The Media is the Measure:

Documenting the relationship between technical change and employment, 1909-49

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Abstract: Difficulties in sorting out the empirical relationship between technical change and employment is attributable, at least in part, to the shortcomings associated with traditional measures of the former. In this paper, we use new indicators of technical change that we believe resolve many issues associated with other methods of identifying technology shocks, and use them to explore the impact of technical change on employment from 1909-49. The payoff to this effort is substantial for at least two reasons. First, it sheds light on both the Real Business Cycle model vs. New Keynesian model debate and more generally, on the role technology shocks play in cyclical fluctuations; second, and related, it helps clarify the part played by the New Deal Policies in the recovery from the Great Depression.

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I. Introduction

In this paper, we employ a new indicator of technological change to identify the relationship between technology shocks and employment in the U.S. for the period 1909-1949. We are motivated by a number of considerations. First, the empirical relationship between technology shocks and employment is a hotly debated topic among macroeconomists. The reason for this is simple. Different business cycle models make very different predictions about the impact of technology shocks on employment – the real business cycle (RBC) theorists claim that it is positive, the new Keynesians that it is, at least initially, negative[1]. The results of empirical studies that attempt to uncover what happens following technology shocks are, therefore, likely to affect both model selection and the assessment of the role of real shocks in cyclical fluctuations.[2] Second, although most efforts to date have concentrated on the post-World War II years, a larger number of business cycles occurred during the first half of the twentieth century, including, of course, the most severe depression ever recorded. In other words, the period is ideal for a study of this sort. Third, Roosevelt and many in his administration believed that technical change contributed to the high rates of unemployment during the 1930s. Finally, by examining the predicted response of employment to technology shocks for this period, we may be able to help determine which of the two benchmark models, neoclassical or new Keynesian, provides the best approximation of the underlying economy, an outcome with important implications for policy debates.

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[1] As noted by Christiano, Eichenbaum and Evans (2004), this outcome depends on the assumption that the monetary authority does not accommodate the technology shock. A sticky price model with accommodation does not have the negative response to technology shocks.

[2] See Christiano, Eichenbaum and Vigfussion (2003) and Fisher (2006) for empirical results that support the RBC view and Gali (1999), Gali and Rabanal (2004), Basu, Fernald and Kimball (2006) for evidence in favor of the new Keynesian model.

One policy issue that has received considerable attention in recent years is the role played by the National Industrial Recovery Act (NIRA) in the economy's recovery from the Great Depression. Cole and Ohanian (1999, 2004), for example, contend that the NIRA transformed an essentially neo-classical economy with competitive product and factor markets into one with cartelized firms and enhanced labor bargaining power. The consequence of this intervention was, ironically, slower than expected economic growth and anemic job creation after 1933. Eggertson (2006), on the other hand, has argued that if the benchmark economy in the 1930s was of the new Keynesian variety with sticky prices, then New Deal policies, including the NIRA, may have been optimal - given that the economy was, at the same time, being hit with deflationary shocks and the monetary authority was constrained by the zero bound on interest rates. The question, of course, is which of the two is correct, and the answer, in part, relies on which of the two models – neoclassical or new Keynesian- provides the best approximation of the economy prior to the **i**nterventions associated with the New Deal? Sorting out the empirical relationship between technical change and employment will help us answer this question.

The problem for researchers is that it is notoriously difficult to determine empirically the link between technical change and employment.[3] The key challenge is to come up with a good measure of technological change. A number of approaches have been used, including reliance on patents or research and development statistics or the introduction of identifying restrictions in a Vector Autoregression.[4] Since all of these approaches have well known downsides, it is not surprising studies using them for the post WWII period have yielded inconclusive results. For example, Gali (1999),

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[3] See, among others, Griliches (1990), for a review of some of these issues.

[4] For example, Gali (1999), Francis and Ramey (2003), Chirstiano et al. (2003) and Fisher () identify technology shocks by using a long-run identifying assumptions in a VAR (namely only technology shocks affect labor productivity in the limit). Basu, Fernald, and Kimbal (2006) argue that their cleansed Solow residual can be used as a reliable proxy for technical change, and Shea (1998) uses information on patents and R&D expenditures to identify technology shocks.

Francis and Ramey (2003, 2004), and Gali and Rabanal (2004) use the same long run identification to show that hours worked decline in response to a positive technology shock, at least in the short run, while Christiano, Eichenbaum, and Vigfusson (2003), and Fisher (2006) contend that the evidence, such as it is, leads to the opposite conclusion.[5] Basu, Fernald, and Kimbal (2004), using a cleansed Solow residual, find a decrease in hours worked following a positive technology shock, while Christiano, Eichenbaum and Vigfussion (2004) argue that these findings are linked to measurement errors. Finally, Shea (1998), relying on patents and R&D statistics, comes up with inconclusive results (largely because the proxies have almost no impact on measured TFP). In a nutshell, then, while a compelling measure of technical change is hard to find, it is certainly worth looking for, since it is likely to help us answer the $64,000 question – what does happen to employment following a technology shock?

We present in this paper, new and, we believe, relatively problem-free, indicators of technological change for the pre-WW II and use them to estimate the impact of new technologies on employment.[6] They are based on data taken from the Library of Congress (LC) on the number of new technology titles in various fields published in the United States during the first fifty years of the last century. They have a number of attractive features. They are objective, unlike innovations counts, they isolate pure technological innovation unlike traditional productivity statistics, and they capture innovations at the moment of their commercialization, unlike patents and research and development outlays. Finally, because the LC data can be used to create a consistent times series of innovative activity on an annual basis for the entire period 1909-1949, both for technology in general and for various sub-groups, they can be employed to estimate statistically the impact of unanticipated changes in

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[5] The two groups of researchers make different assumptions about the stationarity of the log of per capita hours worked. The first group assumes that the first difference is stationary, while the second argues that the log series itself is stationary.

[6] See Alexopoulos (2006) and Alexopoulos and Cohen (2007, 2008) for further discussion of these indicators, and Alexopoulos (2006, 2007) for a similar exercise focusing on the post WWII period.

technology on employment. Although the results may not fully settle the controversies, they will advance our understanding of the interaction between new technologies and employment opportunities.

To summarize briefly our results, our point estimates do indicate a positive relationship between general technology shocks and employment in the short and medium runs. Among subgroups, we find that: (1) innovations in the automotive, mechanical, and electrical sub-sectors had the largest impacts on productivity, and (2) changes in electrical and automotive technologies tended to increase employment in a variety of sectors while other subgroups of technologies seem to have had little or no impact.

These findings are of interest for a number of reasons. First, although we use a different measure of technological change than that employed by Francis and Ramey (2004), our findings are strikingly similar to theirs for this period. Second, we find that over the entire period, even if there were frictions and/or wage and price rigidities in some sub-sectors of the economy, they were insufficient to offset the positive impact of technical change on employment (primarily related to changes in electrical and automotive technologies). Third, our data and approach permit us to pinpoint the spillover effects of sector specific new technologies on the broader economy, effects often missed by detailed sector studies such as those of the National Research Project.[7]

Finally, our data indicate, in keeping with the findings of Field (2003), Mensch (1979), Kleinknecht (1987), and Bernstein (1987), that the 1930s, especially the period 1934-41, was a time of rapid technological progress. In the best of all possible worlds – that is, one approximated by neoclassical market conditions – this should have led to rapid growth in output, productivity, and employment, none of which, in fact, occurred. As noted, Cole and Ohanian (2004), among others,

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[7] This tendency of sectoral studies to overlook the forest for the trees is precisely the shortcoming identified by Cyert and Mowery (1987, pp. 93-94).

attribute this failure to New Deal policies.[8] In an attempt to see if our results are sensitive to the peculiarities of these years, we remove them from our regressions by including dummy variables for the years 1934-9. As it happens, our findings are not altered significantly by this change. Since we do find, overall, a positive relationship between technology shocks (based on our new indicators) and productivity and employment, we would have expected to see, in keeping with Cole and Ohanian (2004), a more robust recovery in job creation. Questions about the wisdom of New Deal policies, therefore, remain.

We proceed as follows in the remainder of the paper. In the next section, we **r**eview some of the related literature, describe our indicators, review their intuitive appeal, and present the data we need for our regressions. In section three, we report and analysis our regression results. In section four, we focus sharply on the depression years and demonstrate first that even in the absence of the NIRA and related policies, unemployment would have remained high and, second, speculate about other causes of the slow recovery. In section five, we summarize our findings and identify areas for future research.

II.1 Other Related Literature on Technical Change and Employment

The idea that machines replace men has a long, if not entirely distinguished, history going back at least to the machine breakers of the early industrial revolution. The creation of the U.S. Bureau of Labor (subsequently the Department of Labor) in 1884 represented, in large part, a response to labor leaders' concern that machines were replacing skilled operatives. In its first report, published in 1886, the Bureau observed that "…mechanization was the essential reason for the unemployment characteristic of depression."

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[8] Bernstein (1987) and Hawley (1964) also argue that the NIRA and related New Deal policies contributed to the sluggish growth of output and jobs after 1934.

The 1920s and especially the 1930s marked a high point in the public's preoccupation with labor displacement. Anecdotal but nevertheless compelling evidence of this can be seen in Figure 1, in which the number of New York Times articles using the phrase 'technological unemployment' is reported by decade between 1920 and 1979. As can be seen, between 1920-29, 13 articles appeared, between 1930-39 the number jumped to 355, in the following decade the number dropped to 63, and, in the post-war decades, the number ranged from a low of 10 between 1970-79 and high in the previous decade of 61. Although the 1930s were, clearly, special, it is worth noting that concern over the perceived tendency of machines to replace workers was accelerating in the years prior to the Great Depression.[9] In Figure 2 we present two graphs published in a February 1928 New York Times Article entitled, "March of the Machine Makes Idle Hands". Three main observations were made in the article. First, starting somewhere around 1919, the data indicate that fewer workers were required to produce a unit of output in the manufacturing sector. Second, this trend started even earlier in the agricultural sector, and, third, the increase in productivity resulted from the introduction of new machines. Technological change was, in short, the evil genius responsible for idle hands.

This view coincided with that of Roosevelt and many in his administration that technological change was displacing labor. At a 1935 press conference, the President stated that even if the nation could immediately restore production to its 1929 level "…the rebound would supply jobs for only about 80 percent of the unemployed, because mechanization had so profoundly increased capital efficiency…"[10] In his 1940 State of the Union address, he retuned to this theme: "While the immediate

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[9] One may question whether this trend is simply reflecting an increased usage of the term 'technological unemployment'. To verify that this was not the case, we also examined the pattern of articles published in the New York Times with keywords such as displaced workers along with other keywords such as technical change or technology. All of the variations we tried yielded a similar pattern – there was a large increase in these types of articles in the 1930s.

[10] See Bix (2000).

number of unemployed has decreased, while their immediate needs for food and clothing…have been met…we have not yet found a way to employ the surplus of our labor which the efficiency of our industrial processes has created.” [11]

In 1935, Harry Hopkins, head of the Works Progress Administration (WPA), sponsored the National Research Project (NRP) to look into the impact of recent changes in industrial techniques across a wide range of sectors – including agriculture - on unemployment and employment. The project was motivated explicitly by the conviction that unemployment was attributable to the substitution of machines for men. Henry Wallace, Secretary of Agriculture and later Vice-President, used words almost identical to those of the President to describe the impact of technological change on employment: “The production of our factories is nearing normal, but the number of unemployed remains unusually large. It is apparent that many of our unemployed may never get jobs again. Machines and younger people have taken their places.”[12]

The notion has continued to thrive in the post-WW II period. Cyert, in his preface to a 1987 report dealing with the impact of technological change on employment and productivity, notes that many Americans believe that new technologies are more likely to destroy than to create jobs – as it happens, contrary to conclusions of the report.[13] A few years later, the idea surfaced again and many journalists reported that we had entered a “new era” in which rapid productivity growth was likely to be associated with permanent labor displacement.[14] Indeed, Kahn (1993), in an article titled, “Sluggish Job Growth: Is Rising Productivity or an Anemic Recovery to Blame?,” determines that there is evidence to support the idea that computer technologies and business restructuring contributed to both the rising

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[11] See Israel (1967).

[12] Quoted in Bernstein 1987, p. 145, taken from a book Wallace published in 1937 entitled *Technology, Corporations, and the General Welfare*.

[13] See Cyert and Mowery (1987).

[14] See, for example, articles by A. Ehrbar, D. Wessel, and W. Bulkeley, in the Wall Street Journal.

productivity and weak recovery in employment from the 1991 recession. In 2004, a special report appeared in Business Week entitled "The Price of Efficiency." In the report, it was pointed out that demand for goods was the strongest in years, profits were robust, business investment was surging, and yet employers were not hanging out help wanted signs. The job killer was the dramatic gains in productivity linked to new technologies that allowed businesses to expand output without increasing employment. King Ludd, it would seem, is still alive and well.

The prime mover in the public's perception is obviously technological change – and herein lies the problem. To identify the impact of technology shocks on output and employment, we require an indicator of innovative activity that is quantifiable, consistent over time and across sectors, objective, and able to capture new technologies at the moment of their commercialization.

II. 2 Data

A. Employment and Productivity

Before we discuss our new indicators, we briefly review the data on employment and unemployment that we use for our analysis. Since there are no official series produced for the early part of our sample, we are compelled to fall back on standard ones used by others for this time period. We rely on data from Kendrick (1961) for output per worker in the private non-farm economy as well as for the manufacturing and transportation sectors. Data for aggregate employment and for the aggregate unemployment rate are taken from the *Historical Statistics of the United States Millennial Edition* (T**able Ba 470-477).** GNP per person (in 1929 and 1947 constant dollars) come from the Economic Almanac of the National Conference Board while Solow (1957) and Goldsmith (1956) are the sources for data required to compute TFP for the private non-farm economy.

We present in Figures 3 and 4 trends in employment, unemployment and productivity for the entire period. A few features of the graphs are worth highlighting. First, unemployment jumped sharply in the 1930s. As the numbers suggest, the drop in employment was seen across a wide variety of sectors including manufacturing and transportation. Second, while the 1930s did witness a large decline in productivity, the decline was limited to the early years. By 1934 productivity was on the road to recovery and by the end of the decade it was booming. According to Field (2003) and Mensch (1979), the decade was one of the technologically most progressive of the last the century. Our findings would seem to confirm their view.

B. New Indicators of Technological change.

We require an indicator of technical change that captures an innovation at the moment of its commercialization for the obvious reason that it is only through its adoption that it affects the demand for labor. All of the usual suspects fail to meet this requirement. Research and development expenditures measure inputs into the inventive process not outputs of commercially viable innovations. Patent applications and/or grants do represent potentially valuable new additions to economic knowledge[15] but the long and uncertain lags associated with their commercial adoption make them at best imperfect indicators. Although innovation counts resolve some of these problems, they are difficult to quantify and are notoriously subjective.[16] Finally, while changes in productivity numbers (even those cleansed using techniques proposed by Basu, Fernald, and Kimball (2006) or Ohanian (2001)) do pick up changes in efficiency, they may also be influenced by factors other than technical change (e.g., changes in regulations).

Our indicators satisfy this requirement. In the following few paragraphs, we first describe them and then explain their appeal. They are based on new technology titles in the MARC (**MA**chine **R**eadable **C**ataloguing) records of the Library of Congress (LC) database. The records are used by the library to run its online book search program and are available to other libraries to help them catalogue new books. They extend back into the nineteenth century and, because of the size and range of the

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[15] See Griliches (1990).

[16] See Cyert and Mowery (1987), Griliches(1990), Alexopoulos and Cohen.(2007).

library's collection (over 130 million items in more than 450 languages), the MARC records provide a virtually complete list of all new titles copyrighted each year in the United States. Although the LC, as the country's principal depository library, receives notification of all new titles copyrighted in the U.S., it is not obliged to hold a copy of each publication. Its holdings are, nevertheless, vast – probably the most extensive in the world – and are certainly adequate for our purposes.[17]

Each MARC record contains information on the type of book (a new title or a new edition of an existing one), the country and language of publication, the publisher, the LC's Classification Code, and a list of major subjects treated in the book. We use these data to compile a list of new titles in different fields of technology (subgroups of T) published in English in the U.S. each year between 1909 and 1949. We exclude from the list all books that include history as a descriptor (or use the term history in the title) since history-related technology books are unlikely to have much to do with the introduction of new products or processes. The final tally includes all manuals and books in the MARC records that deal with new technologies including their nature and function, how they work, and how to use or repair them. Some of the titles are published or sponsored by the innovator or the company that developed the new technology, others by third parties who hope to profits from sales of the book or pamphlet. In all cases, the motive for the publications is the same: to obtain financial gain from spreading the word.

B. Intuition.

There are sound economic reasons to believe that publications provide a good measure of innovations at the time of their commercialization. Innovating companies want to promote their innovations; independent writers want to sell books. For both, timing is critical: too early and potential users are uninterested or, worse, frustrated, too late, and, at best, the work is out of date. A good contemporary example of the timing issue can be seen in the publications associated with Vista,

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[17] See John Y. Cole, *Jefferson's Legacy: A Brief History of the Library of Congress*, http://www.loc.gov/loc/legacy/.

Microsoft's new operating system. Roughly one month prior to its release date, a virtual tsunami of Vista related new titles poured into U.S. bookstores and, just as quickly, retreated.[18]

In addition to getting the timing right, publications also weight the various new technologies differently, a potentially important factor when trying to identify the impact of innovations on output and employment. That is, since more titles are likely to appear on major technologies than on minor ones, our indicators, by their very nature, give greater weight to major than to minor innovations. As we would expect the former to have a greater impact on employment than the latter, our indicators will pick up this effect.[19]

There are, finally, innovations in management techniques and organization that traditional measures are likely to overlook but ones that our indicators will flag. These innovations are often not patentable, they are not the subject of research and development efforts, and they are unlikely to appear in innovation counts. They do, however, show up in new publications for the obvious reason that someone stands to profit by writing about them. Moreover, there impact is often considerable. Weintraub (1939) notes that in a number of manufacturing industries – cotton garment production and automobiles for example – changes in factory layout and, more generally, in the organization of production, resulted in substantial increases in productivity through improvements in the flow of work

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[18] In a companion paper, Alexopoulos and Cohen (2008), we present a number of examples of the relationship between the commercialization date of many of the major innovations identified by Mensch (1979), and the first book date in the LC catalogue. This exercise confirms the intuition just describes. Further case studies in the same paper also highlight that the indicators capture innovation not diffusion.

[19] Although there may be some similarity between what we are calling major and minor innovations and general purpose versus sector specific technologies (see, for example, the attempt by Hall and Trajtenberg (2002) to use patent citations to distinguish between the two), we make no such claim at this point for these data. However, there is good reason to believe that these bibliometric indicators have the potential to provide a compelling way to identify general purpose technologies. We elaborate on this point in the other paper presented at this conference.

and savings in supervisory labor, equipment, floor space, and inventories in the 1930s with little, if any, changes in equipment.

Publications, of course, were not the only means to disseminate information about new technologies although in the period before 1950 they had relatively few competitors. There were, nevertheless, trade journals, professional or scientific conferences, and direct marketing campaigns that all served as sources of information about new technologies. However, it seems reasonable to believe that these other methods of spreading the word act as complements to - not as substitutes for - publications. To the extent that this was not the case, the bias runs against not in favor of our finding a relationship between technical change and employment and thus establishes a lower bound on the true interaction between the two.

D. What do the technology titles tell us?

In Figure 6, we show the number of new titles that appear each year in the MARC records for total technology and for the sub-groups mechanical and manufacturing, electrical (including telecommunications), automotive, and railroad technologies.[20] We also report new titles in children's and medical books and books in fiction, poetry, and music. These last are included to confirm that the pattern of new technology titles represent more than just trends in publishing – if the latter were the case, we would expect the observed patterns for all groups to be the same.[21]

The first thing to note about the graphs in Figure 6 is that the patterns traced by all new technology titles and by the technology subgroups differ from those of the non-technology titles. There is, therefore, little reason to assume that the observed pattern merely represents trends in publishing. Moreover, even among subgroups, the patterns are not the same. Thus, new publications in electrical

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[20] These groups are chosen since the sectors we examine include total, private non-farm, manufacturing, and transportation.

[21] In Alexopoulos and Cohen (2007) we also demonstrate that these non-technology books do not have a statistically significant relationship with TFP or GNP during this time period.

engineering undergo a sharp drop between 1929 and 1932 but then recover nicely through 1941. On the other hand, manufacturing technology titles begin their recovery from the Depression in 1933 and continue with ups and downs through 1942. Different patterns during the war years are due, for the most part, to restrictions on the civilian activities of some subgroups such as automotive and the shift in the re-classification of some technologies from civilian to military sub-categories. In short, prima facie evidence would seem to suggest that our indicators are not mere artifacts of the publishing industry but represent, instead, measures of technological innovation.[22]

III. Exploring the relationship between employment and productivity

III.A. The link between the indicators and productivity

To begin our analysis, we first provide some evidence that productivity was impacted by the type of technical change captured by our indicators. In a companion paper, we find that changes in manufacturing and mechanical, electrical and electronic, and automotive technologies are the most significant predictors of TFP during this time period. To save space, we present here only the results for these groups and for total technology. We also report the relationship between technical change in railroads and productivity in the transportation sector since we would expect to observe an impact of the former on the latter.

We explore the relationship between technological change (as measured by our indicators) and output/worker and TFP by estimating the following bi-variate VARs:

$$Y_t = \alpha + \gamma_0 t + \gamma_1 t^2 + \rho Y_{t-1} + \varepsilon_t \qquad (1)$$

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[22] See Alexopoulos and Cohen (2008) for evidence on the relationship between our indicators and the introduction of new major technologies (as identified by Mensch (1979)), as well as for a comparison of our measures with R&D personnel and the number of scientists.

where $Y_t = [\ln(Z_t), \ln(X_t)]'$, with Z_t being our measure of output per worker or TFP, and X_t is one of our technology indicators.[23] As in Shea (1998) and Alexopoulos (2006), we identify technology shocks by assuming that they affect the Z variables with a one year time lag.[24], [25] Table 1 reports the point estimates on lagged productivity and the lagged technical change measure (as well as the associated standard errors) for the productivity equation.

Figure 7 displays the impulse responses of GNP per worker (in 1929 and 1947 constant dollars), and Figure 8 shows the responses for output per worker (in 1929 dollars) and TFP for the private non-farm economy to a one standard deviation technology shock (as identified by our indicators), and 90 percent confidence intervals. A few findings are worth emphasizing. First, the point estimates suggest that both TFP and labor productivity increase following a technology shock. Second, automotive shocks appear to have the longest significant impact, while electrical and electronic technologies have the most rapid impact on productivity. Third, the price deflators matter. In particular, we find that the productivity measures computed using the 1947 deflators are much more responsive to changes in technology than those based on the 1929 deflators. These results may not be surprising in light of Kendrick's (1961) warning that his 1929 deflators are subject to a fair degree of measurement error,

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[23] Due to the short time series available, the unit root tests are inconclusive. Therefore, we opt to use levels instead of first differences and include a time trend.

[24] Francis and Ramey (2004) use the long-run restrictions approach in a VAR to identify technology shocks in the pre-WWII period and to determine how the response of aggregate hours per capita to these shocks. Their results are similar to the ones reported here.

[25] To determine if ordering has a significant impact on our results, we also ran VARs with the Technology indicator entering before our productivity variables and found little evidence to suggest that it mattered. We have not included them in the paper but they are available on request.

caused in part by the total absence of price data for some goods, such as durable equipment, in the early years.[26]

Figure 9 presents the impulse responses of output per worker for the manufacturing and transportation sectors. The results are similar to those seen at the more aggregate level. Although the standard errors are a little larger than we would have liked (perhaps because of measurement error in the 1929 deflators), the overall point estimates suggest that the relationship between labor productivity and our measures of technical change are positive for these industries.[27]

The results of the Granger Causality tests and the variance decompositions, shown in Tables 2 and 3 respectively, confirm that there is generally a statistically significant relationship between our productivity measures and our indicators. Moreover, for the aggregate economy and private non-farm economy, we find that manufacturing, electrical and automotive technologies had the largest impacts. Using the productivity measures computed using data deflated with the 1947 price indexes, we find that, at a six year horizon, over 40% of the variation in GNP per worker, and 30% of variation in TFP in the private non-farm sector, can be explained by changes in mechanical technologies. Electrical technologies had the largest (and most significant) impact on output per worker in the manufacturing sector, while new automotive technologies explained over 20% of the variation in output per worker in transportation.

III.B. The link between employment, unemployment, and technical change

We turn now to a key feature of this analysis: what relationship, if any, exists between our indicators of technical change and employment/unemployment during this period. To do this, we

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[26] See Alexopoulos and Cohen (2007) for a more complete discussion of this point.

[27] It is useful to note that the time series for manufacturing and transportation are only available in 1929 constant dollars. This may very well account for the relatively large standard errors.

estimate a set of bi-variate VARs similar to those described in the previous sub-section. Specifically we assume that the relationship between technical change and employment (or unemployment) can be represented as:

$$Y_t = \alpha + \gamma_0 t + \gamma_1 t^2 + \rho Y_{t-1} + \varepsilon_t \qquad (1)$$

where $Y_t = [\ln(Z_t), \ln(X_t)]'$, with Z_t being our measure of employment per capita, hours per capita or the unemployment rate, and X_t is one of our technology indicators.[28] Table 4 presents the point estimates and standard errors for these regressions, while Tables 5 and 6 display the Granger-causality tests and the variance decompositions.

We find no evidence that the technology shocks significantly decreased employment (or increased unemployment). Instead, our results indicate that, on the whole, employment opportunities went up following a positive technology shock – even in the short run. The point estimates for total technical change suggest a positive relationship at both the aggregate and the disaggregate levels, and in the case of manufacturing employment, the response to a 'total technology' shock may be viewed as weakly significant (although one could just as well argue that there is no significant increase in aggregate employment or hours).

The findings are stronger for the various technology sub-groups. Overall, we find that electrical and automotive technologies seem to have to led to significant increases in employment (and decrease unemployment) at the aggregate and disaggregate levels. In fact, of all the major sub-groups considered, only new manufacturing/mechanical technology failed to consistently have a large, positive impact on all of the employment/unemployment series we consider.

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[28] Again we use log levels and include a quadratic time trend. Francis and Ramey (2004) also find that the quadratic trend captures the trend in per capita hours worked for this period.

The results for manufacturing/mechanical technologies are actually very interesting when considered in light of the observations contained in the National Research Project reports for these groups. In a number of instances, while it is acknowledged that innovations in mechanical machinery did seem to displace workers at the firm level, the authors of the reports argued that care must be taken when extrapolating the results of the cases studies to an aggregate level. It is pointed out that while employment in some occupations might decrease as machines replace men, the narrowly focused studies fail to pick up the positive effects on employment created by the demand for labor to build the new machines, to repair them, and so on. There were, in short, two effects on employment of advances in this area, one positive, the other negative. One interpretation of our results is that the two forces may very well have cancelled each other out.

The variance decompositions echo these findings and indicate the importance of each type of technical change in explaining the variation in employment/hours and the unemployment rate. For the most part, the results using the total technology measure suggest that these shocks are able to account for only a small percent of the variation in employment. All, however, is not lost. On the basis of our identifying assumptions, zero percent of the variance is explained by our technology indicators in year one but we do find that over time, the percent explained does go up, especially for those linked to automotive and electrical technologies.

Of the different subgroups, changes in automotive technologies had the largest impact. In particular, they account for almost 30 percent of the variation in manufacturing employment, and almost 20 percent of that in aggregate unemployment rate at a six year horizon. In contrast, for the same time horizon, electrical technologies account for close to 11 percent in non-farm per capita hours and per capita employment in manufacturing, and approximately 12.5 percent of the variation in the unemployment rate. Mechanical/manufacturing technologies only had a significant impact on employment opportunities in the transportation sector (where over 11 percent of the variance in per capita employment can be attributed to changes in these technologies at a medium run horizon).

The impulse response functions graphed in Figures 10-12, tell a similar tale using a different metric. The results in the first of these figures show the responses of aggregate employment per capita and the unemployment rate to a 1 standard deviation technology shock. In all cases the unemployment rate falls significantly in response to the positive shock. The overall responses of aggregate employment, with the exception of that to in mechanical/manufacturing, are positive and most significant for the cases of automotive and electrical technology. Figure 11 displays the analogous responses for hours per capita and employment per capita in the private non-farm sector. Again, we find that the response to a general technology shock (or a mechanical/manufacturing technology shock) is insignificantly different from zero. However, both measures of employment rise following automotive and electrical technology shocks. Finally, the graphs for manufacturing and transportation (Figure 12) show a positive relationship between employment opportunities and technology shocks. In fact, in almost all cases, employment in these sectors significantly increased for at least 5 years following the shock.

III.C. Sensitivity Results

We have assumed thus far that the relationship between technology and productivity and employment is similar over the entire time period. The work of Cole and Ohanian (2004) raises serious questions about the validity of this assumption. In particular, if their argument that New Deal legislation led to major changes in the nature of the wage bargain and in the degree of competition is correct, then the assumed constancy of the relationship between technological change and productivity and employment is open to question.

In addition to the parts of the regulation that Cole and Ohanian (2004) focus on, we know that portions of the legislation were explicitly intended to limit the amount of new machinery and/or capital that could be purchased and installed in some sectors of the economy.[29] In a July 16, 1934 article in the New York Times entitled, "Durable Goods Industries," it was reported that of the 280 regulations in the National Recovery Administration (NRA), thirty-six of them "contained restrictions on the installation of new machinery and on increase in productive capacity".[30] In a more in-depth article that appeared in the Times a week earlier, it was noted that the limitations imposed in these thirty-six industry codes fell into four basic categories. [31] In one, which affected steel and iron, a direct prohibition was placed on the expansion of capacity. In nineteen others, capacity could be expanded only with authorization by the code authority.[32] Eighteen codes necessitated a recommendation by the code authority to expand capacity, while one (the motor vehicle storage and parking code) imposed restrictions by agreement. Finally, the article noted that, on top of the explicit restrictions contained in thirty-six of the codes, there were other regulations passed in the first year of the NRA which indirectly discouraged the installation of new machinery by placing limitations on the number of hours machines could be run.

Although there is no general consensus about the actual impact of this legislation on economic activity – the National Industrial Recovery Act was declared unconstitutional by the Supreme Court in 1935 – it is, of course, entirely possible that these restrictions did change the relationship between technical change and employment during the mid to late 1930s. [33] To find out if this was the case, we reran the regressions for private non-farm output per worker and private non-farm per capita

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[29] See also Bernstein (1987) and Hawley (1964).

[30] The NRA was the agency empowered to carry out the provisions of the National Industrial Recovery Act.

[31] See the July 8, 1934 article in the New York Times, entitled Capital Industries Affected by Codes."

[32] Industries that required authorization to expand capacity included: lace manufacturing, cotton textiles, glass, ice, silk throwing, floor and wall clay tiles, transit, crushed stone, air transport, structural clay, cement, excelsior, pyrotechnics, refractories, rayon and silk dying, feldspar, American glassware, and carbon black

[33] See "Some Legal Aspects of the National Industrial Recovery Act", in the *Harvard Law Review*, Vol. 47, No. 1. (Nov., 1933), pp. 85-125.

employment with dummy variables included for the years 1934-1939. The results are reported in Table 7 alongside the original point estimates. While there are some differences, they are negligible, which leads us to conclude our results are unaffected by the inclusion of the NRA years in our original data series.

IV. Conclusions

In this paper we seek to determine the impact, if any, of technical change on employment. This is hardly a new issue – the idea that machines replace men dates back at least to early eighteenth century England if not earlier – but it has resisted satisfactory quantitative analysis because of the well-known difficulties in measuring technical change. The usual suspects are, for various reasons, not up to the task. Total factor or labor productivity provide at best indirect (and quite noisy) indicators of technical change while the traditional direct measures, such as patents, research and development expenditures, and innovation counts are dogged by a variety of problems. In short, a good measure of technical change, while hard to find, is worth looking for. We present in this paper a new indicator of a technical change based on new titles in various fields of technology contained in the Library of Congress' collections that we believe resolves many of the problems associated with other ones and use it to tackle the relationship between technological innovation and employment for the period 1909-1949. Our regression results suggest that technology shocks (and technical change) increased per capita employment/hours during the early part of the century with the largest impacts coming from changes in electrical/electronics and automotive technologies. For the most part, it appears that the economy's responses to technology shocks during this time are more consistent with the predictions of a neoclassical model than a new Keynesian one.

In addition to the issue of model selection, we would argue that our results shed light on an important policy debate –namely, can the slow economic recovery in the U.S. after 1933 be attributed, at least in part, to some of the more interventionist policies of the New Deal? Cole and Ohanian (2004) argue that, prior to 1934, the benchmark U.S. economy was neoclassical which meant that the economy should have bounced back quickly from the negative shocks that hit it in the early years of the decade. Its failure to do so indicates to them that some features of the economy changed fundamentally after 1933 – and they finger as the prime suspect NIRA legislation. Eggertson (2006), in contrast, observes that if the New Dealers were operating in a New Keynesian (instead of a neoclassical) world where there was severe deflation and the zero bound on nominal interest rates had been reached, then the very policies Cole and Ohanian (2004) believe stifled recovery could have actually fostered it. Resolution of the controversy depends at least in part on the nature of the benchmark economy prior to the introduction of NIRA and other New Deal legislation. Our results, based on the overall positive relationship between technological change and employment, would seem to come down on the side of Cole and Ohanian (2004).

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Figure 1: Articles on Technological Unemployment

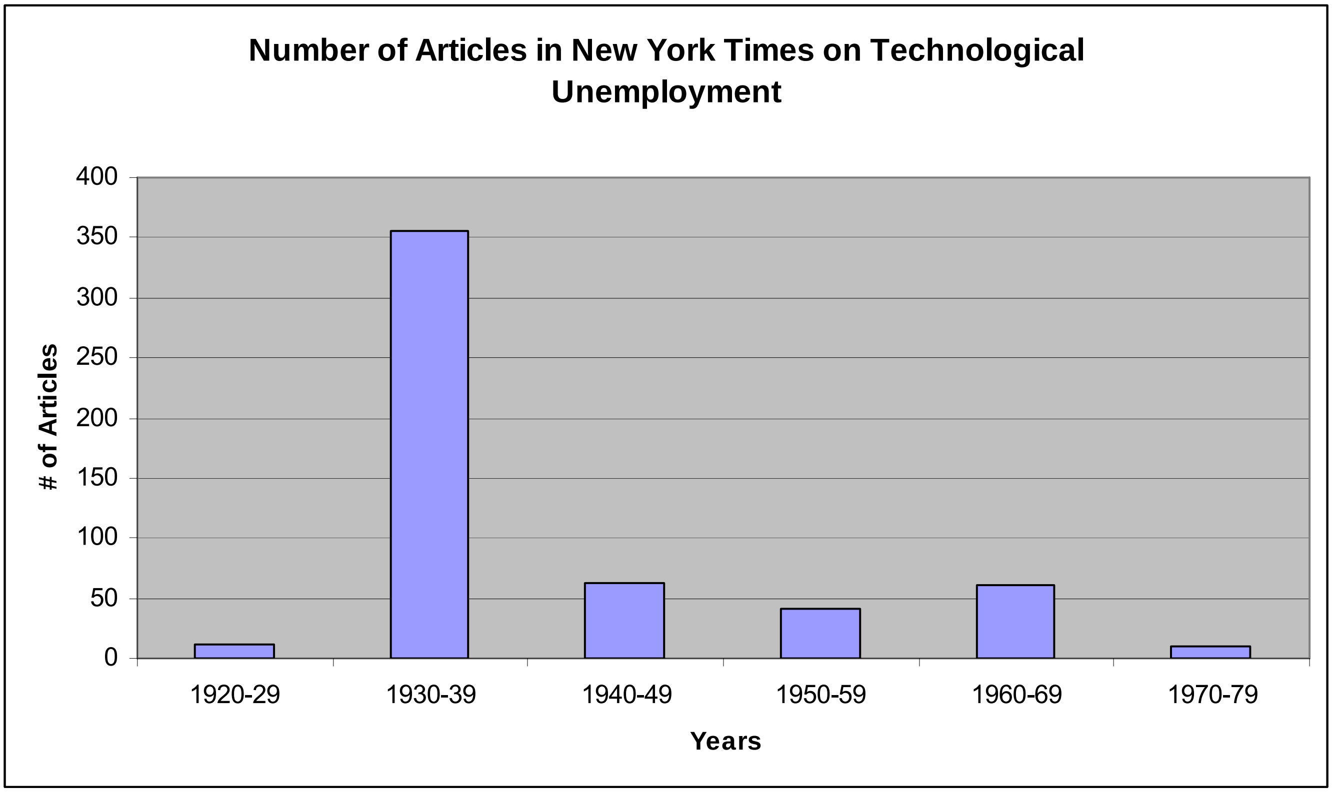

Figure 2: Graphs from New York Times Article, “March of the Machine Makes Idle Hands” by E. Clark (Feb 26, 1928. p. 129)

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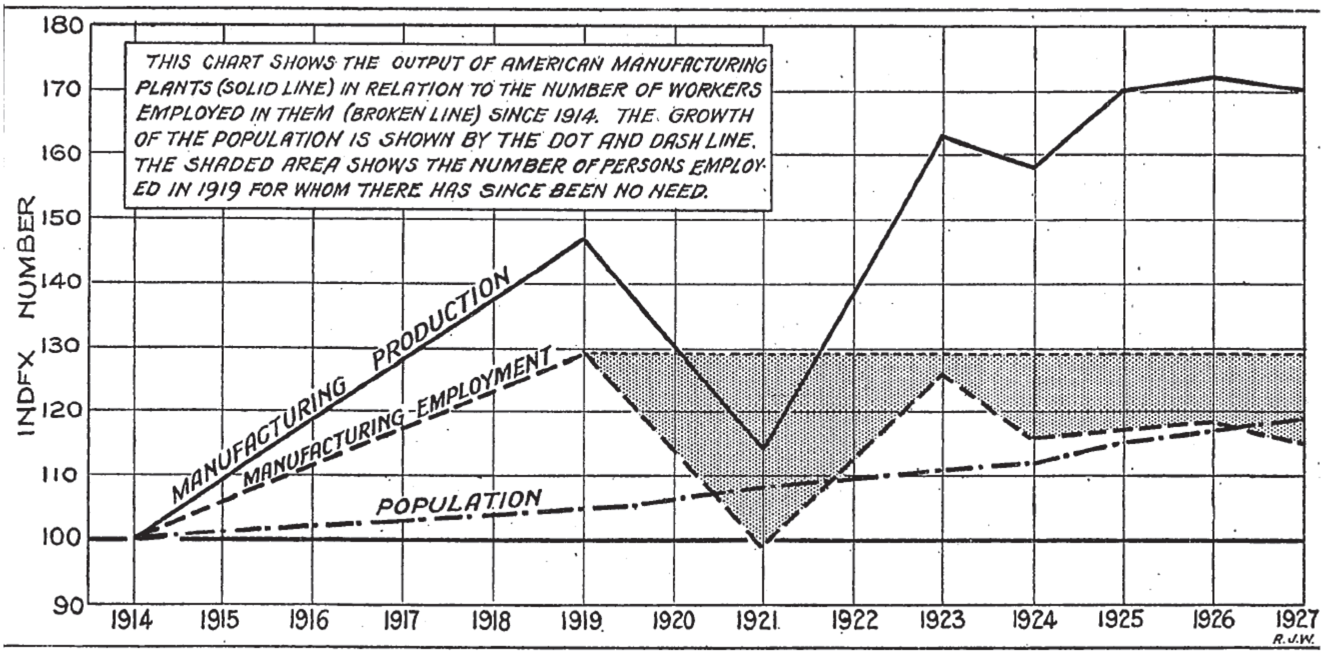
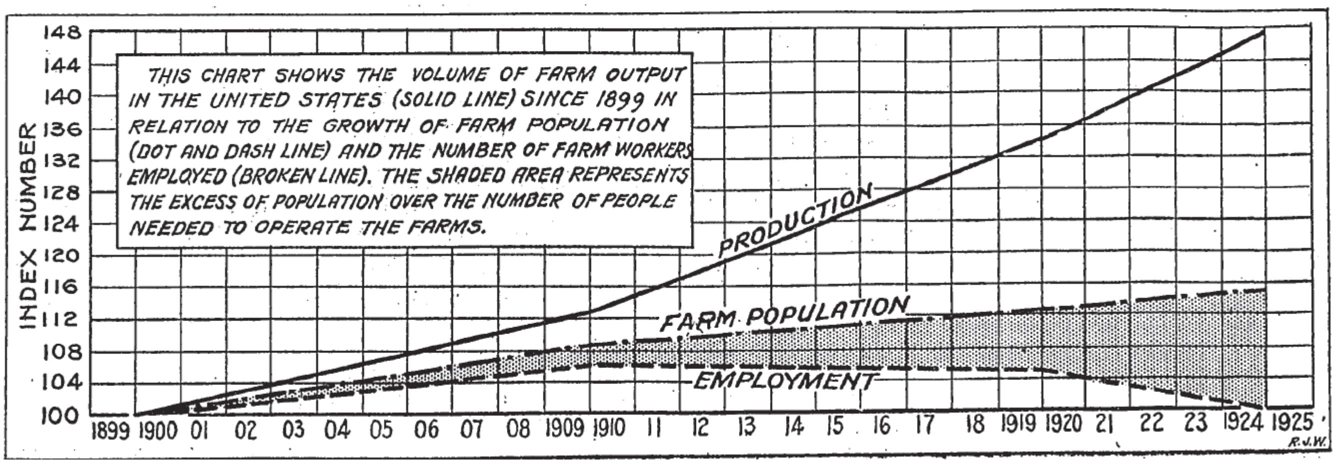


THIS CHART SHOWS THE OUTPUT OF AMERICAN MANUFACTURING PLANTS (SOLID LINE) IN RELATION TO THE NUMBER OF WORKERS EMPLOYED IN THEM (BROKEN LINE) SINCE 1914. THE GROWTH OF THE POPULATION IS SHOWN BY THE DOT AND DASH LINE. THE SHADED AREA SHOWS THE NUMBER OF PERSONS EMPLOYED IN 1919 FOR WHOM THERE HAS SINCE BEEN NO NEED.

INDUSTRY CARRIES ON WITH FEWER HANDS

The Nation's Factories Have Been Turning Out More Goods Than Ever While More Men Look for Work.

FARM EMPLOYMENT LESS WITH INCREASED OUTPUT



THIS CHART SHOWS THE VOLUME OF FARM OUTPUT IN THE UNITED STATES (SOLID LINE) SINCE 1899 IN RELATION TO THE GROWTH OF FARM POPULATION (DOT AND DASH LINE) AND THE NUMBER OF FARM WORKERS EMPLOYED (BROKEN LINE). THE SHADED AREA REPRESENTS THE EXCESS OF POPULATION OVER THE NUMBER OF PEOPLE NEEDED TO OPERATE THE FARMS.

Figure 3: Employment and Unemployment

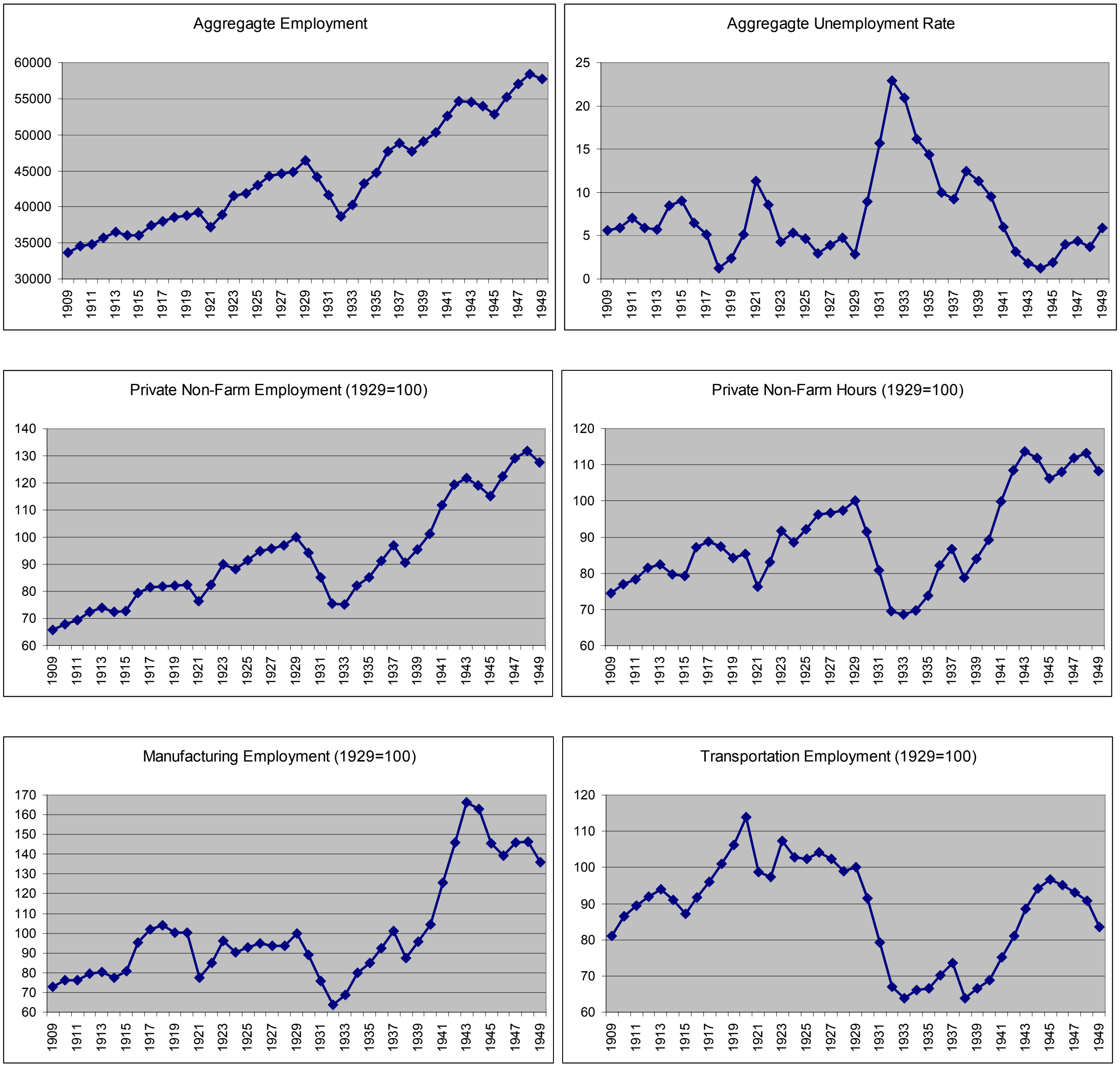


Figure 4: Productivity

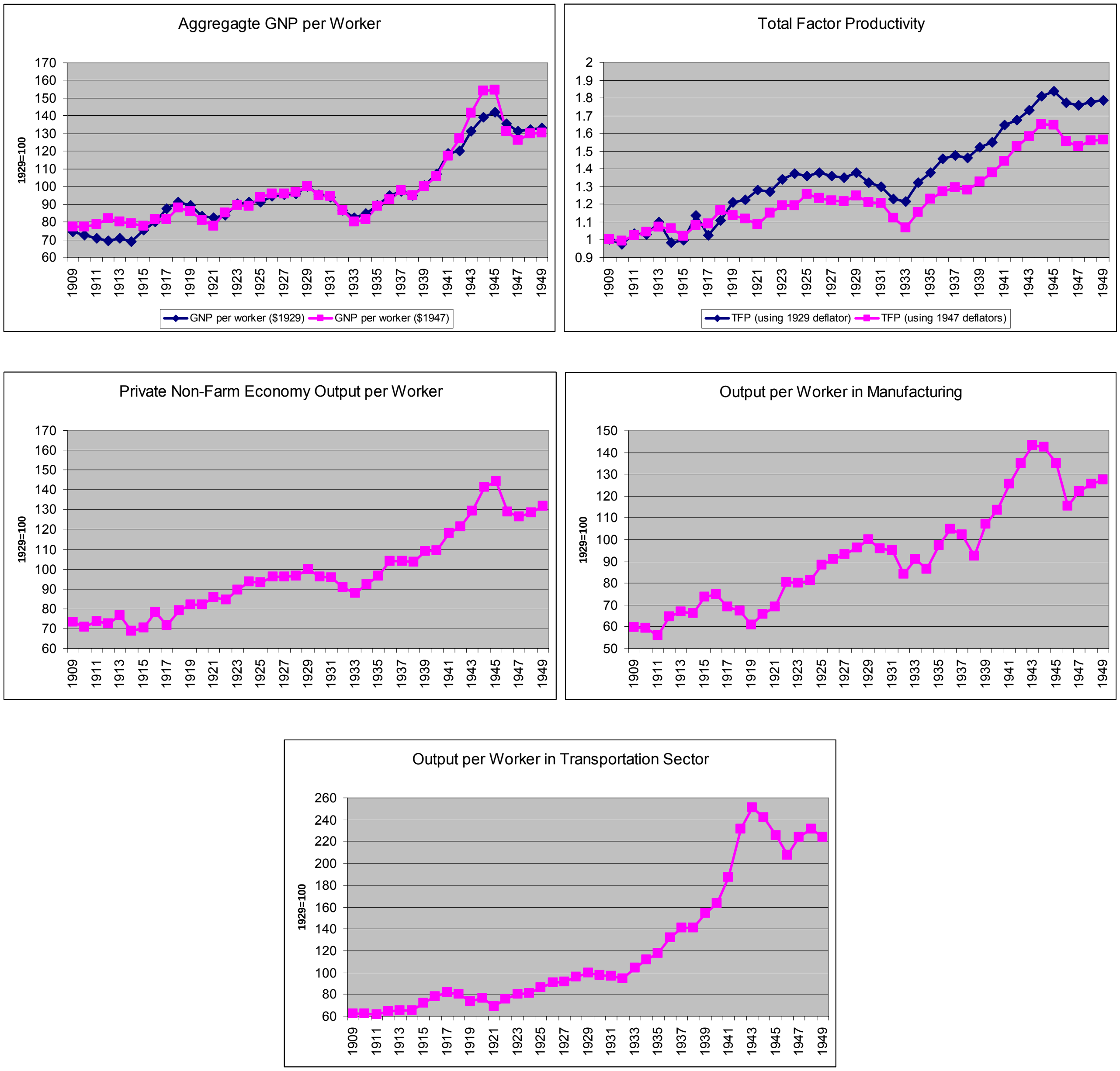


Figure 5: Sample Marc Record

Actual Record:

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0386991004100461-9266583-00000000000000.0-810403s1939    paua         000 0 eng  -  9(DLC)
43040050-  a0bcbccpremunvduencipf19gy-gencatlg-  a   43040050 -  aDLCcCarPdDLC-00aTL260-
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c1939]-  acover-title, 106 p.billus.c19 cm.- 0aAutomobilesxTransmission devices. [from old catalog]-2 -
aInternational correspondence schools, Scranton, Pa. [from old catalog]-  bc-GenCollhTL260i.S77tCopy
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Published/Created: [Scranton, 1939]
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Figure 6: The indicators

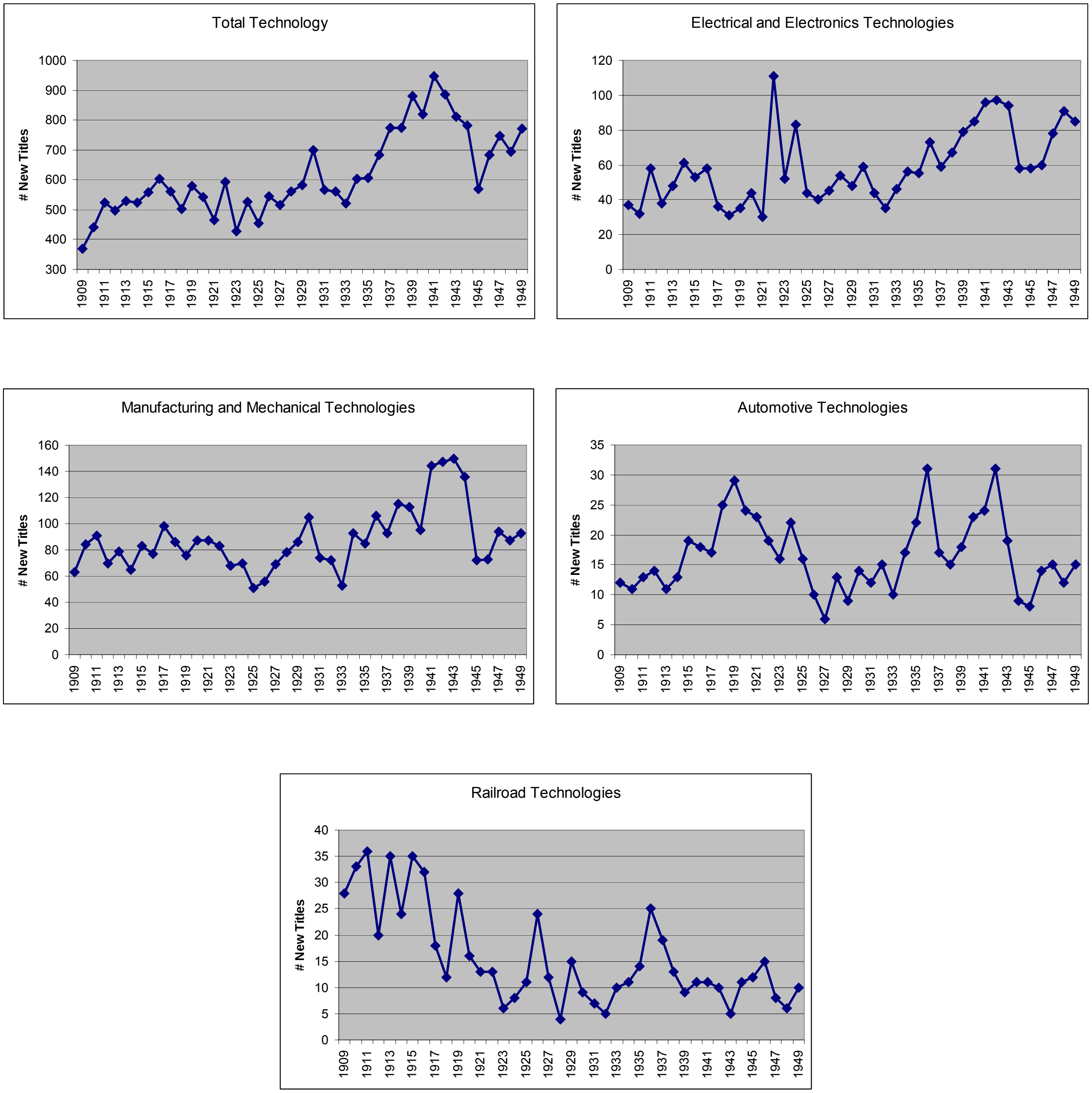
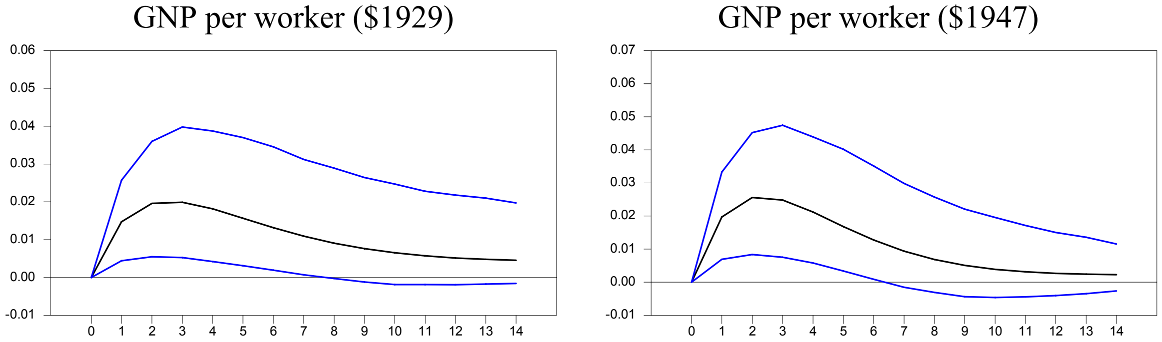
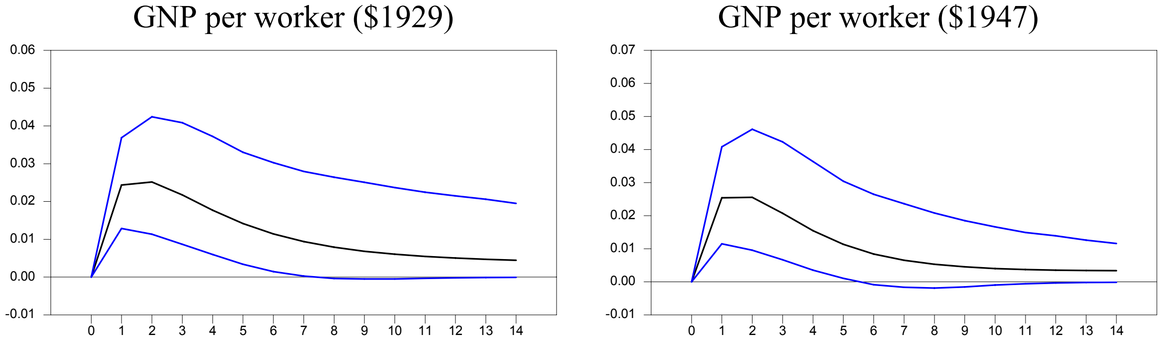


Figure 7: Responses of Labor Productivity in the Aggregate Economy

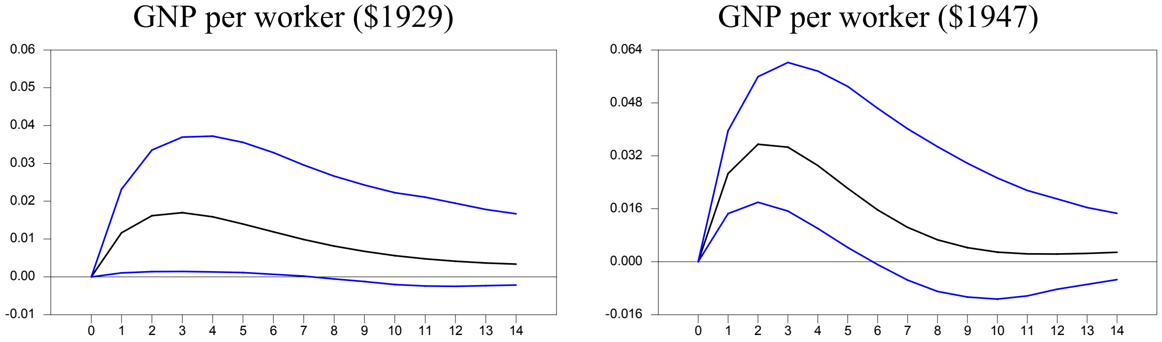
Total Technology Shock



Electrical/Electronics Technology Shock



Mechanical/Manufacturing Technology Shock



Automotive Technology Shock

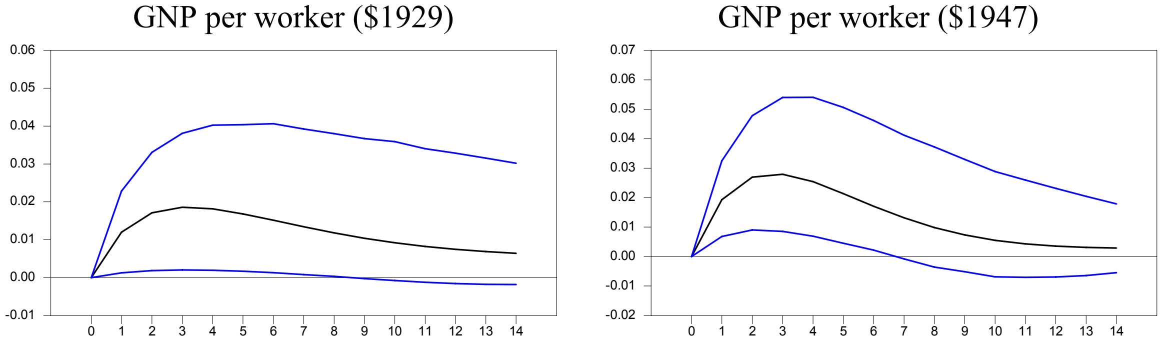
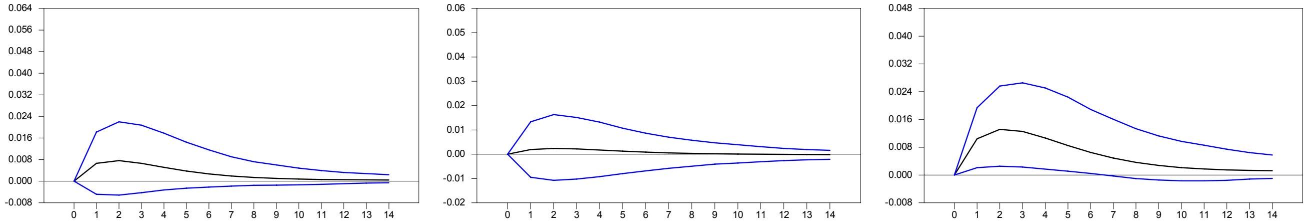
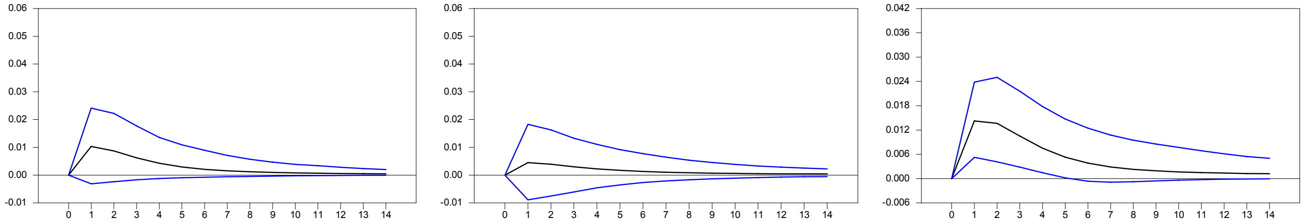


Figure 8. Responses of Productivity to a positive technology shock

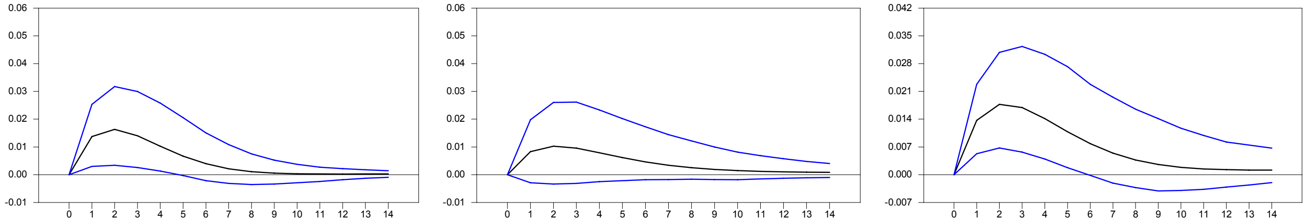
Total Technology Shock


Output per worker ($1929) | TFP (1929) | TFP (1947)

Electrical/Electronics Technology Shock


Output per worker ($1929) | TFP (1929) | TFP (1947)

Mechanical/Manufacturing Technology Shock


Output per worker ($1929) | TFP (1929) | TFP (1947)

Automotive Technology Shock

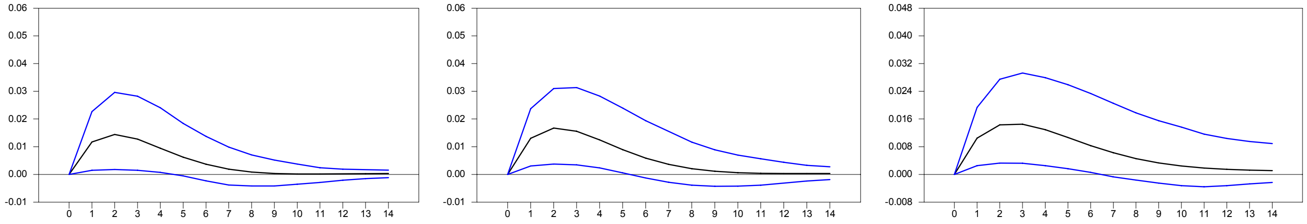
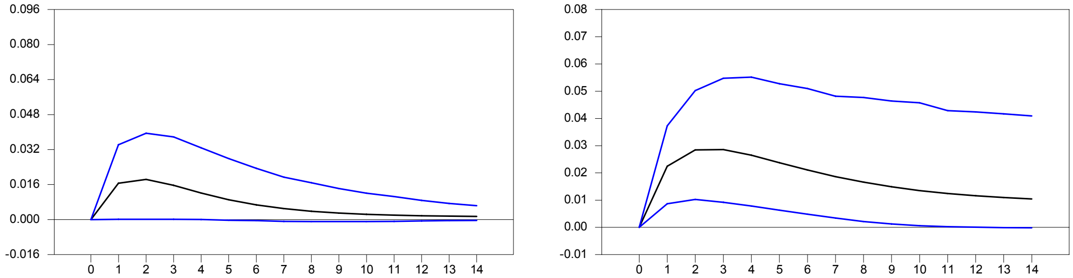

Output per worker ($1929) | TFP (1929) | TFP (1947)

Figure 9. Responses of Output per worker in the Manufacturing and Transportation sectors

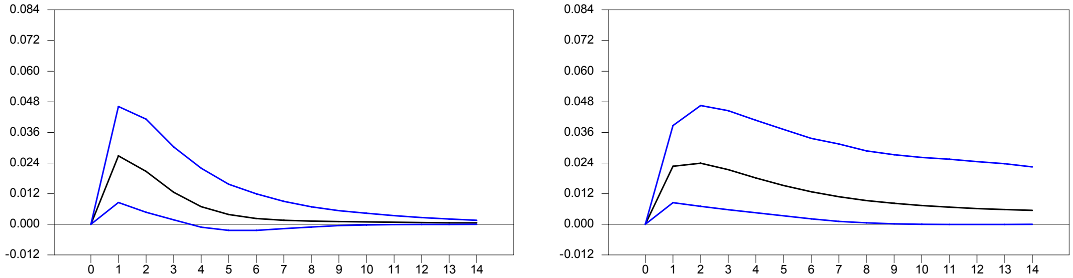
Total Technology Shock



Manufacturing Sector

Transportation Sector

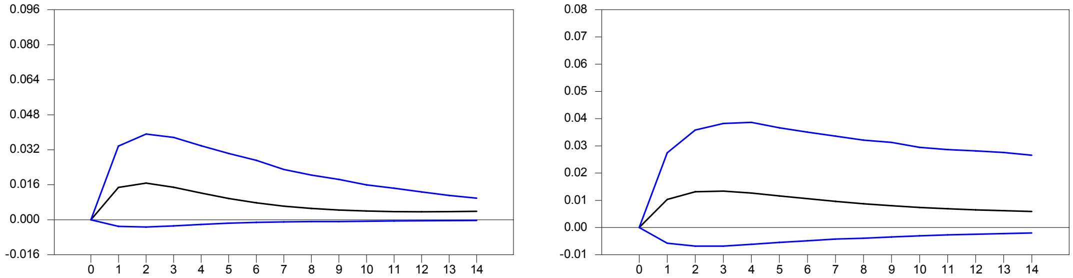
Electrical/Electronics Technology Shock



Manufacturing Sector

Transportation Sector

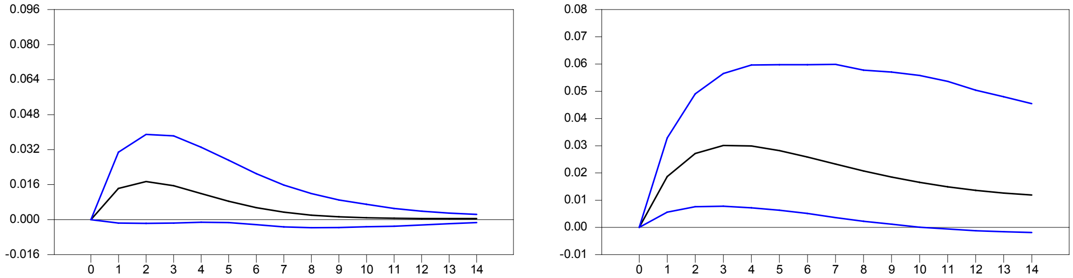
Mechanical/Manufacturing Technology Shock



Manufacturing Sector

Transportation Sector

Automotive Technology Shock



Manufacturing Sector

Transportation Sector

Railroad Technology Shock

Transportation Sector

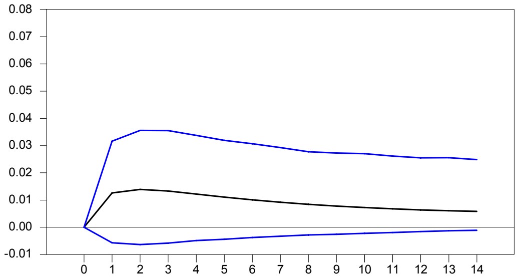

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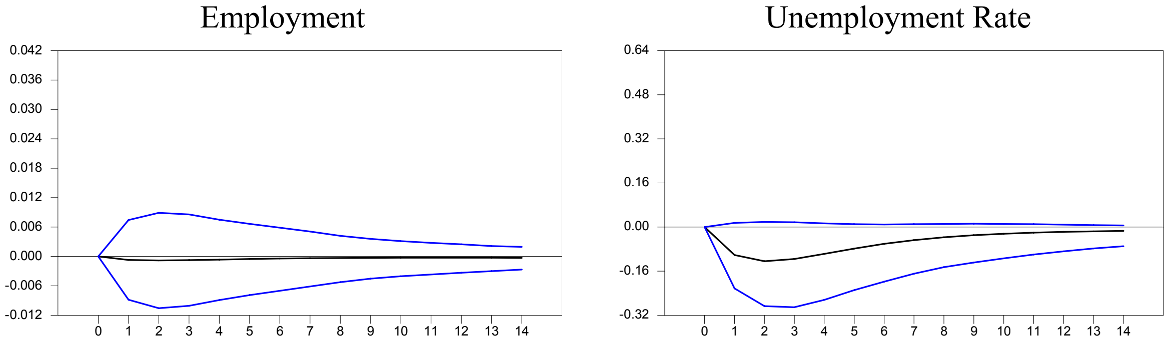
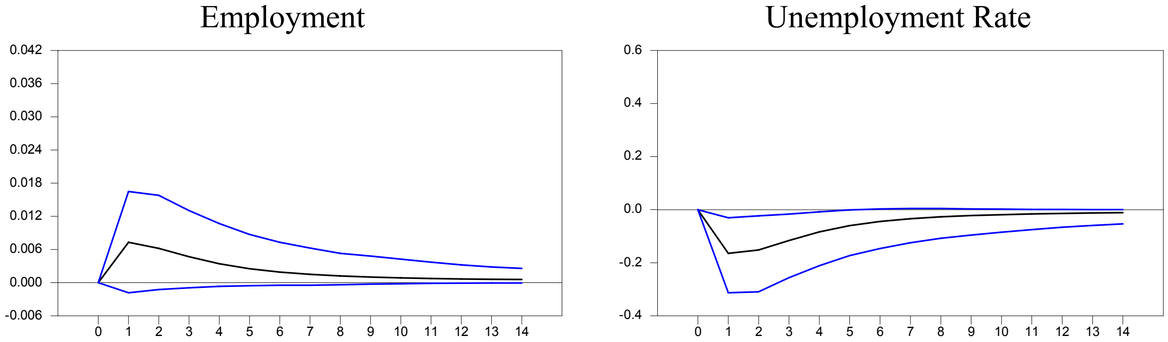
Figure 10. Responses of Employment per capita and the Unemployment rate for the total economy

Total Technology Shock


Employment

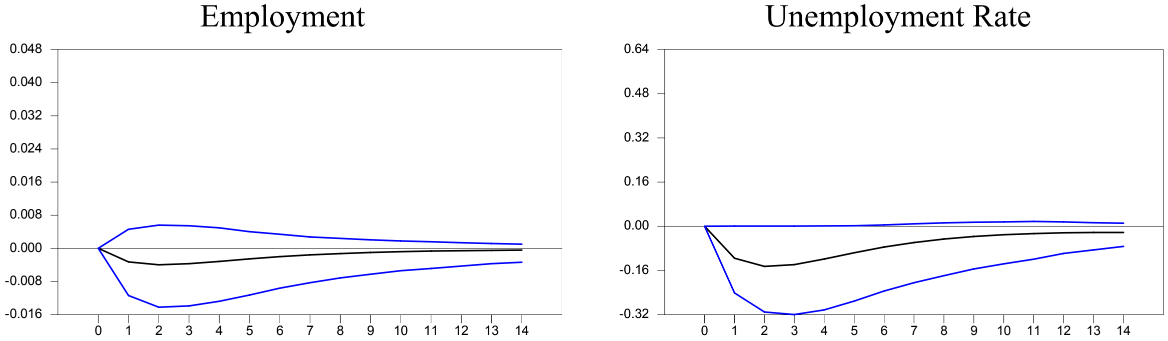
Unemployment Rate

Electrical/Electronics Technology Shock


Employment

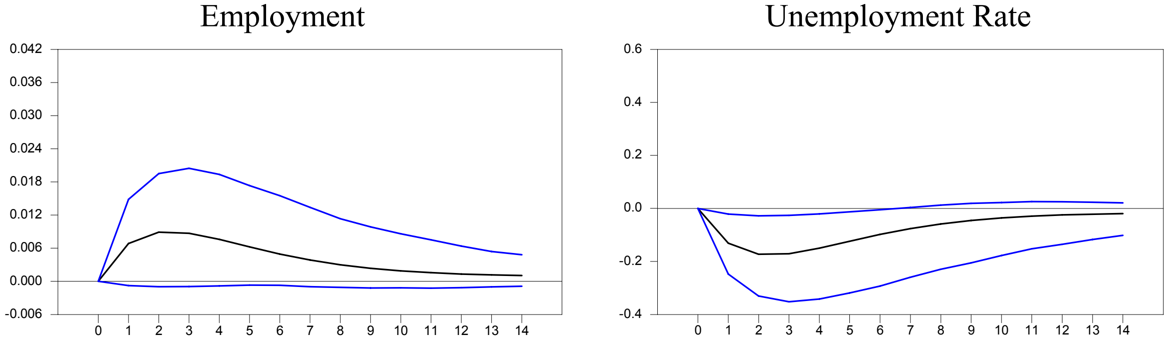
Unemployment Rate

Manufacturing/Mechanical Technology Shock


Employment

Unemployment Rate

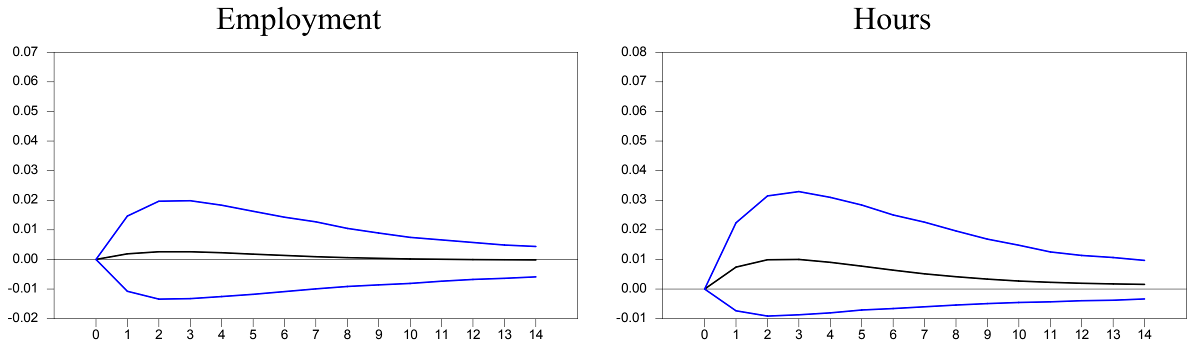
Automotive Technology Shock


Employment

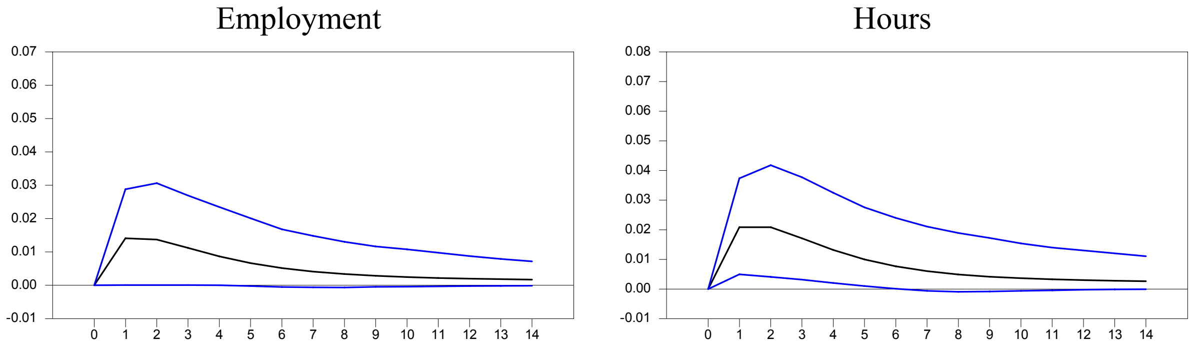
Unemployment Rate

Figure 11. National Non-farm Per capita Employment and hours responses

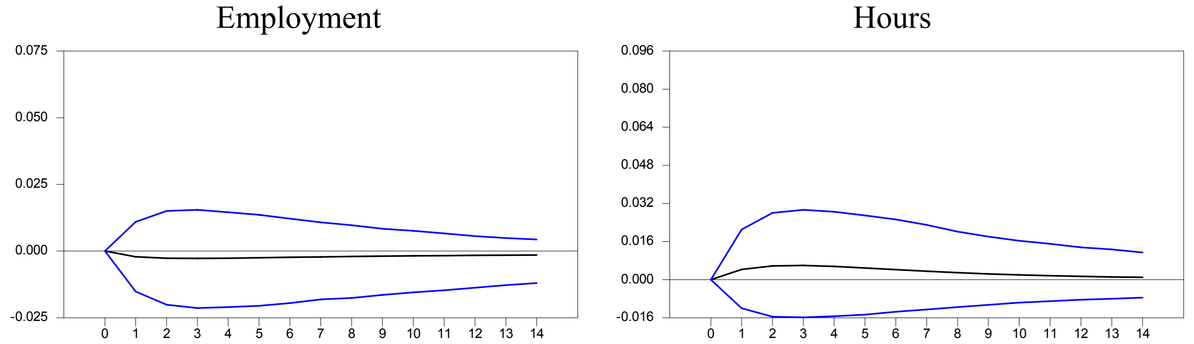
Total Technology Shock



Electrical/Electronics Technology Shock



Manufacturing/Mechanical Technology Shock



Automotive Technology Shock

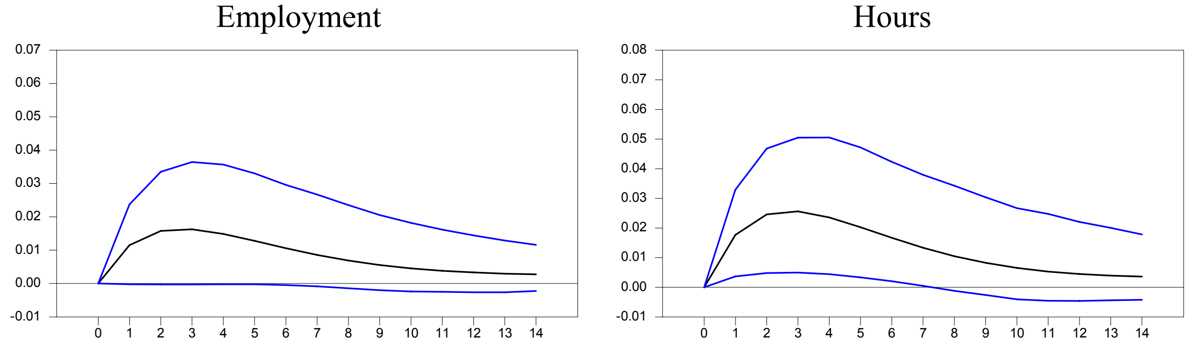
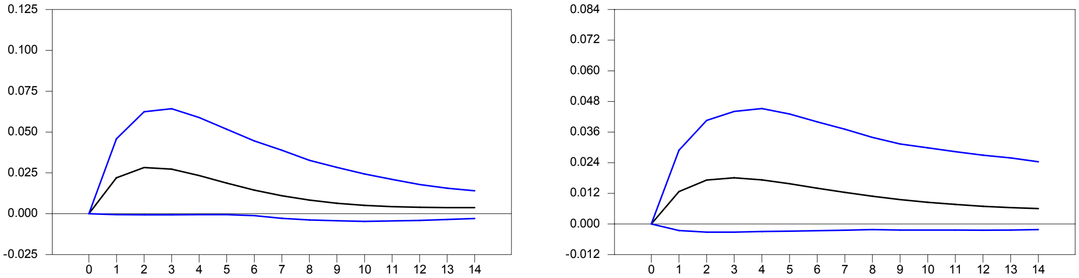


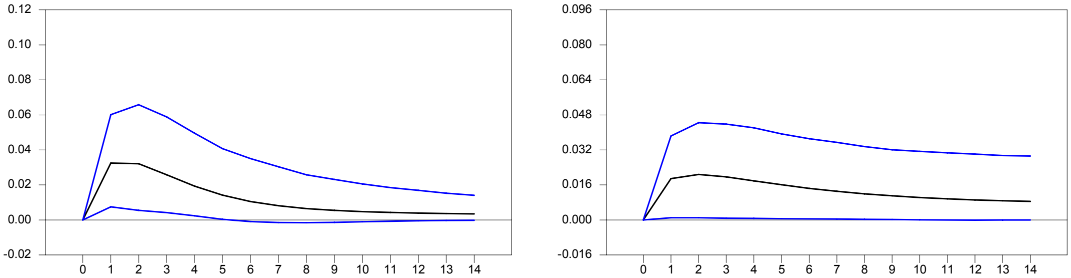
Figure 12. Responses of Per capita Employment in the Manufacturing and Transportation sectors

Total Technology Shock



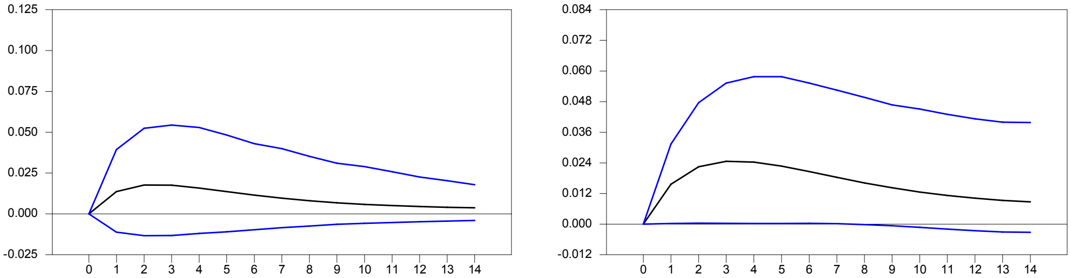
Manufacturing Sector Transportation Sector

Electrical/Electronics Technology Shock



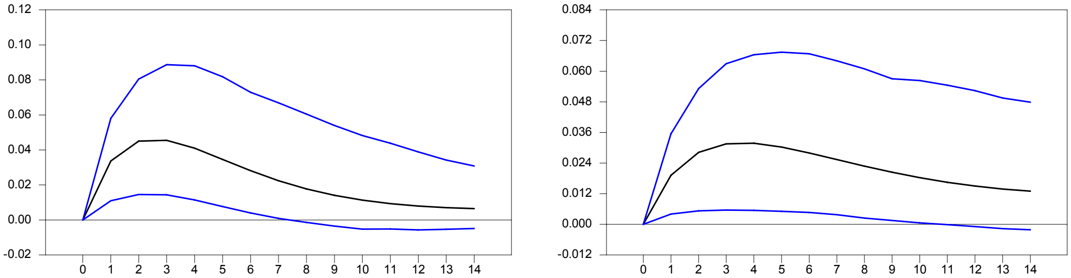
Manufacturing Sector Transportation Sector

Manufacturing/Mechanical Technology Shock



Manufacturing Sector Transportation Sector

Automotive Technology Shock



Manufacturing Sector Transportation Sector

Railroad Technology Shock

Transportation Sector

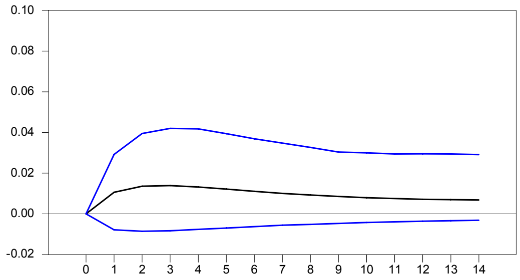

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Table 1. Point Estimates and Standard Errors

Indicator	Aggregate Y/E		Aggregate Y/E 1947		Private Non-Farm Y/E		Private Non-Farm TFP 1929		Private Non-Farm TFP 1947		Manufacturing Y/E		Transportation Y/E	
	ρ	β	ρ	β	ρ	B	ρ	β	ρ	β	ρ	β	ρ	β
All Technology	0.8775	0.1215	0.8308	0.1644	0.6874	0.0541	0.7088	0.0154	0.8082	0.0855	0.6248	0.1324	0.8015	0.1924
	(0.0828)	(0.0498)	(0.0910)	(0.0596)	(0.1267)	(0.0556)	(0.1187)	(0.0523)	(0.0895)	(0.0391)	(0.1258)	(0.0788)	(0.0720)	(0.0702)
Manufacturing & Mechanical	0.8430	0.0596	0.7928	0.1359	0.6611	0.0705	0.7026	0.0397	0.7686	0.0710	0.6217	0.0718	0.8228	0.0564
	(0.0850)	(0.0320)	(0.0837)	(0.0344)	(0.1188)	(0.0327)	(0.1158)	(0.0315)	(0.0865)	(0.0233)	(0.1280)	(0.0502)	(0.0852)	(0.0513)
Electrical & Electronics	0.8912	0.0888	0.8244	0.0957	0.6662	0.0361	0.6926	0.0152	0.7796	0.0537	0.5551	0.1019	0.8238	0.0914
	(0.0749)	(0.0228)	(0.0877)	(0.0291)	(0.1235)	(0.0275)	(0.1198)	(0.0265)	(0.0874)	(0.0192)	(0.1250)	(0.0397)	(0.0700)	(0.0343)
Automotive	0.8643	0.0369	0.8808	0.0625	0.7213	0.0389	0.7057	0.0408	0.8342	0.0306	0.7015	0.0461	0.8648	0.0585
	(0.0847)	(0.0191)	(0.0939)	(0.0230)	(0.1238)	(0.0203)	(0.1107)	(0.0181)	(0.0899)	(0.0146)	(0.1290)	(0.0302)	(0.0690)	(0.0249)
Railroad	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.8398	0.0278
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	(0.0770)	(0.0226)

* For all cases the results correspond to the regression $\ln(\text{productivity}_t)=\alpha+\gamma t+\beta\ln(\text{Tech}_{t-1})+\rho\ln(\text{productivity}_{t-1})+\varepsilon_t$, where productivity is either Y/E or TFP

Table 2. Granger Causality Tests (P-values)

Do the technology indicators Granger Cause labour productivity or TFP?

Indicator	Aggregate Y/E ($1929)	Aggregate Y/E ($1947)	Private Non-Farm Y/E ($1929)	TFP private non-farm (1929)	TFP private non-farm (1947)	Manufacturing Y/E ($1929)	Transportation Y/E ($1929)
All Technology	0.020	0.009	0.337	0.771	0.035	0.102	0.010
Manufacturing & Mechanical	0.071	0.000	0.038	0.216	0.004	0.161	0.279
Electrical & Electronics	0.000	0.002	0.197	0.570	0.008	0.015	0.011
Automotive	0.061	0.010	0.064	0.030	0.043	0.136	0.025
Railroad	n/a	n/a	n/a	n/a	n/a	n/a	0.227

Do the productivity variables Granger Cause the technology indicators?

Indicator	Aggregate Y/E ($1929)	Aggregate Y/E ($1947)	Private Non-Farm Y/E ($1929)	TFP private non-farm (1929)	TFP private non-farm (1947)	Manufacturing Y/E ($1929)	Transportation Y/E ($1929)
All Technology	0.107	0.085	0.140	0.214	0.415	0.661	0.646
Manufacturing & Mechanical	0.224	0.121	0.069	0.245	0.336	0.947	0.249
Electrical & Electronics	0.092	0.095	0.450	0.737	0.525	0.516	0.873
Automotive	0.302	0.047	0.018	0.061	0.141	0.048	0.436
Railroad	n/a	n/a	n/a	n/a	n/a	n/a	0.171

Table 3. Variance Decompostions

Indicator	Horizon	GNP per employee ($1929)	GNP per employee ($1947)	Private Non-Farm Output per Employee	Private Non-Farm TFP (1929)	Private Non-Farm TFP (1947)	Manufacturing Output per employee ($1929)	Transportation Output per employee ($1929)
All Technology	3 years	11.19	14.31	2.43	0.22	10.24	7.41	12.40
	6 years	19.08	23.50	3.79	0.38	17.75	11.17	19.01
	9 years	20.88	24.76	3.91	0.40	19.40	11.48	20.69
Manufacturing & Mechanical	3 years	7.03	26.95	11.08	4.16	18.70	6.03	2.75
	6 years	13.12	41.08	16.78	7.42	31.12	9.66	4.64
	9 years	14.77	42.14	16.90	7.87	33.06	10.11	5.21
Electrical & Electronics	3 years	21.59	15.74	4.51	0.89	13.06	12.91	9.32
	6 years	26.25	19.10	5.39	1.11	16.20	14.18	11.61
	9 years	26.94	19.39	5.44	1.13	16.59	14.19	12.06
Railroad	3 years	n/a	n/a	n/a	n/a	n/a	n/a	3.77
	6 years	n/a	n/a	n/a	n/a	n/a	n/a	5.58
	9 years	n/a	n/a	n/a	n/a	n/a	n/a	6.09
Automotive	3 years	8.58	15.29	8.54	11.31	9.27	5.91	10.93
	6 years	17.80	28.27	13.76	19.52	18.49	9.87	21.84
	9 years	20.90	30.54	13.88	19.97	20.81	10.09	25.60

Table 4. Point Estimates and Standard Errors

Indicator	Aggregate Employment		Aggregate Unemployment Rate		Private Non-Farm Employment		Private Non-Farm Hours		Manufacturing Employment		Transportation Employment	
	ρ	β	ρ	β	ρ	β	ρ	β	P	β	ρ	β
All Technology	0.7375	-0.0057	0.7573	-0.8188	0.7897	0.0156	0.8055	0.0621	0.7606	0.1869	0.9102	0.1082
	(0.1242)	(0.0398)	(0.1115)	(0.5488)	(0.1001)	(0.0599)	(0.0941)	(0.0723)	(0.0999)	(0.1118)	(0.0722)	(0.0777)
Manufacturing & Mechanical	0.7569	-0.0166	0.7286	-0.5694	0.7976	-0.0104	0.8079	0.0213	0.7631	0.0700	0.9004	0.0804
	(0.1225)	(0.0246)	(0.1106)	(0.3410)	(0.1004)	(0.0376)	(0.0952)	(0.0458)	(0.1061)	(0.0744)	(0.0700)	(0.0465)
Electrical & Electronics	0.6786	0.0266	0.7723	-0.5810	0.7585	0.0522	0.7820	0.0795	0.7689	0.1220	0.8917	0.0658
	(0.1209)	(0.0196)	(0.1085)	(0.2709)	(0.0971)	(0.0294)	(0.0893)	(0.0348)	(0.0956)	(0.0542)	(0.0697)	(0.0376)
Automotive	0.7064	0.0211	0.7622	-0.4096	0.7896	0.0360	0.8297	0.0559	0.7451	0.1039	0.9112	0.0604
	(0.1149)	(0.0138)	(0.1087)	(0.2003)	(0.0955)	(0.0214)	(0.0891)	(0.0256)	(0.0948)	(0.0397)	(0.0689)	(0.0274)
Railroad	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.8983	0.0239
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	(0.0721)	(0.0233)

* For all cases the results correspond to the regression $\ln(Y_t)=\alpha+\gamma t+\beta \ln(Tech_{t-1})+\rho \ln(Y_{t-1})+\varepsilon_t$, where Y= per capita employment, the unemployment rate, or per capita hours

Table 5. Granger-Causality Tests (P-values)

Do the technology indicators Granger Cause employment, unemployment or hours?

Indicator	Aggregate Employment	Aggregate Unemployment Rate	Private Non-Farm Employment	Private non-farm Hours	Manufacturing Employment	Transportation Employment
All Technology	0.886	0.145	0.796	0.396	0.103	0.172
Manufacturing & Mechanical	0.504	0.104	0.783	0.644	0.353	0.092
Electrical & Electronics	0.184	0.039	0.085	0.028	0.031	0.089
Automotive	0.135	0.048	0.101	0.036	0.013	0.034
Railroad	n/a	n/a	n/a	n/a	n/a	0.313

Do the productivity variables Granger Cause the technology indicators?

Indicator	Aggregate Employment	Aggregate Unemployment Rate	Private Non-Farm Employment	Private non-farm Hours	Manufacturing Employment	Transportation Employment
All Technology	0.513	0.262	0.322	0.228	0.229	0.043
Manufacturing & Mechanical	0.232	0.370	0.884	0.647	0.923	0.123
Electrical & Electronics	0.815	0.147	0.567	0.332	0.256	0.485
Automotive	0.388	0.235	0.198	0.114	0.492	0.187
Railroad	n/a	n/a	n/a	n/a	n/a	0.225

Table 6. Variance Decompositions

Indicator	Horizon	Aggregate Employment	Aggregate Unemployment Rate	Private Non-Farm Employment	Private Non-Farm Hours	Manufacturing Employment	Transportation Employment
All Technology	3 years	0.06	5.49	0.16	1.63	6.02	3.63
	6 years	0.10	9.35	0.30	3.06	10.47	6.51
	9 years	0.11	9.94	0.34	3.43	11.21	7.42
Manufacturing & Mechanical	3 years	1.30	7.30	0.21	0.58	2.37	5.83
	6 years	2.32	12.82	0.43	1.16	4.42	11.33
	9 years	2.51	13.66	0.51	1.35	4.95	13.22
Electrical & Electronics	3 years	4.32	10.26	6.22	8.71	8.96	6.23
	6 years	5.17	12.54	7.78	10.84	11.10	8.46
	9 years	5.25	12.73	7.98	11.09	11.31	9.04
Railroad	3 years	n/a	n/a	n/a	n/a	n/a	2.31
	6 years	n/a	n/a	n/a	n/a	n/a	3.70
	9 years	n/a	n/a	n/a	n/a	n/a	4.12
Automotive	3 years	6.22	10.50	6.65	10.43	16.46	9.95
	6 years	11.87	19.82	13.35	20.30	29.56	20.59
	9 years	12.86	21.31	14.93	22.49	31.98	24.55

Table 7: Sensitivity Analysis

Indicator	Private Non-Farm Employment				Private Non-Farm output per worker			
	without dummies		with dummies		without dummies		with dummies	
	β	ρ	β	ρ	β	ρ	β	ρ
All Technology	0.0156	0.7897	0.0399	0.8961	0.0545	0.6898	0.0675	0.6954
	(0.0502)	(0.0635)	(0.0588)	(0.1589)	(0.0677)	(0.1255)	(0.0836)	(0.2183)
Electrical & Electronics	0.0522	0.7585	0.0480	0.8583	0.0361	0.6662	0.0374	0.6526
	(0.0214)	(0.0587)	(0.0197)	(0.1452)	(0.0290)	(0.1041)	(0.0325)	(0.1777)
Mechanical & Manufacturing	-0.0105	0.7976	-0.0104	0.9048	0.0705	0.6611	0.0814	0.6612
	(0.0277)	(0.0657)	(0.0317)	(0.1679)	(0.0391)	(0.1093)	(0.0428)	(0.1687)
Automotive	0.0360	0.7896	0.0386	0.8964	0.0389	0.7213	0.0479	0.7501
	(0.0185)	(0.0747)	(0.0218)	(0.1691)	(0.0163)	(0.1190)	(0.0218)	(0.2089)

*For all cases the results correspond to the regression $\ln(Z_t)=\alpha+\gamma t+\beta\ln(Tech_{t-1})+\rho\ln(Z_{t-1})+\varepsilon_t$, where Z= per capita employment, or output per worker

Appendix A. Library of Congress Classification Overview

Subclass T Technology (General)

Subclass TA Engineering (General). Civil engineering

Subclass TC Hydraulic engineering. Ocean engineering

Subclass TD Environmental technology. Sanitary engineering

Subclass TE Highway engineering. Roads and pavements

Subclass TF Railroad engineering and operation

Subclass TG Bridge engineering

Subclass TH Building construction

Subclass TJ Mechanical engineering and machinery

Subclass TK Electrical engineering. Electronics. Nuclear engineering

Subclass TL Motor vehicles. Aeronautics. Astronautics

Subclass TN Mining engineering. Metallurgy

Subclass TP Chemical technology

Subclass TR Photography

Subclass TS Manufactures

Subclass TT Handicrafts. Arts and crafts

Subclass TX Home economics