Railroads and the Rise of the Factory: Evidence for the United States, 1850-70

By

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In the early nineteenth century United States, the overwhelming share of manufacturing production took place in “artisanal shops” where a highly skilled worker – the artisan – crafted a good from start to finish, perhaps with the help of an assistant or two (Sokoloff 1984). Such craftsmen used comparatively little in the way of physical capital – a building, hand tools, and not much else—and their operations were to be found everywhere. While such artisanal shops were still the dominant type of manufacturing establishment in terms of numbers at mid-century, a new organizational form – the factory – had emerged in a wide range of industries as a result of changing technology and economic opportunities. Contemporaries struggled to define this new form. Andrew Ure (1835: 13), for example, defined it as follows: “The term Factory, in technology, designates the combined operation of many orders of work-people, adult and young, in tending with assiduous skill a system of productive machines continuously impelled by a central power.” This “assiduous skill” promoted learning by doing and, thanks to the regularity of machine production, accelerated throughput and enhanced labor productivity. Carroll D. Wright (1883: 533) adopted a somewhat broader definition of the factory as “an association of separate occupations conducted in one establishment in order to facilitate the combination of the processes.” During the second half of the nineteenth century the trend towards factory production continued and it was partly as a result of this that labor productivity in US manufacturing grew rapidly and country became the dominant player in many industries worldwide by the end of the century (Wright 1990; Broadberry and Irwin 2006).

Many scholars have proffered explanations for why the factory displaced the artisanal shop. One classic answer invokes the so-called “transportation revolution” (Taylor 1951).
According to this argument, the market for artisan goods early on was generally limited to the immediate surrounding area because transport costs were very high relative to the value of the good at the point of production. Over time, transportation infrastructure spread and improved dramatically, lowering the costs of transportation domestically and internationally. According to Clark (1916: 351) “when railways brought to transportation the three gifts of directness, speed, and continuity, they created conditions profoundly affecting manufactures.” This greatly expanded the geographic size of markets for manufactured goods which, in turn, provided the economic incentive for establishments to grow larger in size through division of labor. Indeed, as Adam Smith had succinctly put it in a famous passage from *The Wealth of Nations*: “The division of labor is limited by the extent of the market”.

Adam Smith’s reputation alone guarantees that the transportation revolution makes every economic historian’s laundry list of the causes of the factory system. However, this laundry list would also include many other factors. The steam engine, for example, was adopted more quickly by larger-scale enterprises arguably because the positive impact of steam on labor productivity (relative to water or hand power) was increasing in establishment size (see Atack, Bateman and Margo 2008a). All else equal, factories would be more profitable wherever and whenever the wage of unskilled labor was low relative to skilled labor. The factory system in America first appeared in the New England which had abundant, easily developed, water power, and the Middle Atlantic states where there were rich, easily mined coal deposits. Moreover, the relative productivity of children and young women in agriculture in these regions was low spurring their reallocation into more
productive manufacturing activities (Goldin and Sokoloff 1982). At times waves of immigration from Europe expanded the relative supply of unskilled labor, arguably fueling the growth of factories (Rosenbloom 2002).¹

From a quantitative perspective the relative importance of the transportation revolution as a causal factor in the growth of the factory system is unclear. A key difficulty in measuring the impact has been the absence of suitable data linking transportation improvements and factory diffusion along with a plausible identification strategy for establishing causality. In this paper we report on our preliminary efforts to bridge this gap using repeated cross-sections of individual establishments drawn from the 1850-70 federal censuses of manufacturing which we have linked to county-level information on transportation access derived from contemporary maps. Following previous work (Craig, Palmquist, Weiss 1996; Haines and Margo 2008) our measure of rail access is a dummy variable indicating whether or not a railroad passed through the boundaries of a particular county. Some counties already had rail access in this sense in 1850 while others did not. Among the counties that did not have access in 1850, a subset gained access in the 1850s or in the 1860s. In the absence of similar manufacturing data prior to 1850 we have focused our attention on the impact of the diffusion of the railroad rather than other forms of transportation infrastructure, such as canals, which was largely complete by 1850.²

¹ The factors in the paragraph hardly exhaust the laundry list of causes of the factory system; others include the development of financial markets (Rousseau and Sylla 2005) and legal changes in business organization (Lamoreaux 2006; Hilt 2008).

² Sokoloff’s samples from the 1820 Census and from the 1832 McLane Report offer an earlier window into the American industrialization but neither is a representative random sample. Rather, each focuses on a narrow range of specific locations where manufacturing activities were particularly important and where reporting was more complete. Although the non-random nature suited Sokoloff’s purposes it appears difficult to use either to study
We adopt two identification strategies to assess causality. In the first strategy, we employ a difference-in-differences (DID) estimator. It measures whether factory status increased on average in counties that gained rail access over the course of a decade – the “treatment” sample – as compared with the control sample (counties that did not gain access or already had access at the start of the decade). The legitimacy of this estimator rests on the presumption that gaining access to rail transport occurred through the equivalent of random assignment. However, one does not need to read very deeply in the literature of the transportation revolution to conclude that railroads were built purposefully rather than haphazardly. Consequently, we have supplemented our DID estimator with an instrumental variable (IV) procedure whose goal is to isolate exogenous variation in rail access. Our IV is a variation on that developed by Bannerjee, Duflo, and Qian (2007). It is based on “straight lines” between interior cities and the closest major coastal port. Our presumption is that a county would have been more likely to gain rail access by 1850 if it lay on the straight line between these interior centers of concentrated economic activity and the closest port city from which entrepreneurs could take advantage of cheap coastwise and international commerce. Judging by our first stage regression, this logic is correct: our “port” IV strongly and positively predicts rail access in the 1850 cross section of firms.

Our empirical findings suggest that the coming of the railroad was a causal factor in the rise of factories. Both the difference-in-differences and instrumental variable estimates are positive, indicating that gaining access to a railroad was associated with an increase in the impact of transportation improvements. None of the counties in Sokoloff’s sample (obviously) had rail access in 1820 but virtually all did in 1850, making a difference-in-difference analysis similar to the one conducted in this paper not very informative.
establishment size. While the instrumental variable estimates are largely invariant to variations in sample definition, both the magnitude and statistical significance of the difference-in-difference estimator is sensitive in this sense. If, however, we restrict attention to counties for which our rail access variable is likely to reflect true geographic proximity to a rail line then the two approaches yield estimates of treatment effects that are similar in magnitude.

1. The Division of Labor and the Extent of the Market

In this section we present a simple framework illustrating the “Smithian” hypothesis that we are testing. Our premise is that, if markets are local in nature, then firms adopt the artisan technology. But if the markets expand beyond their local boundaries, the artisanal shops may consolidate and utilize division of labor and inanimate power which we term the factory technology since this provides increased output at lower unit cost.

We assume a single good, q, and two types of artisans, type #1 and type #2. To produce q during a production period, an artisan must complete two tasks, t₁ and t₂, each of which entails a marginal cost that differs by artisan type (\(c_{ij}, i = \text{artisan type}, j = \text{task}\)). The marginal cost of completing the first task is lower for type #1 than for type #2 (\(c_{11} < c_{21}\)) but the reverse is true for the second task (\(c_{12} > c_{22}\)). However the total marginal cost of producing a unit of q, \(c_i = c_{i1} + c_{i2}\), is the same for both artisan types (= c). We assume that the artisans operate in a local market whose aggregate demand for q is downward sloping (as for
example, \( p = a - b \times q \). To keep the algebra simple we further assume that aggregate demand is sufficiently small such that the market only supports one artisan of each type.

The two artisans play a one-shot game in quantities. The non-cooperative solution to this game is Cournot-Nash with the players splitting the market. If demand is linear, as in the above example:

\[
q_1 = q_2 = \frac{1}{3} \times \frac{a-c}{b}
\]

The artisans, however, also have the option of colluding to produce the monopoly quantity and divide profits between them. In the usual setup of this game, each player is presumed to produce \( q \) jointly at the same marginal cost incurred when producing alone. However, in our setup, profits under collusion are higher if the players agree to specialize in the task at which they have a comparative advantage (that is, the typical gains from trade story). Thus, type #1 specializes in task #1 and type #2 specializes in task #2. Total marginal cost under this “factory” technology, \( c^* \), is

\[
c^* = \sum \arg \min (c_{1j}, c_{2j})/z = (c_{11} + c_{22})/z
\]

Here, the term \( z (>1) \) reflects the possible use of an inanimate source of power, such as steam. Notice that, by construction, \( c^* < c \).
As in the usual one-shot Nash game, the players must consider whether it would be profitable to deviate assuming that the other player continues to behave collusively. In this setup, the incentive to deviate is less than usual because, if an artisan produces q “on the side” then the artisan technology must be used which is more costly than factory technology. To see this, assume that type #1 and #2 continue to produce the collusive output level during the “regular” working day, but that type #1 considers reverting to the artisan technology to produce additional output surreptitiously if it is profitable to do so. It can be shown that the quantity $z$ that type #1 would produce “on the side” in this way is given by the equation:

$$z = \frac{(a - c - d)}{4b}$$

where $d = c - c^* > 0$. Note that if $d$ is sufficiently positive – that is, if the productivity gains through division of labor are large enough, artisan #1 will not benefit from deviating from the collusive outcome which, ex ante, is more profitable than the Cournot outcome. In other words, this model suggests that a factory could emerge through the desires of the players to endogenously capture monopoly profits provided that the gains through division of labor are large enough. The model thus does not require that the “extent of the market” grow in geographic size for a factory to form.

Next, suppose that consumers in the local market are able to purchase a perfect substitute for $q$ that is produced elsewhere and is shipped into the local area. Let $c''$ be the marginal cost of the imported version of $q$ and suppose that the costs of transport are $t$ per
unit. In general we can argue that $p'' = mc'' + t$ where $m$ (a mark-up factor) > 1. If $p''$ is less than the price supported by the local Cournot-Nash equilibrium the artisans would have no choice but to form a factory if they wished to remain in business.

Factory output in the presence of trade would necessarily be higher than in the no-trade equilibrium and price would be lower. Clearly, one way for $p''$ to be low enough to “cause” the factory to form would be if, initially, $c''$ was lower than $c^*$ but transport costs were too high to support trade. However if transport costs fall sufficiently, then the competitive pressure induced by trade compels artisans either to utilize factory technology or go out of business.

To summarize, our framework predicts that, at the margin, improved access to trade created by progressively cheaper transport costs provides an incentive for factories to form because aggregate demand in the local market becomes perfectly elastic in a neighborhood around the initial quantity. The artisans band together and engage in division of labor so as to remain competitive. If a factory already exists in the market because the players are able to support the cooperative outcome in the one-shot game, consumers still benefit from trade because price falls. In the remainder of the paper we examine whether the coming of the railroad leads to an increase in establishment size.

2. Railroads and the Transportation Revolution

The United States experienced a “transportation revolution” in the nineteenth century (Taylor 1951; Goodrich 1961; Haites, Mak, and Walton 1975). The elements of the
revolution are all well known: dredging and other improvements to harbors and natural inland waterways; improved all-weather roads for travel by wagon; the building of canals; the marine application of steam, and last, and perhaps of greatest importance, the diffusion of the railroad. In principle all of the features of this revolution could have affected the growth of manufacturing – and, undoubtedly did, in many different ways. For the purposes of this paper, however, we focus on the railroads because, as a practical matter, the timing of the manufacturing data used in this paper, beginning as it does with the 1850 federal census, overlaps only with a significant portion of the timing of the diffusion of the steam railroad. By then other forms of transportation improvements, such as canals and the western river steamboat, had largely been completed.

Although plans for railroads were first discussed in the United States in the early 1800s, it was not until the late 1820s that any steam railroads were actually built. The first American railroads were tramways used in mining and quarrying, such as the so-called “Granite Railroad” that commenced operations in Quincy, Massachusetts in 1826. But railroads in the modern sense really originate with the struggles of port cities like Baltimore, Boston, and Charleston that lacked adequate inland waterway connections that would enable greater volume of trade with the hinterland in competition with New York and its Erie Canal. By 1840 some 3,300 miles of track had been laid (of which about 2,800 miles were in operation), the majority of it in New England, the mid-Atlantic, and South Atlantic states, and almost all of it involving trips of short duration (“short line”). Further expansion in mileage took place in the 1840s, much of it again in New England, and also in New York. The South and Midwest were largely bypassed during this decade, except for the
completion of a rail line linking Savannah and Chattanooga, and a rail line through Ohio from Sandusky to Cincinnati. By 1850, about 10,000 miles of railroad track were in operation but split between different gauges, several of which were incompatible with one another thus preventing through-haulage.

The 1850s witnessed a substantial wave of rail expansion (Stover 1978). Approximately 22,000 miles of track were laid between 1850 and 1860 such that, on the eve of the Civil War, total rail mileage exceeded over 30,000. Although the federal government had been involved in railroad expansion prior to 1850 in an indirect way by providing land surveys free of charge (from 1824, when the General Survey Bill was passed and immediately signed into law by President Monroe to 1838, when the law authorizing the surveys was repealed), direct subsidies in the form of land grants were first voted in 1850, and later extended several times during the decade (United States 1940). By 1860, in addition to substantial coverage in the Northeast, rail lines crossed Illinois, Indiana, and Ohio, with significant mileage in operation in Wisconsin and Iowa. The South was less well served, but it too experienced substantial growth in rail access in the 1850s and, later, in the aftermath of the Civil War.

Economic historians have devoted considerable attention to measuring the impact of railroads on total output, or what Fogel (1964; see also Fishlow 1965, Williamson 1974, and Kahn 1988) called the “social savings” of the railroad. Attention has also been paid to the “backward linkages” that railroad expansion created with other manufacturing sectors (Fogel 1964); whether railroads were “built ahead of demand” (Fishlow 1965); and the impact of transportation improvements on regional economic development (Williamson
Our goal in this paper is to add to this literature by examining another “treatment effect” of the railroad, that on factory status in manufacturing. To measure this treatment effect requires a data set linking the diffusion of railroads to the distribution of establishment sizes in manufacturing. We describe such a data set and our estimation strategy in the next section.

3. Data and Estimation

Our empirical analysis relies upon the modified Bateman-Weiss samples of manufacturing establishments (Atack and Bateman 1999) which have been linked to a newly created database of transportation infrastructure for the nineteenth century United States. We briefly describe first the transportation database and then the linked sample.

The transportation database was created in two stages. In the first stage, we combined information from Goodrich (1961) and various nineteenth century sources to produce a county level dataset indicating whether a county had “access” to water transportation from 1850 onwards. Access here means a set of dummy variables indicating if a canal or navigable river passed through the county boundaries (or was, in the case of a river, the county boundary) or if the county bordered on one of the Great Lakes or had ocean frontage. For this purpose county boundaries were fixed as of a given census year (for example, 1850 or 1870) and the tracing of the railroad routes from the digitized maps is
overlaid upon a geographic information system (GIS) boundary file (or “shapefile” in the language of GIS) of navigable waterways at specific dates (Figure 1).³

The second stage was to create similar access variables for railroad transportation. For this stage we assembled extant railroad maps from the nineteenth century that have been digitized, and can therefore be overlaid on shapefiles of the historical county boundaries (Figure 2). This differs from the approach used by other scholars (for example, Craig, Palmquist, and Weiss 1996) who visually compared historical maps to county boundaries (which generally did not appear on the historical maps) and tried to integrate often contradictory maps into a single measure.

Regardless of the approach used, errors arise from multiple distinct sources. First, the dates on the maps tend to be ambiguous. Most list their copyright date rather than the date represented by the data on the map. Mapmakers were attempting to capture a flow—railroad construction—as a snapshot. Moreover, few of the mapmakers had personal knowledge of all of the rail systems they were drawing. Surveys were imperfect (albeit improving), map projections were inaccurate. Last, and certainly not least, rail lines were not accurately and consistently drawn on maps with the result that railroads seemed to

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³ Determination of what constituted a navigable waterway was subject to some interpretation. For example, Fogel’s (1964) map of navigable waterways includes a number of East coast and Gulf rivers: the Coosa, the Conecuh and the Escambia in Alabama, the Edisto in South Carolina, the Black and the Northeast rivers in North Carolina and the Dan and Staunton rivers in Virginia. Nineteenth century traffic on most of these rivers, however, seems to have been by bateaux, carrying small amounts of cargo at relatively high cost, rather than by steamboat or barge. We have defined a navigable waterway as one which accommodated steamboats or canal barges on a regular basis. For this reason, we treat Shreveport as the practical head on navigation on the Red River and ignore navigation on rivers such as the Licking and Big Sandy Rivers in Kentucky where, according to Hunter, “small steamboats occasionally ran for short distances.”
shift location from year to year. While a few railroads may have been realigned and re-graded, in most cases, once a railroad was built in a specific location, it stayed where it was because the bulk of the railroad’s investment was not just fixed but also sunk (literally). For example, according to the 1880 Census, over 80 percent of railroad investment went into construction costs, of which only one or two percent represented the cost of the land itself; the rest went in surveying, grading, removing or bridging obstacles and laying the track. While ties, ballast and the rails might be reused and the land itself could be resold, the grading, cuttings, embankments, bridges, and drainage ditches had few alternative uses—especially in the nineteenth century.

Once a digitized railroad map has been overlaid upon a county boundary file, GIS methods can be used to create various indicators of transportation access. Following previous work and analogous to our water transportation dummies we created a rail access dummy variable equal to one if a railroad passed through the county, and zero otherwise. For additional details on the transportation data base and its construction, see Atack, Bateman, and Margo (2008b).

These transportation data have been linked (at the county level) to samples of manufacturing establishments that were drawn from the 1850-70 manuscript censuses of manufacturing by Bateman and Weiss and modified and extended by Atack and Bateman.4

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4 Although data on manufacturing establishment in 1880 are also available, these are not used here as they undercount the number of factories which are a key component of our analysis here. The problem with the 1880 data is that the collection of data for certain key industries, including iron and steel, textiles and glass, was delegated to special agents rather than being a part of the regular census and these enumerations have since been lost. The 1880 data require special reweighting to be representative and we have yet to integrate the weights into the linked manufacturing-transportation sample.
The censuses of manufacturing recorded outputs and inputs along with other firm level characteristics and identified the location of each plant, including the county. For additional details on the manufacturing data, see Atack and Bateman (1999).

According to Clark (1916: 447) “It is impossible to define precisely at what point the ... mill became a factory ... the definition depended ... upon a combination of equipment and organization.” For this reason, we have chosen to follow the previous literature (Sokoloff 1984) and have defined a factory as an establishment with 16 or more workers. Table 1 shows the fraction of establishments located in counties with rail transportation in each of the sample years and the distribution of factories. In 1850, slightly more than two-thirds of the sample establishments were located in counties with rail access. Rail access increased sharply in the 1850s, to 85 percent of the sample firms, and again in the 1860s, to 95 percent. In 1850 and 1860, the number of workers is the sum of male and female employees. In 1870, the number of workers is the sum of adult males, adult females, and child employees. We have experimented with the adjustment of entrepreneurial labor suggested by Sokoloff (1984) which involves adding one person to the count of workers but as our substantive findings were not affected, we only report results using the unmodified census counts. Similarly, no adjustment has been made to render the number of employees comparable across establishments in terms of adult-male equivalents because at least some of the process of division of labor involved the substitution of women and children for adult men (Goldin and Sokoloff 1982).

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5 Our definition does not separately distinguish mechanized establishments because mechanized power, in principle, was a complement to division of labor (see Atack, Bateman, and Margo 2008a).
As can be seen in Table 1, factories as we have defined them grew more common over time, garnering an ever larger share of the total manufacturing labor force. Indeed, even by 1850, fully 60 percent of all workers in our sample were employed in establishments with 16 or more workers; by 1870 the share was up to 72 percent. It is also clear that factories were common in counties that had rail access by from 5.9 to 9.4 percentage points, depending on the census year. The weighted average of these differences (the weights are the sample sizes in each year) produces an average “treatment effect” of 7.2 percentage points.

If we were to take this estimate seriously, then the diffusion of the railroad from 1850 to 1870 can explain all of the increase in the proportion of establishments that were factories. To see this, note that the proportion of counties with rail access grew by 27.8 percentage points from 1850 to 1870 (from 67.5% to 95.3%); if the treatment effect of rail access is 7.2 percentage points, the predicted increase in the proportion factory is 2.1 percentage points (=0.072 x 0.278 x 100%) compared with an actual increase in the proportion factory of 1.9 percentage points (see Table 1).

Alternatively, we can assess the explanatory power of railroads by assuming that no counties had access in 1820 and compute the impact of the diffusion of rail access from 1820 to 1850, and compare the predicted change in the percent factory to the 1850 level shown in the table. The predicted change in percent factory from this calculation is 4.9 percentage points (=0.072 x 0.675 x100%). This thus accounts for 58.3 percent of the level in 1850 ( = 0.049/0.084 x 100%) but it underestimates the explanatory power of rail
diffusion since some establishments in existence in 1820 would have met our factory definition (see Sokoloff 1982).\(^6\)

This simple calculation suggests that the diffusion of the railroad could have been a major driving force behind the rise of the factory. But the calculation, of course, presumes that the contrast in percent factory between counties with and without rail access in Table 1 is an unbiased estimate of the true treatment effect. However, it is easy to think of reasons why the difference in factory status by rail access shown in Table 1 merely reflects a correlation with other factors that influenced factory status – for example, urbanization, or characteristics of the local labor supply. Or there could have been reverse causality – places with a higher proportion of factories in 1850 may have had more factories before the railroad came, and because there were more factories, the railroad came. To address this problem, we have taken two different approaches to circumventing any endogeneity bias.

**Difference-in-Differences Analysis**

One way to approach this is through a difference-in-differences (DID) analysis.

Specifically, we examine whether counties that were “treated” with a railroad in either the 1850s or the 1860s witnessed an increase in the proportion of manufacturing

\(^6\) In the 46 industrialized counties in his sample from the 1820 census of manufacturing, Sokoloff reports that 237 of the 1,457 firms in his sample (16.3%) had a workforce of 16 or more persons. Because of the specialized nature of the Sokoloff sample and the fact that the 1820 census undercounted small establishments (see Sokoloff 1984) the true percentage of factories in 1820 is far lower than this but obviously greater than zero.
establishments that were factories, according to our definition, relative to a control group of counties. This control group consists of those counties that already had rail access in place at the start of both decades and those which never gained rail access. This analysis, in effect, includes county and year fixed effects and therefore sweeps away many factors that made it more likely that a county got a railroad and also influenced (independently) the likelihood that manufacturing establishments were factories. In all of the various results that follow, the standard errors have been corrected for clustering at the county level.

The results of the DID analysis are shown in Table 2. In the first row we allow for a treatment effect to occur if the county received a railroad after 1850. If no establishment level controls are included in this regression, the estimated treatment effect is far smaller ($\beta = 0.027$) than the estimate derived from Table 1 and is statistically insignificant. However, if we allow the treatment effect to vary by decade, the DID estimate for the 1860s is only slightly smaller in magnitude than the average of the two cross-sectional treatment effects (1860 and 1870) shown in Table 1.

The remaining columns in Table 2 either include establishment level controls (urban status and two-digit SIC industry code) or else restrict the sample in various ways. Adding urban status and industry controls, for example, slightly lowers the estimated coefficient of rail access (column 5) but the coefficient remains statistically significant. Perhaps the most interesting estimate appears in the last column in which we restrict the sample to just urban establishments located in counties that had water access in 1850. Although we have not mapped the precise locations of the firms in the Attack-Bateman samples, it is very likely
that urban firms in counties with water access were also in close geographic proximity to a rail line. The fact that the county had access to water transportation may have produced positive network externalities for running a rail line into the county, and the rail depots would have been situated in urban locations. In other words, firms in such counties would not likely have had to move goods very far in order to gain direct access to a rail depot – a major factor when hauling costs by wagon were very high, as was the case in 1850 (Fogel 1964).

**Instrumental Variable Estimates**

An alternative way of dealing with possible endogeneity bias is to construct an instrumental variable for rail access. We have applied this approach to the 1850 cross section. The idea behind the IV approach is to find a variable that predicts rail access in 1850 but which does not have a direct effect on the probability that an establishment was a factory.

To construct such a variable we have followed the same approach as Bannerjee, Duflo, and Qian (2007) who sought to measure the impact of rail access in modern China on wages (among other economic outcomes). To construct an instrument they drew straight lines between particular locations in inland China to the nearest “treaty port” (for example, Tianjin), an urban center that was established ca. 1860. If this straight line passed through a
Chinese county, then the instrument for that county equaled one, and zero otherwise. The fundamental assumption is that, all other factors held constant, (i) a lower cost rail network is preferable to a higher cost network (ii) a shorter line is less costly to build than a longer line and (iii) the shortest distance between two points is a straight line.

We followed the same general logic for the United States first identifying all cities and towns of population 2,500 or more in the 1820 census (these are named in Figure 3). Next we identified nine major ports in 1820 from customs information. These ports were Baltimore, Boston, Charleston, New Orleans, New York, Norfolk, Philadelphia, Portland (ME), and Savannah. We then drew straight lines from each interior city/town to the nearest port. If a county lay along a straight line as drawn, our instrument takes the value one, zero otherwise (Figure 3).

Table 3 shows the IV results for various sample specifications. The first stage coefficients are uniformly positive and highly significant, indicating that our IV does predict rail access in 1850 as hypothesized. The second stage, or IV estimates, are all positive and significant and quantitatively large. In the first column, we use the full sample of establishments in 1850. According to the IV estimate, rail access increases the likelihood that an establishment is a factory by nearly 19 percentage points, a very large impact relative to the sample mean. In column 2 we exclude observations located in our major ports, in order to be sure that any such observations are not driving our results. The IV coefficient is slightly smaller, but still positive, large, and statistically significant. We further restrict the sample in the last column by excluding states for which the instrument has a
value of zero for all counties in the sample. This change slightly lowers the coefficient, but it remains large, positive, and statistically significant.

Lastly, instead of simply using the size of a firm’s labor force as the discriminant between factories and other types of establishments we have substituted a different dependent variable, the percentage of workers who were female. Goldin and Sokoloff (1982) demonstrate that the percentage of women (and boys) among all workers is a useful measure of the extent to which firms substitute unskilled for skilled labor in the process of capturing economies of scale associated with division of labor. As can be seen in Table 4, the IV estimates are again positive and highly significant. Firms that were located in counties that gained rail access were more likely to employ women relative to men, a sign that they were engaging in division of labor.

4. Concluding Remarks

In the nineteenth century the United States experienced a transportation revolution and an industrial revolution. In this paper we report on a preliminary investigation of a particular link between the two revolutions – whether improved access to transportation networks increased the proportion of manufacturing establishments that were factories. The idea here, a very old one in economics, is that establishments that operated in larger markets were more likely to engage in division of labor.
Our empirical analysis derives from a newly created and linked sample of county level data on transportation access and establishment level data from the 1850-70 censuses of manufacturing. The transportation database has been created from digitized 19th century transportation maps that have been overlaid on maps showing county boundaries, enabling us to measure whether or not, in particular, a railroad operated in a county in a given census year.

Using two separate identification strategies, we showed that rail access was positively and significantly associated with the probability that an establishment was a factory, which we identify to be establishments with sixteen or more workers. The first identification strategy is a difference-in-difference analysis applied to repeated cross sections of establishments, while the second is an instrumental variable estimation applied to the 1850 sample of firms. Although the magnitudes of the coefficients vary, all are positive and many are large and statistically significant -- large enough, indeed, to attribute a quantitatively significant fraction of the rise in factory establishments to the coming of the railroad.
Table 1: Sample Statistics

<table>
<thead>
<tr>
<th>Year</th>
<th>1850</th>
<th>1860</th>
<th>1870</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of</td>
<td>67.5%</td>
<td>85.3%</td>
<td>95.3%</td>
</tr>
<tr>
<td>establishments in counties with rail access</td>
<td>(89.0%)</td>
<td>(93.9%)</td>
<td>(98.0%)</td>
</tr>
<tr>
<td>% factory, establishments in counties with no rail access</td>
<td>3.9%</td>
<td>4.7%</td>
<td>1.3%</td>
</tr>
<tr>
<td>% factory, establishments in counties with rail access</td>
<td>10.6%</td>
<td>10.6%</td>
<td>10.7%</td>
</tr>
<tr>
<td>Difference, Row 3 - Row 2, percentage points</td>
<td>6.7</td>
<td>5.9</td>
<td>9.4</td>
</tr>
<tr>
<td>% factory (≥ 16 workers)</td>
<td>8.4% [60.3%]</td>
<td>9.7% [67.1%]</td>
<td>10.3% [71.6%]</td>
</tr>
<tr>
<td>N(establishments)</td>
<td>5,492</td>
<td>5,210</td>
<td>4,746</td>
</tr>
</tbody>
</table>

Unit of observation is the manufacturing establishment. County has rail access = 1 if railroad passes through county boundary (1850 boundaries). (): county has rail or water access (canal, river, ocean or Great Lakes border). []: percent of workers employed in factories.
Table 2: Difference-in-Differences Estimates: Manufacturing Establishments, 1850-70

<table>
<thead>
<tr>
<th>County gains rail access in:</th>
<th>No Controls</th>
<th>No Controls, Sample restricted to urban establishments</th>
<th>Urban + 2 digit SIC controls</th>
<th>Urban + 2 digit SIC controls, Sample restricted to urban establishments</th>
<th>2-digit SIC controls, Sample restricted to Urban establishments with water access</th>
</tr>
</thead>
<tbody>
<tr>
<td>1850s</td>
<td>0.018 (0.017)</td>
<td>0.006 (0.017)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1860s</td>
<td>0.069* (0.022)</td>
<td>0.056* (0.021)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After 1850</td>
<td>0.027 (0.016)</td>
<td>0.080 (0.065)</td>
<td>0.015 (0.016)</td>
<td>0.098 (0.059)</td>
<td>0.124* (0.063)</td>
</tr>
<tr>
<td>N</td>
<td>15,488</td>
<td>15,488</td>
<td>4,062</td>
<td>15,488</td>
<td>15,488</td>
</tr>
</tbody>
</table>

Observations pooled from 1850-70 samples. All regressions include year and county fixed effects. Urban = 1 if establishment is located in town/village/city of population 2,500 or more. Standard errors (in parentheses) are clustered at county level. *Significant at 5 percent level or better. Column 8: sample restricted to urban observations in counties with water access (canal or river passes through county, or ocean or Great Lakes frontage). In this sample, % of establishments in counties with rail access increases from 87.6 percent in 1850 to 98.3 percent in 1870.
Table 3: Instrumental Variables Estimates: Factory Status in 1850

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Full Sample</th>
<th>Port Cities Excluded</th>
<th>Port Cities and States with IV = 0 Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factory = 1</td>
<td>0.189*</td>
<td>0.165*</td>
<td>0.159*</td>
</tr>
<tr>
<td></td>
<td>(0.062)</td>
<td>(0.058)</td>
<td>(0.061)</td>
</tr>
<tr>
<td>First Stage</td>
<td>0.241*</td>
<td>0.247*</td>
<td>0.224*</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.043)</td>
<td>(0.043)</td>
</tr>
<tr>
<td>Sample mean, factory = 1</td>
<td>0.084</td>
<td>0.076</td>
<td>0.087</td>
</tr>
</tbody>
</table>

Dependent variable = 1 if number of workers (men + women) >=16. Coefficient estimates are virtually unchanged if one (Sokoloff 1984) is added to the count of workers. Independent variables: urban status (pop>2,500), presence of natural waterway in county (river, ocean access, Great Lakes), presence of canal, 2-digit industry, census region. IV = 1 if county lies on straight line between town/city with 2,500 or more population in 1820 and nearest major port (see previous slide). *significant at 5 percent level or better. Standard errors corrected for clustering at county level.
Table 4: Instrumental Variables Estimates: Percent Female in Workforce, 1850 Sample

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Full Sample</th>
<th>Port Cities Excluded</th>
<th>Port Cities and States with IV = 0 excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Female</td>
<td>0.070*</td>
<td>0.066*</td>
<td>0.054**</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.027)</td>
<td>(0.029)</td>
</tr>
<tr>
<td>First Stage</td>
<td>0.241*</td>
<td>0.247*</td>
<td>0.224*</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.043)</td>
<td>(0.043)</td>
</tr>
<tr>
<td>Sample mean, Percent</td>
<td>0.054</td>
<td>0.048</td>
<td>0.056</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>5,492</td>
<td>5,238</td>
<td>3,986</td>
</tr>
</tbody>
</table>

Dependent variable = women/(men + women). See notes to previous table for independent variables. **significant at 10 percent level.
Figure 1: Navigable Waterways Mapped Against 1860 County Boundaries
Figure 2: Counties with Rail Access in 1850 and 1860
Figure 3: Interior Urban Centers (Population > 2,500) in 1820 Connected to Closest Major Port City
References


Atack, Jeremy, Fred Bateman, and Robert A. Margo. 2008b. “Revisiting the Transportation Revolution in America,” unpublished paper, Department of Economics, Vanderbilt University, Nashville TN.


During American Industrialization. New York: Cambridge University Press.


(Washington DC: GPO)