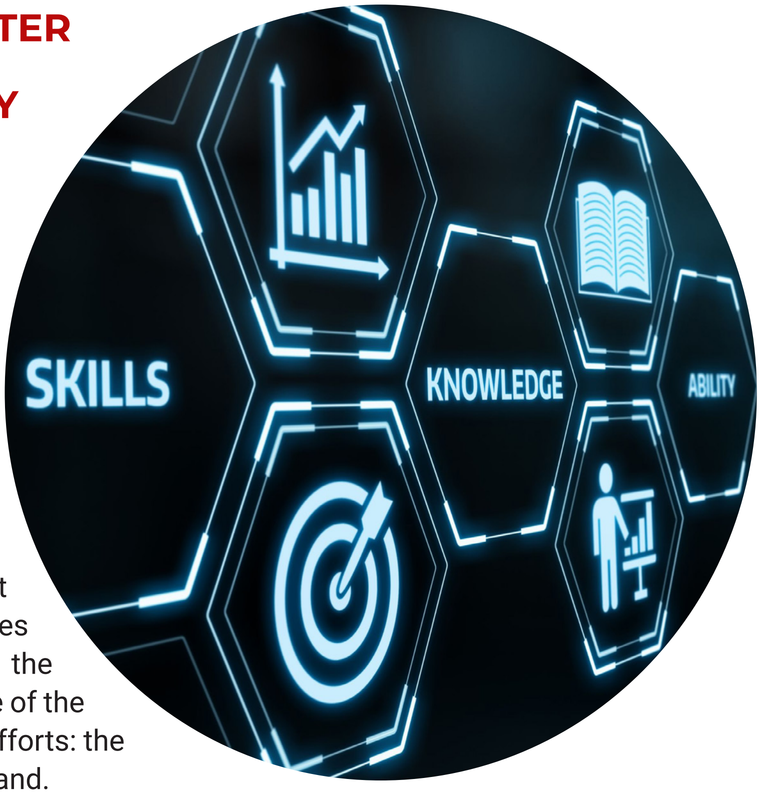
POLICY BRIEF
JULY 2022

FEPS
FOUNDATION FOR EUROPEAN PROGRESSIVE STUDIES

EUROPE NEEDS HIGH-TECH TALENT

INVESTING IN PEOPLE TO COUNTER OLIGOPOLISTIC DYNAMICS AND DEPENDENCIES IN TECHNOLOGY MARKETS



ABSTRACT

A few firms in the US and China control key layers of the digital supply chain. This geographic and economic concentration creates dependencies for the EU. So far, the block has focused on regulating firms to mitigate the risks. Yet it has neglected educating people to support genuine independence. The EU counts too few digitally skilled graduates, and too many leave the continent to join other tech hubs. This shortage reinforces market concentration, as the biggest firms pay the most competitive salaries and attract a large share of the global talent. It also hampers ongoing regulatory efforts: the EU cannot police technologies it does not understand.

The EU acknowledges the need for more skills, but fails to propose adequate remedies, or even to establish the right objective. Its flagship digital strategy focuses on number of ICT specialists – a target that is much too broad to meaningfully support strategic autonomy objectives. The EU needs to refine its success metrics and track unmet employer demand for specific advanced digital skills and unmet student demand for specific programmes. EU action plans, including the European Skills Agenda and Digital Education Action Plan, could help address this. Yet, the lack of clear lines of accountability bode ill for their effective implementation.

Obtaining the requisite skills for a more autonomous digital economy and society requires a co-ordinated approach within and between EU countries – one that leverages a wide range of policy areas and exploits linkages between them. High-tech talent is drawn to vibrant technological centres; and while dynamic digital markets will not exist without a skilled workforce, a skilled workforce without local market dynamism is a recipe for brain-drain.

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STRATEGIC AUTONOMY SERIES
pathways to progressive action

TABLE OF CONTENTS

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Introduction

High-tech skills are critically undersupplied and are a major bottleneck in a digital economy that relies on human talent to turn data into valuable intelligence. Data may fuel the new economy, but it is by no means a scarce resource. What is rare is the ability to turn the raw information into economic value.

The shortage of high-tech skills reinforces the position of global digital leaders: the little talent there is naturally flocks to the highest paying and most prestigious jobs. And as technological leaders absorb more of the global talent, they become ever more productive, further strengthening their advantage.

Digital markets tend to be concentrated, with a few firms mostly residing in the US and with China controlling important layers of the digital supply chain. Such economic and geographic concentration creates economic and geopolitical dependencies for the European Union, which is anxious to ensure it is not too heavily dependent on any one trading partner. Losing sovereignty in the digital space would leave the EU vulnerable to supply shocks in technologies that increasingly power all sectors of the economy. It could also leave the Union susceptible to blackmail or unable to regulate foundational technologies according to its own values.

Strategic autonomy in digital technologies requires the EU to promote dynamism all along the digital supply chain. While the EU fares well when it comes to fundamental research, it does poorly on development. That is in part because it lacks an adequate supply of digital skills.

This policy brief maps the EU digital skills gaps and explores policy measures to counteract the self-reinforcing dynamics that tend to concentrate talent in the hands of a few technological leaders.

1. High-tech skills underpin the EU's digital strategic autonomy

Strategic autonomy revolves around economic, political and operational stability and security.[1] When a country is overly dependent on any one partner (or group of partners), it becomes more vulnerable to political blackmail (for example Russian gas during the war on Ukraine) or supply shocks (for example medical supplies during the COVID-19 crisis). Dependence can also leave countries prey to goods and services of sub-par quality and safety.

The EU exhibits dependencies in several critical digital technologies. In the Staff Working Document which accompanied the 2021 update of the EU's 2020 New Industrial Strategy, the European Commission (EC) warned that the EU may face: 'certain challenges in comparison with its global competitors for several other technologies including AI, Big Data, cloud, cybersecurity, [...] and micro-electronics (including semi-conductors)' (European Commission 2021a). In its 2021 Action Plan on Synergies between Civil, Defence and Space Industries,

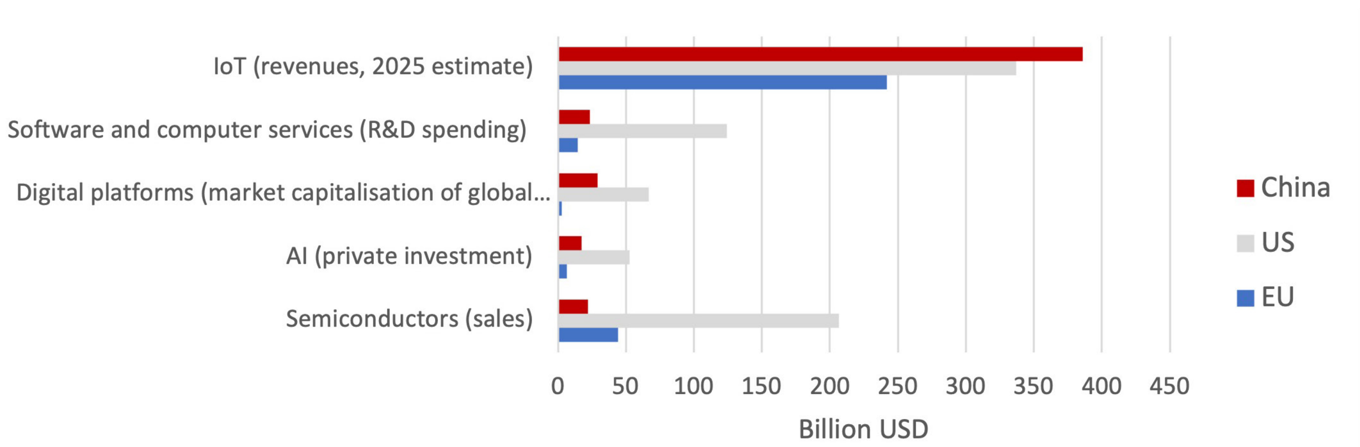
1 https://www.consilium.europa.eu/en/press/press-releases/2020/09/28/l-autonomie-strategique-europeenne-est-l-objectif-de-notre-generation-discours-du-president-charles-michel-au-groupe-de-reflexion-bruegel/

the Commission identifies the following technologies critical to Europe's autonomy (European Commission 2021b):

- **Digital products**: AI (artificial intelligence), advanced analytics and big data; forensic technologies
- **ICT infrastructure**: secure communications and networking
- **Data infrastructure**: high-performance computing, cloud and data spaces; quantum technologies
- **Hardware**: photonic; ultra-low-power microprocessors, lightweight printed or flexible electronics; sensors
- **Cybersecurity**

The dependencies largely reflect an important degree of market concentration in these digital markets, with market leaders residing outside of the EU. The US and China represent 90 percent of the market capitalisation of the largest digital platforms, 94 percent of all funding of AI start-ups, 50 percent of the world's hyperscale data centres, and 79 percent of the cloud infrastructure service market (UNCTAD 2021).[2] The US has about twice as many AI start-ups than the EU, and its top software and computer services firms spend more than eight times on R&D (research and development) than their European counterparts (Castro et al 2021). A notable exception is the IoT (internet of things), where Europe plays a significant role (with a 22 percent market share for Europe as a whole versus 31 percent for North America, UNCTAD 2021). The EU's laggard performance across multiple high-tech markets is captured in Figure 1.

Figure 1. EU industry underperforms all along the digital supply chain (2019 or latest, billion USD)



Source: Castro and McLaughlin (2021), UNCTAD (2021), GSMA (2019).
Note: 2019 figures or latest. For IoT sales and digital platforms, EU figures include the UK, US figures include Canada, and Chinese figures include other countries from the Asia and Pacific region. 'Software and computer industry' covers the 2,500 top software and computer services firms.

2 UNCTAD 2021 documents a brain drain from the public to the private sectors.

High concentration in key digital markets heightens the dependency risks described above, for at least three reasons. First because digital technologies increasingly power, and thus affect, the whole of our economies and societies. Concentrating the control of digital enablers and technologies leaves economies vulnerable to severe shocks in case of disruption or impossible dilemma in case of blackmail.

Second, digital goods are largely based on predictive technologies, which reflect and perpetuate human values. AI technologies can decide who gets a loan, which shampoo to buy, when to maintain a piece of manufacturing equipment. And yet, there is no objectively right or wrong answer to any of these questions: all involve assumptions about preferences and risks. Digital technologies that are made by different players generate different responses. And how digital technologies are made, in turn, reflects the values of the creators, for example a focus on profit, or safety, or control, and so on, as well as the quality and quantity of data they use to train their model. Yet, when it comes to values, democracy dictates diversity. The concentration in the digital sphere thus undermines the market's capacity to generate this desired diversity and leave the value pool unrepresentative.

Third, digital technologies capture an ever-growing share of economic output. Falling behind in digital could leave the EU an economic laggard, and dependent on foreign firms for everything from jobs to tax revenues.

To avoid the outcomes and risks of dependency, the EU set out to establish its autonomy in the digital realm. This ambition, however, does not tend towards perfect self-sufficiency. Such an extreme strategy implies building local capabilities, through heavy investments and onshoring. This is not the EU's preferred approach: it is wasteful for technologies in which the EU lacks a comparative advantage, and likely impossible in some winner-takes-all markets (online search for example). Autarky also runs against the political stance towards open trade. The EU wants to attain not 'perfect' but 'open' strategic autonomy.

The EU can pursue open autonomy by building alliances with likeminded trading partners (Timmers 2022). And to ensure that its values are represented, the EU can regulate and set standards on imported technologies. But alliances require bargaining power and consume diplomatic capital. Similarly, standards and regulation can only go so far: they are often imperfect, subject to capture, and underenforced. For digital technologies, the resource asymmetry between regulators and regulated (including for skills) aggravates these concerns.[3]

The most effective strategy will rely on a co-ordinated combination of the above: regulating and setting standards, making alliances wherever possible, building industrial capacity at home where viable or necessary. And each of these relies on the same essential input: advanced digital skills. The EU cannot regulate or build alliances around technologies it does not understand. And there will be no EU-made technologies without high-tech talent. And yet, the EU suffers from important shortages of professionals with the skills necessary to achieve its ambitions for digital autonomy.[4]

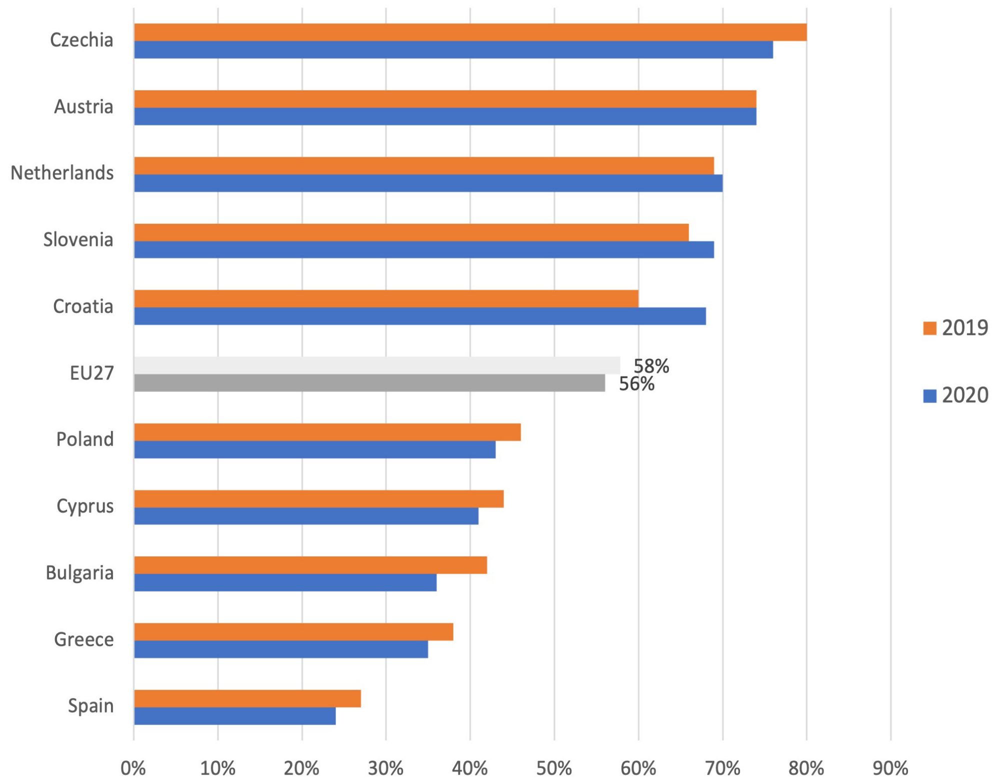
3 UNCTAD 2021 documents a brain drain from the public to the private sectors.

4 Note that the development of advanced digital technologies relies on a wide variety of skills, which include business, management, ethics, law, economics, among others (Dignum 2020). This paper focuses on advanced technological skills.

2. The EU has a high-tech skills shortage

As of 2019, the EU agency Cedefop reported a shortage of ICT professionals[5] in 24 EU member states (Lopez-Cobo et al 2019). Official figures show that, despite a 51 percent growth in the number of ICT specialists in the last ten years (nine times faster than for other professions), 58 percent of EU firms trying to recruit ICT specialists today find it hard (see Figure 2).[6] And the demand keeps growing: in 2020, ICT skills[7] accounted for around half of the growth.[8]

Figure 2. Share of EU firms that had difficulties recruiting an ICT specialist in 2019 and 2020 (top 5 and bottom 5 countries)



Source: Eurostat.
Note: Percentage of enterprises which recruited/tried to recruit personnel for jobs requiring ICT specialist skills (excluding the financial sector).[9]

5 The ICT professionals 'conduct research, plan, design, provide advice and improve information technology systems, hardware, software and related concepts for specific applications; develop associated documentation including principles, policies and procedures; and design, develop, control, maintain and support databases and other information systems to ensure optimal performance and data integrity and security. [...] Typically people in this occupation will have completed between three and six years of higher education.' (JRC, 2019).
6 Note that these figures include firms in the ICT sector but also in other sectors that use digital technologies.
7 Business ICT systems and applications, tools for software and web development and configuration and for data analysis.
8 https://www.cedefop.europa.eu/en/news/coronavirus-and-european-job-market-how-pandemic-reshaping-skills-demand
9 For the purpose of the survey, Eurostat refers to ICT specialists as 'employees for whom ICT is the main job. For example, to develop, operate or maintain ICT systems or applications.'

This trend led the European Commission to estimate that, by 2030, the EU will have a shortage of 8 million ICT specialists (European Union's Digital Compass, 2021).

High-tech competences are in short supply in the EU. Figures on ICT specialists, though not a perfect measure of high-tech skills, provide some evidence. ICT specialists are the professionals, including computer scientists, data engineers and cybersecurity experts, who are required to develop the digital technologies identified as strategically important by the EU (see Box 1). Each of these occupations encompasses a different combination of specialised skills (for example software development, IT automation, and so on), knowledge (for example a particular programing language or database), and qualifications (for example a university degree in Computer Science).

Box 1. Measuring high-tech skills: ICT specialists

ICT specialists are people who have the ability to develop, operate and maintain ICT systems and whose main job is to produce ICT goods and services. ICT specialists tend to be highly educated, and 64 percent have a tertiary degree.[10]

The Eurostat (and OECD) ISCO-08 definition of 'ICT specialists' covers many (though not all) of the high-skilled occupations that drive frontier digital technologies. These include data scientist, computer programmer and embedded system designer. Although ICT specialists also include occupations that do not drive the development of advanced technologies (for example sales professionals), the cross-country information at a disaggregated occupation level is largely missing to filter out these occupations (see Recommendation 1, below). The high-level occupational groups are:[11]

ICT managers, professionals and associate professionals:

- ICT service managers
- ICT professionals: software and multimedia developers and analysts, and database specialists and systems administrators
- ICT technicians: ICT operations and user support technicians, and communications technicians

Unit groups that primarily involve the production of ICT goods and services

- Electronics engineers
- Telecommunication engineers
- Graphic and multimedia designers
- Information technology trainers
- ICT sales professionals
- Electronics engineering technicians
- Electronics mechanics and servicers
- ICT installers and servicers

10 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=ICT_specialists_in_employment
11 https://ec.europa.eu/eurostat/cache/metadata/en/isoc_skslf_esms.htm

ICT skill shortages affect firms across the European economy – the digital innovators as well as the digital adopters. But the impact is most profound in the most digitalised sectors, such as ICT, whose core business critically relies on this talent (in the EU and in OECD countries, ICT specialists account for around 46 percent of total employment in the ICT services sectors).[12,13] The fact that ICT skills command a wage premium in the most digitalised sectors[14] suggests high sectoral needs (Grundke et al 2018).

While granular data is scarce, international comparisons suggest that the EU lags behind other countries in critical frontier skills and technologies (see Section 4 for a more detailed discussion of specific high-tech skills):

- **Computer programming**: OECD research shows that the EU has significantly fewer people with basic coding skills than the US and China on average, though the EU's top five countries perform better than China.[15]
- **Artificial intelligence**: 59 percent of all AI researchers are based in the US, compared to just 10 percent in Europe.[16] Furthermore, according to a study of LinkedIn profiles,[17] the UK has 1.8 times more individuals with AI skills than the EU average. The US has over three times more.[18] The EU's White Paper on AI (European Commission,2020b), highlights that European companies are unable to meet their demand for workers with the skills to develop and deploy AI.
- **Cybersecurity**: An analysis by the EU's Joint Research Centre (JRC)[19] finds that the European cybersecurity research community lacks critical mass and co-sordination in synergic domains and is not always able to connect with the industry.
- Evidence also suggests that the EU lags behind the US in the number of ICT professionals with skills related to **cloud technologies, big data and micro-electronics** (European Commission 2021a).

12 Source: cedefop (2020), available at: https://skillspanorama.cedefop.europa.eu/en/dashboard/browse-sector?sector=05.10&country=#2. See also Calvino et al (2018).
13 Conversely, the ICT services sector which employs 57% (up from 55% in 2019) of ICT professionals work and 50% (up from 45% in 2019) of lower-skilled ICT technicians. Source: cedefop (2020), available at: https://skillspanorama.cedefop.europa.eu/en/dashboard/browse-sector?sector=05.10&country=#2
14 The digital-intensive sectors as defined in Calvino et al (2018). These are the sectors that have the highest share of ICT investment, purchases of intermediate ICT goods and services, and robots and ICT specialists. Under this taxonomy, IT, computer and electronics and telecommunications are among the most digital-intensive sectors.
15 46% fewer than the US and 29% fewer than China.
16 https://macropolo.org/digital-projects/the-global-ai-talent-tracker/
17 AI skills were identified through a combination of keyword filtering and machine-learning screening of more than 645 million profiles. Source: https://economicgraph.linkedin.com/content/dam/me/economicgraph/en-us/reference-cards/research/2019/LinkedIn-AI-Talent-in-the-European-Labour-Market.pdf
18 LinkedIn membership covers around 50% of Europe's active labour force, and its members are not evenly distributed across the EU. However, LinkedIn notes that, although the results are therefore not statistically representative, the digital and tech workforce tends to be well represented in its membership.
19 JRC Technical Reports: European CS Centers of Expertise, 2018.

3. The high-tech skills shortage reinforces oligopolistic dynamics and dependencies

Skill shortages are concerning in any market. Factories stay idle, food spoils, innovations lie dormant. In most markets, the bad effects only last for as long as the shortages. In digital markets however, temporary labour constraints may lead to short-term market concentration if the shortages reinforce spiralling dynamics that drive digital markets towards ever more concentration.

Digital markets feature characteristics of 'tipping markets', or markets in which there is room for only a few players. These characteristics are the combination of:

- consumer inertia (why bother shopping around for a new email provider when the current one works just fine?);
- increasing returns to scale (recommendation algorithms improve with more users);
- low marginal costs (it costs close to nothing to distribute one extra app); and
- strong direct and indirect network effects (the more users frequent a social media site, the more attractive it becomes to other users and to advertisers).

These features tend to concentrate power in the hands of a few technological leaders. Scarce labour pursuing the most attractive offer will naturally favour the firm that offers the best compensation packages, learning opportunities, and/or prestige – at the expense of smaller, younger players.

Market leaders also acquire talent by acquiring competitors ('acqui-hires'). In 2019 for example, Facebook (now Meta) acqui-hired Chainspace, a blockchain venture, to use its staff rather than its technology (to build the now defunct Libra cryptocurrency).[20] Parker et al (2020) estimate that more than half of the 850 acquisitions made by big tech firms[21] in the past two decades involved acquiring talent (up to 92 percent for Facebook).

Technology and skills are highly complementary: you cannot have one without the other. Over time therefore, advantage in one drives advantage in the other and the productivity gap between leaders and the rest slowly widens (OECD, forthcoming).

These dynamics affect the whole digital supply chain, not just social media or internet search platforms. Global digital platforms increasingly control all stages of the digital value chain: from data collection to transmission, storage, processing and use (UNCTAD 2021). These translate into a wide array of products markets, from e-commerce to cloud services (Table 1).

20 https://www.wired.co.uk/article/facebook-libra-startup-privacy-analysis
21 Google, Amazon, Facebook, Apple, and Microsoft.

Table 1. Global digital platforms in markets across the data value chain

Technology markets	Google	Amazon	Microsoft	Apple	Meta
e-commerce		Amazon			Facebook Marketplace
App stores	Google Play Store			Apple App Store	
Search	Google Search		Bing		
Social networking			LinkedIn		Facebook, Instagram
Messaging			Skype, Teams	iMessenger	Messenger, WhatsApp
Operating systems	Android		Windows	MacOS, iOS	
Cloud	Google Cloud	Amazon Web Services (AWS)	Microsoft Azure		
Advertising	Google Display and Search Ad, YouTube Video Ad		Bing Search Ad, LinkedIn Display Ad		Facebook Display Ad, Instagram Display Ad

Source: Mariniello and Martins (2021).

4. Explaining the EU's high-tech skills shortage

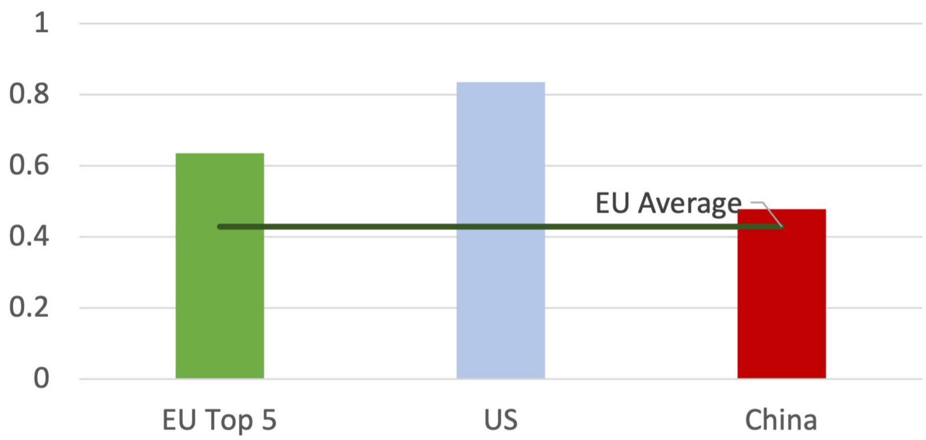
Europe is home to some of the world's best science and engineering research institutions (Veugelers et al 2019). Yet the continent's research excellence does not produce enough talent for the continent's job market. The EU produces too few graduates with the required digital skills, and too many of them leave the continent to join the world's most exciting tech hubs. This section describes these dynamics.[22]

(a) Not enough training

The skills shortage partly reflects a failing of the education system to produce enough qualified graduates. Figure 3 shows that the EU produces fewer ICT graduates than the US and China. Even Europe's top performers exhibit a 20 percent gap compared to the US (though they outperform China).

Just as for occupations, the ICT field of study is the best proxy to study high-tech dynamics. Yet it is imperfect: it is broader than advanced digital technologies and some advanced digital technologies programmes do not fall under ICT (some fall under 'Engineering, manufacturing and construction'). Still, according to a study by the JRC, the field of ICT offers most programmes in high-performance computing (59 percent), cybersecurity (52 percent), AI (41 percent) and data science (37 percent) (Righi et al 2020).

Figure 3. ICT graduates in the EU, US and China (normalised score, 2020)



Source: DESI 2021, European Commission based on Eurostat.
Note: Normalised scores of individuals with a degree in ICT (ISCED-F 2013 classification, upper secondary vocational and tertiary education), normalised scores; EU unweighted averages; top 5 countries for ICT graduates are Austria, Estonia, Finland, Ireland and Sweden.

22 This section sets out general principles and does not distinguish between different means of education delivery (formal/informal) or level of education attainment (eg secondary, tertiary, vocational).

The shortfall in ICT graduates could reflect either a shortage of education opportunities in Europe (that is, be a supply problem), or a lack of interest on the part of Europeans for pursuing such studies (that is, be a demand problem). But there is not enough information to date to validate or disprove either of these theories. A JRC analysis attempts to estimate unmet demand for places in programmes across four advanced technological domains, namely AI, high-performance computing (HPC), cybersecurity and data science (Righi et al 2020). The study finds significant unmet demand in the EU across all technologies, suggesting a supply problem. However, the findings are highly uncertain due to a lack of granular and cross-country data on universities' acceptance rates.

(b) Brain-drain

Initiatives to create more EU high-tech talent creation will not contribute to the EU's sovereign ambitions if talent ends up fleeing for California. Brain-drain is an important problem for Europe. Figure 4 is based on an analysis of the profiles of PhD-holding contributors to top AI conferences.[23] It shows that the EU attracts a relatively small share of international AI talent (right-hand side). Worse still, Europe loses a large share of the PhD-holders it trains, to the US especially (left-hand side).

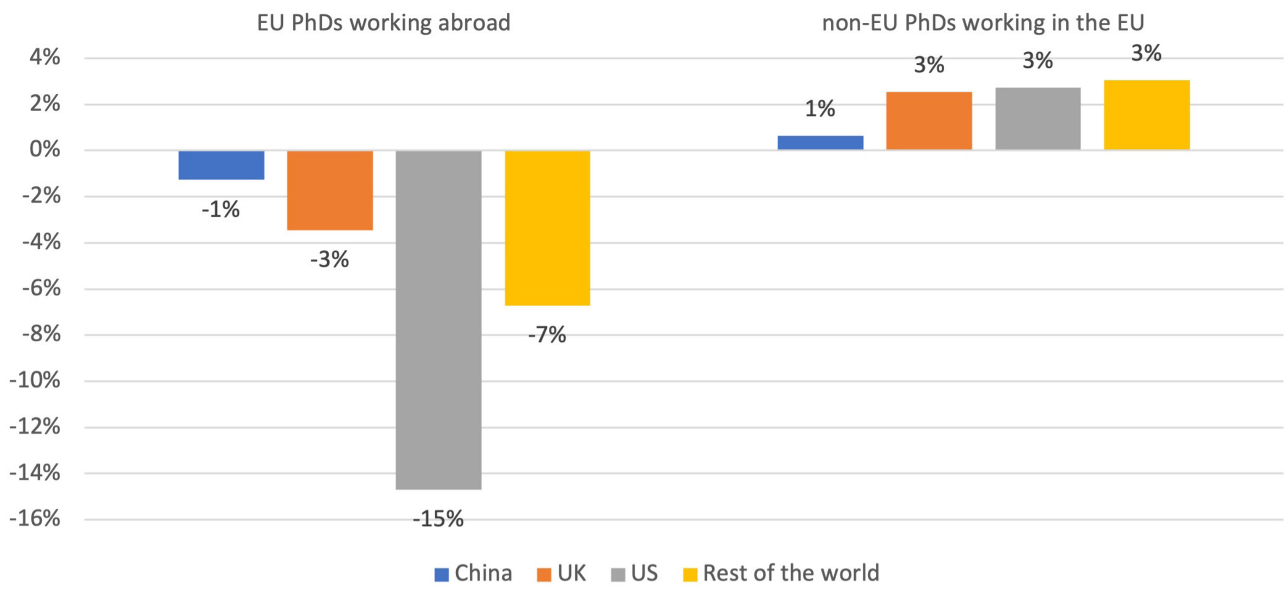
A recent study investigated the personal motivations behind these flows. Zwetsloot et al (2021) surveyed 524 AI researchers at two prestigious AI conferences.[24] In line with the figures presented above, they find that the US is by far the most popular destination. The primary reason is the good professional prospect and environment (91 percent of respondents reported that this factor affects their immigration decision). Lifestyle and culture are also important (79 percent), as well as the political climate of the destination country (66 percent), and having personal relations in the destination country (60 percent). Interestingly, ease of immigration and incentives only mattered for 47 percent of respondents.

Another study confirms that most AI PhD-holders who completed their studies in the US stay there because of the good job prospects (Aiken et al 2020).[25] International PhD-holders base their decision on salaries and benefits, growth opportunities, professional culture, and technical challenges. Eighty percent of all US AI PhD-holders are approached by large companies and 25 percent end up working for one (54 percent go into academia and 13 percent go to small companies).

Further data from the US suggests that technological leaders hire a disproportionate share of the high-tech talent (Wang et al 2021). Just 10 firms account for more than a quarter of all job vacancies requiring AI skills.[26] These include Accenture, Apple, Amazon, IBM, Microsoft, Facebook, and Salesforce.

23 Implying a selection bias in favour of PhD-holders who have the time, connections and financing to attend such conferences.
24 The Conference on Neural Information Processing Systems (NeurIPS) and the International Conference on Machine Learning (ICML).
25 Survey of recent AI PhDs from US universities.
26 US online job-posting data from Burning Glass Technologies (BGT) from January 2010 to June 2020.

Figure 4. Attraction of the EU and other regions for AI PhD-holders (2019)



Source: jfgagne.ai, Global AI Talent Report 2019.
Note: Based on a review of the publications from 21 leading scientific conferences in the field of AI and analysis of the LinkedIn profiles of the authors. 'EU' consists of France, Germany, Italy, Netherlands, Spain, Sweden; 'Rest of the world' consists of Australia, Canada, India, Israel, Japan, Singapore, South Korea, Switzerland, Taiwan.

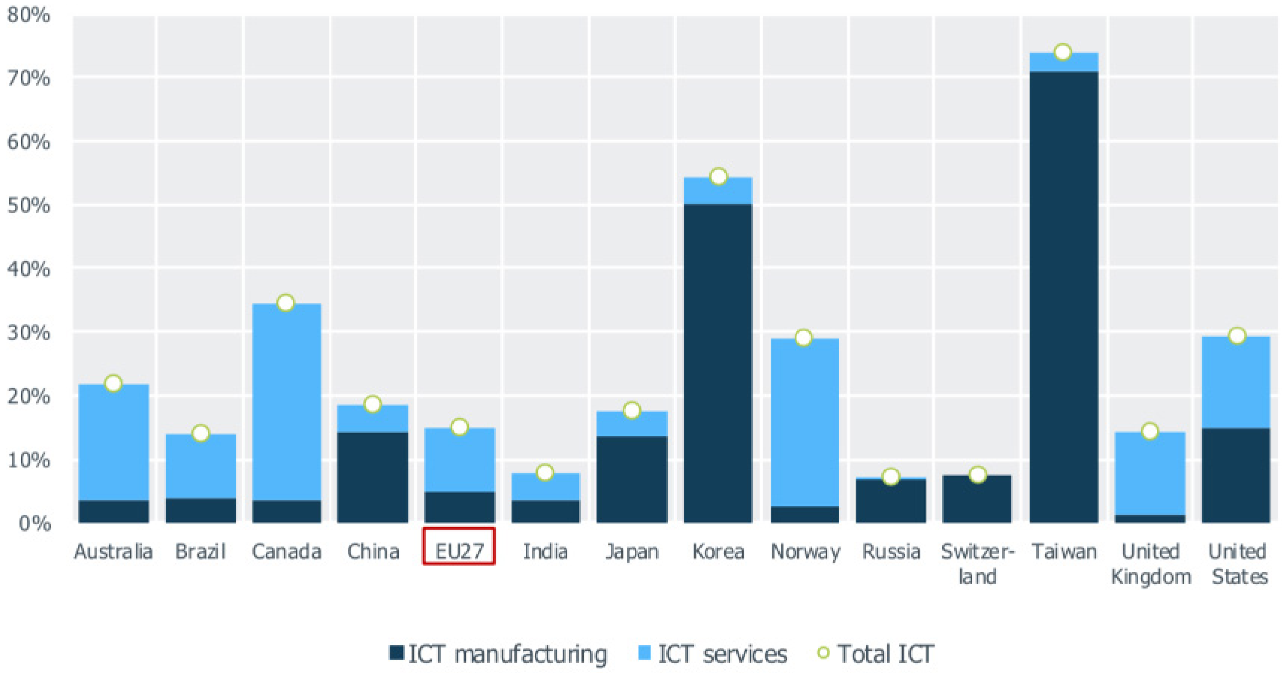
(c) Self-reinforcing dynamics

Ultimately, and as captured in the survey of AI graduates, high-tech talent is drawn to vibrant technological centres, those that promise the most intellectually and financially rewarding careers. The tech skill shortage is thus self-reinforcing in a way that mirrors and exacerbates the agglomerating forces that concentrate economic activity in cities. Digital technology and skills are highly complementary: one needs the other to drive innovation and growth. And so technology firms locate to where the talent is (a recent survey of EU tech founders confirms that access to talent is the most important factor determining the location of tech companies).[27]

Talent hubs thus attract companies, and thus career opportunities, which in turn attract more talent. What is necessary, therefore, is to act on all fronts in a co-ordinated way. Policies to train and retain talent can achieve very little absent strong commitments across other digital policy domains. This includes, for example, measures to boost R&D spending. As Figure 5 illustrates, the EU's ICT sector severely underinvests compared to other countries: R&D expenditure as a percentage of GDP (BERD) represents a mere 5 percent of global spending, while South Korea captures 18 percent, Taiwan 12 percent and the US 11 percent.

27 Source: 'State of European Tech 2020', available at: https://2020.stateofeuropeantech.com/chapter/builders/article/operatorexperience/

Figure 5. ICT sector BERD as a share of total BERD (2018)



Source: Mas et al 2020.
Note: 2017 for Brazil and Switzerland. ICT sector for Switzerland includes only ICT manufacturing.

Epitomising the self-reinforcing dynamics just described, R&D underinvestment itself reflects the lack of talent in the workforce, since 70 percent of EU businesses report that the digital skills shortage is an obstacle to investment according to the Commission. And low R&D expenditures in turn make for a less attractive environment for highly skilled workers. R&D tax credits have proved effective at boosting R&D activities and, more importantly, at increasing the innovative output of firms across the economy (Criscuolo et al, forthcoming).[28]

5. EU initiatives to address the gap

The EU is well aware of its high-tech skills gap. In 2017, the European Council identified the need for the EU to invest in digital skills, to better align with the demands of the labour markets and contribute to Europe's global competitiveness (European Council 2017). Shortly after, in 2018, the European Commission set out its proposal for a funding programme, 'Digital Europe',[29] to reinforce Europe's capacities in advanced digital skills – then defined as specialised skills

28 https://eur-lex.europa.eu/resource.html?uri=cellar:12e835e2-81af-11eb-9ac9-01aa75ed71a1.0001.02/DOC_1&format=PDF
29 To be part of the 2021-2027 EU budget, the Multiannual Financial Framework or 'MFF'.

for the design, development, management and deployment of technologies including HPC, AI and cybersecurity (European Commission 2018).

The EU's ambitions for digital skills were fully operationalised in 2020-21, under the guise of two initiatives and dedicated budget. The European Skills Agenda in July 2020,[30] followed by the renewed Digital Education Action Plan in September 2020,[31] both aimed to address, among other things, the high-tech skills gap. In support of these and other initiatives, the European Parliament and Council adopted a new funding programme in April 2021, to accelerate the digital transformation of EU industry, including by promoting advanced digital skills (the above-mentioned Digital Europe Programme).[32]

Complementing these three headline plans (the Skills Agenda, Digital Education Action Plan, and Digital Europe Programme), the European Commission proposed a set of measurable targets against which to track progress towards a digital Europe (including for advanced skills) in its Digital Compass Communication of March 2021.[33]

Each of the headline plans set out a series of individual actions (see Box 2). These would certainly advance Europe in the direction of more digital skills (see Section 5). Yet, taken as a whole, the EU strategy lacks clear lines of accountability, threatening the strategy's effective implementation. Indeed:

- the plans involve three separate Directorates-General (DG) of the European Commission;[34]
- most actions subsumed under the plans are not monitored through indicators (the European Skills Agenda does not include any indicators at the activity level while the Digital Education Action Plan only includes a few, though it promises more at a later date);
- the few monitoring indicators that are used tend to be used across multiple plans, limiting ownership of these indicators;[35] and
- some actions appear across multiple plans, without a clear delineation of responsibilities (for example, the European Skills Agenda and the Digital Education Action Plan both call for better data on digital skills,[36] but it is not clear how these might be distinct, for example targeting different population groups), also limiting ownership.

Beyond the blurring of accountability lines, potentially resulting in weak implementation, the profusion of plans also makes it hard for the media, civil society and the policy community to comment on an area that already attracts little attention.

30 COM(2020)274
31 COM(2020)624
32 COM(2018)434
33 COM(2021)118
34 The different DG responsible are DG EMPL (DG for Employment, Social Affairs and Inclusion) for the Skills Agenda; DG EAC (DG for Education, Youth, Sport and Culture) for the Digital Education Action Plan; and DG CONNECT for the Digital Europe Programme.
35 Eg 'Share of adults aged 16-74 having at least basic digital skills (in %)', is used as a target indicator in both the European Skills Agenda and the Digital Education Action Plan.
36 Action 2 of the European Skills Agenda 'Strengthening skills intelligence' and Action 11 of the Digital Education Action Plan 'Cross-national collection of data on student digital skills and introduce an EU target for student digital competence'.

Box 2. Actions and activities targeting advanced digital skills in the EU's three headline plans (the Skills Agenda, Digital Education Action Plan, and Digital Europe Programme)

European Skills Agenda:

- **Action 2**: Strengthening skills intelligence
- **Action 6**: Skills to support the twin transitions
- **Action 7**: Increasing STEM (science, technology, engineering and mathematics) graduates
    - Raise the attractiveness of STEM studies and careers, with focused actions to attract girls and women, and by encouraging a cross-disciplinary and innovative teaching and learning approach in schools, vocational education and training, and higher education.

Digital Education Action Plan

- **Action 11**: Cross-national collection of data on student digital skills and introduce an EU target for student digital competence
- **Action 8**: Update the European Digital Competence Framework to include AI and data-related skills
- **Action 9**: European Digital Skills Certificate (EDSC)
- **Action 10**: Council recommendation on improving the provision of digital skills in education and training
- **Action 13**: Women's participation in STEM

Digital Europe Programme (Specific Objective 4 – Advanced Digital Skills)

- **Action 1**: Access to on-the-job training by taking part in traineeships in competence centres and businesses that deploy advanced digital technologies.
- **Action 2**: Access to courses in advanced digital technologies which are to be offered by higher education institutions, research institutions and industry professional certification bodies in co-operation with the bodies involved in the Programme (topics are expected to include AI, cybersecurity, distributed ledger technologies [eg blockchain], HPC and quantum technologies).
- **Action 3**: Participation in short-term, specialised professional training that has been pre-certified, for example in the area of cybersecurity. Interventions shall focus on advanced digital skills related to specific technologies. The European Digital Innovation Hubs shall act as facilitators for training opportunities, liaising with education and training providers.

6. Policy recommendations: train and retain

This final section proposes key principles to inform European policymakers (at the EU and member-state level) as they think about how to best train and retain more global talent.

Recommendation 1: More data and better indicators

To appropriately address the digital skills shortage, policymakers need a detailed picture of market needs and educational offers. Granular supply and demand data would help better allocate funds; inform students about labour market prospects; and enable the update of curricula, occupational standards and qualifications frameworks. The result will be more effective national policies in the areas of education, employment and immigration among others.

While the Skills Agenda and Digital Education Action Plan both call for more and better data, the ambitions remain vague[37] and as described in the previous section, it is unclear which DG will ultimately be responsible for the achievement of this objective – a threat to delivery.

Granular and comparable data would also elevate the EU's own efforts to promote high-tech skills.[38] In March 2021, the Commission set out its ambition for digital skills (the *2030 Digital Compass* communication). The plan targets 20 million ICT specialists by 2030.[39]

The aim to increase the number of ICT specialists is not an adequate target. It is so broad that its achievement may very well fail to drive the desired outcomes, namely to 'empower people and businesses to seize a […] more prosperous digital future' and for Europe to be 'digitally sovereign in an interconnected world'. The EU could have 20 million ICT specialists and yet fail to deliver a strong EU digital ecosystem, and empowering jobs. By 2030, the EU could have 20 million low- and/or inadequately skilled ICT specialists – workers unequipped to continuously adapt to new programming techniques or languages. Recent work by the OECD finds that tertiary-educated ICT workers significantly boost the return to advanced digital technologies in the ICT sector, while ICT workers with secondary education do not.

The Commission should target meaningful indicators that reflect its ambition to became a credible player across high-tech digital markets. Good targets rest on good data and the EU should track measures of unmet student demand for specific programmes and of unmet employer demand for particular advanced digital skills.

Recommendation 2: Target women

The low number of ICT graduates could reflect a lack of interest on the part of prospective students (that is, be a demand problem). In a workshop organised by the European Commission (DG CONNECT) and Informatics

37 Referring to 'new and deepened skills intelligence, including at regional and sectoral levels' (Skills Agenda) or 'expanded coverage of internationally comparable data on digital skills across EU Member States and at the European level supporting evidence-based policymaking' and 'a more accurate picture of the state of young people's digital skills and the factors influencing the acquisition of digital skills within the EU' (Digital Education Action Plan).

38 While education is mainly a national competence, the EU has a mandate to support, supplement, and co-ordinate countries' education actions. This mandate includes target-setting and monitoring.

39 This target is based on the skills scorecard of the Digital Economy and Society Index, or DESI.

Europe, representatives from academia, industry and the policy community lamented that too few pupils decide to pursue higher education in the field of ICT.[40]

Compounding the problem, a significant share of those that do enrol drop out. Only 30 percent of students that enrol on an ICT master's programme end up graduating (ranging from 14 percent in Austria to 50 percent in France).[41] Policymakers should, the participants concluded, make ICT studies more attractive for prospective students.

As discussed above, the 'demand problem' hypothesis cannot be verified with the available data sources. In fact, demand in particular subfields such as AI or cybersecurity may outstrip supply. However, there is one group for which there is a clear gap in demand: women.

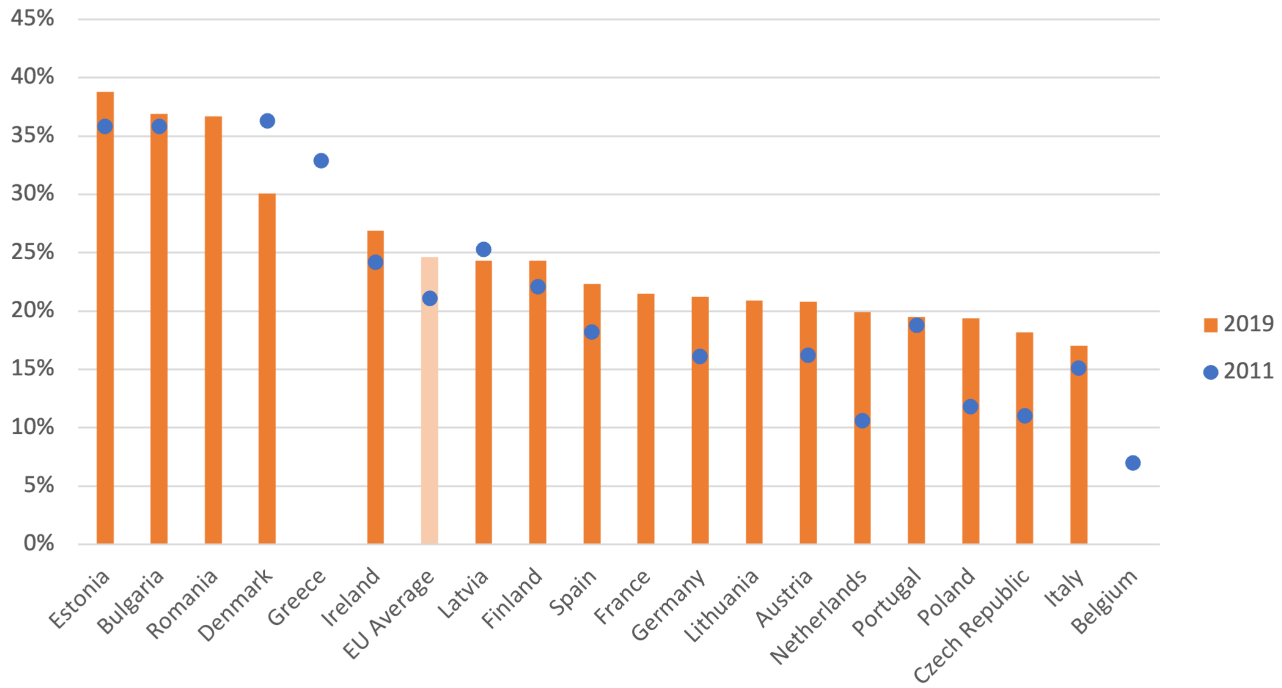
In high school, girls are more digitally literate than boys (European Commission 2020a). And yet, by the time they reach university, women are significantly under-represented in ICT programmes. Figure 6 shows that only a quarter of ICT master's students in the EU are female, ranging from 17 percent in Italy to 39 percent in Estonia (though women complete their studies at a higher rate than men). These figures are broadly in line with the US.[42] Closing the gender gap would significantly boost the overall number of ICT graduates.

Figure 6 also shows important progress in some countries in the last decade. In less than ten years, the Netherlands, Poland and the Czech Republic saw their share of women increase by 60 percent or more. Poor performers should take a close look at initiatives launched in these countries (see OECD 2018b for a comprehensive report) and note that efforts to address cultural biases should target students at a young age (see Box 3 below for a Dutch example).

The EC's Skills Agenda and Digital Education Action Plan both aim to increase the number of women taking up STEM studies. But while the relevant action in the Skills Agenda remains high-level ('encouraging a cross-disciplinary and innovative teaching and learning approach in schools, VET and higher education'), the Digital Education Action Plan includes initiatives that might be subsumed under this action ('new higher education programmes offered for engineering and information and communications technology based on the interdisciplinary STEAM approach').[43] The EC should clarify which plan, and thus DG, owns this particular objective in order to increase the chances of it materialising by 2027.

40 Informatics Europe is a non-profit membership association that represents over 150 public and private research organisations in the field of informatics in Europe and neighbouring countries.
41 Based on Informatics data of student enrolment on Informatics master's programmes in 2018/2019. Informatics includes Computer Science, Computing, IT, and ICT programmes. Based on 19 EU countries.
42 https://ncses.nsf.gov/pubs/nsf19304/digest/field-of-degree-women#computer-sciences
43 STEAM stands for Science, Technology, Engineering, the Arts and Mathematics

Figure 6. Share of women enrolled in ICT master's programmes



Note: Female students in Informatics master's programmes (all semesters). 2019 data not available for Greece and Belgium.
Source: Informatics Europe.

Box 3. Closing the ICT gender divide: example from the Netherlands

The Dutch government financed several projects to increase women's participation in STEM. One such initiative was carried out in 2011 by the specialised non-profit VHTO (the Dutch national expert organisation on girls/women and science/technology). VHTO provided workshops in primary schools, in which children aged 9 to 12 explored their talents with STEM professionals and learned about STEM carriers. The workshops highlighted the role of women in STEM professions and were reportedly eye-opening to both students and teachers, with fewer students viewing the field as 'something for boys'. While the Netherlands still lags behind its European peers, such programmes likely contributed to the significant improvements achieved over the last years.

(Source: OECD 2018b)

Recommendation 3: Invest in quality programmes that are broad and modular

Participants at the DG CONNECT/Informatics Europe workshop also lamented an education system that is too slow to respond to changes in the labour markets. They recommend that universities develop more specialised programmes, for example related to AI, and collaborate more closely with the private sector to design up-to-date curricula.

Similarly, the Commission's 2030 Digital Compass strategy deplores a 'lack of capacity in terms of specialised education and training programmes in areas such as Artificial Intelligence, quantum and cybersecurity'. It calls for countries to join a multi-country project that would 'build a bridge between demand and supply' including though public-private partnerships so as to increase the quantity and the quality of specialised programmes and generally increase the responsiveness of higher education to the demands of a digital labour market (using Recovery and Resilience Facility funds). Furthermore, the Digital Europe Programme allocates Multiannual Financial Framework (MFF) funding to the design and development of specialised courses in key digital technologies.

A detailed analysis by the JRC shows that the EU may in fact already have a good mix of broad and specialised programmes. In the 2020 study, researchers analysed the programmes offered in four technological domains (AI, HPC, cybersecurity and data science), distinguishing between broad or specialised programmes (Righi et al 2020).[44] The study provides a view of the EU's offering which is not fully in line with the negative assessment by the Commission and Informatics Europe. Indeed, while the US certainly offers the highest number of programmes in almost all technologies and combinations, the gap between the US and the EU is very small for AI and data science. Cybersecurity is the only field in which the EU severely underperforms (a fact that the JRC authors find concerning).

In terms of the level of specialisation of the programmes, the EU is in line with other countries. Another JRC study finds that 75% of technology-specific programmes on offer in the EU are broad, while the remainder are specialised (Lopez-Cobo et al 2019).[45] The predominance of broad programmes, the authors suggest, mirrors the industry practice of hiring employees with generic academic backgrounds and training them on the job. This practice does not appear to raise concerns on the part of the JRC.

So, while dusting off curricula certainly sounds like a good idea, a degree of caution should be exercised when targeting programmes to the specific technology of the day (such as a specific machine-learning technique). Indeed, the technological frontier is in constant flux. Educational programmes that are too specific risk producing graduates whose skills are irrelevant by the time they enter the job market (OECD 2018b).

A balanced approach would offer a strong generalist core, along with more specialised modules or short courses, available to both

44 Note that analysis is solely based on programmes taught in English. As a result, it is not representative for bachelor's programmes. Therefore these are not discussed here.

45 In the case of AI, for example, broad programmes include 'Internet Science and Technology', 'Applied Mathematics', 'Life Science Informatics', 'Biofluid Mechanics', and 'Finance and Banking'. Specialised programmes include 'Artificial Intelligence – Cognitive Science', 'Automation and Computer Vision', 'Advanced Computer Science (Computational Intelligence)', and 'Applied Image and Signal Processing'.

students enrolled in formal and informal education (that is, post-graduate as well as lifelong learning opportunities).

European countries should also invest in the quality of their programmes. The EU is home to only three of the world's 50 highest-ranking universities for computer science globally.[46] None make it to the top 10.[47] EU universities also underperform on AI.[48]

Box 4. EU countries are not using recovery funds to boost advanced digital skills

The EU seized the €670 billion COVID-19 recovery packages, the Recovery and Resilience Facility, as an opportunity to nudge countries towards digital investments, including in skills. At least 20 percent of the budget of each national plan must be allocated to the digital transformation. Among the list of suggested measures is to increase the offer of university programmes in advanced technologies such as AI, cybersecurity or quantum computing.[49]

Analysis by Bruegel finds that, for the 21 countries it analyses, governments committed around 20 percent of their digital transformation budget to digital skills and digital inclusion projects (Darvas et al 2021). Zooming into specific budget items shows that 10 countries are looking to use the funds to upgrade their education offering (formal or informal, not including digital inclusion projects). This amounts to €1.1 billion (or 1 percent of the total digital transformation budget).[50] These figures do not suggest that countries are giving high priority to the high-tech education agenda.

Measures include 'digital strategy for higher education and adult education' (Belgium), the 'promotion of ICT specialists through vocational training and university graduates' (Spain) and the 'establishment of a federal program of continuing education networks' (Germany).

46 Technical University of Munich (ranked 14), Paris Sciences et Lettres – PSL Research University Paris (45), KU Leuven (50).
47 Ranking by the *Times Higher Education Supplement*.
48 Ranking by CSranking on the basis of publication output.
49 https://digital-skills-jobs.europa.eu/en/latest/news/recovery-and-resilience-facility-supports-promotion-digital-skills
50 Belgium, Estonia, Finland, France, Germany, Latvia, Portugal, Romania, Slovakia, Spain, Denmark.

Recommendation 4: Rethinking immigration – less draining, more investing

The success of the US further suggests that strict immigration policies are an ordeal that motivated talent are willing to brave. While most foreign AI researchers trained in the US stayed in the US, 60 percent reported having had significant problems with the US immigration system (compared to 12 percent for other countries, Aiken et al 2020).

This might explain the relative lack of success of tech-orientated visa schemes. In the last few years, countries around the world have relaxed immigration rules to attract and retain tech talent (OECD 2019). In France, for example, a Tech Visa grants tech workers and entrepreneurs four years' residency permits and offers a clear path to permanent residency (Huang and Arnold 2020). However, participation in these schemes has been low so far; where countries have set aside permit allotments, they have not been used up.[51]

As mentioned in the previous section, good job prospects are much more important than ease of immigration matters for AI researchers. But here is a catch-22: job prospects are best where the talent already is, namely today's thriving innovation hubs. A better strategy for attracting talent might thus focus resources on generating talent-growth at home, including by investing in quality programmes that cater to the migrants who already live within EU borders (for example increasing resources for initiatives such as Konexio, which offers free tech education to youth refugees and migrants).

Recommendation 5: Tax incentives for workers, with a focus on small firms

One way of keeping high-tech talent in Europe is to raise pay. A 100 percent income tax break for workers in IT in Romania provides interesting evidence in that regard. As described in Manelici et al (2019), Romania has emerged over the past two decades as the 'unlikely Silicon Valley of Europe', and a tax break may have contributed to this success.

The measure, introduced in 2001, fully exempts graduates at the bachelor's level with certain IT degrees from income tax. Manelici et al examined the effects of the policy on the IT sector. They find that the sector grew faster in Romania than in otherwise similar countries after the measure was introduced. They conclude that the policy was effective in promoting the development of the IT sector.

However, data limitations prevent the authors from linking the measure to local skills outcomes in terms of education attainment and retention. As regards education outcomes, it is not clear that the measure contributed to more students pursuing the targeted IT degrees. The number of students enrolled in tertiary education in the fields of 'Science, mathematics, and computing' and in 'Engineering and engineering trades' did grow after the measure was introduced, and more than in other European countries. However, since the two education fields include both exempted and non-exempted degrees, this growth cannot be robustly linked to the tax measure.[52]

It is also not clear that the tax breaks reduced emigration among the target IT graduates. The authors document a large decrease in the

51 According to a presentation by the OECD, 'Start-up visa, an overview' (2019).
52 A previous version of the paper included this evidence, based on Eurostat.

emigration rate to the EU15 in the broad sector that includes the targeted workers, from 16.7 percent in 2000 to 4.8 percent in 2006. However, the level of aggregation of the data prevent any causal claims about the effect of the tax measure on reducing emigration flows.

We do know, however, that foreign direct investment into the Romanian IT sector significantly increased in the early 2000s, when multinational IT firms started offshoring operations to the country and smaller foreign companies began acquiring Romanian firms.[53] By 2017 the biggest players in the IT sector of Romania were multinational – both American (Oracle, IBM) and European (Ericsson, Endava). Foreign-owned IT companies generated 73 percent of the gross revenues and hired 59 percent of the workforce.[54]

The tax breaks may thus have contributed to Romania's attractiveness compared to other countries in the region with a similar skills base. While the foreign outcome may be desirable from a pure national-revenue standpoint, outsourcing operations may not help address the autonomy concerns raised in the EU. Indeed, such foreign imports would not necessarily inspire a local ecosystem, as would have been the case in other sectors.

Traditionally, foreign firms bring technological knowledge and knowhow to their host countries. And as the intelligence diffuses through hosting economies, local competition emerges. But this process may be muted in new technological sectors: there is increasing evidence that knowledge does not diffuse well in digital-intensive industries (see for example Akcigit and Ates 2019). Indeed, the intangible assets, such as big data and intellectual property (IP) rights that drive digital businesses, are hard to replicate and be incorporated by small firms. Therefore, attracting large multinationals may not produce the usual positive knowledge effects in digital sectors. Policies designed to attract foreign technological leaders may not succeed in stimulating local ecosystems.

In the case of the Romanian tax break, however, Manelici and Pantea (2021) find that the measure did benefit small firms (which are likely to have been local start-ups) just as much as large ones. Better data, in line with Recommendation 1, would help grasp the mechanism underlying the measure's success (for example more graduates, or reduced migration outflow, or stronger incentives to innovate) and help target the measure to ensure start-up firms benefit most.

Recommendation 6: Co-ordinated policy approach

It is beyond of the scope of this paper to detail the benefits of these and other related measures that promote dynamic high-tech markets. The key message is that the EU and national governments need to deploy a range of policy measures, and exploit linkages between them, to tackle the complex and self-reinforcing dynamics. The relevant policy areas encompass digital infrastructure, business environments (including competition), migration policies, lifelong learning and managerial quality, labour market policies and institutions, industrial policy, tax policies, housing and transport, and social protection (OECD 2019). A co-ordinated policy response requires a whole-of-government approach, embodied in a national digital plan. It also requires co-ordination by the central government, rather than ministries acting in isolation (OECD 2019) .

53 eg Adobe Systems Inc. acquired InterAKT.
54 In software and IT services.

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