exposure to software induces a smaller decline in magnitude, with a negative relationship between 7% and 11% for employment, and between 2% and 6% for wages. When looking at AI, the paper finds that exposure to AI technologies affects labour markets very differently as compared to the other two type of technologies considered. First, low-wage jobs are less exposed than high-wage ones, reflecting the fact that AI technologies are more likely to be used by high-skilled workers typically receiving higher compensations. Indeed, high-skill occupations, also requiring higher level of accumulated experience, are found to be more exposed to AI, with a peak observed at the 90th percentile. It follows that older workers are also more exposed to AI than younger individuals. As regards the gender dimension, men appear to be more exposed than women, as they are more likely to be employed in technical jobs most exposed to AI.

EASTERN POST-SOCIALIST TRANSFORMATIONS

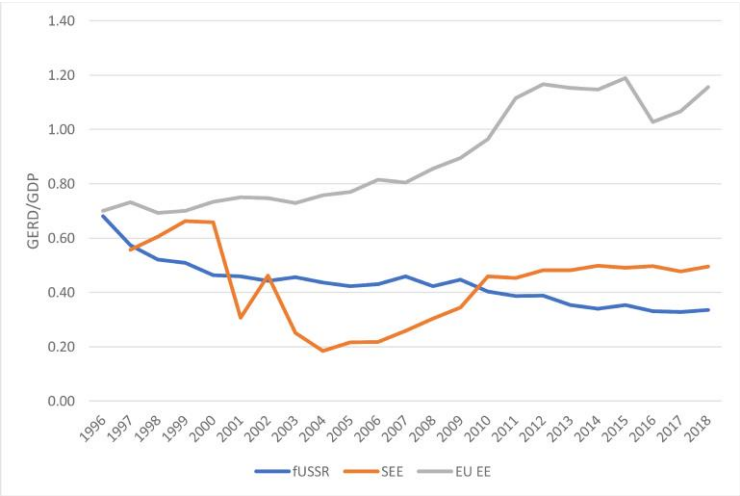
Radosevic, S. (2022) Techno-economic transformation in Eastern Europe and the former Soviet Union – A neo-Schumpeterian perspective. **Research Policy**, 51(1): 104397.

Messages	**1. Post-socialist transition is characterised by lacking dynamic interactive capabilities as the core precondition for the technological catch-up. 2. The challenge for EE&fSU economies is how to align domestic technology absorption, and generation with open access to FDI and GVC.**

In this essay, the author uses a neo-Schumpeterian lens to explore various dimensions of the socialist and post-socialist transformation in Eastern Europe (EE) and former Soviet Union (fSU) economies.

It builds on two principles of Christopher Freeman. First, his belief that technical change rests on governance regimes which are hybrid - simultaneously public and private. Second, his recognition that technological change is also a social and a political process.

The analysis is based on several arguments. First, post-socialist transformation of enterprises from production to business units not only involved a change in ownership, but also required a major change in their role as carriers of capabilities and source of innovation.



Second, in the post-socialist period, firms interacted either with weak organisational capabilities (firms), unreformed (R&D organisations) or external actors (notable Foreign Direct investment, FDI).

Third, sudden confrontation with open markets led to a shift from 'domestic-led' to dominantly 'foreign-led' technological modernisation. This did not lead to catch up, which occurs only if reliance on foreign sources of knowledge is complemented by local technology accumulation and the growth of interactive dynamic capabilities.

Fourth, technology accumulation and innovation systems are necessarily hybrid systems. The swing from one pure mode of coordination (plan) to other (market) explains limited technological upgrading in both periods.

Crucial to this is an understanding of the role which the state plays, both as a contributor and as an obstacle to the transformation towards sustainable economic growth.

DIGITAL CHANGE, BEYOND MARKET DYNAMICS

Mansell, R. (2021) Adjusting to the digital: Societal outcomes and consequences. Research Policy, **Research Policy**, 50(9): 104296.

Messages	**1. Assessment of changes in techno-economic paradigm and, specifically, in relation to the ICT paradigm, need to go beyond market dynamics to examine social, cultural and political issues.**

In this paper, the author uses three themes of Christopher Freeman to examine contemporary developments in the ICT paradigm (5G mobile networks, artificial intelligence-as-a-service (AIaaS) and taxation policy). The themes are (i) ambiguity of technological innovation outcomes, (ii) the role of guiding principles in influencing expectations about societal outcomes, and (iii) the importance of political factors in shaping the consequences of technological innovation.

In the case of 5G innovation, the author highlights the clear interdependence of political and economic power. The expectations underpinning claims and counterclaims about national security threats, 5G network vulnerabilities and state subsidies are difficult to resolve empirically because much information is subject to national security protections. There are consequences for society, nonetheless. 5G presents new risks to citizen privacy and to regulatory regimes for data protection, based on a very substantial expansion in the availability of both personal and non-personal data for monetisation controlled by larger and smaller companies. This outcome receives far less attention when the focus in 5G research is predominantly on market expansion prospects.

As regards AIaaS (AI as a Service), which enables the commercialisation of data using AI-driven algorithms, the European response to dominant American and Chinese-owned cloud providers involves the provision of guiding principles for the data economy that are both economically motivated to achieve growth and politically or socially motivated to support European public values. However, according to the author, the success of European policies (including antitrust measures) in addressing the asymmetric power between foreign-owned and domestic cloud platforms in a way that enables competing values to be balanced is still speculative at the time of writing.

The centrality of commercial datafication strategies and the dominance of very large foreign-owned digital platform companies are presenting challenges to the sustainability of the tax base. The author stresses that, at the writing in early 2021, there is renewed momentum towards a shift in the priorities and values underpinning the international tax rules to create a fairer regime.

TECHNOLOGY HYPE AND DISILLUSIONMENT

Kriechbaum, M., Poscha, A., Hauswiesner, A. (2021) Hype cycles during socio-technical transitions: The dynamics of collective expectations about renewable energy in Germany, **Research Policy**, 50(9): 104262.

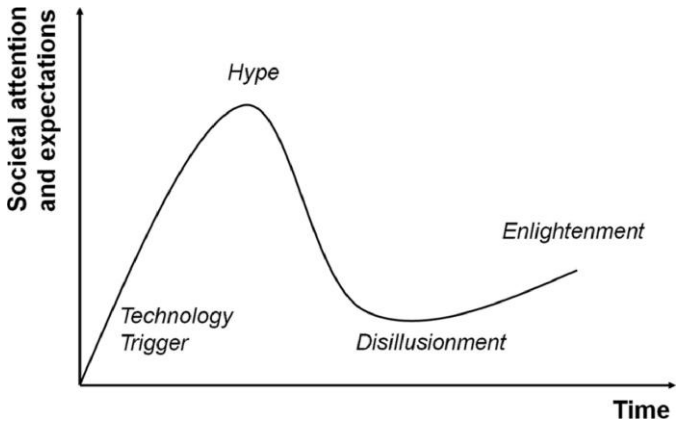
Messages	**1. Patterns of hype and disappointment are identified for wind power, PV and biogas in Germany 2. Societal hopes and fears play a crucial role in shaping these hype cycles**

This paper proposes a new framework for explaining the formation of collective (or widely shared) expectations about emerging niche technologies.

The notion of hype cycles originally referred to three pre-defined phases through which emerging technologies inevitably pass: hype, disillusionment, and enlightenment. Novel technologies tend to be overestimated when introduced, which leads to a high level of societal attention and inflated expectations (Hype). Because expectations do not translate into reality, a phase of disillusionment sets in. Over time, this disillusionment is overcome, and the technology reveals its true value and diffuses widely (Enlightenment).

The study identifies the dynamics of expectations regarding wind power, solar PV and biogas from 1992 to 2017 by applying a content analysis of newspaper articles published by Germany's largest national newspaper.

It shows that all three analysed technologies were associated with patterns of hype and disillusion-ment.



However, the hype cycles differed in terms of their shape, magnitude, and duration (for instance, the hype about wind power was by far the strongest- and longest-lasting). Moreover, different events could be correlated with the relevant 'turning points'. For instance, the hypes about solar PV and biogas were mainly induced by niche-internal developments (favourable feed-in tariffs and market growth), while the hype about wind power emerged during a wind market downturn and was primarily triggered (and maintained) by external factors (i.e. the strong and rapid increase in public climate awareness in 2007 and the decision to phase out nuclear power in 2011).

While the hypes were driven by positive frame expectations (e.g. hopes for climate change mitigation, job creation, or energy security), disillusionments were characterised by 'framing struggles' in which negative frame expectations, such as fears of high policy costs, were contrasted with and challenged these hopes.

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The aim of the Review is to inform policymakers on the latest findings from the literature that links R&I economics to R&I policy.

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