# Is Modern Technology Responsible for Jobless Recoveries?

*By* Georg Graetz and Guy Michaels*

Since the early 1990s, recoveries from recessions in the US have been plagued by weak employment growth. Employment growth during the two years after each recession's trough was a little over five percent before 1990, and just under one percent since then (Gali, Smets and Wouters, 2012). One possible explanation for the slower recovery of jobs is related to technological change. Middle-skill jobs, often involving routine tasks that are particularly susceptible to replacement by new technologies, might be destroyed permanently during recessions. The displaced workers are then forced into time-consuming transitions to different occupations and sectors, resulting in slow job growth during the recovery. This explanation has been proposed, along with empirical evidence, by Jaimovich and Siu (2014), and we confirm that it fits the employment patterns in the US. But we also examine whether this mechanism is at work in the rest of the developed world: labor market polarization (or "hollowing out" of middle-skill jobs) has been documented in the US as much as in other countries, and there is evidence that technology is one of the drivers of this change (Goos, Manning and Salomons, 2014; Michaels, Natraj and Van Reenen, 2014). Our main research question is therefore: could modern technology also be contributing to jobless recoveries across developed economies?

In order to examine technology's role in employment recoveries from recessions, we use data on 71 recessions, which took place in 17 developed countries from 1970-2011.[1] We use both aggregate data and harmonized data on 28 industries within each of these countries. We investigate how recoveries changed since the late 1980s, and whether these changes are likely attributable to technological change.

First, we examine whether recoveries from recessions after 1985 produced slower employment growth than earlier recoveries. Second, we test whether industries that make more intensive use of routine jobs, and are therefore more susceptible to technological change, have had particularly slow employment growth in recoveries. Finally, we investigate whether routine-intensive industries have seen more replacement of middle-skill jobs during recessions and recoveries.

We find that in contrast to the US, recoveries in other developed countries as a whole have not become significantly more jobless since the late 1980s, even though GDP did recover more slowly. Routine-intensive industries did experience deeper recessions and slower recoveries than other industries, but this pattern did not change significantly after 1985. Finally, we find that middle-skill employment grew similarly in routine-intensive industries and other industries during recent recoveries. Taken together, this evidence suggests that technology is not causing jobless recoveries in developed countries outside the US.

## I. Data

We obtain industry-level real value added, total hours worked, and hours worked by skill group, as well as country-level hours worked, from the EUKLEMS data set (O'Mahony and Timmer, 2009)

* Graetz: Uppsala University, P.O. Box 513, 75120 Uppsala, Sweden (email: georg.graetz@nek.uu.se). Michaels: London School of Economics, Houghton Street, WC2A 2AE, London, UK (email: g.michaels@lse.ac.uk). We thank Daron Acemoglu, Mikael Carlsson, Francesco Caselli, Lisa Kahn, Larry Katz, Per Krusell, Barbara Petrongolo, Steve Pischke, and seminar participants at the Greater Stockholm Macro Group for helpful comments. All errors are our own.

[1] The countries included are Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, The Netherlands, South Korea, Spain, Sweden, the UK, and the US.

and the World Input-Output Database (Timmer et al., 2015, WIOD).[2] EUKLEMS covers the period 1970-2007 (for the US, 1977-2007) and also includes information on the share of ICT services in total capital services. WIOD covers 1995-2011.[3]

Our source for country-level GDP data, at both quarterly and annual frequency, is the OECD (2016). We obtain business-cycle peak and trough dates from the Economic Cycle Research Institute (ECRI).[4] For countries not covered by ECRI, we assign peak and trough dates using quarterly GDP data from the OECD, defining a recession as two or more consecutive quarters of negative GDP growth.[5]

Since our industry-level data are only available at annual frequency, we classify each country-year as an expansion, recession, or recovery year, based on quarterly peak and trough indicators. Our final sample contains 71 recessions for which we observe at least the first year of recovery. We choose 1985 as the last year of our pre-period, consistent with Jaimovich and Siu (2014), who consider the 1990 recession in the US to be the first to feature a jobless recovery.

One might be concerned that our use of annual data causes measurement error in the timing of business cycles. However, prior literature on jobless recoveries focusses on cumulative employment growth, say over four or eight quarters as in Gali, Smets and Wouters (2012), after a trough. This suggests that annual data, though admittedly not ideal, can be used to study jobless recoveries. Because the distinction of recession and recovery years may be noisy in some cases, we report coefficients on indicators for recession years, as well as recovery years, in all our results. Reassuringly, for the US we do detect patterns consistent with those documented by Jaimovich and Siu (2014) in our annual data. Furthermore, there are no significant differences in the frequency of recession years (about one in six) or the distribution of peak and trough quarters, between our pre-period (1970-1985) and post-period (1986-2011). It is therefore unlikely that measurement error due to using annual cycle indicators is driving our results.

We measure the extent to which industries are subject to technological change using routine intensity (RTI) as constructed in Autor and Dorn (2013). Consistent with prior literature, we find routine intensity to be positively related to the ICT share in total capital services in 1995: a one-standard-deviation increase in routine intensity is associated with a 0.2 increase in the share of ICT in total capital. This relationship does not vary between the US and other countries. The most routine-intensive industries include financial intermediation, retail trade, and various manufacturing industries, while the least routine-intensive industries include agriculture, transportation, and education.

Further details on data construction, as well as more extensive results, can be found in the working paper version (henceforth WPV) of this paper (Graetz and Michaels, 2017).

## II. Results

We begin by examining aggregate changes in recoveries from recessions. We do this by estimating regressions of the form

$$\begin{aligned}\Delta \log Y_{ct} = \\ &\mathbf{d}'_{ct}\boldsymbol{\beta}_1 + \mathbf{x}'_c\boldsymbol{\beta}_2 \\ &+\mathbb{1}\{t \geq 1986\} \times \mathbf{d}'_{ct}\boldsymbol{\beta}_3 \\ &+\mathbb{1}\{t \geq 1986\} \times \mathbf{x}'_c\boldsymbol{\beta}_4 + \varepsilon_{ct},\end{aligned} \tag{1}$$

using aggregate level data on annual changes in outcomes $Y_{ct} \in \{\mathrm{GDP}_{ct}, \mathrm{hours}_{ct}\}$ in country $c$ and year $t$. The vector $\mathbf{d}_{ct}$ collects indicators for year $t$ being a recession year, a year after a recession, or a year that comes two years after a recession. The

[2] EUKLEMS and WIOD provide data on three different skill groups: high (college and above), middle (high school, some college) and low (less than high school).

[3] We use the more recent WIOD data during years of overlap with EUKLEMS.

[4] See their table "Business Cycle Peak and Trough Dates, 21 Countries, 1948-2015", available at `https://www.businesscycle.com/download/report/3723` (accessed on Nov 1, 2016).

[5] The countries not covered by ECRI include Denmark, Finland, Ireland, and The Netherlands.

matrix $\mathbf{x}_c$ contains country dummies. We cluster standard errors by country, using the small-group adjustment that Stata implements by default (Brewer, Crossley and Joyce, 2013). To detect any changes in business cycles coinciding with the period of rapid technology adoption after 1985, we interact all variables with a dummy indicating this later period.

As column (1) of Table 1 shows, employment growth in the two years after the trough of a recession was negative during the period 1970-1985. After 1985, employment recoveries were not significantly slower than in the previous years, although the point estimates in this later period were a little lower. But to put these point estimates in context, the next column of Table 1 shows that GDP recovery was also slower in the post-1985 period, especially in the first year of the recovery. Relative to GDP growth, there is little to suggest that employment growth in recent recoveries in the developed world has been particularly weak.

Next, we examine the differential behaviour of routine-intensive industries over the business cycle. We are motivated by a large literature documenting that routine-intensive jobs have been more exposed to technological change.[6] The focus on routine-intensive industries is also in the spirit of Jaimovich and Siu (2014).

To examine whether industries that are more intensive in routine tasks display a different pattern of recovery from recessions, we estimate regressions of the form

$$\begin{aligned}(2)\qquad &\Delta \log Y_{ict} = \\ &\mathbf{d}_{ct}'\boldsymbol{\gamma}_1 + \mathrm{RTI}_i \times \mathbf{d}_{ct}'\boldsymbol{\gamma}_2 + \mathbf{x}_{ic}'\boldsymbol{\gamma}_3 \\ &+\mathbb{1}\{t \geq 1986\} \times \mathbf{d}_{ct}'\boldsymbol{\gamma}_4 \\ &+\mathbb{1}\{t \geq 1986\} \times \mathrm{RTI}_i \times \mathbf{d}_{ct}'\boldsymbol{\gamma}_5 \\ &+\mathbb{1}\{t \geq 1986\} \times \mathbf{x}_{ic}'\boldsymbol{\gamma}_6 + \nu_{ict},\end{aligned}$$

where the data are year-on-year changes at the country-industry level. $\mathrm{RTI}_i$ is routine intensity in industry $i$, standardized to have zero mean and unit variance. The matrix $\mathbf{x}_{ic}$ contains country and industry dummies.[7] We continue to cluster standard errors at the country level. We weight all industry-level regressions by the within-country employment share of each country-industry, averaged over time. Weights sum up to one within countries, so that each country receives equal weight, as in our country-level regressions above.

Column (3) of Table 1 contains our main result. Employment recovered more slowly in routine-intensive industries already during the early period, and there is no statistically significant change in this relationship after 1985. The same is true for value added, as seen in column (4) of Table 1.[8]

Column (5) and (6) of Table 1 show estimates of the same regressions as in columns (3) and (4), but this time only for the US. These results show a picture that is broadly consistent with Jaimovich and Siu (2014): in the US, employment and value added growth were slower in recent recessions, and even more so in routine-intensive industries. In other words, the phenomenon of "jobless recoveries" as observed in the US could be related to technological change—but, as the results in the previous columns show, the same conclusion does not apply outside the US.

We conduct a series of robustness checks, which we document in the WPV. These checks include adding year fixed effects to the regressions; estimating unweighted regressions; and using EUKLEMS instead of WIOD for the years when they overlap. In all cases the basic picture outlined above remains unchanged, and there is little evidence that routine-intensive industries experienced more-jobless recoveries after 1985.

While our main specifications follow the literature in using industries' routine inten-

[6]See Acemoglu and Autor (2011) for an overview, and more detailed references in Graetz and Michaels (2017).

[7]In the WPV we also report results from specifications that omit industry dummies and include the non-interacted routine index instead. They are quantitatively very similar to our baseline results.

[8]For some observations we have data on hours but not on value added. We show in the WPV that results for hours are unchanged if we restrict the sample to observations with non-missing value added.

sity as a measure of exposure to technological change, we also consider an alternative and more direct measure of technology adoption, namely, the share of ICT in total capital (measured in 1995). The results, contained in the WPV, show a similar pattern as before, although there is some evidence that in recent recessions employment in ICT-intensive industries grew more slowly during the first year of recovery (but not in the second year of recovery). Again, results for the US when using a direct measure of ICT adoption, are more consistent with Jaimovich and Siu (2014) than results for the whole sample.

In the WPV we also examine industries that were more exposed to robotization, because their (pre-robotization) employment was more concentrated in occupations that robots could eventually replace (Graetz and Michaels, 2015). We show that these industries did not experience deeper recessions and slower recoveries after 1985.

To shed more light on the differences in our results between the US and other developed countries, we also investigate whether the relationship between long-run employment growth and industries' routine intensity differs between countries. We document in the WPV that routine intensity was associated with faster employment growth across all countries during 1970-1985. Afterwards, routine-intensive industries experienced slower employment growth in the US, but not in other countries. If technology were behind jobless recoveries, we would expect that countries experiencing a larger degree of routine-biased technological change, as measured by long-run employment declines associated with routine intensity after 1985, should also feature increasingly slow recoveries in routine-intensive industries after 1985. However, we show in the WPV that there is no such relationship in our data.

Lastly, we examine whether recoveries from recessions have become particularly bad for the employment of middle-skill workers, whose jobs are more intensive in routine tasks than those of other skill groups. Detailed results from these exercises are reported in the WPV. We first estimate specification (1) separately for high-skill, middle-skill, and low-skill workers and find some suggestive evidence that after 1985 recessions became worse for middle-skill workers. But there is no evidence that employment changes during recoveries increasingly work against middle-skill workers in particular. We then consider the possibility that in routine-intensive industries recoveries worked against middle-skill workers, estimating specification (2) using each group's employment change as outcomes. Again the results show no evidence of a worsening in the employment prospects of middle-skill workers in routine-intensive industries in more recent recessions.[9]

## III. Discussion

The main conclusion of our paper is that in developed countries outside the US, modern technologies are unlikely to be causing jobless recoveries. This conclusion stems from our findings that in most developed countries, recent recoveries are not particularly jobless; that recent recoveries have not become more jobless in routine-intensive industries, which are more prone to technological change; and that middle-skilled workers are not being differentially hurt during recent recoveries—both in general and specifically in routine-intensive industries.

Our results do, however, pose a puzzle as to the nature of recent jobless recoveries in the US. There are two (and perhaps more) possible explanations. The first builds on our finding that across industries in the US, technological change is associated with the recent joblessness of recoveries, consistent with Jaimovich and Siu (2014).[10] Although secular changes in occupational employment, likely driven by technology, have been very similar across the

[9] Even when we examine these results separately for the US there is still no evidence that middle-skill employment suffered disproportionately in routine-intensive industries in recent recessions.

[10] This is also consistent with Hershbein and Kahn (2016), who document that skill requirements in vacancy postings increased more in local labor markets that were more affected by the Great Recession, and that these patterns persisted.

US and other developed countries, there are aspects of technology adoption that differ—see for instance Bloom, Sadun and Van Reenen (2012). Perhaps such differences could explain the absence of jobless recoveries outside the US. The second possible explanation appeals to US-specific policy and institutional changes. For instance, Mitman and Rabinovich (2014) show that unemployment benefit extensions, which increase workers' reservation wages, may slow down employment growth during recoveries. Berger (2015) proposes that the substitution of workers during recessions and recoveries may have become more pronounced in recent decades because of the decline of unions. Establishing the relative merits of the technology- and policy-based explanations, which of course need not be mutually exclusive, is a task for future research.

## REFERENCES

**Acemoglu, Daron, and David Autor.** 2011. "Skills, Tasks and Technologies: Implications for Employment and Earnings." In *Handbook of Labor Economics.* Vol. 4, Chapter 12, 1043–1171. Elsevier.

**Autor, David H., and David Dorn.** 2013. "The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market." *American Economic Review*, 103(5): 1553–97.

**Berger, David.** 2015. "Countercyclical Restructuring and Jobless Recoveries." working paper.

**Bloom, Nicholas, Raffaella Sadun, and John Van Reenen.** 2012. "Americans Do IT Better: US Multinationals and the Productivity Miracle." *American Economic Review*, 102(1): 167–201.

**Brewer, Mike, Thomas F. Crossley, and Robert Joyce.** 2013. "Inference with Difference-in-Differences Revisited." IZA Discussion Paper 7742.

**Gali, Jordi, Frank Smets, and Rafael Wouters.** 2012. "Slow Recoveries: A Structural Interpretation." *Journal of Money, Credit and Banking*, 44: 9–30.

**Goos, Maarten, Alan Manning, and Anna Salomons.** 2014. "Explaining Job Polarization: Routine-Biased Technological Change and Offshoring." *American Economic Review*, 104(8): 2509–26.

**Graetz, Georg, and Guy Michaels.** 2015. "Robots at Work." CEP Discussion Paper 1335.

**Graetz, Georg, and Guy Michaels.** 2017. "Is Modern Technology Responsible for Jobless Recoveries?" CEP Discussion Paper 1461.

**Hershbein, Brad, and Lisa B. Kahn.** 2016. "Do Recessions Accelerate Routine-Biased Technological Change? Evidence from Vacancy Postings." NBER Working Paper 22762.

**Jaimovich, Nir, and Henry E. Siu.** 2014. "The Trend is the Cycle: Job Polarization and Jobless Recoveries." working paper.

**Michaels, Guy, Ashwini Natraj, and John Van Reenen.** 2014. "Has ICT Polarized Skill Demand? Evidence from Eleven Countries over Twenty-Five Years." *The Review of Economics and Statistics*, 96(1): 60–77.

**Mitman, Kurt, and Stanislav Rabinovich.** 2014. "Unemployment Benefit Extensions Caused Jobless Recoveries!?" PIER Working Paper 14-013.

**OECD.** 2016. "National Accounts of OECD Countries." Volume 2016 Issue 1.

**O'Mahony, Mary, and Marcel P. Timmer.** 2009. "Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database." *Economic Journal*, 119(538): F374–F403.

**Timmer, Marcel P., Erik Dietzenbacher, Bart Los, Robert Stehrer, and Gaaitzen J. Vries.** 2015. "An Illustrated User Guide to the World Input Output Database: the Case of Global Automotive Production." *Review of International Economics*, 23(3): 575–605.

Table 1—Growth in hours and output over the business cycle, by period and routine intensity

| | Countries | | Industries | | Industries, US | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | H | GDP | H | VA | H | VA |
| 𝟙{recession} | -1.78 | -3.46 | -1.74 | -3.38 | -4.07 | -6.80 |
| | (0.33) | (0.41) | (0.28) | (0.46) | (0.96) | (1.85) |
| 𝟙{recovery 1} | -1.95 | -1.74 | -2.00 | -1.59 | -2.80 | -2.01 |
| | (0.35) | (0.34) | (0.38) | (0.35) | (0.51) | (0.97) |
| 𝟙{recovery 2} | -0.49 | -0.46 | -0.58 | -0.77 | -0.17 | 0.62 |
| | (0.21) | (0.36) | (0.25) | (0.34) | (0.45) | (0.97) |
| RTI×𝟙{recession} | | | -0.72 | -0.97 | -0.50 | -0.32 |
| | | | (0.13) | (0.22) | (1.00) | (1.96) |
| RTI×𝟙{recovery 1} | | | -0.57 | -1.43 | 0.66 | 1.65 |
| | | | (0.15) | (0.54) | (0.43) | (1.24) |
| RTI×𝟙{recovery 2} | | | -0.10 | -0.38 | 0.47 | -0.84 |
| | | | (0.20) | (0.45) | (0.43) | (1.09) |
| 𝟙{recession}×𝟙{$t \geq 1986$} | -0.50 | -0.43 | -0.65 | -0.23 | 2.02 | 4.74 |
| | (0.48) | (0.51) | (0.47) | (0.56) | (0.55) | (1.30) |
| 𝟙{recovery 1}×𝟙{$t \geq 1986$} | -0.29 | -1.09 | -0.44 | -1.44 | -1.41 | -1.74 |
| | (0.57) | (0.43) | (0.58) | (0.44) | (0.86) | (1.14) |
| 𝟙{recovery 2}×𝟙{$t \geq 1986$} | -0.47 | -0.24 | -0.24 | -0.22 | -2.21 | -0.85 |
| | (0.43) | (0.35) | (0.53) | (0.38) | (0.98) | (0.95) |
| RTI×𝟙{recession}×𝟙{$t \geq 1986$} | | | 0.20 | -0.39 | -0.93 | -1.16 |
| | | | (0.22) | (0.33) | (0.65) | (1.56) |
| RTI×𝟙{recovery 1}×𝟙{$t \geq 1986$} | | | -0.27 | 0.25 | -2.01 | -3.15 |
| | | | (0.30) | (0.54) | (0.77) | (1.96) |
| RTI×𝟙{recovery 2}×𝟙{$t \geq 1986$} | | | 0.19 | 0.12 | -0.66 | -0.59 |
| | | | (0.31) | (0.63) | (0.92) | (0.72) |
| Observations | 690 | 690 | 19,320 | 18,284 | 952 | 896 |

*Notes:* Indicators for "recession", "recovery 1", and "recovery 2" equal one if a given year features a recession, follows a recession year, or comes two years after a recession year, respectively. Columns (1) and (2) report results from country-level regressions, while all other columns contain results from industry-level regressions. "H", "GDP", and "VA" refer to hours worked, gross domestic product, and value added, respectively. The dependent variables are annual changes in the log of these variables, multiplied by 100 so that coefficients are in log points. "RTI" refers to an index for routine intensity, which is standardized to have zero mean and unit variance. Regressions in columns (1)-(4) control for country fixed effects, and in columns (3)-(6), for industry-fixed effects. All fixed effects are allowed to vary between pre- and post-period. Robust standard errors, clustered by country (by industry in the last two columns), in parentheses.