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Robots and non-participation: Evidence and lessons from the US and Europe

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Robots and Non-Participation: Evidence and Lessons from the US and Europe

Giuseppe Di Giacomo, Benjamin Lerch

- Between 1993 and 2014, each additional industrial robot in the US displaced four workers from the labor force
- Automation hits workers with lower levels of education the hardest. While younger cohorts upskill, older workers exit the workforce permanently
- In heavily automated US regions, exits stem from early retirement or disability insurance uptake
- Robots also affect European labor markets, with job losses occurring in non-adopting firms that lose competitiveness
- To mitigate AI and automation risks, policymakers must fund targeted upskilling and coordinate social safety net programs

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Robots and Non-Participation: Evidence and Lessons from the US and Europe

Giuseppe Di Giacomo
Benjamin Lerch*

The rapid diffusion of industrial robots since the early 1990s has profoundly reshaped labor markets. While automation has generated new job opportunities, it has also displaced a large number of workers and contributed to the long-run decrease in male labor force participation in the United States. In a recent study (Di Giacomo and Lerch 2026), we provide new evidence on how workers exposed to robot adoption adjust their labor force participation decisions and on the pathways of displaced workers after they exit the labor market. In particular, we show that between 1993 and 2014, each additional industrial robot is associated with four workers in the US leaving the labor force. Most displaced workers either retire early or enter disability insurance, while younger workers tend to enroll in college. In Europe, the adverse labor market effects of automation are less pronounced, since employment growth in other occupations and industries partly offsets these losses. However, displaced workers may still exit the labor force due to skills mismatches with newly created jobs. Our findings provide important insights into the labor market consequences of automation and can help inform policies aimed at supporting workers and strengthening labor market resilience in the face of ongoing technological progress.

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When Technology Displaces Workers

Recent breakthroughs in generative artificial intelligence (GenAI), including systems such as ChatGPT and agentic AI models, have made the transformative potential of new technologies more salient. While these innovations fuel optimism about future productivity gains (Autor, Chin, Salomons and Seegmiller 2024), they have also revived longstanding concerns that automation may displace large numbers of workers. Such concerns are not new. Nearly a century ago, John Maynard Keynes (1930) warned of the risk of "technological unemployment." Although technological progress since then has been substantial, mass unemployment has not materialized. This, however, does not imply that new technologies have been neutral for workers. On the contrary, successive waves of automation have repeatedly displaced workers from their jobs, with recent advances disproportionately affecting routine and manual occupations. While new roles have emerged, some displaced workers fail to transition and instead leave the labor force altogether.

Industrial Robots Adoption across Countries

One of the most important automation technologies of the past decades is industrial robots. Industrial robots are programmable machines capable of autonomously performing a range of manual tasks – such as assembly, material handling, packaging, and welding – without direct human intervention.

The rapid advances in robotics technology, together with declines in their quality-adjusted prices, have fueled the widespread adoption of industrial robots across countries, with significant implications for labor markets (Graetz and Michaels 2018). According to the International Federation of Robotics (IFR), the global stock of operational industrial robots surpassed 4.6 million in 2024. As shown in Panel A of Figure 1, around half of the global stock of industrial robots is located in China (2 million), followed by Japan (450 thousand), the United States (394 thousand), South Korea (392 thousand), and Germany (279 thousand). Italy, France, and Spain follow, each with 100 thousand robots or fewer.

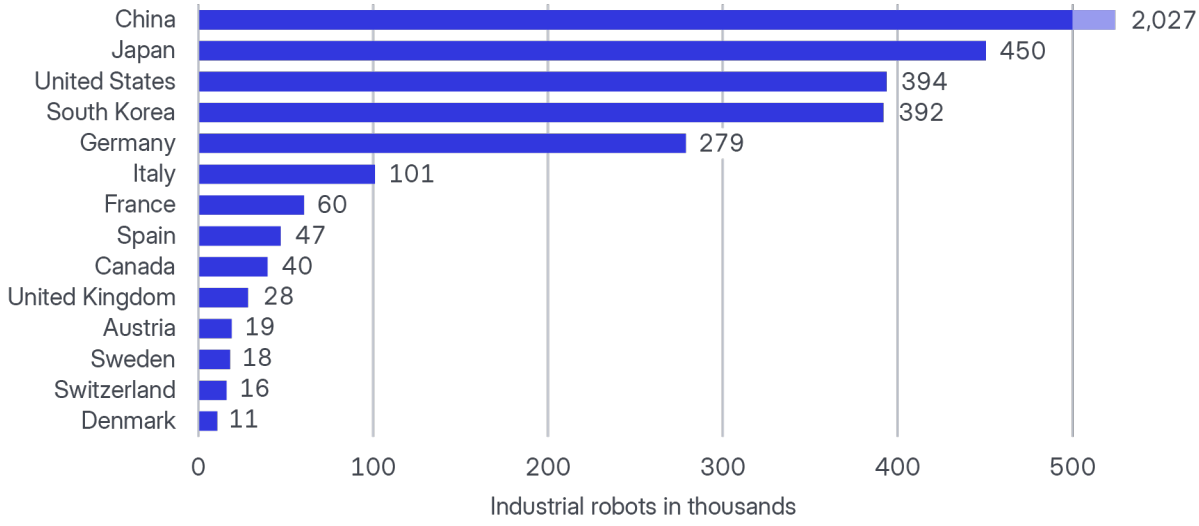
While these countries dominate in absolute terms, the picture changes when accounting for workforce size. Measured per worker, South Korea leads with nearly 14 robots per thousand workers, followed by Germany and Japan at around 7 robots per thousand workers. With 2.3 robots per thousand workers, the United States has a lower robot density than many European countries (see Panel B).

From an industry perspective, robot adoption is concentrated in manufacturing, particularly in the automotive industry, electronics, and metal production.

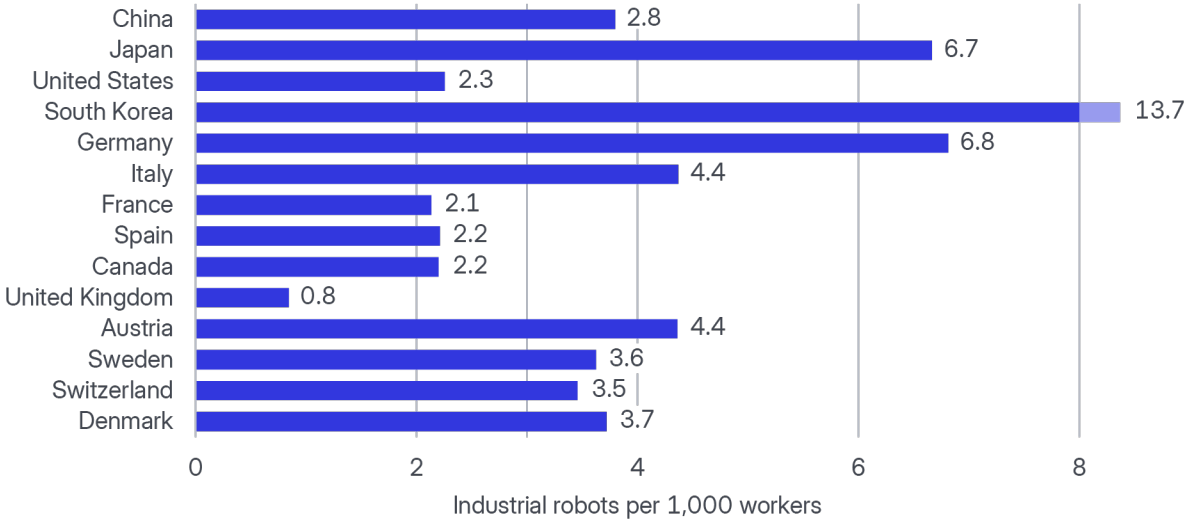
Figure 1

Industrial Robot Adoption Across Countries in 2024

Panel A: Industrial robots in thousand units



Panel B: Industrial robots per 1,000 workers



Notes: Panel A shows the absolute stock of industrial robots by country in 2024 (in thousands). Panel B shows the stock of robots per 1,000 workers in 2024.
Source: Authors' calculations based on data from the IFR, Eurostat, US Bureau of Labor Statistics, UK Office for National Statistics, Canadian LFS, Statista.

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Labor Force Participation

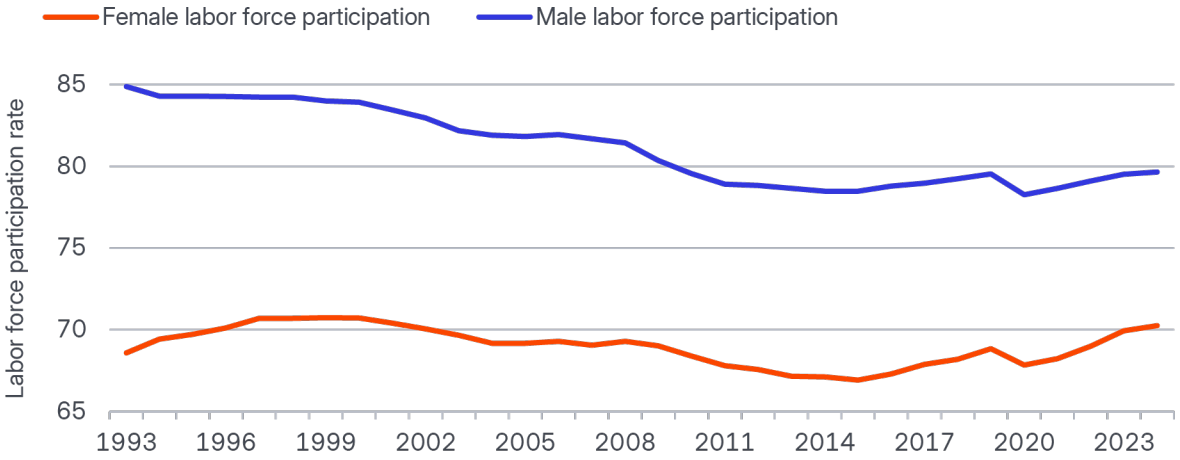
To understand how industrial robots affect labor market dynamics, it is necessary to distinguish between unemployment and labor force non-participation, particularly when workers face displacement. While unemployed individuals are without work but actively searching for a job, non-participants are neither employed nor seeking employment. This distinction is fundamental, since non-participation often signals a deeper and more persistent detachment from the labor market, with potentially long-lasting economic and social consequences.

In the United States, aggregate labor force participation has remained relatively stable since the early 1990s, declining only slightly from nearly 77 percent in 1993 to 75 percent in 2014, with a temporary drop to 73 percent in 2020 due to the COVID-19 pandemic (OECD 2026). However, this apparent stability masks substantial heterogeneity between men and women, as shown in Panel A of Figure 2. Male labor force participation has experienced a pronounced secular decline, falling from 85 percent in 1993 to 78 percent in 2015 and recovering only modestly thereafter, remaining below 80 percent as of 2024. In contrast, female labor force participation has fluctuated within a relatively narrow range – between 67 percent and 71 percent – over the same period.

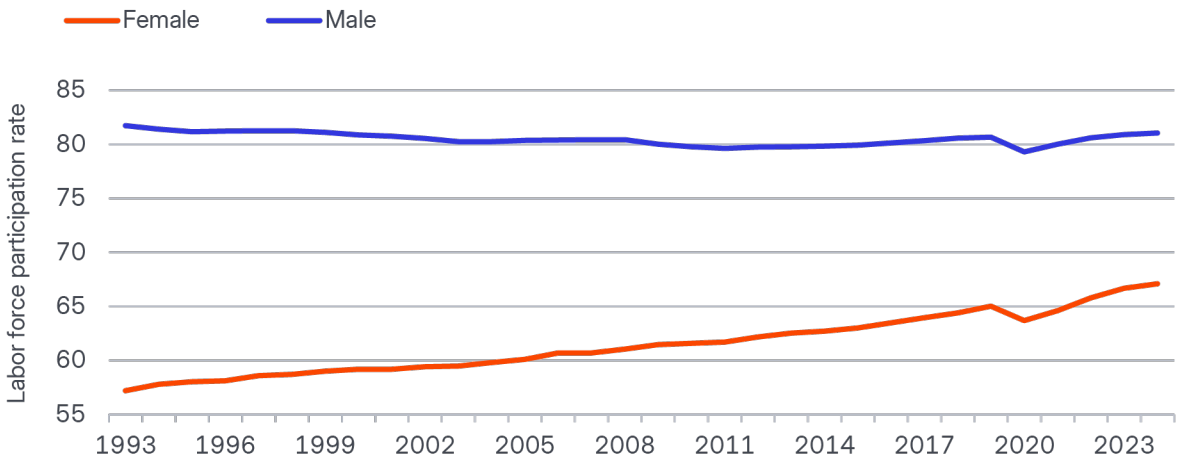
Figure 2

Labor Force Participation Rates (1993–2024)

Panel A: United States



Panel B: Labor force participation rates in OECD countries



Source: Di Giacomo and Lerch (2026) and OECD (2026).

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As shown in Panel B of Figure 2, OECD countries have also experienced, on average, a decline in male labor force participation. Although more moderate, this suggests that the trend is not unique to the United States.

In Di Giacomo and Lerch (2026), we investigate how exposure to industrial robots across local labor markets in the US has contributed to this long-run decline in male labor force participation between 1993 and 2014. A central mechanism linking automation to labor market outcomes is skills mismatch. Automation through industrial robots tends to substitute for routine and manual tasks. As a result, displaced workers may lack the capabilities required to transition into emerging occupations – often requiring more analytical, technical, and interpersonal skills – increasing the likelihood of prolonged unemployment or a permanent exit from the labor force (Grigoli, Koczan and Topalova 2020; Jaimovich, Saporta-Eksten, Siu and Yedid-Levi 2021).

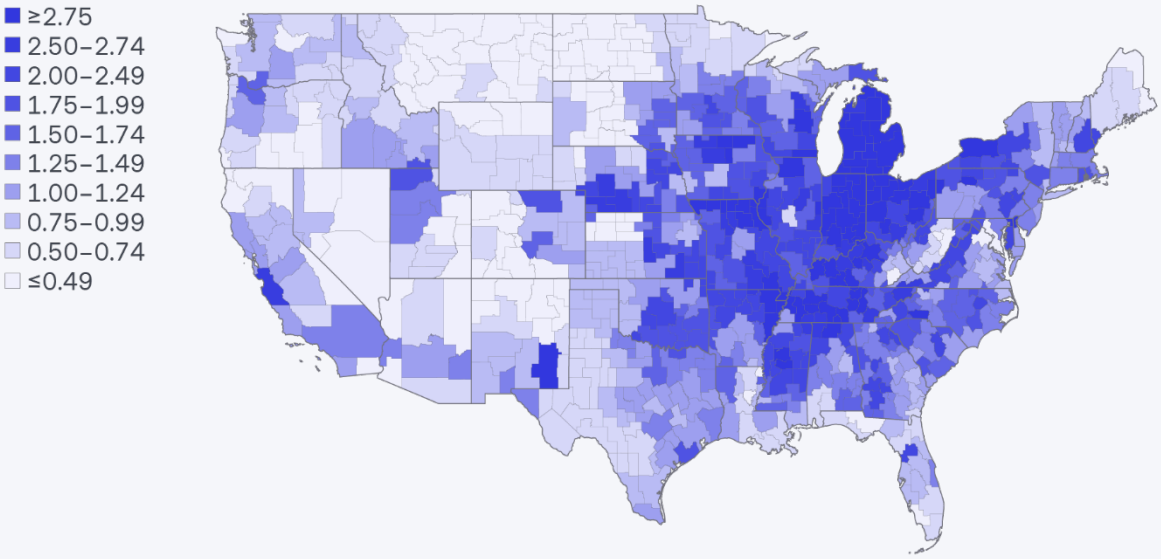
How to Measure Robot Exposure and Its Impact on Labor Force Participation

Our empirical strategy exploits differences in industrial composition across local labor markets in the US to identify the causal effects of industrial robots on labor market outcomes. Specifically, we employ a shift-share design, which was first introduced to the robotics literature by Acemoglu and Restrepo (2020) and is now widely used.

Local exposure to robots is constructed by interacting two components: (i) national changes over time in the stock of industrial robots across industries, and (ii) the pre-existing industry employment structure of each local labor market, measured at the level of commuting zones (CZs). Local labor markets that initially specialized in industries experiencing large increases in robot adoption face greater exposure to automation than areas concentrated in less automated industries. For example, the US Rust Belt region – including the cities of Detroit (Michigan) and Cleveland (Ohio), which traditionally specialized in the automotive and steel industries – is among the areas most exposed to industrial robots (see **Figure 3**).

Figure 3

US Robot Exposure at the Commuting Zone Level (1993–2014)



Source: Di Giacomo and Lerch (2026).

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To address the concern that industry-level robot adoption in the United States may be correlated with contemporaneous demand shocks (potentially biasing our estimates), we implement a strategy that isolates supply-driven variation in robot adoption.

Following the literature, we instrument US industry-level robot growth with contemporaneous robot adoption in a group of seven comparable European countries. The underlying intuition is that global technological progress and declining robot prices create common international incentives to adopt robots. Variation in robot adoption across Europe thus captures exogenous, supply-side technological shocks that are plausibly unrelated to local demand conditions in the United States, allowing us to isolate the causal impact of industrial robots on labor-force participation rates at the US local labor market level.

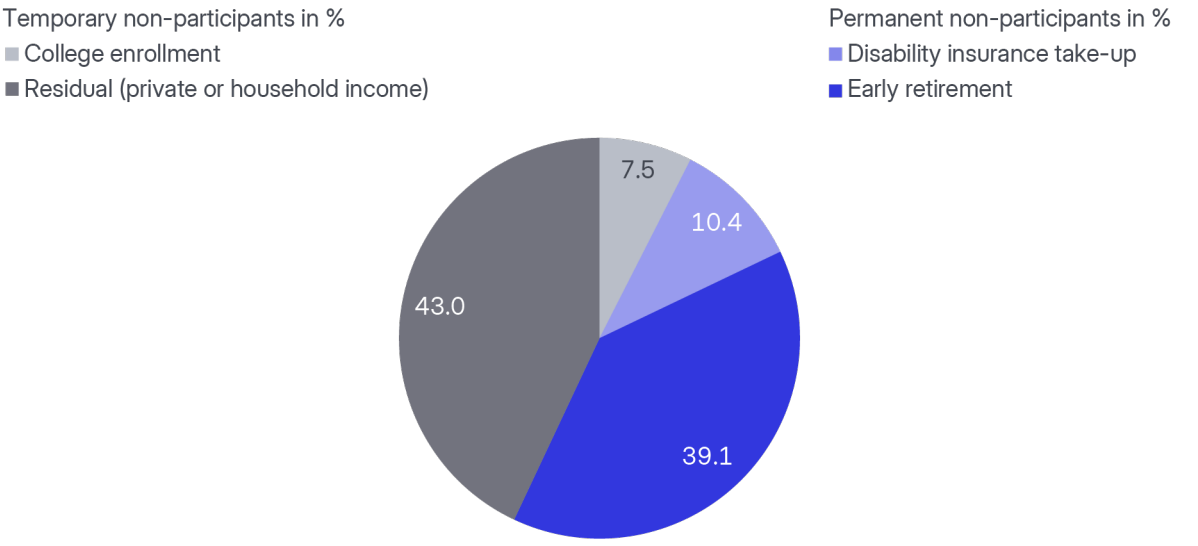
How Do Robots Affect Labor Force Participation, and Where Do Displaced Workers End Up?

Using the methodology detailed in the focus box, we estimate that each additional industrial robot installed in a local labor market leads, on average, to four workers exiting the labor force. This effect is driven entirely by men, who are more often employed in manual jobs in manufacturing industries. According to our estimates, industrial robot adoption between 1993 and 2014 accounts for roughly 18 percent of the total decrease in male labor force participation in the United States over this period (see **Figure 2**). This result is driven by significant declines in local labor force participation rates; we find no evidence of workers systematically relocating away from areas more exposed to robots. This finding underscores that local labor markets bear the full adjustment costs of automation, highlighting the importance of location-based policy responses.

We then investigate the margins of adjustment of workers who exit the labor force in response to robot exposure. The results are summarized in **Figure 4**.

Figure 4

Margins of Adjustment of Non-Participants



Source: Illustration based on results from Di Giacomo and Lerch (2026). © ifo Institute

We show that approximately 40 percent of displaced workers who exit the labor force do so through early retirement. These are primarily older workers who face limited re-employment prospects following displacement and are sufficiently close to retirement age to access social security benefits or employer-sponsored pensions. For these workers, early retirement represents both a financially viable and socially accepted adjustment mechanism.

Around 10 percent of displaced individuals enroll in Social Security Disability Insurance (SSDI). Two channels are likely to contribute to this increase. First, exposure to industrial robots is associated with deteriorating physical and mental health, raising the likelihood that affected workers meet SSDI eligibility criteria. Second, some displaced workers may turn to disability insurance as a source of long-term income support

when employment opportunities worsen. While we document negative health effects linked to robot exposure, these alone are unlikely to fully account for the observed rise in disability enrollment, suggesting that labor market conditions also play an important role.

Taken together, these two pathways imply that roughly half of all displaced workers who exit the labor force do so permanently, since both early retirees and disability beneficiaries exhibit very low rates of subsequent re-employment, indicating persistent detachment from the labor market.

By contrast, about 7.5 percent of individuals, predominantly younger cohorts, enroll in college or other degree-granting programs. This reflects two potentially distinct adjustment margins. First, some workers exposed to robots temporarily leave the labor force to invest in further education to improve their future labor market prospects. Second, students may delay their labor market entry by extending their time in higher education. These individuals are likely to represent temporary non-participants and to (re)join the labor market in the future, possibly with skills that complement robots.

The remaining non-participants either live in households with employed members, relying on income from spouses, parents, or other relatives, or draw on recent earnings or savings. These individuals are likely to be temporary non-participants as well, who may re-enter the labor force as financial constraints tighten or job opportunities improve.

Policy Implications

Industrial robots have contributed significantly to the decline in male labor force participation in the United States, with roughly half of workers who exit the labor market likely to do so permanently. This finding highlights that automation has the potential to not only displace workers from their jobs but also push them into long-term inactivity, with far-reaching consequences for earnings, productivity, and social cohesion.

Impact and Policy Implications of Industrial Automation in Europe

The adverse labor market effects of robots are not limited to the United States (Acemoglu and Restrepo 2020). A growing body of literature on European countries documents negative, though generally smaller, labor market effects of industrial robots (Graetz and Michaels 2018), including studies on Germany (Bertermann, Dauth, Suedekum and Woessmann 2025), Italy (Dottori 2021), and France (Aghion, Antonin and Bunel 2019). Importantly, evidence using microdata from France shows that the negative employment effects of robots often reflect competitive pressure on non-adopting firms rather than direct layoffs within firms that adopt robots (Acemoglu, Lelarge and Restrepo 2020). Moreover, in Germany, declines in manufacturing employment have been offset by job creation in other sectors, rather than resulting in workers exiting the labor force (Dauth, Findeisen, Suedekum and Woessner 2021). This result may be due to European labor market institutions attenuating the short- to medium-term adverse employment impacts of automation.

However, labor market adjustment processes are not without costs, as younger labor market entrants appear to bear a disproportionate share of the burden. In addition, while employment protection can support short-term stability, it may also dampen longer-term productivity gains from technological progress by discouraging firms from adopting new technologies and investing in innovation, potentially slowing overall productivity growth.

What Lessons Can Be Learned for the Current Automation Wave?

Our findings highlight that the labor market consequences of automation extend well beyond job displacement, since for many individuals, they result in a permanent exit from the labor force. While the effects of recent AI technologies are still unfolding, this evidence already points to clear policy priorities for managing the ongoing technological transition.

In the European context, characterized by demographic aging, persistent labor shortages, and policy efforts to extend working lives, such exits impose high economic costs and directly undermine current policy objectives. Preventing permanent labor market detachment should therefore be a central goal of policy responses to automation.

This requires a shift in focus from passive income support toward active labor market integration. While wage-loss insurance and targeted re-employment services should be strengthened, particularly for mid-career workers facing substantial earnings declines after automation-induced displacement, policymakers should also expand access to retraining opportunities that are better aligned with labor market needs. Moreover, disability insurance systems should be reformed to better accommodate partial and temporary work capacity, thereby facilitating continued labor force participation.

Finally, given the documented links between job loss and deteriorating health, in a context of rapidly evolving digital environments, policies should prioritize access to mental and physical health services in regions most affected by structural change. Such interventions can play a critical role in preserving employability, reducing the risk of permanent labor market exit, and limiting increases in healthcare expenditure associated with chronic diseases.

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