National Network
For Critical
Technology Assessment

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CMU NNCTA 2-Pager: The Impact of AI Invention

Research Issue

After decades of disappointingly slow progress, artificial intelligence (AI) has made impressive strides over the past few decades, prompting talk of a 4th industrial revolution. However, aggregate productivity growth in the U.S. remains stuck at historically low levels, holding down growth in future living standards, geopolitical power, and fiscal sustainability. Will AI live up to its promise, generating an industrial revolution that raises productivity growth? The full impact on aggregate productivity of past technological revolutions has taken decades to emerge, because of the slow process of adoption. A definitive assessment of the impact of AI is years away, but we can obtain preliminary evidence on this question by exploring the impact of AI invention on the inventing firms, who are likely to be in the vanguard of any AI revolution. Using fixed effects and event study regressions, we find that AI-invention leads to economically and statistically significant increases in output, employment, and productivity. This strengthens the case that AI will eventually bring a broader productivity resurgence to the U.S. economy.

Methods and Data

Our team developed an ensemble of machine learning algorithms that parse the text of patents granted by the U.S. Patent and Trademark Office to identify AI-related patents. These algorithms not only identify AI-related patents but also provide a univariate measure of the AI-intensiveness of each patent, allowing us to experiment with various thresholds of "AI-ness." Through a partnership with the U.S. Census Bureau, we can link these patents to the U.S. firms that create the inventions the patents protect, using the carefully developed and regularly updated "crosswalk" created by the Census Bureau that links patent owners to U.S. firms. Because both patent data and Census surveys are regularly updated, we can continue to use these data to track the impact of AI invention on inventing firms in future years.

Insights

AI is not new, and our algorithms can identify significant numbers of AI patents going back to the 1990s, although the numbers generated then are dwarfed by the scale of AI invention in the 2010s. This long panel dimension to our data allows us to compare the subsequent productivity growth of AI-inventing firms to the productivity growth of firms that did not generate AI-inventions – a dimension of comparison economists refer to as the extensive margin. We can also observe how the same firm's output and productivity vary as it invents additional AI-related technologies, which is a dimension of comparison we refer to as the intensive margin. The figures below illustrate the estimated impact of AI invention on firm outcomes across both dimensions, with an emphasis on the productivity effects, measured in different ways. In generating these results, we use two different statistical approaches – fixed effects models and event study models.

We see evidence that AI invention boosts firm output per employee by 15-27%, value added by 10-23%, and total factor productivity (TFP) by 6-8%. These are economically large effects, and they are all statistically significant. While it is not possible to confirm that these effects are causal, our ability to

track firms over time gives us some degree of leverage around the possibility that both AI invention and productivity increases are driven by some omitted third variable. Despite concern that AI might lead to significant declines in employment, our results suggest that AI invention leads to subsequent growth in employment rather than declines.

In addition to these regression-based results, possession of data on AI-related patenting also enables us to examine the distribution of AI invention across geographic boundaries, time, firms, and industries. Figure 2 illustrates the cumulative distribution of AI patenting across U.S. cities.

Figure 1: Impact of AI on Firm Employment and Productivity

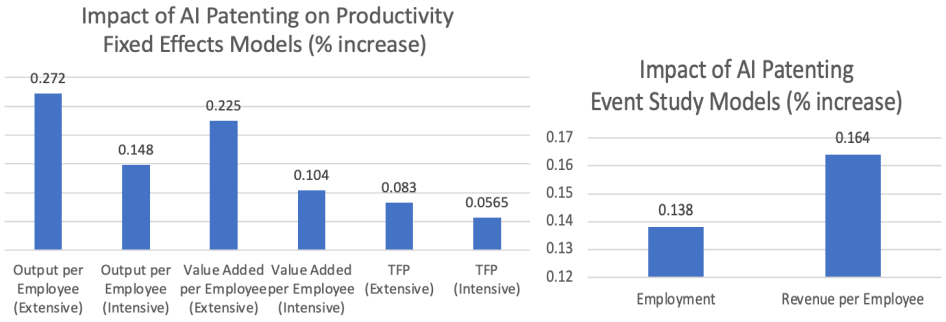
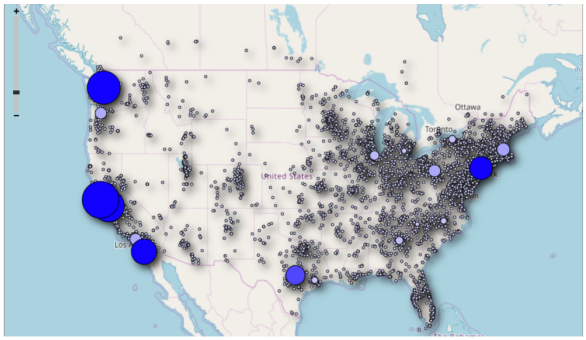


Figure 2: Distribution of AI Invention Across U.S. Cities



Options and Trade-offs

The most important determinant of growth in future U.S. living standards, economic size, and global power is arguably our rate of productivity growth. Since the mid-2000s, the U.S rate of productivity growth has been stuck at low levels. Our results provide grounds for optimism that continued innovation in AI could help bring about a significant and lasting acceleration in productivity growth. The federal government should seek to support this by 1) continuing it invest in AI-related basic research, 2) expand the domestic pipeline for AI talent by supporting graduate education in AI-related disciplines, 3) take meaningful steps to increase the number of foreign graduates of U.S. AI-related programs who receive permission to work in the U.S., and 4) ensure that regulations imposed to ensure the safety of AI do not impede AI-related innovations.

Next Steps

Not all AI Inventions are patented. How do we measure AI invention when patents are not generated? We address this challenge by noting that any firm seeking to use AI to introduce new products or services or substantially re-engineer existing products or services needs to hire AI experts trained up to the technology frontier. Ongoing work by the CMU team is using publication data to identify star AI scientists and the doctoral students and post-docs with whom they co-author. We then use a mix of publication and social media data to trace the movement of these experts from the academy, where they are trained, and into firms. Using our link to Census data, we can test the hypotheses that firms acquiring a critical mass of PhD-level AI experts trained by star scientists experience large productivity gains.