

Global economic drivers

How humanoid robotics matters for macro

Humanoid robotics have expanded automation to physical services; together with AI cognitive advances, this should boost productivity on a macro level. A jobless future is unlikely, but income could further shift from labour to capital and make access to electricity more important than demographics.

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Humanoid robotics: Advances continue

Long tradition of task automation

Machines that resemble humans in size and shape, can seamlessly move, communicate with humans and, thus, integrate into environments designed for humans have long captured imaginations. Such humanoid robots are no longer just in the realm of science fiction but are becoming reality. Recent progress on artificial intelligence allows for the fusing of the mechanical ability of existing robotics with artificial intelligence: humanoid robotics can be seen as 'embodied AI', bringing AI from the digital world of ideas on screens into the physical world.

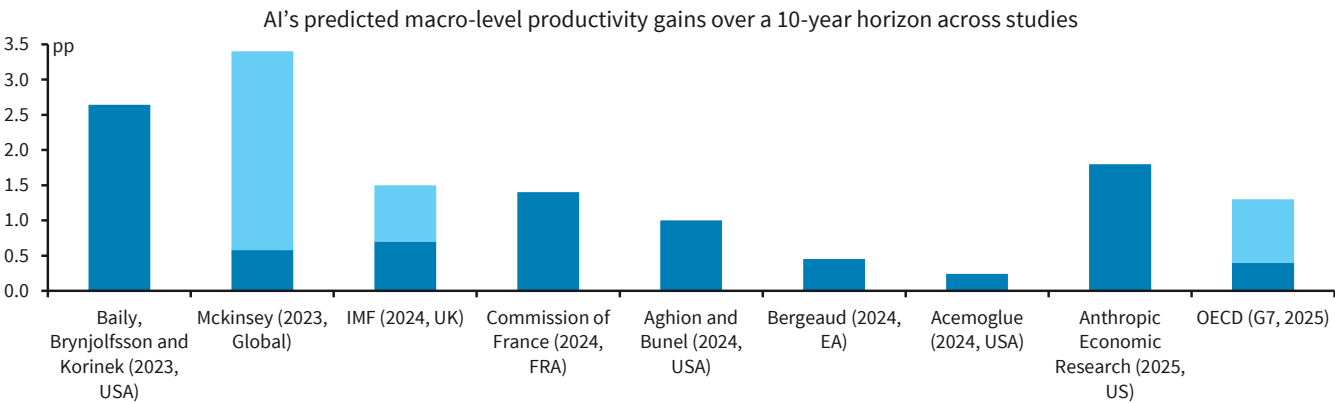
But does that make them conceptually different from the automation of the past? Automation has a long history. It started with the industrial revolution and in recent decades has occurred mainly through industrial robots and personal computing in combination with the internet. There is a rich body of research into how this automation has affected productivity, employment and wages, both with regard to the aggregate share of labour versus capital income and how it has affected different skill sets and region.¹

Please see analyst certifications and important disclosures beginning on page 16.

¹ literature references: Autor, Acemoglu, Milanovic, etc

More recently, generative AI, predominantly in the form of large language models (LLMs), has dramatically expanded automation to cognitive tasks and has exposed services considered 'high-skill' (ie, requiring higher education), which thus far had been less affected by automation. Such high-skill cognitive work had in past decades typically also seen better trends in remuneration than 'mid-skill' work, which experienced downward pressure on their wages (eg, manufacturing, accounting). Given the potentially huge effect of gen AI, much research is has been directed in the last few year towards estimating AI's automation potential and effect on productivity, but also its distributional consequences.²

FIGURE 1. Estimates for the economy-wide productivity gains from AI vary widely



Note: When the source presents a range of estimates as the main result, the lower bound is the dark blue column and upper bound is shown by the light blue column. The estimates refer to the countries shown in brackets.
Source: OECD Artificial Intelligence Papers (November 2024), Various articles and papers.

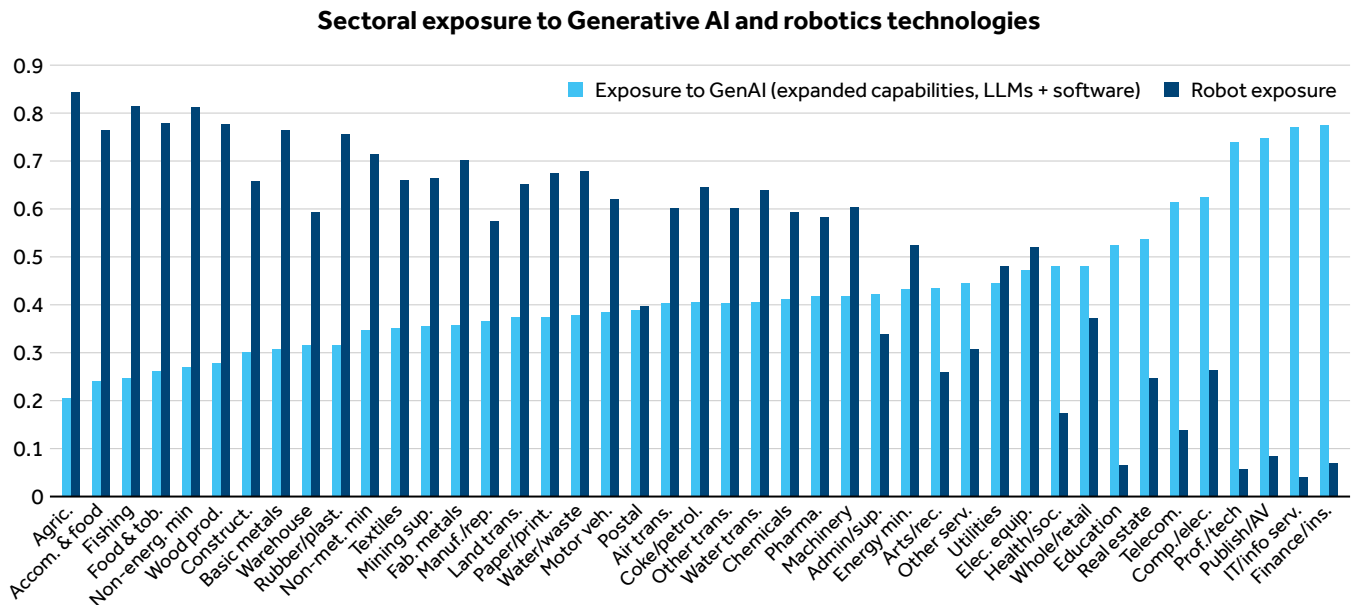
Cognitive meets physical: From tasks to occupations

However, even this new automation through gen AI has something in common with the previous forms: it remains largely task specific. Current automation through LLMs still focuses on cognitive micro-tasks (eg, coding), the way software helped with word processing or accounting tasks and large factor robots performed certain task in auto manufacturing.

Humanoid robots join the cognitive with the physical. They could introduce an AI-enabled physical generality, exposing not only more individual physical tasks to automation, but also being able to perform various heterogeneous tasks combined. They could be broadly adaptable across a wide range of functions, instead of just optimising single tasks (as traditional robots), thus serving in many industries. Being able to move between environments designed for humans, they could replace bundles of low- and mid-skill tasks. In addition to assembling parts on production lines and transporting goods in warehouses, they could operate in less-structured environments, performing services in hospitality, maintenance, household work and healthcare, including as nurses in hospitals or assisting with eldercare.

In sum, humanoid robots might not only broaden the universe of tasks that can be automated but also be able to collapse previous task boundaries. This could enable a shift from from task to occupation-wide substitution. Put in the terms of economic theory: by merging cognitive and physical tasks, humanoid robots would increase the elasticity of substitution between labour and capital, especially in services thus far protected form automation due to their 'physical messiness'.

² references: Acemoglu, Johnson, IMF, OECD, European Commission etc

FIGURE 2. Humanoid robotics increases automation exposure to areas where AI does not reach

Source: OECD Artificial Intelligence Papers (November 2024)

Hello productivity, bye bye Baumol and bottlenecks

From micro- to macro-level productivity gains

Exposure, adoption and diffusion: From task, to sector, to economy

Paul Krugman famously stated that 'productivity isn't everything, but in the long run, it is almost everything'. Hence, the fundamental question with every new technology is how to estimate its potential macro-level (ie, economy-wide) productivity gains. Initially, a new technology typically shows large productivity gains in certain tasks, but it is far from clear that these micro-level gains will translate into comparable improvements on an aggregate macro level.

Approaching this task, the first set of question is: what are the observed productivity gains from the new technology in certain tasks; how many tasks in a sector are exposed to the new technology; and to what extent and how quickly will the technology be adopted in the relevant sectors so that potential gains are actually realised? Expressed as a formula:

$$\text{task-specific productivity gains} * \text{exposure} * \text{adoption rate} = \text{sector's productivity gain}$$

As a next step, the economy-wide productivity gains should be the sum of the sectoral gains weighted by the share each sector has in the economy's output (ie, its share in GDP):

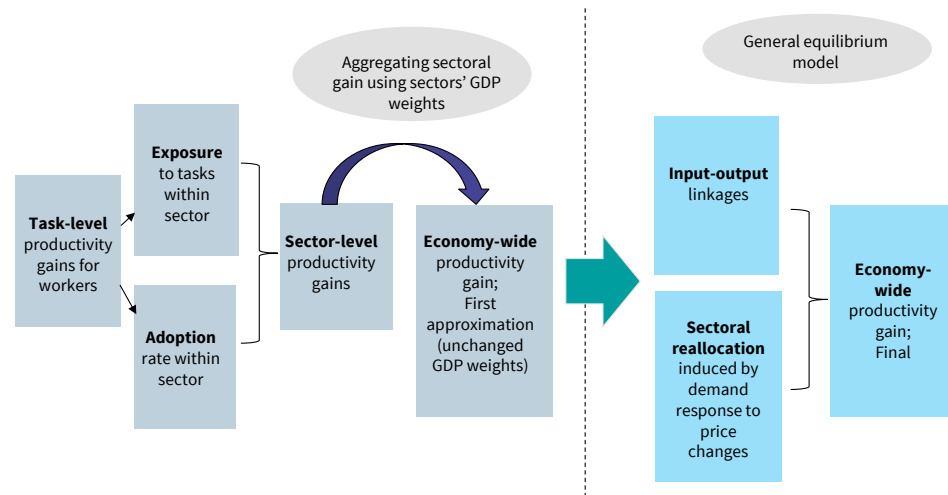
$$\text{sectoral productivity gains} * \text{sectoral weights in GDP} = \text{GDP-wide productivity gain}$$

This provides a first-order approximation of a positive microeconomic productivity shock on the aggregate economy, known as the Hulten's theorem (ie, formulated by economist Charles R. Hulten in 1978). It shows that under perfect competition and efficient allocation of resources, the effect of a shock to a firm's total factor productivity (TFP) on the economy's output can be approximated by the firm's sales share in the economy.³

³ Brynjolfsson (2023) and (Baqae and Farhi, 2019).

FIGURE 3. Micro-level productivity gains in specific task do not automatically result in macro-level productivity gains for the aggregate economy.

Technology-driven productivity gains: from micro task-level to economy-wide macro-level



Source: Inspired by OECD Artificial Intelligence Papers (November 2024), Barclays Research

In-elasticities, frictions, reallocation: How growth is lost

Such estimates of productivity gains based on Hulten's theorem provide a first approximation. However, they depend on several crucial conditions, including no frictions and perfect competition that allows efficient resource allocation. These often do not reflect the economic reality, complicating any extrapolation from sectoral productivity gains to economy-wide gains.

As an entire economy adjusts to sectoral productivity shocks (ie, a 'general equilibrium mechanism'), the demand response, the related reallocation of resources across sectors and changes in the input-output linkages play an important role in shaping the aggregate productivity change. Inelastic demand and adjustment frictions in the factor reallocation can lower the aggregate gains.

The so-called 'Baumol's growth disease' explained an important part of this phenomenon. Baumol (1967) observed that sectors with rapid productivity growth (eg, agriculture and manufacturing in history), often had their share of GDP decline, while those with relatively slow productivity growth experienced increases: technologically stagnant sectors (eg, mostly services not exposed to automation, such as health care, certain maintenance work, etc.) would experience above-average cost and price increases, but because demand for them would be price-inelastic, their share of nominal GDP would increase. This, in turn, slows an economy's aggregate productivity growth. 'Baumol's growth disease' has been estimated to have lowered annual productivity growth for the US economy by slightly more than 0.5pp in the second half of the 20th century (Nordhaus, 2008).

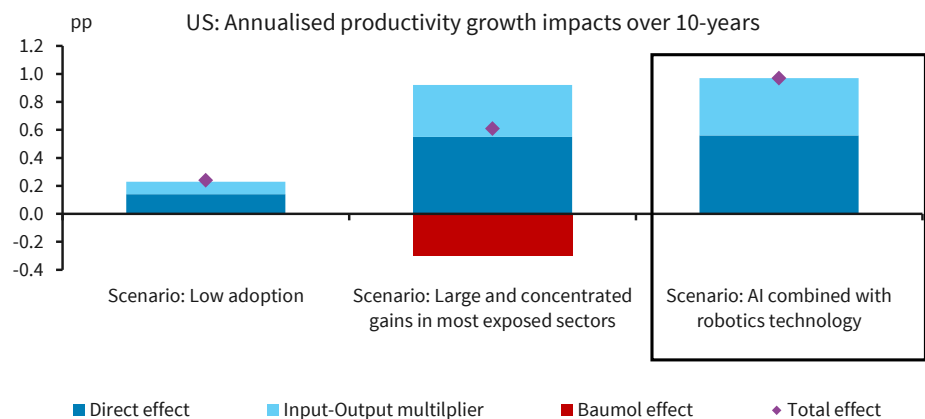
An example for illustrative purpose: the services sectors 'legal services' and 'finance and insurance' contribute about 1.5% and 8%, respectively to US GDP. Together, that is roughly the same as the sector 'Educational services, health care, and social assistance' with 9% of GDP. Assuming that AI radically improves the productivity in the first two sectors but does not affect the latter, market prices for 'legal services' and 'finance and insurance' would likely fall: eg, advice on legal matters or on, say, the construction of an investment portfolio could be obtained via a few clicks on the mobile phone at minimal cost. If, at the same time, the demand for these services was relatively inelastic, eg, assuming the appetite for starting additional law suits would be saturated at some point regardless, demand in response to the lower price for these services would remain limited. Their share in GDP would decline relative to 'Educational

services, health care, and social assistance', where productivity is unaffected by AI and demand remains steady or may even rise from the additional available income from cheaper legal and financial services.

Empirical studies on generative AI typically find that sectors are unevenly 'exposed' (ie, the share of tasks performed in a sector that benefits from gen AI). Knowledge-intensive services with strong reliance on cognitive tasks are typically most highly exposed versus low exposure of sectors dominated by manual tasks (eg, Eloundou et al, 2024; Felten et al, 2021). Hence, differences in sectoral productivity gains from AI and the related effect on sectoral output and prices could be quite large.

In line with this, a comprehensive analysis by the OECD (2024) on the potential macroeconomic productivity gains from AI finds that applying the historically observed dispersion in sectoral productivity performance would generate significant negative Baumol effects reducing the estimated aggregate productivity gains from AI by nearly a third.

FIGURE 4. Combining AI with robotics eliminates the negative Baumol's disease effect



Source: OECD Artificial Intelligence Papers (November 2024), Barclays Research

'Weak links' as the bottlenecks to a growth explosion

In a recent paper on the question of whether AI can lead to a growth explosion, Jones and Tonetti (2026, NBER) focus on the role of 'weak links': the limitation of gains by tasks where performance remains weak. Their argument starts with the observation that historically, total factor productivity (TFP) growth was driven primarily by improvements in capital productivity, with the latter outgrowing labour productivity on a task level by several percentage points, on average. Thereby, the key benefit of automation is not the switching from humans to capital by itself (as that switch occurs when the costs of using labour vs. using capital are equal). The gain comes from shifting the production of an increasing share of task from slowly improving human labour to rapidly improving machines.

In a model in which AI allows for endogenously automated production of goods and ideas, automation leads to an acceleration of economic growth. This happens because the automation process endogenously speeds up, due to a flywheel effect: automation leads to more new ideas, which lead to more automation.

However, even in this optimistic scenario, the acceleration is relatively slow, due to the prominence of weak links (ie, an elasticity of substitution among tasks substantially less than one). Put differently: even when most tasks are automated by rapidly improving capital, output is constrained by those tasks still performed by slowly improving labour and that are difficult to

substitute. It is only when these last weak links are automated away that the explosion of growth from AI fully unfolds.

Hence, as also emphasised in earlier research (Aghion, Jones and Jones; 2019), an acceleration of growth is not constrained by 'what we do well', but rather by 'what is essential and yet hard to improve'.

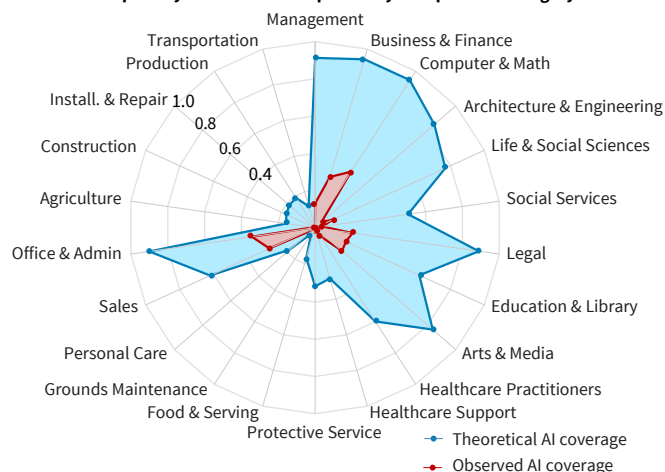
How humanoid robotics changes the game

The limitations from Baumol disease, weak links and bottlenecks for faster productivity gains all relate to uneven dispersion of AI's benefits among tasks and sectors and low elasticity of substitutability among tasks. This is, in turn, due to the mainly cognitive capabilities of generative AI, which imply very high exposure of sectors dominated by cognitive tasks versus the limited exposure of sectors with still many physical tasks.

Humanoid robotics would allow for the expansion of the benefits of AI from cognitive to physical tasks, which should boost the potential aggregate productivity growth in several ways:

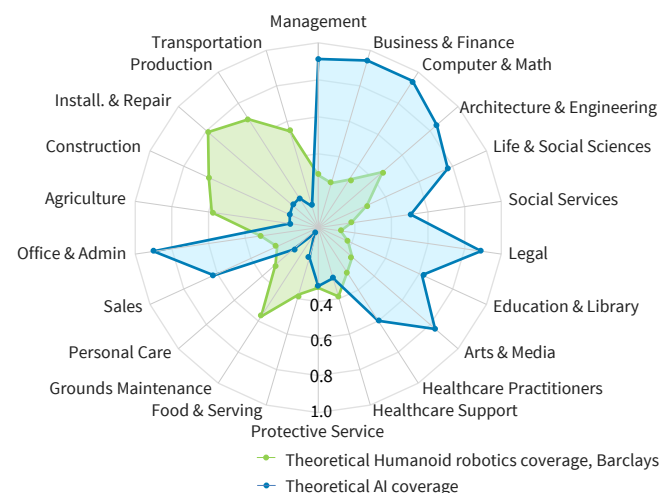
- 1) they would expose more tasks and possibly also speed up adoption, thus leading to higher productivity gains for the economy in the Hulten's theorem first approximation approach; as [Figure 5](#), [Figure 6](#) and [Figure 7](#) show, the sectoral exposure to Gen AI and humanoid robotics is quite complementary: it is exactly in the sectors relatively untouched by Gen AI, where the exposure to robotics is large, and vice versa.
- 2) by spreading out the productivity gains much more evenly across cognitive and physical tasks, it should reduce 'Baumol's growth disease'; and, in a similar vein,
- 3) by increasing the elasticity of substitution, it should reduce the number of weak links that act as bottlenecks to growth (even if not yet bringing the full automation that in theory would unleash the explosion of ever accelerating growth).

The OECD study explicitly models a scenario in which AI is integrated with new 'robotics technology': the shift from large and concentrated AI gains to widespread gains eliminates the negative Baumol effect and improves the net productivity growth by 0.3pp, to about 1%.

FIGURE 5. Exposure to AI is high in many occupations...**Theoretical capability and observed exposure by occupational category**

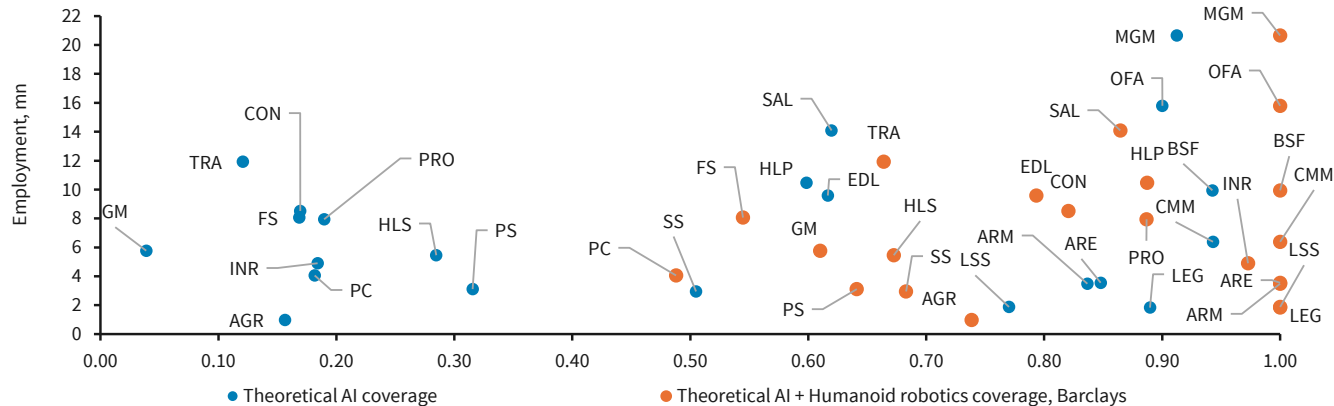
This figure shows the share of job tasks that LLMs could theoretically perform (blue area) and Anthropic's own job coverage measure derived from usage data (red area)

Source: Elondou et al. (2023), Anthropic (2026),

FIGURE 6. ...and humanoid robotics adds exposure in occupations not reached by AI**Theoretical capability and observed exposure by occupational category**

This figure shows the share of job tasks that LLMs could theoretically perform (blue area) and Barclays' theoretical humanoid robotics coverage (green area), which captures the share of tasks within an occupation group that could, in principle, be performed by humanoids.

Source: Elondou et al. (2023), Anthropic (2026), Barclays Research

FIGURE 7. The combined AI + humanoid robotic exposure implies very high exposure of many occupations with high employment levels**Theoretical AI & Humanoid robotics exposure by occupation**

MGM= Management, BSF= Business & Finance, CMM = Computer & Math, ARE = Architecture & Engineering, LSS = Life & Social Sciences, SS = Social Sciences, LEG = Legal, EDL = Education & Library, ARM = Arts & Media, HLP = Healthcare Practitioners, HLS = Healthcare Support, PS = Protective Service, FS = Food & Service, GM = Grounds Maintenance, PC= Personal Care, SAL = Sales, OFA = Office & Admins, AGR = Agriculture, CON = Construction, INR = Install. & Repair, PRO = Production, TRA = Transportation.

Source: Elondou et al. (2023), Anthropic (2026), Barclays Research

'Hasta la vista' moment for human workers?**Unlikely to signal the end of human work...**

The increasingly human-like abilities of new generations of humanoid robots raises the question whether machines eventually substitute all tasks, cognitive and physical, leaving nothing for humans to do. The question is not new and has been raised at each point in history when a new technology allowed for large-scale automation in certain sectors.

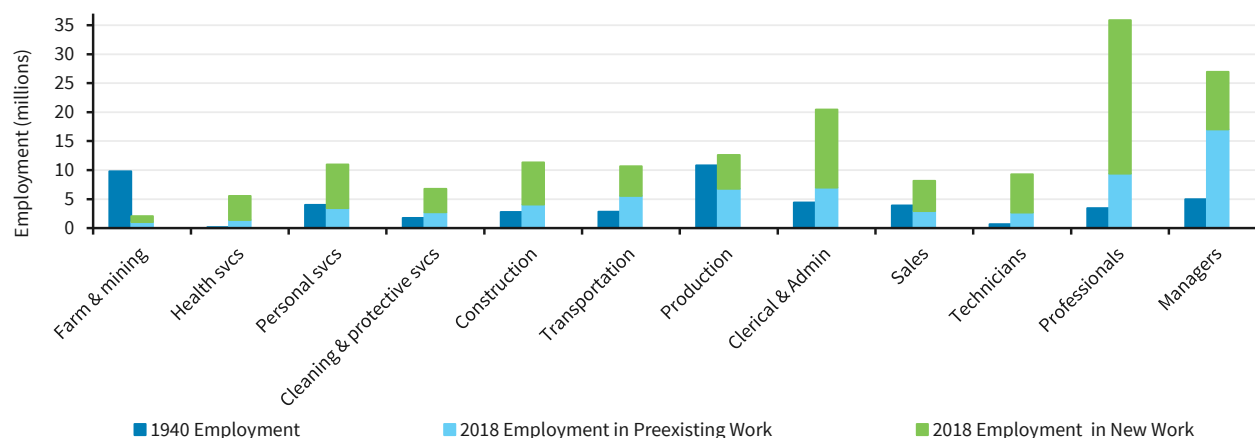
In the 4th-century BC, Aristotle speculated in his work *Politics* that if machines could become sufficiently advanced, there would be no more need for human labour.⁴ Thomas More in 1516 described a utopian society with six hour-long workdays and in the 1930s, John Maynard Keynes predicted in his famous essay *Economic Possibilities for our Grandchildren* that by today, technological advancements would have reduced the work week to 'three-hour shifts or a fifteen-hour week'.

Today, nearly 100 years since Keynes wrote this essay, many of his predictions about the growth in per capita income and technology-driven efficiencies reshaping entire industries have been 'eerily accurate'.⁵ However, his prediction about the work week remains quite off. Although working hours in advanced economies have decreased since the 1930s, full-time work of 35-42 hours per week is still the societal norm, more than double what Keynes projected. Paradoxically, gains in income, education, and productivity sometimes have translated into increased, rather than decreased work hours.

The reasons why full-time work of 35 hours or more per week is still common may be manifold, including societal norms, psychological needs etc. What it does show, however, is that the anxiety about machines replacing human workers has not played out. Despite the dramatic rise of automation, there has been no dramatic rise in unemployment.⁶

This is because work tasks are not static, but evolve. Demand for new skills and expertise arise that were previously unimagined. Using the Census Bureau's internal occupation classification manual, research in this field shows how since the 1940s new occupational titles have been added each decade.⁷ Analysing new work creation in eight decades of data from 1940-2018, Autor et al (2021) find that more than 60% of employment in 2018 was in job titles not yet existent in 1940.

FIGURE 8. Automation does replace some jobs, but technological advances also lead to new jobs through augmentation, while rising incomes and changing tastes create new occupations often unimaginable in the past



Employment Counts by Broad Occupation in 1940 and 2018, Distinguishing between Titles Present in 1940 versus Those Added Subsequently
Source: Autor et. al (2024)

Many such new jobs are closely related to new technologies (eg, wind turbine technician, AI specialist or cybersecurity analyst); as such, they will likely also emerge related to the

⁴ see: Campa, Riccardo (February 2014). "Technological Growth and Unemployment: A Global Scenario Analysis". *Journal of Evolution*

⁵ (Ohanian, [Reference Ohanian2008](#))

⁶ see Autor, [Reference Autor2015](#);

⁷ David Autor (2022) and Autor et al. (2024)

introduction of AI and humanoid robots.⁸ Others just reflect changes in taste, income and demography (eg, tattoo artist, sommelier, mental health counsellor). Similarly, such changes are likely to continue as income grows and societies' preferences evolve, again suggesting that new jobs will emerge.

Although technology-driven automation does lead to some jobs being lost, not all technological innovation leads to automation. In many cases, new technologies do not automate but augment the outputs or services generated by a certain work, which leads to employment growth in these occupations. The history of technological innovation thus far has been one of newly emerging jobs ('labour reinstatement') counterbalancing the erosive effect of labour displacing automation.

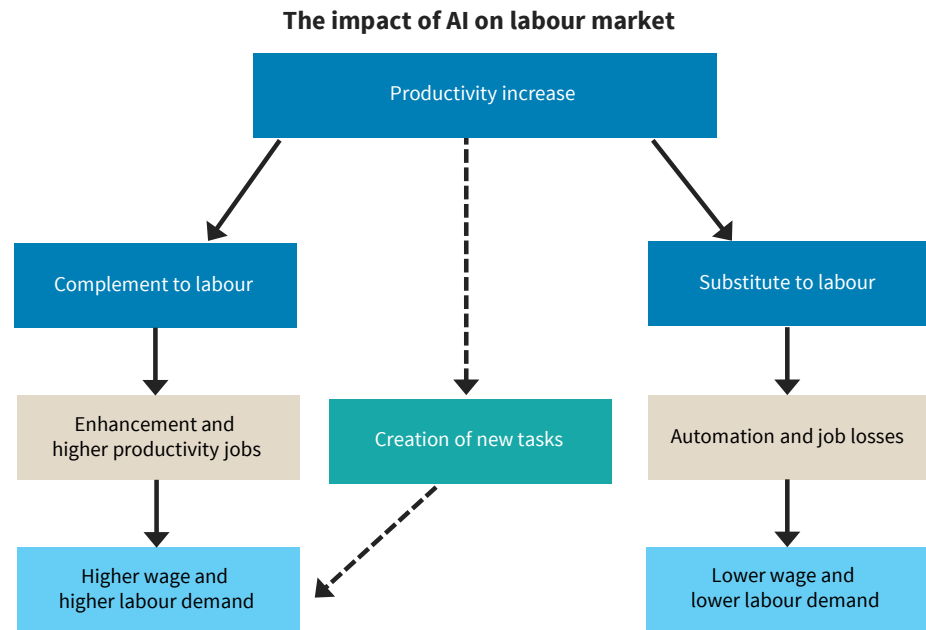
Could AI, especially if combined with humanoid robotics, change this? Some research suggests that already in the past four decades, there has been more automation and less augmentation than in the prior four,⁹ thereby intensifying the labour demand-eroding effects of automation, while the labour demand-increasing effects of augmentation have been slowing. The combination of AI and humanoid robotics could shift the balance further, as it allows for automation across an expanding set of occupations. Other than codified computer software, generative AI can now accomplish non-routine tasks (ie, find solutions without a specified set of rules and procedures), and humanoid robots could introduce this capability of performing non-routine tasks also to the physical world. This could be a very powerful change; indeed, it is for this potential of much increased task automation that we are hopeful for an economy-wide acceleration in productivity gains.

However, even when combined with robotics, AI is not exclusively automating. Short of the artificial general intelligence (AGI) that could usher in 'singularity', humans will continue to have comparative advantage in some cognitive (eg, judgement, hypothesis formulation, causal analysis) and physical skills (eg, dexterity, adaptability). Therefore, AI and robotics will continue to complement many human skills, suggesting that the increasing effect on labour demand by augmentation (ie, new work) should continue to play an important role. In parallel, rising societal wealth and changes in tastes and institutions will likely continue to create demand for new human specialisation and, thus, new jobs.

Last but not least, some increase in automation and related job replacement may be welcome in a world where demographic changes in industrial countries are making labour increasingly scarce. With more job openings coming up than workers to fill them, humanoid robots may be a welcome help, rather than creating a jobless future.

⁸ E.g. roboticsjobs.co.uk lists the potential new jobs of: (i) Human robot interaction designer (ii) Bio-Robotics Engineer (iii) Swarm robotics coordinator (iv) robotics ethics officer (v) Robotic systems cyber security specialist (vi) soft robotics designer (vii) autonomous vehicle robotics engineer (viii) robotic data trainer (ix) disaster response robotics specialist and (x) space robotics engine

⁹ Acemoglu and Restrepo (2019a)

FIGURE 9. The effect from technological progress on labour demand and wages is ambiguous

Source: Barclays Research

... but likely a falling income share for labour

Even if the twin-force of AI and robotics may not eliminate the demand for human labour as such, the speed and the breadth of their progress could make them particularly disruptive and cause significant distributional consequences.

The pre-AI decades of conventional computing capabilities have been shown to have fomented occupational polarisation and increasing wage inequality to the advantage of high-skilled workers performing non-routine tasks. This might not continue under an AI-driven technology change. AI will allow automation of mid- to high-level decision-making tasks typically performed by the managers and professionals who in the past have seen their wages grow disproportionately. As AI turns their formerly specialised expertise into routine tasks, they might find themselves in a similar situation as those affected by conventional computers before. Indeed, in some areas (eg, call centres), AI has shown to be a potential equaliser, as AI tools helps boost the performance of less-skilled workers.

Independently of what may happen to the distribution of *wages*, however, the distribution of *income* may become the more important topic. Because to the extent that AI + humanoid robotics accelerates the process of automation relative to augmentation, it will likely skew the distribution of national income further from labour towards capital. This has already occurred over past decades, and the aggregate slice that labour receives from the income generated by economy could shrink further, as labour can be more easily substituted.¹⁰

This does not imply rising unemployment. Indeed, because those without capital income need to work to earn income, employment could even rise as wages fall. Or the large productivity increases from automation could even allow for average wages to rise (even if very unevenly). In that case, the aggregate income would expand faster than labour's share of income shrinks. However, labour would still see its share of national income decline in relation to that of capital.

¹⁰ Although 'humanoid' robots may seem to blur the line between what is considered human labour or that of a machine, from an economic perspective humanoid robots are capital. They require a capital investment and are owned by someone who receives income from them.

Hence, the inequality of *income* (wages + capital income) is likely to become a more important issue than *wage* inequality.

FIGURE 10. The share of labour income has been falling since 1970s and this trend could accelerate under AI and robotics



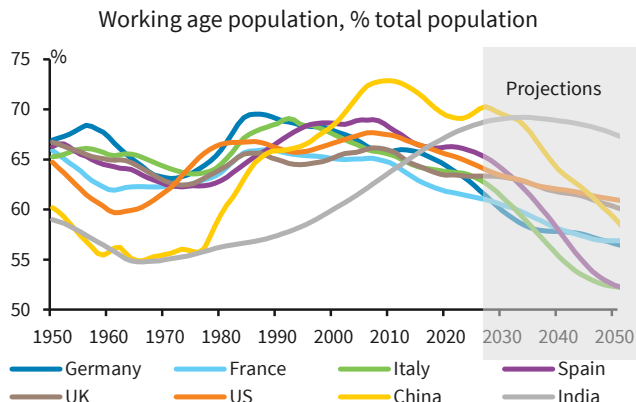
Source: BEA, Haver Analytics, Barclays Research

Energy beats demographics

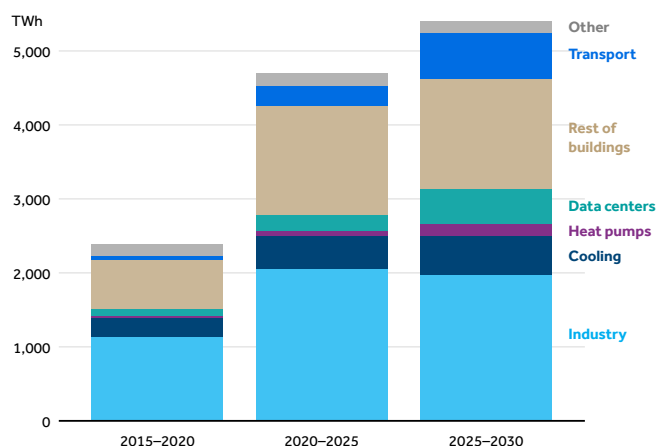
From demographic dividends and burdens ...

Demographic change has been a prominent economic theme for some time. Rapid population ageing in the most advanced economies versus the continuing demographic dividend in economies such as India has been much discussed. Especially China's 'Lewis turning point' and its rapid decline in the share of working age population (due to its previous one-child policy) have been studied. Similarly, the rising share of older populations in advanced industrialised countries (Europe, Japan, Korea, etc.) and the associated effect on labour markets, pension systems and health care, are much discussed.

The widespread emergence of affordable humanoid robots could change this debate. They could effectively fill in for missing human workers, including not only in manufacturing but also in care services such as eldercare. The latter is already being experimented with in Japan, while in China the advances in robotics are supporting its dominance in global manufacturing, regardless of a decline in the working age population.

FIGURE 11. The effect of demographics on economies has received much attention...

Source: UN, Haver Analytics, Barclays Research

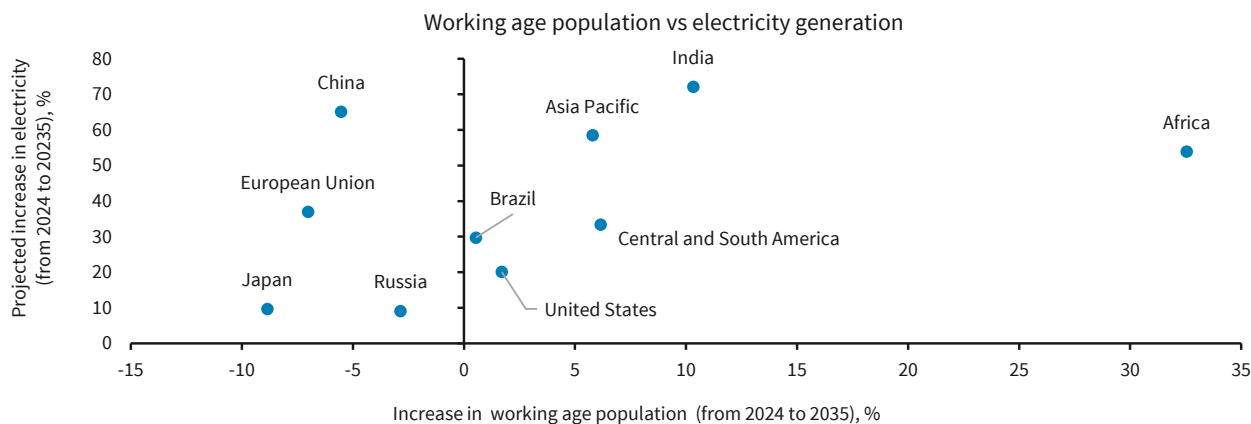
FIGURE 12. ...but in a world of AI and robotics, electricity generation may become more important

Source: IEA, Barclays Research

... to electricity availability

However, AI and robotics will need a lot of energy, in their production and use, especially if humanoid robots require AI cognitive functions to run permanently in the background. In addition, data centre equipment and robots need many critical minerals, including rare earths for the crucial actuators in robots. Simply put, while humans will continue to consume energy, the emergence of humanoid robots will add to energy demand, more specifically, electricity.

Electricity demand is projected to increase rapidly over the next decades, and a more rapid adoption of AI and robotics could further accelerate it. The ability to generate sufficient electricity could be key challenge in regions where AI and humanoid robotics are needed to help offset a lack of human labour, but which at the same time rely on imports of energy and critical minerals (eg, Europe and Japan). In contrast, China seems well prepared with its ongoing rapid electricity build-out, as well as its dominance in critical minerals.

FIGURE 13. Economies that wish to offset a declining human labour force with increased AI and robotics use must prepare for rising electricity demand

Source: UN, IEA, Haver Analytics, Barclays Research

Implications for investors

The advance of generative AI, in combination with humanoid robots, looks to expand automation and augmentation potential across a wide range of cognitive and physical tasks in an economy. The associated benefits across sectors could unleash a significant acceleration of economy-wide productivity growth, much more so than AI advances concentrated in cognitive tasks only.

Although this is unlikely to lead to a jobless future and may also not deepen wage inequalities, it will likely further increase the share of capital income in an economy at the expense of labour income. Humanoid robots' ability to perform more tasks previously reserved for humans will also shift the focus away from demographics towards the access to electricity and capital.

Rising productivity, combined with large capital expenditure needs, points to a higher neutral real interest rate (ie, real r^*). Although the effect on average wage growth is ambiguous, what seems more clear-cut is a continued thirst for electricity and the commodities needed for the build-out and the maintenance of the AI + robotics infrastructure. This should support commodity prices and suggests inflationary pressure will originate from prices of raw materials, rather than labour market-related wage increases.

With regard to regional effect, the emergence of humanoid robotics, in combination with AI, should alter the discussion of demographics. The traditional emphasis on rising shares of working age populations as demographic dividend vs. the burden of a rising share of the elderly may fade, as humanoid robotics can perform tasks previously reserved for humans, and AI-related achievements blur the lines between 'working age' versus 'retirement age'. This could improve the outlook for industrialised economies with ageing populations as well as access to the capital to make the necessary investments, including in energy generation and electrification.

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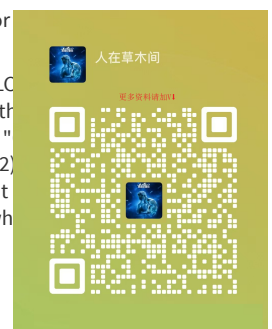
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