EMPLOYEE OF THE MONTH

JANUARY

FEBRUARY

MARCH

APRIL

MAY

JUNE

JULY

AUGUST

SEPTEMBER

OCTOBER

NOVEMBER

DECEMBER

Robots may seem dangerous not only to cinema action heroes but also to the average manufacturing worker. To assess whether such concerns are well founded, **Guy Michaels** and **Georg Graetz** analyse the labour market effects of industrial robots, which have been widely adopted in the past 25 years.

Robots at work:
the impact on productivity and jobs

Robots' capacity for autonomous movement and their ability to perform an expanding set of tasks have captured writers' imaginations for almost a century. Recently, robots have emerged from the pages of science fiction novels into the real world, and discussions of their possible economic effects have become ubiquitous (see, for example, *The Economist*, 2014; and Brynjolfsson and McAfee, 2014). But a serious problem inhibits these discussions: to date, there has been no systematic empirical analysis of the economic effects that robots are already having.

Our research begins to remedy this problem. We have compiled a new dataset spanning 14 industries (mainly manufacturing industries, but also agriculture and utilities) in 17 developed countries (including Australia, European countries, South Korea and the United States). Uniquely, our dataset includes a measure of the industrial robots employed in each industry in each of these countries, and how it has changed between 1993 and 2007. We obtain information on workers' hours and other economic indicators from the EU KLEMS database (Timmer et al, 2007).

We find that industrial robots increase labour productivity, total factor productivity and wages. At the same time, while industrial robots have no significant effect on total hours worked (as we explain below), there is some evidence that they reduce the employment of low-skilled workers and, to a lesser extent, middle-skilled workers.

What exactly are these industrial robots? Our data come from the International Federation of Robotics, which considers a machine as an industrial robot if it can be programmed to perform physical, production-related tasks without the need of a human controller. (The technical definition refers to a 'manipulating industrial robot as defined by ISO 8373: An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications'.)

Industrial robots dramatically increase the scope for replacing human labour compared with older types of machines, since they reduce the need for human intervention in automated processes. Typical applications of industrial robots include assembling, dispensing, handling, processing and welding – all of which are prevalent in manufacturing industries – as well as harvesting (in agriculture) and inspecting equipment and structures (common in power plants).

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Rapid technological change reduced the prices of industrial robots (adjusted for changes in quality) by around 80% between 1993 and 2007. Unsurprisingly, the use of robots grew dramatically during this period: the ratio of the number of robots to hours worked increased on average by about 150%. The rise in robot use was particularly pronounced in Germany, Denmark and Italy; and the industries that increased robot use most rapidly were producers of transport equipment, chemicals and metals.

To estimate the impact of robots, we take advantage of variation across industries and countries and over time. A consistent picture emerges in which robots appear to raise productivity, without causing total hours to decline. This may seem surprising at first, but it is due to offsetting effects. Robots increase productivity, which means that fewer human hours are needed to produce a given output. But higher productivity also reduces production costs and output prices. This in turn increases the quantity demanded by consumers, and firms hire workers to meet this increased demand.

But could it be that higher productivity growth causes a larger increase in robot use, rather than the other way around? To address this and related concerns, and to shed further light on the effect of robots, we develop a novel measure of increased robot use – namely, workers' 'replaceability' by robots. This is based on the tasks prevalent in industries before robots were widely employed.

Specifically, we match data on tasks performed by industrial robots today with data on similar tasks performed by US workers in 1980, before robots were used. We then compute the fraction of each industry's working hours in 1980 accounted for by occupations that subsequently became prone to replacement. Our industry-level replaceability index strongly predicts increased robot use between 1993 and 2007.

When we use our index to capture differences in the increased use of robots, we again find that robots increased productivity, and we detect no significant effect on hours worked. As an important check on the validity of this exercise, we find no significant relationship between replaceability and productivity growth in the period before the adoption of robots.

We conservatively calculate that on average, the increased use of robots contributed about 0.37 percentage points to annual GDP growth, which accounts for more than one tenth of total GDP growth over this period. The contribution to labour productivity growth was about 0.36 percentage points, accounting for one sixth of productivity growth.

This makes robots' contribution to the aggregate economy roughly on a par with previous important technologies, such as the railroads in the nineteenth century (Crafts, 2004) and the US highways in the twentieth century (Fernald, 1999). The effects are also comparable to the recent contributions of information and communication technologies (see, for example, O'Mahony and Timmer, 2009). But it is worth noting that robots make up just over 2% of capital, which is less than previous technological drivers of growth.

Our findings on the aggregate impact of robots are significant given recent concerns in macroeconomic research that the productivity gains from technology in general may have slowed down. Gordon (2012, 2014) expresses a particularly pessimistic view, and there are broader worries about 'secular stagnation' (Summers, 2014; and Krugman, 2014), although others remain more optimistic (Brynjolfsson and McAfee, 2014).

We expect that the beneficial effects of robots will extend into the future as new robot capabilities are developed, and service robots come of age. But our

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findings do come with a note of caution: there is some evidence of diminishing marginal returns to robot use – 'congestion effects' – so they are not a panacea for growth.

Although we do not find evidence of a negative impact of robots on aggregate employment, we see a more nuanced picture when we break down employment (and the wage bill) by skill groups. Robots appear to reduce the hours and the wage bill shares of low-skilled workers and, to a lesser extent, those of middle-skilled workers.

At the same time, robots have no significant effect on the employment of high-skilled workers. This pattern differs from the effects that recent research finds for information and communication technologies, which seem to benefit high-skilled workers at the expense of middle-skilled workers (Autor, 2014; and Michaels et al, 2014).

In summary, we find that industrial robots make significant contributions to labour productivity and aggregate growth, and their use also increases wages and total factor productivity. While fears that robots destroy jobs at a large scale have not materialised, we find some evidence that robots reduce the employment of low- and middle-skilled workers.

This article summarises 'Robots at Work' by Georg Graetz and Guy Michaels, CEP Discussion Paper No. 1335 (http://cep.lse.ac.uk/pubs/download/dp1335.pdf).

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Further reading

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