European Commission

Quarterly R&I literature review 2021/Q3

Research, innovation and human capital

R&I PAPER SERIES
LITERATURE REVIEW

Research and Innovation

Research, innovation and human capital

European Commission
Directorate-General for Research and Innovation
Directorate G — Common Policy Centre
Unit G.1 — Common R&I Strategy & Foresight Service

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Research, innovation and human capital

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Literature review

2021 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: Alessio Mitra, Océane Peiffer-Smadja, Julien Ravet (team leader).

Human capital policies represent a widely recognised tool for enhancing long-term innovation, production of knowledge and **economic growth**. The analysis of human capital is a historical stepping-stone for economic theory, with Paul Romer and Robert Lucas developing endogenous growth theory in the nineties. In these new growth theories, technological change is made endogenous, explained *within* the model as the product of efforts by researchers and inventors who respond to economic incentives.

Furthermore, to meet the **twin transition** objectives, the EU will require all collective knowledge and cutting edge technologies that its innovation ecosystem can provide. It is therefore not only crucial to pay attention to the researchers and inventors of today, but also to nurture the talents of tomorrow.

The selected papers cover recent **empirical evidence** on the role of education for R&I, from the development of human capital, the production of knowledge by highly skilled individuals, to the interaction between the different entities that compose the innovation ecosystem. Furthermore, in light of the current COVID-19 pandemic, the presented literature review highlights how and which education policies can prepare for a strong and inclusive recovery.

The first five reviewed papers investigate how COVID-19, **school closures** and **online learning** affected human capital formation, raising important elements of concern related to inequality and long-term productivity. The last five papers focus on the role of **STEM education** in fostering innovation and patents production, as well as how the **job market environment** and institutions can foster inventors and researchers to innovate.

SCHOOL CLOSURES AND LEARNING OUTCOMES

Maldonado, J. E., & De Witte, K. (2020). The effect of school closures on standardised student test outcomes. ***British Educational Research Journal***.

Messages	**1. School closures during the 2020 COVID-19 crisis significantly and negatively affected learning outcomes of primary school students. 2. Inequality in learning outcomes both within and across schools increased because of the COVID-19 crisis. 3. Students from poorer socioeconomic background have been more affected than less disadvantaged ones.**

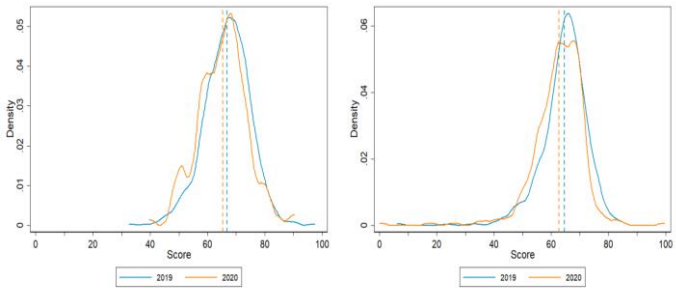
The paper provides evidence on the effects of school closures during the 2020 COVID-19 crisis on standardized student test scores at the end of primary school. The authors employ individual level standardized test scores from a large share of Flemish schools over a period of six years spanning from 2015 to 2020 as well as administrative data at the school level.

A difference-in-differences methodology, together with the panel structure of the data, is employed to evaluate the impact of school closures on learning outcomes.

The authors find that the school closures resulted in significant learning losses and a substantial increase in educational inequality. Indeed, students of the 2020 cohort have school averages in mathematics 0.19 of a standard deviation lower than students in the five previous years have. Science scores decreased by 0.32 standard deviations, Dutch language scores decreased by 0.29 standard deviations and French language scores decreased by 0.3 standard deviations, in 2020 compared to previous years. Overall, the results show a significant decrease in GPA of 0.25 standard deviations.

The paper also finds that the difference between the top and bottom performers increased significantly due to the school closures: (1) Inequality in learning outcomes as measured by the 90/10 ratio (ratio of the score of the 90th percentile to the score of the 10th percentile) increases by 0.23 for mathematics and 0.22 for Dutch. (2) The within-school Gini coefficient increases by 0.02 in both mathematics and Dutch. Inequality in learning outcomes increased across schools as well, with similar magnitudes as the within-school variation. These impacts on learning outcomes are linked to the pre-existent socio-economic background of the students' families.

Given these results, and the well-known long term implications on future income and well-being that early age education has, the authors call for urgent implementation of corrective policies (such as classes on Saturdays and during holidays), particularly for disadvantaged schools and students, in order to maximise the recovery of learning losses.



(a) Mathematics (b) Dutch

SCHOOL CLOSURES AND FUTURE ECONOMIC OUTPUT

Fernald, J., Li, H., & Ochse, M. (2021). Future Output Loss from COVID-Induced School Closures. ***Future***, *2021*, 04.

Messages	**1. Disruptions to children's learning today can have a persistent and large impact on the production capacity of the economy and harm future growth. 2. In the US, COVID-19 related learning disruptions are predicted to reduce the number of college-educated workers by 2.7% and increase the number of workers with less than high school education by 3.8% (in the next 25 years). 3. Compared with a no COVID scenario, annual economic output is predicted to be lower over the next 70 years due to school closures in the US.**

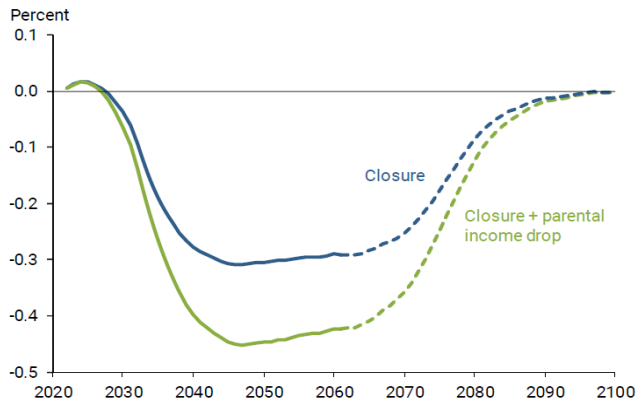
The paper performs a growth accounting exercise to estimate the future impact of COVID-19 related school closures on long-term economic output.

According to the Household Pulse Survey by the Census Bureau nearly 86% of US students at all levels were exposed to some form of remote learning as of November 2020. The same survey reported that 45% of students were spending less time on schoolwork than before the pandemic. Hence, the authors investigate whether such loss in human capital formation can affect long-run productivity and economic output.

To obtain the estimated effect on long-term economic output, the authors first estimate how disruptions will affect the lifetime educational attainment of the workforce. In the second step, since highly educated individuals are more productive, the authors derive its implications for aggregate economic output.

Interestingly, the analysis detects an initial positive effect of schools disruptions on output. This happens because more children choose to enter the workforce earlier, without going to college. However, the impact becomes increasingly negative as soon as the fewer college students reach their working age. The negative effect peaks at 0.5% of GDP from 2045 to 2050 when the affected children reach ages 29 to 39. The effect lasts until the affected cohorts will have retired. On average, the path of output will be 0.23 percentage points lower over the next 70 years because of pandemic school closures.

Impact of learning disruptions today on level of future GDP



Given these results, and the importance of economic prosperity to tackle the diverse set of challenges that we face today, the authors call for urgent policies to incentivise students in continuing their education.

ONLINE TEACHING AND LEARNING OUTCOMES

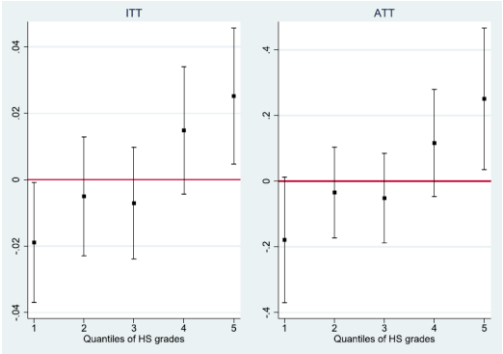
Cacault, M. P., Hildebrand, C., Laurent-Lucchetti, J., & Pellizzari, M. (2021). Distance learning in higher education: evidence from a randomized experiment. ***Journal of the European Economic Association***, *19*(4), 2322-2372.

Messages	**1. Live streaming university lectures lower achievement for low-ability students and increase achievement for high-ability ones. 2. Offering the live streaming lecture option reduces in-class attendance only mildly. 3. Students tend to use the live streaming technology only when random events make attending class too costly (due to shocks to health or commuting conditions).**

The paper provides novel experimental evidence on the impact of a distance learning technology on student performance and classroom attendance in a standard European public university. In the experiment, first-year bachelor students were randomly offered access to a live streaming platform for many of their compulsory courses. Not all students could attend the classes online, but all students could always choose to attend the classes face to face. Randomization happened both across students and over time.

Such design (large-scale randomized experiment) allowed the authors to provide counterfactual (causal) evidence on the impact of online teaching on students' performances and attendance. Overall, the main sample consisted of 1,459 students from the University of Geneva.

Thanks to the experiment, the authors find that having access to the streaming platform (the intention-to-treat [ITT] effect) reduces the probability of answering exam questions correctly by 2 percentage points for students in the lowest quintile of the ability distribution. At the same time, students on the highest quintile of the ability distribution enjoy an increase of 2.5 percentage points in the likelihood of answering correctly the exam questions. The actual access to the platform (average treatment effect on the treated [ATT]) gives similar results. Noticeably, only a minority of students that had the possibility to use the online learning tool actually used it.



The authors rationalise these results by highlighting that high-ability students may prefer own study because they understand the material just by reading the notes, whereas low-ability ones benefit more from in class attendance due to the higher value added of the professors' lectures and the interactions with their peers.

Given these results, the authors propose different policy implications. Firstly, streaming traditional classroom lectures is unlikely to solve problems of physical overcrowding. Secondly, online learning can potentially exacerbate education inequalities. Thirdly, offering such distance learning tools on a merit base may be beneficial.

SCHOOL CLOSURES AND CHILDRENS' WELL-BEING

Di Pietro, G., Biagi, F., Costa, P., Karpiński, Z., & Mazza, J. (2020). The likely impact of COVID-19 on education: Reflections based on the existing literature and recent international datasets (Vol. 30275). ***Publications Office of the European Union***.

Messages	**1. Students are, on average, likely to experience a learning loss during the lockdown. 2. COVID-19 and the move to remote learning and teaching are expected to cause greater inequality in cognitive abilities, as well as in students' emotional well-being and motivation. 3. This may have important consequences not only in the short -term, but also in the long-term.**

What is likely to be the effect of the long school closure caused by COVID-19 on children's learning in the short-term? Will this crisis have any impact also in the long-term? The crisis is unprecedented, but this report uses existing studies and pre-COVID-19 data to tell us more on these issues.

The authors draw four main conclusions. First, student learning is expected to suffer a setback, on average. Online learning has potential, but student progress will not be the same as if schools were open. The learning loss is due mainly to less time spent in learning, stress, a change in students' interactions and lack of learning motivation.

Second, the effect of COVID-19 on students' achievement is likely to vary according to socio-economic status, with students from less advantaged backgrounds likely to experience a larger decline in learning. This is likely driven by differences in parental support (financial, but also non-financial such as skills and time at home with children), school attendance and students' digital skills.

Third, inequality in socio-emotional skills may also increase. Children from lower socio-economic status may be more exposed to a stressful home environment (e.g. sharing limited space and a limited number of digital devices). Parents in these households, who may be under pressure because of financial and job security issues due to the crisis, are probably not in the best position to support their children in these circumstances.

Fourth, the widening social gap in both cognitive and socio-emotional skills may have implications also in the long-term. This increased inequality may have consequences on later educational outcomes as well as future labour market performance. The authors illustrate this by estimating a 700-800 million euro annual earning loss that current French primary students are likely to experience in the future due to COVID-19.

The authors highlight two key challenges for policymakers: (i) quick and effective measures should be taken to ensure that more vulnerable students will be able to make up for the learning loss they experienced during the lockdown; (ii) alternative methods of delivering teaching and learning should be put in place, but the blended/rotating learning system also presents challenges.

HOW DO RESEARCHERS COPE UNDER A PANDEMIC?

Sachini, E., Labrianidis, L., Sioumalas-Christodoulou, K., Chrysomallidis, C., Siganos, G., Belouli, A., Karampekios, N. (2021) Research on Researchers. Coping during COVID-19. Results on a Nation-Wide Survey, ***Science and Public Policy***, 48(4), 451–461

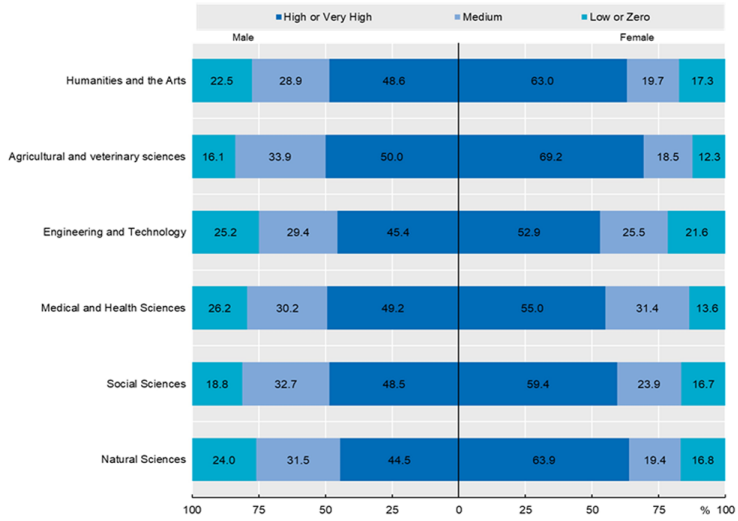
Messages	**1. Data on researchers in the Greek context show that COVID-19 significantly affected their psychological state. 2. Female researchers experienced a higher level of personal as well as family mental strain. 3. 72.4% of the survey's participants believe that science and technology, as a distinct field of human activity, will emerge enhanced from the pandemic in the public sphere.**

This paper provides insights on how researchers have been affected during the pandemic. The authors stress how very few research has been conducted regarding the COVID-19 impact on the scientific community and how little evidence we have today on, e.g. their research performance and future priorities and their personal and family strains.

Data were collected through a survey sent in April 2020 to 4,719 researchers, which are the recipients of the European Social Fund funding through the Greek Operational Programme 'Human Resource Development, Education and Lifelong Learning'. Results of the paper are based on 2,323 survey responses.

Results show that COVID-19 significantly affected the psychological state of the researchers: 53.3 per cent of the researchers reported that they were experiencing a high to very high level of personal psychological strain due to the lockdown and social distancing measures. Additionally, 53.7 per cent of the researchers said the lockdown had taken a toll on their family environment adding a further burden. Below 8 per cent of researchers stated that they experienced no personal or family mental strain.

Figure 4. Distribution of respondents' answers (%) regarding COVID-19 effects on personal mental strain according to …



Female researchers experienced a higher level of personal as well as family mental strain than male researchers, with the highest burden inflicted upon female researchers of Agricultural and veterinary sciences.

72.4 per cent of the survey's participants believe that popular trust in science and technology will emerge enhanced from the pandemic. However, researchers that indicate personal and/or family mental strain have also been most negative in terms of viewing the pandemic as an opportunity for science and technology.

HIGH-SCHOOL TRAINING AND LABOUR INEQUALITIES

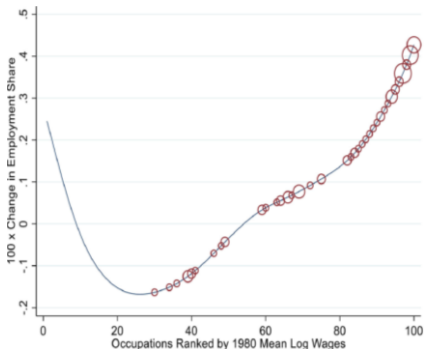
Black, S. E., Muller, C., Spitz-Oener, A., He, Z., Hung, K., & Warren, J. R. (2021). The importance of STEM: High school knowledge, skills and occupations in an era of growing inequality. ***Research Policy***, 104249.

Messages	**1. Between 1980 and 2019, US employment in STEM occupations has counteracted trends of employment declines in various parts of the occupational wage distribution 2. Individuals taking more advanced levels of high school mathematics enjoy occupations with a higher percentile rank in the average wage distribution 3. Mathematics courses enabled workers to adapt to changing labour market demands.**

The paper investigates the evolution of the U.S. occupational structure of employment between 1980 and 2019, with a particular focus on Science, Technology, Engineering and Mathematics (STEM). The authors analyse the importance of advanced math and science training for labour market success later in life.

First, they use the U.S. Census and American Community Survey to depict changes in the share of employment from 1980 to 2019. Second, they use data from the National Center for Education Statistics (NCES) on a cohort of 14 710 students across 1000 U.S. high schools, surveyed in 1982 (when most were high school seniors), 1984, 1986, 1992 and in 2014 (when most were 50 years old). This cohort was in high school at a time period in which computers and information technology just started to become wide-spread.

The authors first show that the U.S. labour market has experienced a polarisation of employment between 1980 and 2019, with the declining share of middle-wage occupations offset by the increase in employment in high- and low-wage occupations. They find that employment in STEM occupations evolved very differently compared to employment in non-STEM occupations between 1980 and 2019, and that it counteracted trends of employment declines in various parts of the occupational wage distribution.



Smoothed Changes in Employment Shares 1980–2019 and Number of STEM Occupations (indicated by radius of circles) by 1980 Percentile Rank of Mean Occupations' Wage

The authors demonstrate that individuals who took more advanced levels of high school mathematics coursework enjoyed occupations with a higher percentile rank in the average wage distribution, and that the mathematics coursework enabled workers to adapt to changing labour market demands and obtain more easily STEM-related occupations.

The authors conclude that such evolution leads to workforce inequality as STEM-related occupations are more numerous and more valorised in terms of wages.

Policy recommendations include that pupils should enrol more in high school courses that prepare them for the increasing STEM skill requirements of work, and that more schools should establish STEM programs.

STEM EDUCATION AND PATENT PRODUCTION

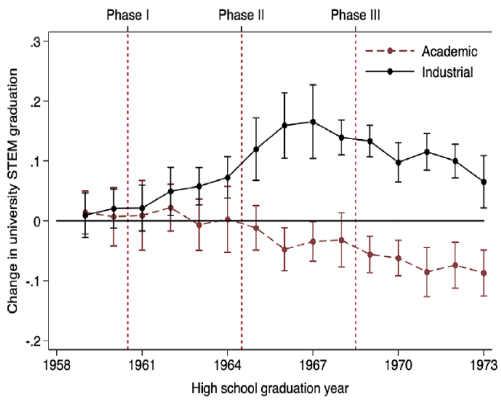
Bianchi, N., & Giorcelli, M. (2020). Scientific education and innovation: from technical diplomas to university STEM degrees. ***Journal of the European Economic Association***, *18*(5), 2608-2646.

Messages	**1. Scientific higher education makes individuals more likely to patent in STEM-oriented fields, such as medicine, chemistry, and IT. 2. Scientific higher education makes individuals that choose to work in private firms more likely to reach managerial positions. 3. Scientific higher education generates more opportunities for entering self-employed professions and public jobs.**

The paper presents novel evidence in support of the positive correlation between education and innovation by focusing on the impact of STEM graduate training on patent production and labour market outcomes.

The authors exploit a policy change in the enrolment requirements in Italian STEM majors to infer causality. Indeed, before 1961 Italian technical high school students were not allowed to enrol in STEM majors at university level (only academic students could), while after 1961 an education reform allowed them to do so. Hence, the study exploits such change to compare variations in innovative activities between cohorts of technical students before and after the reform.

Overall, data on 46,473 students and 2,662 patents is employed. The sources are administrative records on students who completed high school in Milan between 1958 and 1973, the Italian Patent Office (IPO), the European Patent Office's (PATSTAT) database and the Italian Social Security Institute (INPS) database.



The authors find that obtaining a STEM degree increases the likelihood of producing scientific oriented patents (medicine, chemistry, and IT) and that the 1961 education reform boosted STEM innovative activities by 164%– 245%, relative to the pre-reform baseline.

Furthermore, relative to the pre-reform cohorts, industrial students with a STEM degree became more likely to work as self-employed engineers (+4.3 pp); other self-employed professionals (+3 pp); public employees for the central government (+2.6 pp); or local governments (+1.9 pp). On the other hand, they became less likely to be employed in the private sector (-5.3 pp), or to work as artisans (-4.8 pp); entrepreneurs (-3.1 pp); and self-employed surveyors (-1.2 pp). This said those that entered the private sector had better chances to reach high managerial positions.

Given these results, the authors confirm the importance of STEM education for fostering innovation.

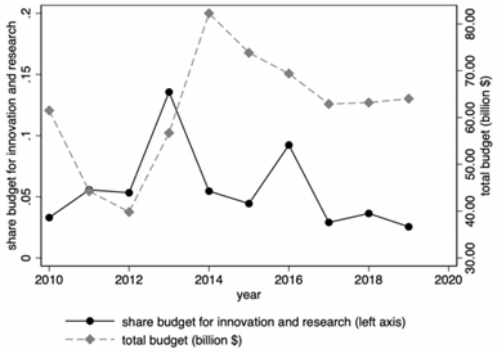
LINKING EDUCATION TO INNOVATION

Biasi, B., Deming, D. J., & Moser, P. (2021). Education and Innovation. ***National Bureau of Economic Research***, Working Paper 28544.

Messages	**1. Increasing investment in basic skills would help ensure that all potential future innovators are able to reach the knowledge frontier and take advantage of their natural talents. 2. Educational institutions are an important source of innovation. 3. While technology alone is not a panacea, there is much potential for technology to lower the cost of providing effective personalised education.**

This paper reviews the existing literature on the linkages between education and innovation. The review first covers the theoretical frameworks that link education and innovation, then the existing evidence on linkages between universities, entrepreneurship, and innovation, and finally tackles the effects of innovation on education.

FIGURE 1 – DEPARTMENT OF EDUCATION'S TOTAL BUDGET AND SHARE EARMARKED FOR INNOVATION



Despite the strong evidence that links human capital with economic growth, the authors find that there is little direct evidence of a causal effect of human capital on innovation. The authors also highlight that high-quality education builds cognitive and non-cognitive skills, which increase the productivity of future innovators. However, they stress that there is also no real consensus on the type of education that is most successful in encouraging innovation (e.g., training in math and science vs. soft skills).

On the link between universities and innovation, their findings suggest that educational institutions foster innovation by teaching skills that keep workers near the technology frontier and that they are an important source of innovation.

The authors also conclude that, while technology alone is not a panacea, there is much potential for digital tools to lower the cost of effective personalised education. For example, computer assisted learning (CAL) software can automatically adapt content and difficulty level based on diagnostic assessment and students' previous responses.

When it comes to policy implications, the authors recommend to increase investment in basic skills, which would help ensure that all potential future innovators are able to reach the knowledge frontier and take advantage of their natural talents. They also recommend to democratise access to universities as well as to increase public investment in them. Finally, they recommend using technology to provide personalised support and feedback, helping more future innovators succeed in the early years of school and widening the talent pipeline.

COLLABORATION AND TECHNOLOGY TRANSFER

Stojčić, N. (2021). Collaborative innovation in emerging innovation systems: Evidence from Central and Eastern Europe. ***The Journal of Technology Transfer***, *46*(2), 531-562.

Messages	**1. Collaborations between Central and East European firms and both domestic and foreign partners have strong positive effects on the commercialisation of innovative products (both incremental and radical innovations). 2. Collaboration with partners from China, India and US enhances success in commercialisation of radical innovations.**

This paper explores whether collaboration at firm level with partners of different origins facilitates commercialisation of innovative products.

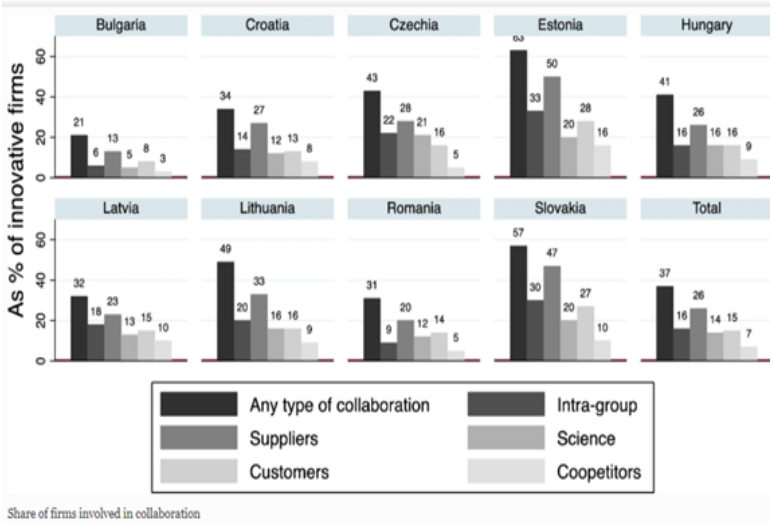
The study focuses on nine Central and East European (CEE) innovation systems characterised by low innovation and technology transfer intensity. The authors use a treatment analysis on a sample of over 10,000 firms from Eurostat's Community Innovation Survey.

They assess whether being part of a collaboration has an effect on sales revenues coming from unchanged or marginally improved products, incrementally innovation products or radically innovative products. They consider different types of collaboration: with CEE, other EU MS or international partners, as well as partners- rivals, suppliers, customers, firm group members, research centres and universities.

About 37% of all firms included in the sample have been involved in collaborative innovation; about 26% with suppliers and about 15% with customers and with universities and research entities.

Results show that collaborations with only foreign rivals have a positive effect on the commercialisation of incrementally novel innovations. Collaborations with both domestic and foreign partners have strong positive effects on the commercialisation of both incremental and radical innovations. Finally, collaboration with partners from China, India and US enhances success in commercialisation of radical innovations.

They conclude that a combination of geographical proximity with some partners and cognitive proximity with other partners from abroad act in a mutually reinforcing way to facilitate commercialisation of innovative products. They recommend to support all kind of collaboration to boost technology transfer.



MORE FLEXIBLE LABOUR MARKET MAY NOT HELP R&I

Hoxha, S., & Kleinknecht, A. (2020). When labour market rigidities are useful for innovation. Evidence from German IAB firm-level data. ***Research Policy***, *49*(7), 104066.

Messages	**1. While adherents of structural reforms of labour markets argue that more flexible labour relations might be favourable to innovation, evidence suggests that counter-arguments may have more weight. 2. A major specificity for innovation activities in this context is the key accumulation of past knowledge in high and med-tech sectors, which is mostly embodied in people.**

What is the impact of labour relations on innovation? The authors recall that while some have suggested that more flexibility in labour markets might enhance innovation, there is a literature that argues the opposite.

Advocates of labour market deregulation suggest easier engagement in risky new ventures if firing is easier. Also, an enhanced inflow of 'fresh blood' and (latent) threat of dismissal might lead to greater effort by employees.

However, and in particular in the case of innovation, the authors argue that labour market rigidities (such as firing protection, job guarantees for insiders, or centralised bargaining) increase mutual trust, commitment and loyalty, which, in turn, makes the management of innovation, mobilisation of (tacit) knowledge from the work floor and knowledge accumulation easier. More trust and loyalty also reduce costs of supervision and reduce externalities as committed employees will not so easily leak knowledge to competitors.

The authors use data over 2007–2015 from a German annual survey (IAB Establishment Panel) covering more than 16,000 establishments in Germany. They use panel probit models, explaining which factors influence the probability that a firm would have research and innovation activities.

The authors do not find a positive relationship between firing flexibility and the probability that a firm will innovate. However, they find a significantly negative relationship between firing flexibility and innovation indicators in those industries in the highly innovative segments of manufacturing and services. On the other hand, in more traditional industries and services, results suggest a much weaker support for the hypothesis that labour relations matter for innovation.

The authors highlight that the results do not support pleas for perfectly competitive and flexible markets in the case of labour markets and innovation, and tend to actually support the Schumpeterian view that innovation may need imperfect markets - which hints to a trade-off between static Walrasian efficiency (how to allocate scarce resources efficiently?) and dynamic Schumpeterian efficiency (how to make resources less scarce through innovation?).

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The "Quarterly R&I Literature Review" provides a brief summary of a selection of recent publications on R&I economics and policy.

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.

This edition of the literature review covers papers that focus on the role of education for R&I, from the construction of human capital, the production of knowledge at the hand of highly skilled individuals, to the interaction between the different entities that compose the innovation ecosystem.

The Literature Review, together with the Working Papers and the Policy Briefs, is part of the "R&I Paper Series" which serves as a repository of analytical papers that supports an evidence-based EU policy, for R&I and beyond.

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