The Ties that Bind: Railroad Gauge Standards, Collusion, and Internal Trade in the 19th Century U.S.

Daniel P. Gross*
Harvard Business School and NBER

July 5, 2017

first draft: March 22, 2016

for latest draft, click here

Abstract:

Compatibility standards are pervasive in the modern economy, and a target for public and private investments, yet evidence on their economic importance is scarce. I study the conversion of 13,000 miles of railroad track in the U.S. South to standard gauge on May 31 and June 1, 1886 as a large-scale natural experiment in compatibility. Using route-level freight traffic data, I find a large redistribution of traffic from steamships to railroads that declines with distance, but no effect on aggregate shipments or prices, possibly due to carriers' anticompetitive conduct. Counterfactuals suggest that in a more competitive market, half of the cost savings from compatibility might have been passed through to prices, generating nearly a 10% increase in shipments – though in the absence of collusion, the gauge change itself may come into question.

JEL Classification: F15, L15, L92, N71

Keywords: Railroad gauge; Standards; Integration; Incompatibility; Trade

---

*Address: Harvard Business School, Soldiers Field Road, Boston, MA 02163, USA; email: dgross@hbs.edu. I am grateful to Dominick Bartelme, Brad DeLong, Barry Eichengreen, Shane Greenstein, Josh Lerner, Marty Olney, and Claudia Steinwender for their feedback at early stages of this project, and to audiences at BU Questrom, Harvard (Economics and HBS), Haverford, Hebrew University, LMU-Munich, MIT Sloan, NYU Stern, Queen's University in Canada, Tel Aviv University, Tufts, Vanderbilt, Yale, the 2016 Georgetown Colloquium on the Economics and Regulation of the Freight Rail Industry, the 2017 ASSA meetings, and the 2017 Searle Conference on Innovation Economics for their many helpful comments. I also thank the Historical Collections team at Baker Library for their phenomenal support in providing access to historical data, and the Berkeley Economic History Lab and the Harvard Business School Division of Faculty and Research for financial support. This research began during graduate studies and was thus was conducted in part with the support of NSF Graduate Research Fellowship Grant No. DGE-1106400 and an EHA Graduate Fellowship. All errors are my own.

On November 10, 2006, seventeen Asian countries ratified the Trans-Asian Railway Network Agreement, under which they agreed to integrate into a continental railroad network by connecting lines but refrained from adopting standards for interoperability (UNTC 2006), namely a common gauge (track width). There are now five distinct gauges in use across the Asian network, necessitating costly interchange where railroads connect. Over the same period, former Soviet republics such as Lithuania, Latvia, Estonia, and Ukraine have been seeking increased economic integration with Europe, and several have gained accession to the European Union, but the movement of goods and labor to and from Europe is similarly impeded by differences in gauge.

Compatibility is not only an important feature of transport networks: compatibility standards are pervasive in the modern economy, as evidenced by the vast collection of standards and standards-setting organizations (SSOs) convened around the world today (Baron and Spulber 2015).[1,2] In theory, incompatibilities impose a tax on transactions in the form of a fixed cost of conversion, but there is little evidence that documents whether these costs can ever be large enough to materially affect economic activity, especially when adapters can help bridge the gap. Due to the challenge of tying economic outcomes to compatibility, and a lack of standards-adoption events at large enough scale to have measurable effects, such questions remain unanswered.

This paper studies the conversion of all 13,000 miles of non-standardized railroad track in the U.S. South to a standard-compatible gauge on May 31 to June 1, 1886 as a test of the effects of compatibility in railway networks on trade. In the 1860s, breaks in gauge were pervasive across the U.S. railway network, with railroads constructed in as many as 23 distinct gauges (Siddall 1969). By the 1880s, this count had effectively narrowed to two: 5' 0'' gauge in the South, and 4' 8.5'' ("standard") gauge throughout the rest of the country. The gauge change instantly integrated the South into the national transportation network. Using historical freight traffic data from the Southern Railway & Steamship Association – a cartel of the major Southern railroads and steamship lines – this paper estimates the effects of railroad gauge standardization on freight shipments between the developing South and the industrial North at the end of the nineteenth century.

I find that the gauge change triggered a significant redistribution of freight traffic into the South from steamships to all-rail but did not affect total shipments through 1890. Over the same period,

[1]A significant economics literature on compatibility standards has developed over the last 30 years, in the context of research on information and communications technology with network effects. The theoretical literature traces back to the seminal contributions of Farrell and Saloner (1985, 1986, 1988, 1992) and Katz and Shapiro (1985, 1986). The empirical literature is considerably less developed, due to a lack of data (as noted by Baron and Spulber 2015). Existing empirical research has studied related topics, such as standards battles in consumer electronics (Augereau et al. 2006) and the behavior, impacts, and antitrust treatment of SSOs (e.g., Simcoe 2012, Rysman and Simcoe 2008, Anton and Yao 1995). A third subliterature studies path dependence in standards and technological lock-in, concentrating on the history of the QWERTY keyboard as an example (Arthur 1989, David 1985, Liebowitz and Margolis 1990, 1995). However there are few papers that examine the impacts of standards directly.

[2]Technical standards for interoperability also have a long history: standardization was one of the hallmark features of the American system of manufacturing that propelled the U.S. to the forefront of industrialization in the 19th century and is now pervasive in the U.S. and abroad (Hounshell 1985).

records show that the cartel maintained its prices, implying that railroads did not pass through any of the cost-savings achieved by the conversion. I then estimate a model of supply and demand for freight transport on the sampled routes and show that had the cartel been broken, the gauge change might have produced a 10 percent decline in average freight rates and a 9 percent increase in aggregate shipments on the sampled routes. The effects of the gauge change were thus large yet potentially hindered by the collusive conduct of the industry.

The first U.S. railroads were constructed as local and regional enterprises to serve local needs. At this time, opinions over the optimal gauge varied, and technical specifications of each railroad were in the hands of the chief engineer. Without the vision of a national network, distinct gauges were adopted by early railroads in different parts of the country, and subsequent construction tended to adopt the neighboring gauge – leading to the formation of nine different "gauge regions" in the U.S., and a tenth in eastern Canada, by the 1860s (Puffert 2000, 2009). As a national network began to emerge, the costs of these incompatibilities became too great to bear, and railroads gradually converged on a common gauge, through conversion and new construction.

By the 1880s, nearly all U.S. railroads had adopted the 4'8.5'' gauge, except for those in the South. Data from both the U.S. Department of the Interior and Poor's Manual of Railroads confirm that whereas other regions had 95% or more of their track in standard gauge, 75% of that in Southern states was in an incompatible, 5'0'' gauge (even more if excluding Virginia and North Carolina). Though adapters had developed to overcome breaks in gauge, all were imperfect, and accounts suggest they were a substantial second-best to a fully integrated network.

In 1881 and 1885, two major 5'0'' railroads connecting the South to the Midwest converted their tracks to standard gauge, increasing pressure on the remaining Southern railroads to follow suit and providing a template for execution. In early 1886, the members of the Southern Railway & Steamship Association (SRSA) cartel, which together comprised a majority of mileage in the South, agreed to convert all track to the standard-compatible gauge of 4'9'' en masse over the two days of May 31 and June 1, 1886, with all traffic halting on May 30 and resuming by the evening of June 1, effortlessly traversing the former breaks in gauge.[3] The conversion was carefully planned, seamlessly executed, and well-documented by contemporaries.

The primary purpose of the cartel was to create and enforce noncompetitive pricing. It pursued this goal via rate maintenance agreements and an enforcement mechanism whereby members were allotted a fraction of route-level traffic, and those exceeding their allotment paid the excess revenue

[3]The gauge of 4'9'' was selected to conform to that of the Pennsylvania Railroad – an important connecting line – and with the belief that a smaller change would reduce the expense of converting rolling stock, but it was understood to be compatible with the 4'8.5'' standard (Taylor and Neu 1956, Puffert 2009). As Taylor and Neu write, "such a deviation was not considered a serious obstacle to through shipment." The U.S. Government similarly noted in 1880 that "gauges from 4'9.375'' to 4'8'' may be considered standard," as the same rolling stock may be used on either "without objection" (U.S. Department of the Interior 1883).

into a central fund for redistribution to other members. To implement this mechanism, the SRSA collected records of freight traffic carried to and from Southern cities where two or more members operated, which were then reported to members for key routes.

I use SRSA freight traffic data at the route-year level to estimate the effects of the gauge change on merchandise shipments from the North into the South. Invoking a variant on a triple-differences design, I compare within-route traffic borne entirely by rail versus by steamship, before and after the conversion to 4' 9'' gauge, allowing the effects to vary with route length, which generates route-level variation in the unit cost of a break in gauge. Steamships are a natural comparison group for all-rail traffic, as seaborne freight circumvented the gauge breaks and was therefore operationally unaffected by the conversion to a standard-compatible gauge.

The cartel records yield a balanced panel of 52 routes with inbound merchandise shipments data pre- and post-standardization. Within this sample, I find that the gauge change caused a sharp increase in all-rail traffic relative to steamship traffic, with the effect strongest on shorter routes and dissipating after roughly 700 to 750 miles; when split across the two all-rail pathways into the South, I find relatively larger increases for the less-trafficked routing. The results are robust to a variety of fixed effects, as well as within assorted subsamples.

Market share models return similar results, indicating a redistribution of traffic from steamships to railroads, with effects dissipating at similar distances. However, I find no differential growth in total shipments on shorter versus longer routes through 1890: the effects are limited to substitution across modes. One possible explanation is that adjustment on the aggregate margin took several years, and the panel is too short for these effects to appear in the data. However, the presence of the cartel is a distinctive feature of the setting, and is further accentuated by evidence that cartel prices did not decline following the gauge change. I thus turn to the question of whether collusive pricing may have constrained growth in aggregate shipments.

I estimate a model of supply and demand for freight shipment over the sampled routes and use the estimates to simulate a counterfactual in which the all-rail and steamship modes compete on price. The results suggest that if the cartel were broken, the conversion to a compatible gauge could have increased total traffic by roughly 10 percent, primarily due to a significant reduction in prices: in stark contrast to history, on average 50 percent of railroads' post-change cost savings are passed through to prices in this counterfactual. As it were, stock returns to U.S. railroads at the time of the conversion indicate that investors believed it would generate a windfall for Southern railroads, particularly those where the breaks in gauge were once located.

These results contribute first and foremost to the economics literature on technical standards and compatibility, which has rich theoretical origins (Farrell and Saloner 1985, 1986; Katz and Shapiro 1985, 1986), but where empirical evidence remains thin. This paper shows that compatibility can have a large effect on economic activity in settings where traffic is exchanged across interconnected networks, such as communications and transportation. In doing so, it provides this literature with a clear example of the costs of incompatibility and the potential inadequacy of conversion devices, and it challenges the view that technology lock-in is an inherently rare phenomenon or confined to communications industries (e.g., Spulber 2008): as previously noted, breaks in gauge persist around the world today. The fact that incompatible gauge persisted for decades in the United States, and that a cartel was at the center of the gauge change, also challenges the idea that lock-in is unlikely to be the result of market failures (Liebowitz and Margolis 1995).

The results also add a new dimension to research on how transportation infrastructure historically facilitated trade (e.g., Donaldson 2015), bringing into focus the importance of compatible gauge in railway networks. In doing so, the paper addresses a gap in the literature relating compatibility to trade, an issue which long been a concern for policy (WTO 2005) but on which there is almost no empirical work (Gandal 2001), excepting two recent studies on containerization in international shipping (Rua 2014, Bernhofen et al. 2016). This paper provides insight into the role that compatibility in transport networks can play in promoting trade – indeed, incompatibility could be binned as one of the sources of the well-documented border effect in the trade literature (e.g., McCallum 1995). These findings bear immediate relevance given that breaks in gauge continue to impede rail transportation in regions seeking more economic integration.

Finally, this paper brings into focus a tension between compatibility and product market competition in networked industries: collusion (or consolidation) may be necessary for firms to internalize the external returns to compatibility and recover the fixed cost of the investment, but it also reduces the likelihood that resulting cost savings will be passed through to consumers, limiting the scope for welfare gains. To my knowledge, this tension has not been fully explored, but further study is beyond the scope of the paper and I leave it to future research.

The paper is organized as follows. Section 1 reviews U.S. railroad history and the natural experiment at the heart of the paper. Section 2 introduces the data and the estimation strategy. Section 3 estimates the effects of the gauge change on mode traffic shares and total shipments, identifies the empirical puzzle, and discusses potential explanations, emphasizing the role of the cartel. Section 4 then estimates supply and demand for freight transport on the sampled routes, and Section 5 uses the results to evaluate the effect of the gauge change in a counterfactual with competition. Section 6 then shows what actually happened to affected carriers' stock prices following the gauge change. Section 7 discusses key lessons, particularly as related to (i) the benefits of interoperability and (ii) the mediating influence of product market competition, as well as the implications for modern international railway networks. Section 8 concludes.

1 History of U.S. Railroads and Gauge Standards

Diversity in gauge characterized U.S. railroads for most of the 19th century. The first railroads were built with a local or at most regional scope, and "there was little expectation that [they] would one day form an independent, interconnected" network (Puffert 2009), obviating any perceived benefits of coordinating on a common gauge. Gauges were instead chosen by each railroad's chief engineer, and without clear evidence of an optimal gauge standard, diversity proliferated. As Puffert (2009) recounts, the first wave of construction in the 1830s used four distinct gauges (4'8.5'', 4'9'', 4'10'', and 5'0''), a second wave in the 1840s added three broader gauges to the mix (5'4'', 5'6'', 6'0''), and a "third wave of experimentation" in the second half of the century introduced several narrow gauges, the most common of which were 3'0'' and 3'6''. Amongst this set, only 4'8.5'' and 4'9'' were mutually compatible and allowed for seamless interchange of traffic.[4]

The industry nevertheless recognized the advantages of interoperability, as subsequent construction typically adopted the gauge of neighboring railroads. By the 1860s, a national network had begun to emerge, but it was plagued by breaks in gauge as well as minor gaps in the physical network – such that there were nine distinct "gauge regions" in the U.S. during the Civil War, and a tenth in Canada, each predominantly using a different gauge than neighboring regions. Panel (A) of Figure 1 shows the state of U.S. railroads east of the Mississippi River at this time, identifying lines with 4'8.5'' ("standard" gauge), 5'0'' ("Southern" gauge), and other widths.

[Figure 1 about here]

Precise estimates of the cost of breaks in gauge are not available from the historical literature, but contemporaries in the 1850s noted that each break in gauge imposed a full-day delay on through shipments and necessitated significant labor and capital for transshipment, which at the time was performed manually, aided by cranes (Poor 1851, Taylor and Neu 1956). Diversity also required railroads to preserve a large fleet of idle rolling stock at each break for transferring freight. Several adapters developed to reduce these costs, such as bogie exchange (whereby each rail car would be hoisted, and its chassis replaced with one of a different gauge), transporter cars (which carried cars of a different gauge), adjustable-gauge wheels, and multiple-gauge track. Although bogie exchange was the most common means of interchange, it was time-consuming and yielded a mismatched car and bogie, which ran at reduced speeds and were prone to tipping on curves. The alternatives were equally deficient: transporter cars were difficult to load and similarly created instability; variable-

[4] See Puffert (2009) for a comprehensive discussion of the origins of U.S. railroad gauge. To this day, experts' opinion over the optimal gauge varies, though the choice is (i) understood to vary with operating conditions, and (ii) involves tradeoffs, such that there is no dominating standard. Even so, experts tend to agree that wider gauge is preferable to the modern standard (4'8.5'') for its speed, stability, and carrying capacity (Puffert 2009).

gauge wheels loosened, causing derailment; and third rails required a gauge differential of at least eight inches and were prohibitively expensive to construct and maintain.

After the Civil War, several pressures coincided to induce private efforts towards standardization, including growing demand for interregional freight traffic and increasing trade in perishable goods, which were sensitive to delays at breaks in gauge; competition within routes (to provide faster service); and consolidation across routes (internalizing the externalities). Despite known technical shortcomings (Puffert 2009), 4' 8.5'' became the standard to which railroads conformed: not only did standard gauge comprise a majority of U.S. mileage in every decade since the first railroads were built, but it was also the principal gauge in the Northeast and Midwest, the loci of trade in manufactured and agricultural goods. By the early 1880s, the common-gauge regions using 4' 10'', 5' 6'', and 6' 0'' had all converted to standard gauge, effectively leaving only two gauges in widespread use: 5' 0'' in the South, and 4' 8.5'' in the rest of the country.[5]

1.1 The Southern Railway & Steamship Association

Concurrent with (but independent of) these trends, Southern freight carriers self-organized into the SRSA cartel in 1875, following a series of rate wars. The cartel's express purpose was rate maintenance: the preamble to the cartel agreement asserts the intent of achieving "a proper correlation of rates," to protect both its members and consumers from "irregular and fluctuating" prices and "unjust discrimination" that favored certain markets over others (SRSA 1875). Membership was open to all railroads and steamships operating south of the Potomac and Ohio Rivers and east of the Mississippi and included nearly all major carriers in the region. Despite a rocky start, and no clear model to follow, by the 1880s the SRSA was sophisticated, successful, and "one of the most powerful and disciplined" traffic pools in the country (White 1993) – one that has been documented many times over (e.g., Hudson 1890, Joubert 1949, Argue 1990).[6]

The cartel had its own full-time administration, which had the responsibility of carrying out the terms of the cartel agreement, making new rules as necessary, and settling internal disputes. The mechanism used to ensure that members adhered to the prices set by the cartel's rate committee

[5] Over this same period, physical gaps in the network were also being closed by cross-town connections between depots (e.g., Richmond in 1867) and bridges over the major rivers (e.g., the Ohio River at Louisville in 1868 and Cincinnati in 1877), such that differences in gauge were the primary obstacle to a physically integrated network. Even where rivers were not bridged, gauge differences on either side of a river crossing were costly, as railroads typically ferried entire rail cars across the river. A third impediment to through traffic was the moral hazard inherent to relinquishing control over rolling stock on adjoining lines, or allowing other railroads' cars to use (and potentially damage) one's own tracks. These issues were resolved around the same time by contracting innovations that established joint ownership of rolling stock (Puffert 2009). Vertical relationships are discussed further in Appendix B.

[6] The SRSA both preceded and was the model for future railroad cartels, including the Joint Executive Committee, which governed railroads running between the Midwest and East Coast and has been widely studied in the economics literature (e.g., Ulen 1979, Porter 1983, Ellison 1994, and others). Though the SRSA has received less attention, contemporaries claimed that it "came nearer to fulfilling the purposes for which it was intended than any other association ever formed for the regulation of competition in this country" (Haines 1905).

was apportionment: carriers serving a competed route were allotted a fixed proportion of traffic, determined by "the average amount of freight hauled in past years" (Joubert 1949). In the cartel's early years, carriers who exceeded their allotment were required to submit the excess revenue for redistribution to other members, less a one-cent (later half-cent) per ton-mile allowance for the cost of carriage. This plan quickly unraveled when members reneged ex-post, and the agreement was amended to require members to deposit 20% of revenue with the cartel at the time of shipment, out of which these transfers would be made. To enforce the agreement, the cartel installed agents at stations to record carriers' daily traffic and revenue, appointed inspectors to ensure that freight was being properly weighed and classified, and regularly audited members' accounting records. For a select set of routes, the cartel also compiled these data into monthly traffic reports, which it then circulated to cartel members and have since been preserved.

The SRSA initially governed inbound merchandise shipments, and outbound cotton and textiles, between a dozen interior Southern cities where two or more members competed and points in the North. Coverage soon grew to include many other interior Southern cities. In 1885, the cartel was further expanded to cover passenger traffic on these routes, and in 1887, it folded rapidly-growing "Western" routes (between the South and the Midwest) into the agreement. Given the late addition of these routes to the cartel, this paper focuses on the effects of the gauge standardization on so-called "Eastern" traffic between the North and South.

The amended mechanism proved so effective that in 1887, the cartel reported that "since 1878, all balances have been paid and rates thoroughly maintained," excepting one month in 1878 (Hudson 1890) – a sharp contrast to frequent pre-cartel rate wars. There are several reasons why the cartel was successful, beginning with the mechanism itself, which muted carriers' incentives to cut prices to capture a greater share of traffic. Railroads that refused to join the cartel were denied through traffic, which effectively amounted to a boycott. The SRSA also demonstrated early on that when competing carriers (members or not) deviated from cartel prices, it would act quickly and decisively by setting destructively low rates until compliance resumed.

The passage of the Interstate Commerce Act (ICA) in February 1887 presented a new kind of threat to the cartel. The ICA prohibited traffic pooling, making the cartel's apportionment mechanism illegal, however the act "by no means put an end to the power of the Association" (Hudson 1890).[7] The SRSA responded by transitioning to a system of fines for price deviations, with mileage-based deposits, and it continued collecting and disseminating members' traffic and revenue. The SRSA

[7] The act had little impact in its early years, and if anything may have empowered carriers and helped stabilized prices (Prager 1989, Blonigen and Cristea 2013), consistent with the revisionist interpretation of Kolko (1965), who notes that railroads welcomed the regulation. Other sources suggest that the content of the ICA, and the Interstate Commerce Commission it created, were subject to near-total regulatory capture. Gilligan et al. (1990) point out that Albert Fink, the founder and first commissioner of the SRSA and "among the most respected railway officials in the nation" (White 1993), provided much of the structure for the ICA, and that southern railroads were among its "chief beneficiaries" as evidenced by abnormal stock price returns following its enactment.

continued to operate in this way until 1890, when the Sherman Act delivered the lethal blow by prohibiting combinations in restraint of trade. At this point, the cartel stopped circulating traffic tables. Though it took several years for the courts to resolve initial ambiguities over whether the SRSA met the statute's definition, by 1897 the cartel had dissolved.

1.2 The Gauge Change

As trade between the South and other regions accelerated during Reconstruction, incompatibilities became increasingly costly: by the 1880s, "not a prominent point could be found on the border [of the South] without its hoist and acres of extra trucks" (Hudson 1887), and the total cost of delays were growing one-for-one with volume. The first cracks in the 5' 0'' network developed in 1881 and 1885, when two major lines linking the South to the Midwest (the Illinois Central and the Mobile & Ohio) converted their tracks to standard gauge, increasing pressure on their Southern competitors and connections to follow suit, and providing a template for execution.

On February 2-3, 1886, cartel members convened to discuss the compatibility problem and agreed to convert all of their track to a 4' 9'', standard-compatible gauge on May 31 and June 1 of that year.[8] The gauge change was carefully planned and seamlessly executed: in the weeks leading up to the event, railroads removed the ties on their tracks and took a subset of their rolling stock (rail cars, locomotives) out of service to adjust its gauge; then, on the evening of May 30, all traffic halted, and teams of hired labor worked up and down each line, removing remaining ties, shifting one rail 3'' inwards, resetting ties, and moving to the next segment. By midday on June 1, 13,000 miles of track had been converted to 4' 9'', and traffic had resumed, with freight now moving freely across Southern borders in a physically integrated railroad network.[9]

To verify the scale of the conversion, I collect individual railroads' gauges and mileage from Poor's Manual of Railroads (1882-1890), an annual publication listing the universe of railroads in North America. Table 1 shows the fraction of railroad track in standard-compatible gauge by region and year throughout the 1880s. Whereas other regions generally had 95% of their track in standard or standard-compatible gauge by 1881, nearly 70% of Southern railroad mileage began the decade in 5' 0'' gauge. The discrepancy remained until the year of the gauge change: between 1885 and 1887, the total in 5' 0'' gauge declined by 13,006 miles, and the fraction of Southern railroad in standard or standard-compatible gauge discretely jumped from 29% to 92%. Panels (B) and (C) of Figure 1

[8] The 4' 9'' gauge was selected to match the Pennsylvania Railroad system, an important connection in the Mid-Atlantic, and because it was thought that smaller adjustments were less costly (Puffert 2009).

[9] The execution of the gauge change is covered in greater depth by several other sources. For extended summaries, see Taylor and Neu (1956) or Puffert (2009). For a detailed, contemporary discussion of the nuts and bolts of the planning and execution, see Hudson (1887). Extrapolating from the costs of converting the Louisville & Nashville system (detailed in its 1886 annual report) to all 5' 0'' mileage, the total cost of the gauge change was likely around \$1.2 million in 1886, equivalent to \$31 million today. To put the cost in perspective, the L&N's expenditure on the gauge change was roughly 30% of its construction expense in 1886 and 37% of net income.

show the updated gauge of the 1861 railroad network as of 1881 and 1891, respectively (omitting new construction), illustrating the geographic scope of the conversion.

[Table 1 about here]

The historical record indicates that network externalities were important in propelling the gauge change and were recognized by contemporaries. The returns to adopting a compatible gauge were low for railroads on the periphery if interior neighbors did not follow – the effect would be to shift the break from the top to the bottom of the line, with no benefits to through traffic – and negative for interior railroads acting alone. But the gains to all parties were high under a coordinated, regional conversion. Because the returns to conversion were increasing in the size of the standard gauge network, one large system could also induce a cascade of standardization.[10]

The cartel thus served three roles in supporting the gauge change. First, it provided an institutional venue for coordinating on a common gauge and organizing the conversion event itself. More importantly, collusion internalized the externalities to adopting the common standard, and non-competitive pricing ensured that railroads could recoup the expense of conversion. Without either collusion or consolidation, the gauge change itself might not have occurred at this time or scale, and integration would likely have been significantly retarded.

2 Data and Empirical Strategy

I use SRSA records of freight traffic into and out of the South by railroad and steamship to study the effects of the gauge change.[11] I restrict attention to annual merchandise shipments from Northern port cities to cities in the interior South, as merchandise comprised the largest fraction of tonnage in the South at this time and an even greater fraction of value (U.S. Department of Interior 1883).[12] The sample throughout the paper is a balanced panel of 52 North-South routes (4 origins x 13 destinations) with merchandise shipments apportioned, monitored, and reported by the cartel both

[10] As one contemporary noted, once the Louisville & Nashville (the largest railroad in the South at the time, with over 2,000 miles) determined that it must adopt a standard-compatible gauge to compete for interregional traffic, other large systems recognized that they "must move with the Louisville and Nashville," and smaller railroads then "had no choice in the matter but to join ranks" (Hudson 1887, p. 668).

[11] Route-level traffic data (both freight and passenger) from this period are rare. Data on the routes in this paper are available only because they were compiled into tables which were circulated to SRSA members, by order of the cartel's commissioner, and later bound and preserved. Despite an extended effort, I have been unable to find comparable data for other routes to supplement those discussed and studied below.

[12] Cotton shipments in the reverse direction comprise a smaller sample, were dwindling over the period due to growth in Southern textile production, and could potentially be influenced by fluctuations in foreign demand, and are thus excluded. Shipments of merchandise and commodities from the Midwest are also excluded, as they grew rapidly over the decade and only became part of the collusive agreement (and thus, had their traffic monitored and recorded) beginning in 1887, subsequent to the gauge change (Hudson 1890).

before and after the gauge change, observed over the 1883-84 to 1889-90 fiscal years. Figure 2 provides a map of the origins and destinations in this sample. The gauge change coincides precisely with the end of the SRSA's 1885-86 fiscal year on May 31.

[Figure 2 about here]

Due to the diffuse ownership of the network, shipments to the interior South necessarily traversed multiple railroads, or a steamship and a railroad, to reach their destination.[13] The SRSA tables report traffic and revenue by routing (see Appendix A), which I aggregate up to mode: all-rail versus steamship. I include separate observations for the two all-rail paths into the South, the Atlantic Coast Line (ACL) and the Piedmont Air Line (PAL), each of whose constituent railroads shared a common owner, and which are explicitly denoted in the SRSA tables. The primary sample thus has 1,092 (= 52·3·7) observations at the route-mode-year level.[14]

The empirical strategy compares all-rail and steamship traffic within individual routes before and after the gauge change. Because they bypassed breaks in gauge, steamships were not directly affected by the gauge change and accordingly provide a comparison group for all-rail shipments. In all cases, I relax the effects to vary with distance: breaks in gauge imposed a fixed cost on through shipments, and would be a larger proportion of total costs on short routes relative to long routes. The first set of specifications thus take the following form:

$$\begin{aligned}\ln(Q_{mrt}) = \beta_0 + \beta_1 Rail_{mrt} + \beta_2 Post_t + \beta_3 Rail_{mrt} Post_t \\ + \beta_4 Rail_{mrt} Post_t Dist_r + X_{mrt}\gamma + \varepsilon_{mrt} \ , \end{aligned} \qquad (1)$$

where Q_{mrt} is pounds of traffic carried by mode m, on route r, in year t; $Rail_{mrt}$ is an indicator for the all-rail mode (ACL and PAL); $Post_t$ indicates the post-period; and $Dist_r$ is the distance from origin to destination. Throughout the analysis, I measure distance as straight-line distance, rather than traveled distance, which is not observed for either mode and unobservable for seaborne shipments (contemporary sources in Appendix A indicate straight-line and rail network distance are in fixed proportion for the sampled routes). The X_{mrt} term includes all other interactions plus fixed effects. In all specifications, I cluster standard errors by route.

As Appendix Table A.3 shows, the sampled routes provide sufficient variation in distance (from 500 to 1,100 miles) to identify the elasticity with respect to the unit costs of breaks in gauge. The above specification will establish whether all-rail and steamship traffic diverged following the gauge

[13] Appendix B discusses the vertical structure of the industry at this time, including how equipment and cargo were transferred, and how revenue was divided, across connecting carriers. It appears that whereas revenues were prorated according to mileage, costs were privately incurred – including the costs of breaks in gauge.

[14] To simplify the exposition, the specifications below are presented as if the ACL and PAL were aggregated into a single observation, but the tables in Section 3 include them as separate observations.

change, but it does not identify the effects of standardized gauge on all-rail shipments per se, as steamships may have concurrently lost traffic to the railroads, magnifying the estimated differences. In a second set of specifications, I estimate a simple logit demand model on market shares, rather than quantities, which can account for this interdependence. Suppose mode shares are generated by discrete consumer choices, where each mode has utility:

$$\begin{aligned} u_{imrt} = \big[&\beta_0 + \beta_1 Rail_{mrt} + \beta_2 Post_t + \beta_3 Rail_{mrt} Post_t \\ &+ \beta_4 Rail_{mrt} Post_t Dist_r + X_{mrt}\gamma + \xi_{mrt}\big] + \eta_{imrt} \equiv \mu_{mrt} + \eta_{imrt} \ , \end{aligned}$$

where η_{imrt} is an error term distributed type-I extreme value. The market share for each mode is then $s_{mrt} = \frac{\exp(\mu_{mrt})}{\sum_{\ell=1,2}\exp(\mu_{\ell rt})}$, which is jointly determined with that of the other mode. Indexing railroads as $m = 1$ and steamships as $m = 2$, we can write:

$$\begin{aligned} \ln(s_{1rt}) - \ln(s_{2rt}) &= \mu_{1rt} - \mu_{2rt} \\ &= \tilde{\beta}_0 + \tilde{\beta}_1 Post_t + \tilde{\beta}_2 Post_t Dist_r + \gamma_r + \varepsilon_{rt} \ , \end{aligned} \tag{2}$$

where the γ_r are route fixed effects, which will subsume the $Dist_r$ variable. This model can then be estimated by OLS on the set of all-rail observations.

Finally, to evaluate the effects of the gauge change on combined traffic, I collapse the sample to route-years and estimate a regression for total shipments:

$$\ln\left(Q_{rt}\right) = \beta_0 + \beta_1 Post_t + \beta_2 Post_t Dist_r + \gamma_r + \varepsilon_{rt} \tag{3}$$

To the extent that the gauge change differentially impacted shorter versus longer routes, the effects on aggregate shipments should emerge in the interaction.

3 Standardization and Freight Shipments

In this section, I examine the first-order effects of the gauge change, showing that the standardization of Southern gauge triggered a large redistribution of traffic from steamships to railroads but does not appear to have affected aggregate shipments. It may be helpful to provide a roadmap to these results in advance. I first present descriptive statistics for the sampled routes, pre- and post-gauge change, which foreshadow the results that follow. I then estimate the effects of the gauge change on all-rail versus steamship traffic, as well as on aggregate shipments, where the empirical puzzle emerges. At the end of the section, I discuss possible explanations for the results, focusing especially on the ways in which cartel pricing may have limited the growth in aggregate shipments and ultimately the consumer welfare gains from standardization.

3.1 Descriptive Statistics

Table 2 provides descriptive statistics for the sampled routes, comparing shorter and longer routes (<25th and >75th percentiles, respectively), pre- versus post-gauge change. The table shows means and standard errors of tonnage, revenue, and all-rail shares. The shorter routes in the sample had less traffic than longer routes throughout the sample period but carried more of this traffic by rail. Total shipments grew at similar rates for the shorter and longer routes over the sample period. However, following the gauge change, the all-rail share of traffic on shorter routes jumped from an average of 40% to an average of 56%, an increase significant beyond the one percent level. In contrast, the all-rail share on longer routes declined from 23% to 19%, not a statistically significant difference. These results provide the first hints of the puzzle that will emerge below: the gauge change was important enough to prompt substitution across modes, but evidently not enough to increase aggregate shipments in the short- to medium-run.

[Table 2 about here]

3.2 Effects of the Gauge Change

3.2.1 Distributional Effects

Table 3 estimates the specification in Equation (1), regressing log traffic for route-mode-years on (i) indicators for the all-rail mode and the post-period, (ii) route length (in units of 100 miles), and (iii) all two-way and three-way interactions. Column (1) estimates this model as specified, while Columns (2) through (6) add an assortment of fixed effects for routes, modes, years, route-modes, and route-years. Only the focal parameters are shown in the table.

[Table 3 about here]

This first cut indicates that all-rail traffic grew significantly more quickly than steamship traffic on short routes after the gauge change, with the effect diminishing with route length and reaching zero at around 750 miles – the median route in the sample. The effects are consistent across all specifications, irrespective of the choice of fixed effects. To put the magnitudes in perspective, the estimates imply an 80% higher increase in all-rail traffic on the shortest route in the sample (which is 500 miles long), versus a decrease on the longest routes.

In Table 4, I explore heterogeneity in these effects across the two all-rail paths between the North and South, the ACL and PAL. This exercise is also in part a robustness check to see that both lines were affected by the conversion to the new gauge. The results show that they were, with the less-trafficked line (the ACL) experiencing a larger percentage increase in traffic. I find that the effects dissipate at similar distances for both carriers, roughly 710 miles – statistically comparable to the break-even distance in the previous table at usual significance levels.

[Table 4 about here]

As previously discussed, a specification in quantities can establish whether all-rail and steamship traffic diverged following the gauge change, and whether the results are robust to controls. However, the estimates are not causal effects, due to the interdependence of all-rail and steamship traffic with imperfect competition: steamships may have been indirectly affected by the gauge change if they lost traffic to railroads. In Table 5, I estimate a simple logit demand model that accounts for this interdependence (Equation 2), in which the outcome variable is the log difference in all-rail and steamship shares of traffic in the given route-year. In taking this difference, most fixed effects from the previous table are eliminated, such that Table 5 contains only two variants of the regression: without and with route fixed effects (Columns 1 and 2, respectively).

[Table 5 about here]

The results continue to show positive effects on all-rail shares that decline with distance, significant beyond the one percent level. The estimates are similar across the two specifications, and the effect of the gauge change is estimated to dissipate at roughly 730 miles, statistically and economically comparable to the previous tables. In Table 6, I split the effects out for the ACL and PAL. The effects are present for both carriers, relatively larger for the ACL (the smaller of the two carriers), and dissipate at around 710 miles, consistent with previous results.

[Table 6 about here]

We can also break the regression out into annual effects, to test for pre-trends and to explore how the response to the gauge change varied over time. *A priori* it is unclear whether the effects would be immediate or would phase in: on the one hand, the change was immediate and comprehensive, and improved service available from the first day after the conversion; on the other hand, it may have taken time for information to spread, or for shippers to adjust. Table 7 estimates a variant of the model in Equation (2), allowing the coefficients to vary by year.

[Table 7 about here]

Relative to the omitted year of 1884, the table shows that all-rail and steamship shares did not change in a statistically significant way over the next two years leading up to the gauge change – if anything, the signs of the estimates suggest all-rail shares were declining. However, beginning in the first year post-gauge change, we see a significant jump in all-rail shares that grows each year through the end of the panel, leveling out around 1890.

In Appendix D, I test the sensitivity of these results to dropping individual origins, destinations, and years from the cartel sample. Given the limited number of routes (52) and the somewhat short panel (3 years pre-gauge change, 4 years post), these checks are necessary to establish that the results are not driven by outliers or subsamples (for example, by routes originating in Baltimore, the origin nearest to the South). I find consistent results throughout. I also run similar regressions for revenue, which is provided alongside the traffic statistics in the SRSA tables, and find identical effects of the gauge change in sign and magnitude. This result is a natural consequence of the high correlation between traffic and revenue in the data ($\rho = 0.99$).

3.2.2 Aggregate Effects

The results thus far show that the gauge change caused growth in all-rail market share, but leave ambiguous to what degree this effect is strictly substitution across modes versus new activity in the market. Table 8 addresses this question, collapsing the data to the route level and examining the effects on total traffic and revenue (Equation 3). The even-numbered columns include route fixed effects. Across all specifications, we see no evidence that shorter routes (where previous tables showed the gauge change had the strongest effects on market shares) grew more quickly than longer routes following the gauge change: the variation in post-gauge change traffic growth for routes of different length is a true, and precisely-estimated, zero.

[Table 8 about here]

3.3 Explaining the Results

The evidence that traffic shifted from steamships to all-rail following the gauge change is sensible, albeit not self-evident, given the existing use of technologies that reduced the cost of breaks in gauge. This result alone contributes to a long-running literature on compatibility, which thus far has lacked clear examples of its impact on economic activity. Large effects were anticipated by contemporaries: the secretary of the SRSA asserted in an 1886 U.S. Treasury Department report that all-rail shipments "will in the next few years develop very much, because of the change of all lines to one uniform gauge" (Sindall 1886). On the eve of the gauge change, the *Commercial and Financial Chronicle* (CFC) wrote that its importance "can hardly be overstated," as shippers "will be saved delays," railroads "will be able to cheapen the cost of handling traffic," and the event will stimulate "the development of trade and industry between the different sections" of the country (CFC 1886). However, given the observed effects on all-rail traffic shares, the absence of an effect on total shipments is surprising: existing shippers were sensitive to the gauge change, but marginal or extramarginal shippers were not. As a result, any welfare gains were in fact limited to the railroads and to inframarginal shippers and consumers.

One potential answer to this puzzle may lie with the cartel itself. An additional piece of evidence is that although the gauge change increased railroads' capacity and reduced their costs of carriage, nominal cartel freight rates did not change around the conversion, which may have precluded any growth in aggregate shipments. The SRSA's Circular Letters periodically include rate tables, which list current cartel freight rates on different routes, by class of merchandise.[15] These tables show the prices that all carriers on the given route were committed to charging shippers, and they make it possible to track route-level price changes over time.

Figure 3 shows the distribution of rate changes on the routes in these circulars that are also in the sample for this paper (total of 36 routes, out of the 52 routes with traffic data). The left panel of the figure shows a histogram of changes in class-level freight rates from February 1885 to March 1886, a few months prior to the gauge change. The right panel shows the equivalent histogram for March 1886 to July 1887, one year after the gauge change. Each observation in the figure is a route-class, and with 36 routes and 13 freight rate classes, there are 468 observations per panel. An overwhelming fraction of routes do not see any price changes over this period. The handful of price changes after the gauge change were increases, rather than decreases, and were limited to two routes: Philadelphia-Montgomery and Philadelphia-Selma.[16]

[Figure 3 about here]

Theoretical predictions for prices are ambiguous, as the quality of all-rail service increased simultaneously as the cost of providing that service declined. But there are other reasons why prices were unlikely to change, starting with the fact that costs were privately borne by each carrier in a given line, whereas revenues were collected jointly at the time of shipment and divided, under terms negotiated outside of the cartel and typically *pro rata* according to mileage.[17] As a result, only

[15] The SRSA classified freight into 13 different categories (classes) and set prices at the route and class level. More irregular, fragile, or valuable goods were classified into higher classes, which were charged the highest rates. Rates on lower classes were generally a fixed proportion of the first-class rate for each route.

[16] Cartel prices were not always this stable: until the early 1880s, prices were reduced regularly, under pressures of competition from alternative routing outside the scope of the cartel. Multiple sources have documented this decline, while also observing that price reductions ended in the early- to mid-1880s (e.g., Hudson (1890) documents prices from Boston, New York, Philadelphia, and Baltimore to Atlanta from 1875 onward, and shows that rate reductions occurred every 1-2 years until 1884, after which rates went unchanged).

[17] The division of joint revenue across connecting carriers was negotiated outside of the cartel, and is not detailed in

railroads connecting the South to other regions necessarily benefited from the removal of breaks in gauge at the border. Given that the cartel freight rates applied uniformly to all shipments on a given route to avoid perceptions that individual members were favored, steamship companies in the cartel were unlikely to accede to rate reductions, as were interior railroads – neither of which saw direct cost savings as a result of the gauge change. In the event of disagreement, rate-setting escalated to the cartel's board of arbitration, which in practice was often the rate-setting body, and it did not view a rate reduction as the appropriate response. In effect, it appears the cartel believed its prices to be sufficiently close to profit-maximizing to leave them unchanged. In doing so, the cartel avoided passing through the cost savings from compatibility, enriching its members and limiting consumer welfare gains from the gauge change.

The idea that cartel pricing explains the empirical puzzle is merely one possibility. Another is that the market for final goods needed more time to adjust, and the time horizon of the cartel data is too short to see the aggregate effects materialize. But the presence of the cartel is a conspicuous feature of the setting. To further explore whether cartel pricing could have limited the effects of the Southern gauge change, the next two sections estimate a joint model of demand and supply for freight shipment on the sampled routes, and use the estimates to simulate the effects of the gauge change in a counterfactual in which railroads and steamships compete.

4 The Market for Shipping

To model the market for North-South freight shipment, suppose shippers in a given route and year make a discrete choice between all-rail and steamships to maximize utility, and that railroads and steamships set prices to maximize joint or individual profits (under collusion or competition, respectively), under the constraint that collusive prices must be the same for all carriers on a given route (as was the case for the cartel). This choice problem is true to the setting, insofar as shippers selected their routing at the time of shipment (Haines 1905), but it reduces the dimensionality of the choice to the level of modes rather than specific carriers.[18]

In this model, markets are defined as route-years and treated as independent. There are 244 markets with traffic data for which prices are also known, and these markets comprise the sample for this

cartel records. However, both contemporary sources and cartel documents indicate that joint revenue was typically divided *pro rata* on the basis of mileage. These sources discuss the possibility of allowances for terminal expenses or other fixed costs, but there is no discussion of allowances for breaks in gauge, and the precise arrangement may have varied from route to route, or line to line. See Appendix B for discussion.

[18] Although the SRSA traffic data are provided by routing, because routing between origin and destination in general involves multiple connecting carriers, varies across markets, and can partly overlap for short segments such as the last mile (see Appendix A), as well as the fundamental distinction between all-rail and steamship modes in both the data and the narrative record, reducing the dimensionality of the competitive question to modes is a compromise choice, but it is sufficient to evaluate the question to a first approximation.

exercise. Within each, I observe the share of traffic carried by each mode, but as in other models of demand we must assume a latent market size, which I fix to twice the observed traffic. Appendix E tests the sensitivity of the results (particularly the counterfactual) to the market size assumption and finds qualitatively similar results for other values.

Each market is characterized by prices $\{P_{1rt}, P_{2rt}\}$, quantities $\{Q_{1rt}, Q_{2rt}\}$, and marginal costs $\{MC_{1rt}, MC_{2rt}\}$ where $m = 1$ denotes the all-rail mode and $m = 2$ denotes the steamship mode. Under the cartel, $P_{1rt} = P_{2rt} = P_{rt}$, whereas under competition mode prices are allowed to differ. Quantities throughout this and the next section are measured in 100-pound units, while prices and marginal costs are in dollars per 100 pounds of freight on the given route.[19] Though the SRSA priced freight according to a complex classification scheme (with more valuable, irregular, or fragile goods charged higher prices, and bulk commodities charged the lowest prices), the SRSA traffic tables aggregate shipments across classes of merchandise. I thus calculate a weighted average price for each route, weighting by the share of route traffic in each class in 1880, and treat freight as being homogeneous in composition and priced at this index.

4.1 Demand

Suppose the latent utility of each mode m for shipper i on route-year rt is u_{imrt}, and shippers make a discrete choice over mode to maximize utility, as follows:

$$\max_m u_{imrt} = G_{mrt} \left(\beta_1 + \beta_2 Dist_r\right) - \alpha P_{mrt} + \gamma_m + \xi_{mrt} + \eta_{imrt} \equiv \delta_{mrt} + \eta_{imrt} \ ,$$

where G_{mrt} indicates that mode m includes a break in gauge or requires transshipment in route-year rt, $Dist_r$ is distance between route r's origin and destination, P_{mrt} is the price of mode m in route-year rt, γ_m are mode dummies reflecting inherent preferences for one mode or the other, ξ_{mrt} is a mean-zero, route-mode-year specific unobservable, and η_{imrt} is an i.i.d. type-I extreme value error. Mean utility of each mode is denoted as δ_{mrt}, and the outside option (withholding shipment) is indexed $m = 0$ and normalized to have $\delta_{0rt} = 0$.

Under this specification, consumers may have an inherent preference for a given mode, but choices are also influenced by prices and by breaks in gauge or transshipment. From this specification, we obtain choice probabilities (market shares) with the following form:

$$s_{mrt}(P_{mrt}) = \frac{\exp(\delta_{mrt}(P_{mrt}))}{1 + \sum_{\ell} \exp(\delta_{\ell rt}(P_{\ell rt}))}$$

We can log-difference the outside good market share to obtain the following reduced-form equation, which can then be used to estimate the demand parameters:

[19]Marginal costs should be interpreted as the costs of carriage for 100 pounds of freight on a given route, via a given mode, in a given year, and are a function of the mode, distance, and transshipment or breaks in gauge.

$$\ln(s_{mrt}) - \ln(s_{0rt}) = G_{mrt}\left(\beta_1 + \beta_2 Dist_r\right) - \alpha P_{mrt} + \gamma_m + \xi_{mrt} \tag{4}$$

When this model is taken to the cartel data, P_{mrt} will effectively be reduced to P_r, as prices on the sampled routes are constant within routes across modes and nearly constant over time. I estimate this model by 2SLS, instrumenting for prices with route length, a principal determinant of costs and prices for long-distance freight shipment. The necessary assumption to satisfy the exclusion restriction is that distance only affects total demand and the choice of mode through prices. Although one of the most established results in the trade literature is that trade declines with distance, this fact does not undermine the exclusion restriction here, since the model is estimated on market shares, and the inside goods' combined share is exogenously fixed to 50% for all markets as a result of the assumption over the latent market size.

4.2 Supply

The cartel is assumed to have set a single price in each route-year to maximize joint profits, with this price common to both modes. Formally, the cartel's problem is:

$$\begin{aligned}\max_{P_{rt}} \Pi_{rt} &= \sum_m (P_{rt} - MC_{mrt}) \cdot Q_{mrt}(P_{rt}) \\ &= M_{rt} \sum_m (P_{rt} - MC_{mrt}) \cdot s_{mrt}(P_{rt})\end{aligned}$$

with

$$MC_{mrt} = \lambda_m Dist_r + \theta_m G_{mrt} + \omega_{rt} \ ,$$

where λ_m is the marginal cost of shipping an additional 100 pounds of freight per 100 miles of route length via mode m, θ_m is the cost of interchange at breaks in gauge (for all-rail traffic) or transshipment at port (for steamship traffic), and ω_{rt} is a mean-zero cost shock shared by both modes on a given route, in a given year.

The cartel's first-order condition for each route-year is:

$$(s_1 + s_2) + (P - MC_1) \cdot \frac{\partial s_1(P)}{\partial P} + (P - MC_2) \cdot \frac{\partial s_2(P)}{\partial P} = 0$$

which can be rewritten to be linear in the cost parameters, as in Equation (5) below. I invoke this equation to estimate the supply parameters by OLS.

$$\begin{aligned}\left(P + \frac{s_1 + s_2}{\partial s_1/\partial P + \partial s_2/\partial P}\right) &= \lambda_1 \left(\frac{Dist_r(\partial s_1/\partial P)}{\partial s_1/\partial P + \partial s_2/\partial P}\right) + \lambda_2 \left(\frac{Dist_r(\partial s_2/\partial P)}{\partial s_1/\partial P + \partial s_2/\partial P}\right) \\ &\quad + \theta_1 \left(\frac{G_1(\partial s_1/P)}{\partial s_1/\partial P + \partial s_2/\partial P}\right) + \theta_2 \left(\frac{G_2(\partial s_2/\partial P)}{\partial s_1/\partial P + \partial s_2/\partial P}\right) + \omega \end{aligned} \tag{5}$$

4.3 Estimation

I proceed with estimation via a bootstrap procedure, in five steps:[20]

1. Estimate demand (Equation 4) via 2SLS, with clustered standard errors
2. Draw demand parameters from their joint distribution
3. Use draws to predict market shares and calculate elasticities
4. Estimate supply (Equation 5) via OLS with clustered SEs
5. Bootstrap: Repeat steps 2 through 5 (x2000)

This procedure will return a single set of estimates for demand, with standard errors clustered by route as before, and 2,000 sets of estimates for supply, which account for the parameters' sampling variance as well as the variance of the predicted market shares and elasticities entering the supply equation, which are generated from estimated parameters themselves.

4.4 Parameter Estimates

Table 9 shows the estimates for demand and supply. The demand estimates (left panel) indicate an embedded preference for steamships versus all-rail and a negative effect of breaks in gauge on demand, diminishing with route length as before and breaking even around 790 miles. We also see that distance strongly predicts freight tariffs ($F > 220$), validating the choice of instrument, and a price coefficient that implies high price-sensitivity ($\alpha = -9$).

[Table 9 about here]

The cost estimates (right panel) show that breaks in gauge imposed a large fixed cost on through shipments, at roughly 8 cents per 100 pounds – over 10% of the median freight tariff for routes in this sample. This estimate reflects not only the direct cost of interchange, but also indirect costs of time delays, the idle rolling stock kept at points of interchange, and the purchase and maintenance of steam hoists and other equipment, which could be capitalized into prices (White 1993). Breaks in gauge were still cheaper than transshipment at ports, the cost of which is estimated at nearly $0.21 per 100 pounds, due to the increased labor intensity, delays, and risk of stolen or damaged goods. We see similar operating costs per 100 miles of straight-line distance for each mode, approximately 4 cents per 100 pounds, or 0.8 cents per ton-mile – in the same neighborhood as the 0.5-1 cents per

[20] In concept, a supply and demand system can be jointly estimated via GMM or by a bootstrap, but a GMM procedure here is complicated by the different dimensionalities of the demand and pricing equations (specified at the level of route-mode-years and route-years, respectively) and sensitive to starting values. Given its transparency and computational simplicity in this setting, I opt for the bootstrap.

ton-mile that the cartel reimbursed its members for costs of carriage (see Section 1). Although the variable costs of steamships were lower than those of railroads per mile traveled, steamships (and their last-mile railroad connections) would have had to travel a longer, less-direct path to interior Southern cities, offsetting this cost advantage in the estimates. Quantitatively, the cost of a break in gauge was similar to that of extending the route by 180 miles (= [0.079/0.044] × 100), and the cost of transshipment similar to that of adding 450 miles.[21]

5 Standardization with Competition

We can apply the estimates to simulate a counterfactual in which railroads and steamships compete on prices in a Nash-Bertrand equilibrium. This exercise assumes a single price-setter for each mode and abstracts away from the vertical industry structure, which the historical record indicates was orthogonal to pricing (see Appendix B), but thus only partially breaks the cartel. To simulate this counterfactual, we need to solve for the competitive equilibrium. Each mode m will set prices to maximize profits, with the following first-order condition:

$$s_{mrt}(P_{1rt}, P_{2rt}) + (P_{mrt} - MC_{mrt}) \cdot \frac{\partial s_{mrt}}{\partial P_{mrt}} = 0$$

This condition can be rearranged into the familiar pricing equation:

$$\begin{bmatrix} P_{1rt} \\ P_{2rt} \end{bmatrix} = \begin{bmatrix} MC_{1rt} \\ MC_{2rt} \end{bmatrix} + \begin{bmatrix} \frac{\partial s_{1rt}}{\partial P_{1rt}} & 0 \\ 0 & \frac{\partial s_{2rt}}{\partial P_{2rt}} \end{bmatrix}^{-1} \begin{bmatrix} s_{1rt}(P_{1rt}, P_{2rt}) \\ s_{2rt}(P_{1rt}, P_{2rt}) \end{bmatrix}$$

into which we can plug the parameter estimates and numerically solve for prices $\{\tilde{P}_{mrt}\}$, which in turn imply quantities $\{Q_{mrt}(\tilde{P}_{1rt}, \tilde{P}_{2rt})\}$ and profits $\{\Pi_{mrt}(\tilde{P}_{1rt}, \tilde{P}_{2rt})\}$.

Comparisons between collusive and competitive pricing, shipments, and profits per mode are shown in Table 10, separately for the pre-period (Panel A) and the post-period (Panel B). In the pre-period, competition would drive down average all-rail prices by 27% and steamship prices by 6%. The reduction in prices would generate a 21% increase in total traffic, powered by a near doubling in all-rail shipments from its relatively low base. In the post-period, railroads would have passed nearly half of the cost-savings from the gauge change through to prices, yielding even larger reductions in all-rail prices and increases in all-rail and total traffic in the post-period, relative to their realized

[21] Contemporary point estimates on the cost of a break in gauge could not be found, however observers in the 1850s claimed that breaks in gauge generated handling costs of "at least a half dollar per ton" (Poor 1851), or 2.5 cents per 100 pounds (at the lower bound of the 95% confidence interval for the estimate in Table 9), and a delay of 24 hours, equivalent to adding roughly 300 miles to the route. The handling costs and time delays would have been reduced by adapter technologies in use by the 1880s, but these estimates do not account for other, indirect costs (e.g., the cost of maintaining excess rolling stock), which may be large.

values. In both periods, industry profits would have declined sharply, although railroad profits are bolstered by the growth in traffic and cost savings generated by the gauge change.

[Table 10 about here]

The most direct test of the impact that the gauge change could have had on total shipments in a competitive market is to simulate a competitive post-period with and without breaks in gauge. This comparison avoids any potential contemporaneous changes in the market that could challenge the attribution of pre- versus post-gauge change differences in Table 10 to compatibility alone. Table 11 provides this comparison, showing that relative to a competitive post-period with incompatible gauge, standardizing the gauge reduces all-rail prices by 10% and increases total traffic by 9%, driven entirely by growth in all-rail shipments, which comes partly at the expense of steamships and partly from attracting new traffic into the market.

[Table 11 about here]

6 The View from Wall Street

The core results thus far suggest that the gauge change generated a windfall for Southern railroads, at the expense of steamship operators, and with only limited benefits to consumers. Although the data for studying the real effects of the gauge change and the implications for consumer welfare are limited to what is available in the cartel's records, our understanding of the effects on the carriers themselves can be rounded out by looking at stock prices.

To do so, I collect daily New York Stock Exchange (NYSE) closing prices from historical editions of the *New York Times* for January 1 to October 31, 1886. The vast majority of traded securities at this time were issued by railroads (146 of 177, including separately-listed preferred stock), and a dozen Southern railroads were traded during this period. Using these data, we can perform an event study around the gauge change. Although some information about the impending conversion was disclosed in advance, the discussion was limited to Southern newspapers and specialized railroad journals (see Appendix C) until late May, and the event itself was uncertain until the date drew closer. The gauge change appears to have only become a focus of the financial press on May 29, 1886, when the *Commercial and Financial Chronicle* (CFC) published a lengthy article notifying readers of the impending event and explaining its importance.

To execute the event study, I define an event window of two months around the gauge change (May 1, 1886 to June 30, 1886), estimate a standard market returns model on the preceding four months of railroad stock returns (through April 30, 1886), predict returns through the event window, and compute cumulative abnormal returns for each of the Southern railroads. Throughout this exercise, I restrict the sample to securities with at least 50 trading days in the estimation window and 100 trading days in the full sample to ensure that all estimates and tests are sufficiently-powered, but the results are not sensitive to the precise restriction.

The gauge change coincides with large, positive abnormal returns to the Southern railroads that were most directly affected. Figure 4 shows the cumulative abnormal returns to the Louisville & Nashville (L&N), the largest railroad in the South by mileage and one of two that directly connected the South to other regions and were listed on the NYSE. The L&N's cumulative abnormal returns are near zero and roughly constant until May 29 – the date that the CFC article is published – when it realizes a 4 percentage point positive abnormal return. Between May 29 and the end of the event window, the cumulative abnormal returns grew to 17 percentage points, as the impacts of the gauge change began to materialize. I find similar (albeit slightly higher variance) patterns for the Richmond & Danville, the other major system connecting the North and South, but no such effects for interior Southern railroads – suggesting that investors believed the benefits were mainly realized by the lines where breaks in gauge were located.

[Figure 4 about here]

7 Lessons and Modern Applications

These results offer lessons for both research and policy. Compatibility standards can be found in nearly every technical product and industry, and have been the focus of an important theoretical literature, yet to-date there is little evidence directly linking compatibility to economic outcomes, at large or for individual applications. In unveiling the ways in which the Southern gauge change affected trade, this paper provides an initial datapoint on the importance of compatibility standards and has implications for other settings where traffic is exchanged across connecting, incompatible networks, such as IT and communications. The episode challenges the view that long-lived incompatibility is inherently rare and confined to communications industries, and it brings into question whether firms in a competitive market will always have sufficient incentive to establish compatibility on their own (e.g., Liebowitz and Margolis 1995, Spulber 2008).

The counterfactual exercise also suggests there may be a deeper lesson on the interaction of standards with product market competition. In many networked settings, transactions are executed via intermediaries who provide physical or digital infrastructure for transmission, such as freight carriers (for physical trade), Internet service providers (for communications), and financial exchanges (for asset purchases). These intermediaries often must interconnect with others for delivery. This paper shows that compatibility at connection points can generate large consumer welfare gains –

but only if the cost savings are passed through to consumers, which may be unlikely to occur if service is not competed. Because these settings experience network effects and are inherently likely to be concentrated, a lack of competition is often a reality, making this issue of concern to antitrust regulators and a potential target for future research.

Direct Applications: Modern International Railways

The results also have direct application to modern-day railway networks. Breaks in gauge are still common around the world, especially in developing regions such as parts of Asia, Africa, and Latin America, and eastern Europe. These breaks often occur at national boundaries, though in some cases they are present within them as well – most notably in India, which is nearing the end of an effort to standardize the gauge of its 100,000-mile network. Appendix Figure F.1 illustrates how pervasive the problem is, showing a world map of countries color-coded by their principal gauge. Developing regions can have as many as four gauges in use.

The problem has not escaped the attention of policymakers: resolving differences in gauge has been a focal point in repeated international negotiations to integrate domestic railways into transcontinental networks in Europe, Asia, and the Middle East. The most recent example of such an agreement was the United Nations-brokered Trans-Asian Railway Network Agreement, ratified by 17 Asian countries in 2006 (UNTC 2006). The negotiations behind this agreement date back to the 1950s, when the U.N. Economic Commission for Asia and the Far East (now the U.N. Economic and Social Commission for Asia and the Pacific) set out to link Istanbul to Singapore. The intent was to establish more direct, overland routes between Europe and East Asia to support and promote continental trade, but the negotiations were "frustrated ... by the lack of a uniform railway gauge ... and by the presence of gaps, or missing links, in the route" (UNESCAP 1996). Gaps could be filled, but it proved impossible to agree on a common gauge, and when a treaty was finally ratified, it contained no provisions for standardizing the gauge.

The most germane example may be in Europe, where countries on the eastern European periphery such as the Baltic states, Belarus, and the Ukraine have been seeking to become more economically integrated with Western Europe, but freight and passenger rail traffic are impeded by differences in gauge: Western Europe is almost universally on standard gauge, whereas many eastern European countries remain on the Soviet broad gauge, which requires costly and time-consuming interchange to get people or goods across the border by rail. Moreover, the same adapters discussed in this paper (transshipment, bogie exchange, and variable gauge) are still the principal methods of interchange at these breaks in gauge, as can be seen in Appendix Table F.2.

Against this backdrop, the results of this paper offer lessons for present-day railway network integration. The main lesson is that eliminating breaks in gauge has historically significantly improved the quality of rail-based freight shipping services, enough to divert traffic from other modes – and if operators' cost-savings are passed through to consumers, perhaps enough to increase the total amount of exchange. It is important to nevertheless be cautious in extending these results to a different time period, geography, and market structure, but given the parallels, it seems appropriate to view the evidence in this paper as instructive of some of the potential benefits of compatibility in transnational railway networks.

8 Conclusion

This paper studies the conversion of 13,000 miles of railroad in the U.S. South to a standard-compatible gauge in 1886 on internal trade between the South and the North. The gauge change integrated the South into the national railroad network, and it provides an application with large-scale natural experiment to study the effects of compatibility standards on economic activity. Using records of merchandise shipments on 52 North-to-South routes from a cartel that governed this traffic, I find that the gauge change generated significant growth in all-rail market share that declines with route distance, but it did not affect total shipments.

As a potential explanation to this puzzle, I turn attention to the cartel, which held prices constant around the conversion, potentially hindering growth in aggregate shipments. I then ask whether the cost savings from the gauge change might have passed through to prices and increased freight traffic in a more competitive market: I estimate a model of the industry and simulate counterfactuals in which railroads and steamships compete on prices. The results of this exercise suggest that in a more competitive industry, the gauge change could have generated a 10% reduction in average all-rail prices and 9% growth in overall shipments.

The results offer several lessons, the foremost of which is that compatibility can have a large, material effect on economic activity in industries where exchange takes place over interconnected networks. The paper in particular sheds light on the potential benefits to standardizing the gauge of global railroad networks, which continue to suffer from breaks in gauge that necessitate costly interchange. Finally, the results point to a complex interaction of standardization and product market competition in networked environments: while collusion (or consolidation) increases firms' incentives to make their connecting networks compatible by internalizing the externalities, it also limits the pass-through of cost savings and the potential consumer welfare benefits. This tension presents a tradeoff for antitrust regulators that is underappreciated in the literature on standards and competition but is ripe for attention, given recent antitrust scrutiny of IT and communications firms whose network services benefit from interoperability.

References

Anton, James J. and Dennis A. Yao, "Standard-setting Consortia, Antitrust, and High-technology Industries," *Antitrust Law Journal*, 1995, *64* (1), 247–265.

Argue, David A., *Cartel Operation with Revenue Pooling and Output Quotas: The Southern Railway and Steamship Association* 1990. Unpublished dissertation.

Arthur, W. Brian, "Competing Technologies, Increasing Returns, and Lock-in by Historical Events," *The Economic Journal*, 1989, pp. 116–131.

Atack, Jeremy, *Historical Geographic Information Systems (GIS) database of U.S. Railroads for 1861* September 2015.

_ and Robert A. Margo, "The Impact of Access to Rail Transportation on Agricultural Improvement: The American Midwest as a Test Case, 1850–1860," *Journal of Transport and Land Use*, 2011, *4*, 5–18.

_ , Michael Haines, and Robert A. Margo, "Railroads and the Rise of the Factory: Evidence for the United States, 1850–1870," in Paul W. Rhode, Joshua Rosenbloom, and David Weiman, eds., *Economic Evolution and Revolutions in Historical Time*, Palo Alto: Stanford University Press, 2011.

Augereau, Angelique, Shane Greenstein, and Marc Rysman, "Coordination versus Differentiation in a Standards War: 56k Modems," *The RAND Journal of Economics*, 2006, *37* (4), 887–909.

Baron, Justus and Daniel F. Spulber, *Technology Standards and Standards Organizations: Introduction to the Searle Center Database.* 2015. Working paper.

Bernhofen, Daniel M., Zouheir El-Sahli, and Richard Kneller, *Estimating the Effects of the Container Revolution on World Trade.* 2013. CESifo Working Paper Series No. 4136.

Berry, Steven, James Levinsohn, and Ariel Pakes, "Automobile Prices in Market Equilibrium," *Econometrica*, 1995, *63*, 841–890.

Blonigen, Bruce A. and Anca Cristea, "The Effects of the Interstate Commerce Act on Transport Costs: Evidence from Wheat Prices," *Review of Industrial Organization*, 2013, *43* (1-2), 41–62.

David, Paul A., "Clio and the Economics of QWERTY," *American Economic Review*, 1985, *75* (2), 332–37.

Davis, Champion McDowell, *Atlantic Coast Line: Fragments of its History During Over a Century*, New York: Newcomen Society in North America, 1950.

Donaldson, Dave, "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," *American Economic Review*, 2015, *forthcoming.*

Ellison, Glenn, "Theories of Cartel Stability and the Joint Executive Committee," *The RAND Journal of Economics*, 1994, *25* (1), 37–57.

Farrell, Joseph and Garth Saloner, "Standardization, Compatibility, and Innovation," *The RAND Journal of Economics*, 1985, *16* (1), 70–83.

_ and _ , "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation," *American Economic Review*, 1986, *76* (5), 940–955.

_ and _ , "Coordination through Committees and Markets," *The RAND Journal of Economics*, 1988, *19* (2), 235–252.

_ and _ , "Converters, Compatibility, and the Control of Interfaces," *Journal of Industrial Economics*, 1992, *40* (1), 9–35.

Gandal, Neil, "Quantifying the Trade Impact of Compatibility Standards and Barriers: An Industrial Organization Perspective," in K.E. Maskus and J.S. Wilson, eds., *Quantifying the Impact of Technical Barriers to Trade: Can it be Done?*, Univeristy of Michigan Press 2001, pp. 137–154.

Haines, Henry S., *Restrictive Railway Legislation*, New York: The MacMillan Company, 1905.

Hudson, Henry, "The Southern Railway and Steamship Association," *Quarterly Journal of Economics*, 1890, *5* (1), 70–94.

Joubert, Willam H., *Southern Freight Rates in Transition*, Gainesville: University of Florida Press, 1949.

Katz, Michael L. and Carl Shapiro, "Network Externalities, Competition, and Compatibility," *American Economic Review*, 1985, *75* (3), 424–440.

_ **and** _ , "Technology Adoption in the Presence of Network Externalities," *Journal of Political Economy*, 1986, *94* (4), 822–41.

Kolko, Gabriel, *Railroads and Regulation, 1877-1916*, Princeton: Princeton University Press, 1965.

Liebowitz, S. J. and Stephen E. Margolis, "The Fable of the Keys," *Journal of Law & Economics*, 1990, *33* (1), 1–25.

_ **and** _ , "Path Dependence, Lock-in, and History," *Journal of Law, Economics, and Organization*, 1995, *11* (1), 205–226.

Louisville & Nashville Railroad, *Annual Report to Investors* 1886. Fiscal year ending June 30, 1886.

McCallum, John, "National Borders Matter: Canada-US Regional Trade Patterns," *American Economic Review*, 1995, *85* (3), 615–623.

Minnesota Population Center, *National Historical Geographic Information System: Version 2.0*, Minneapolis: University of Minnesota, 2011.

Organization, World Trade, *World Trade Report 2005: Exploring the Links between Trade, Standards, and the WTO.* 2005.

Poor, Henry V., "Cincinnati and Seaboard Railways," *American Railroad Journal*, 1851, *7* (37), 386.

_ , *Poor's Manual of Railroads of the United States.* 1868. Volumes 1882, -84, -86, -88, -90.

Porter, Robert H., "A Study of Cartel Stability: The Joint Executive Committee, 1880-1886," *The Bell Journal of Economics*, 1983, *14* (2), 301–314.

Prager, Robin A., "Using Stock Price Data to Measure the Effects of Regulation: The Interstate Commerce Act and the Railroad Industry," *The RAND Journal of Economics*, 1989, *20* (2), 280–290.

Puffert, Douglas J., "The Standardization of Track Gauge on North American Railways, 1830-1890," *The Journal of Economic History*, 2000, *60* (4), 933–960.

_ , "Path Dependence in Spatial Networks: The Standardization of Railway Track Gauge," *Explorations in Economic History*, 2002, *39* (3), 282–314.

_ , *Tracks across Continents, Paths through History: The Economic Dynamics of Standardization in Railway Gauge*, Chicago: University of Chicago Press, 2009.

Rua, Gisela, *Diffusion of Containerization.* 2014. FRB Finance and Economics Discussion Series No. 2014-88.

Rysman, Marc and Timothy Simcoe, "Patents and the Performance of Voluntary Standard-setting Organizations," *Management Science*, 2008, *54* (11), 1920–1934.

Siddall, William R., "Railroad Gauges and Spatial Interaction," *Geographical Review*, 1969, *59* (1), 29–57.

Simcoe, Timothy, "Standard Setting Committees: Consensus Governance for Shared Technology Platforms," *American Economic Review*, 2012, *102* (1), 305–336.

Sindall, Charles A., "Development of the Traffic between the Southern States and the Northern and Northwestern States," in Treasury Department, ed., *Report on the Internal Commerce of the United States*, Washington: Government Printing Office, 1886.

Southern Railway and Steamship Association (SRSA), *Circular Letters.* 1875. Volumes 1-24.

Taylor, George R. and Irene D. Neu, *The American Railroad Network, 1861-1890*, Urbana and Chicago: University of Illinois Press, 1956.

Ulen, Thomas S., *Cartels and Regulation: Late Nineteenth Century Railroad Collusion and the Creation of the Interstate Commerce Commission* 1979. Unpublished dissertation.

__ , "The Market for Regulation: The ICC from 1887 to 1920," *American Economic Review: Papers and Proceedings*, 1980, *70* (2), 306–310.

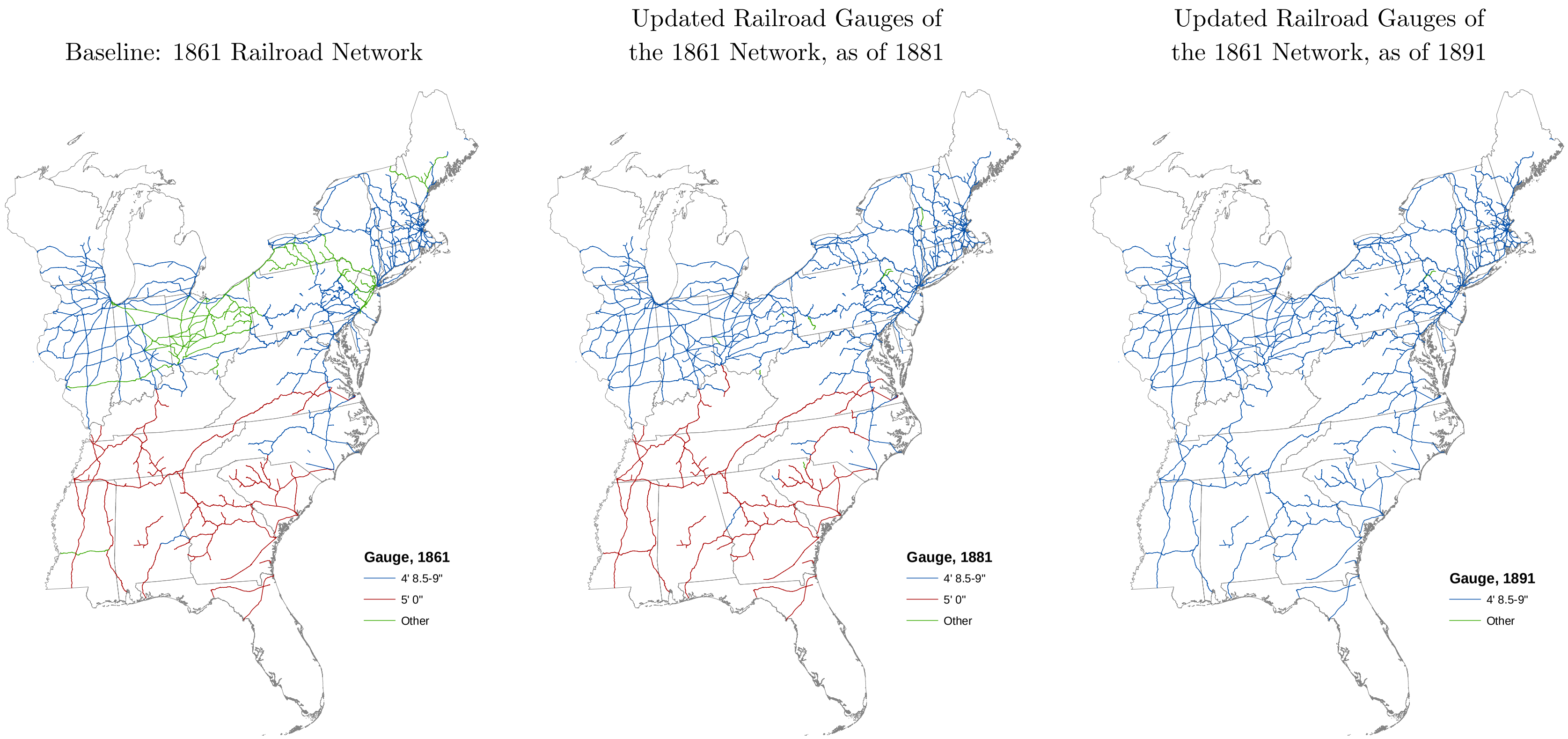
United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), *Trans-Asian Railway Route Requirements: Development of the Trans-Asian Railway in the Indo-China and ASEAN Subregion.* 1996.

United Nations Treaty Collection (UNTC), *European Agreement on Important International Combined Transport Lines and Related Installations (AGTC).* February 1991.

__ , *Intergovernmental Agreement on the Trans-Asian Railway Network.* April 2006.

U.S. Department of the Interior, *Statistical Report of the Railroads in the United States in 1880*, Washington: GPO, 1883.

Figure 1: Installed Railroad Gauge East of the Mississippi River, 1861–1891 (holding network fixed)

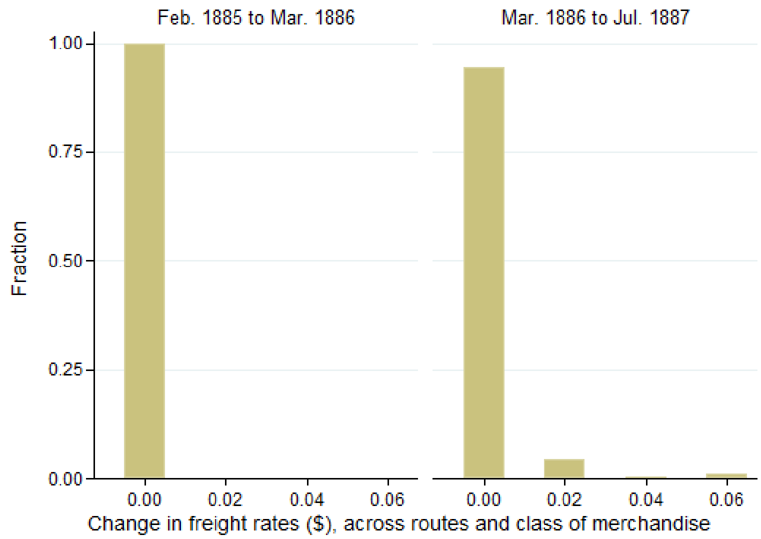


Notes: Figure illustrates the United States' transition to a unified, standard-gauge railroad network in the second half of the 19th century. The left-most panel shows the state of the railroad network east of the Mississippi River in 1861, color-coding segments of railroad by their gauge. The middle and right-most panels show the gauge in use in 1881 and 1891, respectively, holding the network fixed (omitting new construction). Network and gauge data for 1861 railroads obtained from the Atack (2015) Historical Transportation Shapefile of Railroads in the United States. Contemporary gauges for these same railroads or their subsequent acquirers in 1881 and 1891 were obtained from Poor's Manual of Railroads volumes for all railroads that could be matched. Over 99.5% of track miles in the 1861 network shown above were matched to the Poor's data in both 1881 and 1891.

Figure 2: Map of Sampled Origins (North) and Destinations (South)

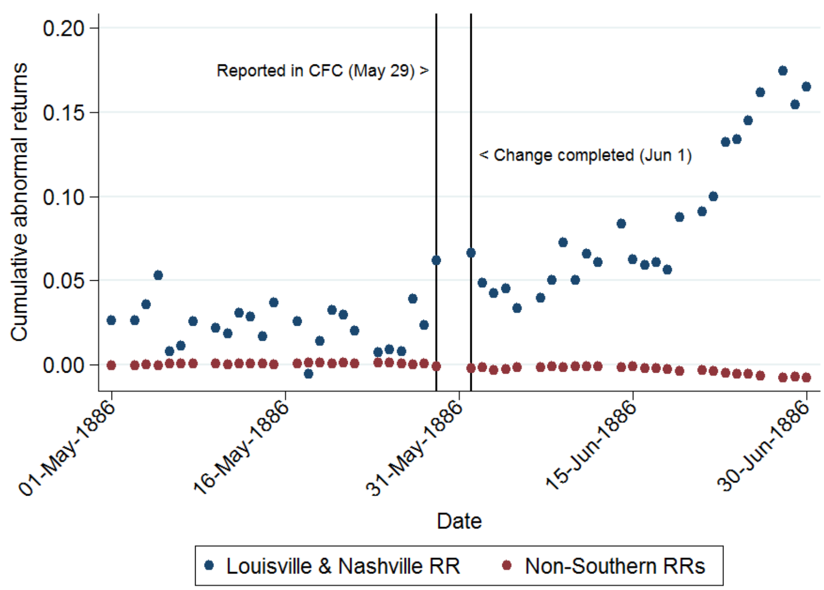
Notes: Figure shows the northern route origins and southern destinations for routes in the sample. These destinations are those for which data was reported by the Southern Railway and Steamship Association both before and after the gauge change. Not shown are two additional destinations in the data, "A. & W. Pt. Stations" (stations on the Atlanta and West Point Railroad between East Point and West Point, GA, 70 mi., whose traffic was reported collectively), and "W. & A. Stations" (stations on the Western and Atlantic Railroad between Chattanooga, TN and Marietta, GA, 87 mi.); these destinations are geotagged to the centroid of their respective endpoints. Freight transportation was available by all-rail routes traversing Virginia, Tennessee, and the Carolinas or by a combination of steamship and railroad, via southern port cities such as Charleston, Savannah, Norfolk, and Port Royal.

Figure 3: Distribution of Cartel Price Changes, pre- vs. post-Gauge Change



Notes: Figure shows the distribution of cartel price changes across routes and classes of merchandise from February 1885 to March 1886 (left panel) and March 1886 to July 1887 (right panel), for the subset of routes included in the SRSA rate tables. The handful of rate increases in the latter period come entirely from two routes: Philadelphia to Montgomery, and Philadelphia to Selma. Data from SRSA Circular Letters, Volumes 13-24.

Figure 4: Cumulative Abnormal Returns to L&N Stock, May 1 to June 30, 1886



Notes: Figure shows cumulative abnormal returns to the stock of the Louisville & Nashville Railroad, the largest railroad in the South by mileage and one of two that directly connected the South to other regions and were listed on the NYSE, in a two-month window around the gauge change. The figure marks two key dates around the gauge change: May 29, when the event was first announced and discussed at length in the *Commercial and Financial Chronicle*, and June 1, when the change was completed. See text for additional discussion. Data from *New York Times* historical stock quote tables.

Table 1: Approx. Miles of Railroad in each Gauge, by Region, 1881-1889 (Poor's Manual of Railroads)

	Pre-Gauge Change			Post-Gauge Change	
New England	**1881**	**1883**	**1885**	**1887**	**1889**
Miles in gauge:					
4' 8.5-9"	6,060.2	6,082.6	6,237.8	6,600.3	6,627.6
5' 0"	0.0	0.0	0.0	0.0	0.0
Other	191.1	201.2	180.4	184.6	116.5
Total Miles	6,251.3	6,283.8	6,418.2	6,784.9	6,744.1
Pct. 4' 8.5-9"	97%	97%	97%	97%	98%
Mid-Atlantic					
Miles in gauge:					
4' 8.5-9"	14,855.0	17,590.3	18,923.4	18,648.6	20,210.7
5' 0"	0.4	0.4	0.5	0.2	0.0
Other	990.2	997.4	868.3	772.0	682.5
Total Miles	15,845.6	18,588.1	19,792.2	19,420.9	20,893.3
Pct. 4' 8.5-9"	94%	95%	96%	96%	97%
Midwest					
Miles in gauge:					
4' 8.5-9"	34,904.3	38,669.2	37,904.4	42,241.2	45,938.1
5' 0"	0.0	0.0	0.0	0.0	0.0
Other	2,342.1	2,800.7	2,591.3	1,318.3	1,028.7
Total Miles	37,246.4	41,470.0	40,495.6	43,559.5	46,966.7
Pct. 4' 8.5-9"	94%	93%	94%	97%	98%
South (focal region)					
Miles in gauge:					
4' 8.5-9"	4,306.8	4,759.6	6,048.6	21,593.6	25,252.7
5' 0"	11,908.1	12,964.5	13,274.2	268.2	19.5
Other	1,042.7	1,592.6	1,371.5	1,734.9	1,521.2
Total Miles	17,257.5	19,316.6	20,694.3	23,596.7	26,793.4
Pct. 4' 8.5-9"	25%	25%	29%	92%	94%
Western States					
Miles in gauge:					
4' 8.5-9"	26,272.5	33,817.6	36,435.9	47,694.8	54,352.6
5' 0"	135.0	135.0	0.0	0.0	0.0
Other	3,427.4	5,623.2	4,642.0	4,253.6	3,965.9
Total Miles	29,834.8	39,575.8	41,078.0	51,948.4	58,318.5
Pct. 4' 8.5-9"	88%	85%	89%	92%	93%

Notes: Table shows the approximate miles of railroad in the U.S. from 1881 to 1889 in two-year intervals, by region and gauge, confirming the scale of the conversion: 13,000 miles of Southern railroad converted from 5'0" to 4' 9" between 1885 and 1887. Data from Poor's Manual of Railroads, which provides a near-complete, annual enumeration of U.S. railroads. The data are subject to regional classification errors which tend to over-attribute mileage to the Midwest, pulling from the Mid-Atlantic and West, as a result of railroads with principal operations in the Midwest extending into these regions. The table uses the regional definitions of the Poor's Manual; the southern states are Virginia, West Virginia, Kentucky, Tennessee, Mississippi, Alabama, Georgia, Florida, the Carolinas, and Louisiana.

Table 2: Descriptive Statistics: Traffic, Revenue, and All-Rail Shares, for Short vs. Long Routes

	Short Routes (<25th pctile)		**Long Routes (>75th pctile)**	
	Pre	**Post**	**Pre**	**Post**
Route-years	39	52	39	52
Route Distance (mi)	589.01	589.01	977.65	977.65
	(6.90)	(5.95)	(10.54)	(9.09)
Tons (1,000s)	715.88	818.55	1066.39	1161.54
	(130.58)	(134.66)	(210.85)	(221.31)
Revenue ($1,000s)	8.61	8.97	14.59	15.21
	(1.48)	(1.41)	(3.03)	(3.02)
All-Rail Share, Tonnage	0.40	0.56	0.23	0.19
	(0.04)	(0.03)	(0.03)	(0.03)
All-Rail Share, Revenue	0.41	0.57	0.24	0.20
	(0.04)	(0.03)	(0.03)	(0.03)

Notes: Table reports average tonnage, revenue, and all-rail shares of traffic and revenue for shorter versus longer routes (below the 25th percentile and above the 75th percentile of route length, respectively), before versus after the gauge change. Standard error of each mean in parentheses.

Table 3: Change in All-Rail Traffic

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.437***	2.429***	2.425***	2.484***	2.466***	2.541***
	(0.460)	(0.455)	(0.455)	(0.466)	(0.559)	(0.582)
* distance (100 mi)	-0.322***	-0.328***	-0.328***	-0.334***	-0.331***	-0.341***
	(0.059)	(0.059)	(0.059)	(0.060)	(0.073)	(0.075)
Breakeven distance	756.5	740.5	740.1	742.8	744.1	745.6
	(34.9)	(32.7)	(32.7)	(32.7)	(39.8)	(39.7)
N	1036	1036	1036	1036	1036	1036
R^2	0.32	0.67	0.67	0.73	0.70	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: Table estimates effect of the gauge change on merchandise shipments from North to South. Observations are route-mode-years. The treated group consists of the all-rail mode; the control group, the steamship mode. The "breakeven distance" at which the effects of standardization dissipate to zero is provided below the regression estimates. The dependent variable in all columns is log pounds of traffic. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table 4: Change in All-Rail Traffic, ACL and PAL

	(1)	(2)	(3)	(4)	(5)	(6)
A.C.L. x post-change	2.840***	2.852***	2.851***	2.826***	2.848***	2.809***
	(0.527)	(0.559)	(0.560)	(0.552)	(0.686)	(0.671)
* distance (100 mi)	-0.398***	-0.402***	-0.402***	-0.396***	-0.403***	-0.396***
	(0.071)	(0.076)	(0.076)	(0.074)	(0.094)	(0.090)
P.A.L. x post-change	1.809***	1.743***	1.733***	1.808***	1.748**	1.829**
	(0.555)	(0.610)	(0.609)	(0.607)	(0.754)	(0.754)
* distance (100 mi)	-0.238***	-0.244***	-0.243***	-0.248***	-0.247**	-0.253**
	(0.071)	(0.080)	(0.079)	(0.080)	(0.100)	(0.101)
Breakeven distance (A.C.L.)	713.6	709.6	709.7	713.4	705.9	709.8
	(32.5)	(32.7)	(32.8)	(34.5)	(39.0)	(41.5)
Breakeven distance (P.A.L.)	759.0	715.7	713.5	728.3	707.3	723.9
	(53.2)	(58.6)	(58.8)	(55.6)	(70.4)	(66.5)
N	1036	1036	1036	1036	1036	1036
R^2	0.48	0.83	0.84	0.89	0.86	0.91
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: Table estimates effect of the gauge change on merchandise shipments from North to South. Observations are route-mode-years. The treatment group consists of these carriers. The control group remains the steamship mode. The "breakeven distance" at which the effects of standardization dissipate to zero is provided below the regression estimates. The dependent variable in all columns is log pounds of traffic. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table 5: Effects on Traffic Shares

	(1)	(2)
All-rail x post-change	2.281***	2.400***
	(0.428)	(0.450)
* distance (100 mi)	-0.315***	-0.327***
	(0.056)	(0.058)
Breakeven distance	724.6	734.4
	(32.3)	(32.6)
N	676	676
R^2	0.12	0.45
Route FE		X

Notes: Table estimates effect of the gauge change on all-rail traffic shares. The dependent variable is the log difference in all-rail and steamship shares within route-years. The "breakeven distance" at which the effects of standardization dissipate to zero is provided below the regression estimates. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table 6: Effects on Traffic Shares, ACL and PAL

	(1)	(2)
A.C.L. x post-change	2.848***	2.809***
	(0.554)	(0.542)
* distance (100 mi)	-0.403***	-0.396***
	(0.076)	(0.073)
P.A.L. x post-change	1.461**	1.647***
	(0.593)	(0.576)
* distance (100 mi)	-0.216***	-0.232***
	(0.076)	(0.076)
Breakeven distance (A.C.L.)	705.9	709.8
	(31.5)	(33.5)
Breakeven distance (P.A.L.)	676.8	708.8
	(73.1)	(57.3)
N	676	676
R^2	0.45	0.77
Route FE		X

Notes: Table estimates effect of the gauge change on all-rail traffic shares. The dependent variable is the log difference in all-rail and steamship shares within route-years. The "breakeven distance" at which the effects of standardization dissipate to zero is provided below the regression estimates. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table 7: Increasing Effect on Shares over Time

	(1)	(2)
All-rail x 1885	-0.914	-0.914
	(0.701)	(0.729)
* distance (100 mi)	0.071	0.071
	(0.093)	(0.097)
All-rail x 1886	-0.711	-0.630
	(0.863)	(0.813)
* distance (100 mi)	0.079	0.073
	(0.111)	(0.105)
All-rail x 1887	1.343**	1.500**
	(0.543)	(0.576)
* distance (100 mi)	-0.183**	-0.199**
	(0.074)	(0.078)
All-rail x 1888	1.622**	1.753**
	(0.751)	(0.790)
* distance (100 mi)	-0.271***	-0.282***
	(0.098)	(0.103)
All-rail x 1889	1.938**	2.069**
	(0.777)	(0.819)
* distance (100 mi)	-0.290***	-0.300***
	(0.102)	(0.107)
All-rail x 1890	2.040***	2.197***
	(0.678)	(0.720)
* distance (100 mi)	-0.314***	-0.331***
	(0.093)	(0.098)
N	676	676
R^2	0.12	0.45
Route FE		X

Notes: Table estimates the effect of the gauge change on all-rail traffic shares by year, relative to the omitted year of 1884. The dependent variable is the log difference in all-rail and steamship shares within route-years. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table 8: Change in Total Traffic/Revenue

	Ln(Freight traffic)		Ln(Revenue)	
	(1)	(2)	(3)	(4)
Post-change	0.039	0.051	-0.114	-0.091
	(0.230)	(0.222)	(0.183)	(0.186)
* distance (100 mi)	-0.000	-0.006	0.009	0.003
	(0.031)	(0.028)	(0.023)	(0.022)
N	360	360	360	360
R^2	0.01	0.96	0.01	0.97
Route FE		X		X

Notes: Table estimates the effect of the gauge change on total shipments. Observations are route-years. The dependent variable in Columns (1) to (2) is log pounds of traffic; in Columns (3) to (4), log dollars of revenue. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table 9: Supply and Demand Estimates

Demand Parameters		*Marginal Costs ($ per 100 lbs.)*	
Break in gauge	-3.42***	Break in gauge	0.079***
	(0.71)		(0.027)
* distance (100 mi)	0.43***	Transshipment	0.207***
	(0.09)		(0.088)
Rail dummy	4.54***	Distance, rail	0.044***
	(1.11)		(0.008)
Steam dummy	6.41***	Distance, steam	0.042***
	(1.13)		(0.009)
Price ($ per 100 lbs.)	-8.98***	N	244
	(1.54)	Mean R^2	0.77
Breakeven distance	792.7		
	(95.7)		
N	488		
R^2	0.62		
1st-stage F-stat	222.5		
Instrument	Distance		

Notes: Table shows estimates from the joint estimation of demand and supply for freight traffic on the subsample of routes for which prices are available. Demand is estimated over a dataset at the route-mode-year level, with N=244 route-years and J=2 modes. Because cartel policy constrained railroads and steamships serving a given route to the same prices, there are only as many pricing FOCs as there are route-years, hence the halved sample for estimating costs. The price variable is computed as a weighted average of published class rates for the given route, weighting by the share of route traffic in each class in 1880. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Bootstrapped SEs are provided in parentheses.

Table 10: Prices, Quantities, Profits, and Margins in Competitive Counterfactual

	Average price ($ per 100 lbs.)		**Freight Traffic (million lbs.)**			**Carrier Profits (thousand $s)**			**Gross Margins**	
	Rail	**Steam**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**
Panel A: Pre-period (1884-1886)										
Collusion (observed)	0.72	0.72	30.6	100.8	131.4	$95.1	$200.7	$295.8	44%	28%
Competition	0.53	0.68	59.2	100.1	159.3	41.5	106.3	147.8	15%	17%
Percent change	-27%	-6%	94%	-1%	21%	-56%	-47%	-50%		
Panel B: Post-period (1887-1890)										
Collusion (observed)	0.72	0.72	32.9	119.9	152.8	$127.9	$246.5	$374.4	56%	28%
Competition	0.49	0.68	99.1	94.9	194.0	126.8	123.1	249.9	29%	20%
Percent change	-32%	-6%	201%	-21%	27%	-1%	-50%	-33%		

Notes: Table provides a summary of prices, quantities, profits, and margins under collusion (i.e., as observed) and in a counterfactual in which the all-rail and steamship modes compete on prices.

Table 11: Post-Period Competitive Outcomes: Without vs. With Gauge Change

	Average price ($ per 100 lbs.)		**Freight Traffic (million lbs.)**			**Carrier Profits (thousand $s)**			**Gross Margins**	
	Rail	**Steam**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**
No gauge change	0.55	0.69	72.9	104.8	177.8	$69.7	$136.1	$205.8	20%	20%
Gauge change	0.49	0.68	99.1	94.9	194.0	126.8	123.1	249.9	29%	20%
Percent difference	-10%	-1%	36%	-9%	9%	82%	-10%	21%		

Notes: Table provides a summary of counterfactual competitive prices, quantities, profits, and margins in the post-period (1887-1890) without versus with a uniform gauge.

Appendix for Online Publication

A Data Appendix

This paper draws on several sources of data, most importantly the SRSA records of freight traffic on the set of routes apportioned, monitored, and reported to cartel members. As the paper explains, the SRSA collected daily data on the traffic and revenue of carriers on any route where at least one member requested apportionment, compiled these data into monthly and annual totals, and then circulated the data for select routes to cartel members. These tables, as well as other SRSA circulars, were organized into semiannual volumes and have been preserved in original hard copy at the New York Public Library and Yale University archives.[1]

Figure A.1 provides an example table from these records. The table shows pounds and revenue of merchandise shipments from Boston to Augusta, GA for the 1886-87 and 1887-88 fiscal years. The table lists five different paths that freight traveled for this route: three by steamship plus rail, and two entirely by rail. All-rail shipments can be identified as "via A.C.L." or "via P.A.L.", while the steamship line items indicate the intermediate ports where freight was transshipped (here, Savannah and Charleston). Similar tables are available for other destinations, origins, and years, although in most cases a table shows data for one period only.

Figure A.1: Example of Table from SRSA Traffic Reports

COMPARATIVE STATEMENT OF MERCHANDISE, *by Routes or Lines, June 1st, 1886, to May 31st, 1887, and June 1st, 1887, to May 31st, 1888, from and through* BOSTON *to Points named.*

TO AUGUSTA, GA., AND BEYOND.

ROADS AND ROUTES.	1886–1887.		1887–1888.		INCREASE.		DECREASE.	
	Pounds.	Revenue.	Pounds.	Revenue.	Pounds.	Revenue.	Pounds.	Revenue.
Central R. R. via Savannah	1,890,257	$ 9,065 47	2,364,324	$ 10,160 47	474 067	$ 1,095 00	....	$ ....
So. Car. R. R. via Charleston.	412,023	1,760 50	735,310	3,534 23	323,287	1,773 73	....	....
Pt. R. & A. R. R. via Charleston	61,750	216 71	....	....	....	....	61,750	216 71
R. & D. R. R., S. C. Div., via A. C. L.	377,814	1,833 66	351,092	1,868 53	....	34 87	26,752	....
" P. A. L.	622,823	3,889 69	776,224	4,718 97	153,401	829 28	....	....
Total	3,364,697	16,766 03	4,226,950	20,282 20	950,755	3,732 88	88,502	216 71

Notes: Figure shows an extracted table from the source data. The table lists total pounds of traffic and revenue from merchandise shipments from Boston to Augusta, GA by carrier, for June 1 to May 31, 1886 and for the same period in 1887. All-rail paths (termed "routes" in the table) can be identified as either A.C.L. or P.A.L.

For the second half of the sample, the cartel operated on a June to May fiscal year and reported annual data accordingly. This accounting period is ideally suited to the purposes of this paper, as the gauge change occurred over May 31 and June 1, 1886 – such that the cartel's annual data provide the cleanest possible comparison. However, until 1886, the cartel operated on a September to August fiscal year. For this earlier period, I therefore collected year-to-date (YTD) traffic in May and August, in order to back out shipments for the June to May period. Concretely: The 1884 fiscal year spanned September 1883 to August 1884, but this paper requires totals from June to May. To obtain them, I transcribed data from three YTD tables in the cartel traffic reports: September 1882 to May 1883 (1), September 1882 to August 1883 (2), and September 1883 to May

[1] A subset of the content in these circular letters are also available on microfilm from HBS Baker Library, though the microfilm omits the monthly traffic reports which yield the data in this paper.

1884 (3). I then impute June 1883 to May 1884 traffic as (2)-(1)+(3).

The primary sample in the paper contains 52 routes, with 4 Northern origins and 13 Southern destinations. Table A.1 lists the origins and destinations in this sample (also mapped in Figure 2). To make clear how all-rail freight reached Southern interior cities, Figure A.2 shows maps of the A.C.L. and P.A.L. circa 1885. Both served nearly every route in nearly every year, with a few exceptions: the P.A.L. did not deliver freight to Macon in 1884-86, Athens in 1886, or Albany in any year, and the A.C.L. did not deliver to Albany in 1890 (as inferred from their absence from the respective traffic tables). Additionally, no data is available for Albany in 1887. As a result, the sample reported in tables is reduced from 1,092 ($= 52 \cdot 3 \cdot 7$) to 1,036.

Table A.1: Origins and Destinations for Sampled Routes

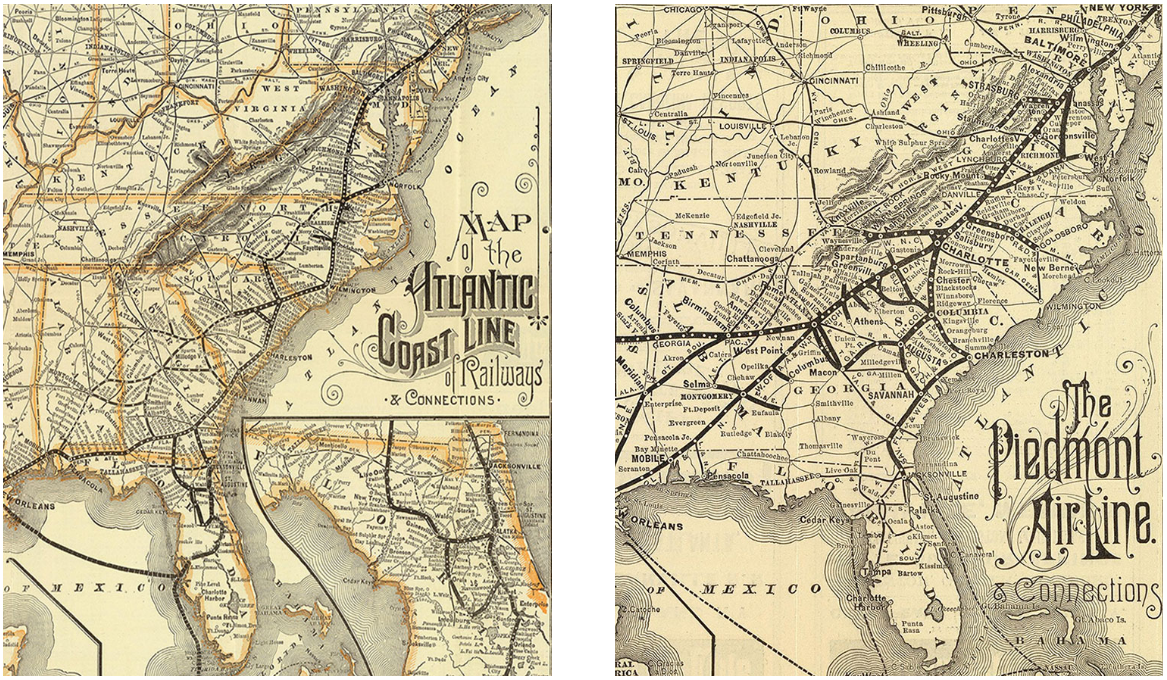
Destinations (south)		**Origins (north)**	
Albany	GA	Boston	MA
Athens	GA	New York	NY
Atlanta	GA	Philadelphia	PA
Augusta	GA	Baltimore	MD
Macon	GA		
Milledgeville	GA		
Newnan	GA		
Rome	GA		
Montgomery	AL		
Opelika	AL		
Selma	AL		
A. & W. Pt. stations (GA)			
W. & A. stations (GA)			

Notes: Table lists the origin and terminus of routes in the sample of Northern merchandise shipments used in the remainder of this paper. These 52 routes (4 origins x 13 destinations) are those for which data was reported by the Southern Railway and Steamship Association both before and after the gauge change. "A. & W. Pt. Stations" refers to stations on the Atlanta and West Point Railroad between East Point and West Point, GA (70 mi), whose traffic was reported collectively; "W. & A. Stations" refers to stations on the Western and Atlantic Railroad between Chattanooga, TN and Marietta, GA (87 mi). These destinations are geotagged to the centroid of their respective endpoints.

Figure A.2: All-Rail Paths connecting North and South ca. 1885

Panel A: Atlantic Coast Line (A.C.L.)

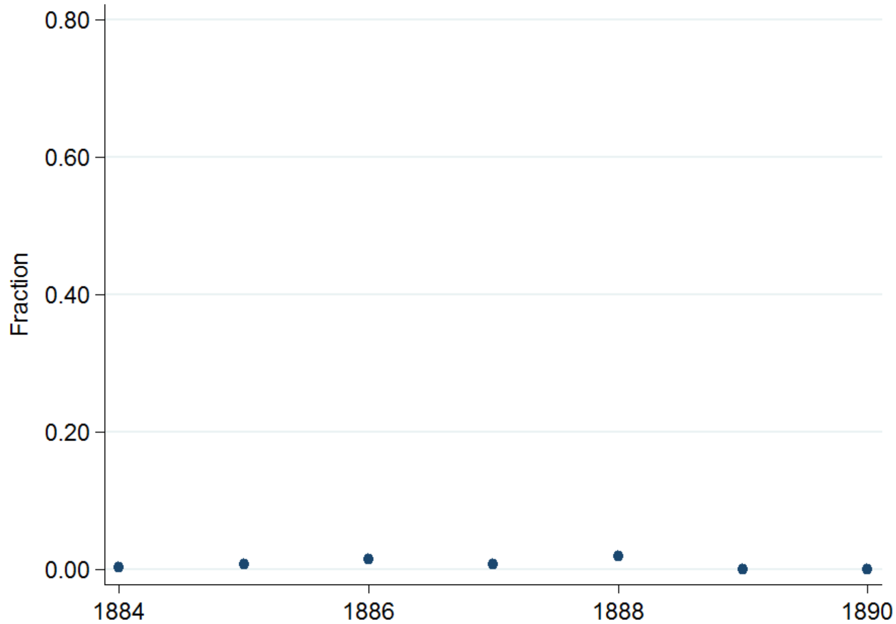
Panel B: Piedmont Air Line (P.A.L.)



Notes: Figure provides maps of the two all-rail paths between the North and South, as of 1885: the Atlantic Coast Line and Piedmont Air Line. Each was established by mutual agreement among the traversed railroads to facilitate interregional traffic. Maps acquired from the David Rumsey Historical Map Collection.

On a few routes, merchandise shipments between Northern and Southern cities are occasionally indicated to have entered the South from the West, via the Louisville and Nashville or the Cincinnati Southern – crossing the Ohio River at Louisville and Cincinnati, respectively. In these cases, it remains ambiguous whether the active mode was all-rail versus river steamer plus connecting railroad. I thus omit these shipments from the analysis. As Figure A.3 shows, little is lost: the omitted shipments on average comprise 0.8% of traffic in any given year.

Figure A.3: Western paths' share of North-South traffic



Notes: Figure shows the annual proportion of total traffic on the sampled routes reported to have been by the L. & N. and the C.S. Railroads, ostensibly after having crossed the Ohio River. Due to ambiguity over the mode of westward travel, this traffic is omitted from all analysis.

To estimate effects that vary with route length, I must measure distances between origin and destination. Throughout the paper, I measure distance as "straight-line" (geodesic) distance, rather than traveled distance, which is not observed. Though traveled distance can in concept be computed for all-rail routes using maps and mapping software, the same cannot be done for steamships, and it is unclear what additional information is generated. Indeed, one early-twentieth century source (Ripley 1913) lists all-rail shipping distances from Boston, New York, Philadelphia, and Baltimore to Atlanta, and as Table A.2 shows, straight-line distance is a roughly fixed proportion (85%) of the point-to-point track length between origin and destination.

Table A.2: Comparison of Straight-line and Track Distances

Origin	**Destination**	**Straight-line (mi.)**	**All-rail (mi.)**	**Ratio**
Boston	Atlanta	937	1089	0.86
New York	Atlanta	747	876	0.85
Philadelphia	Atlanta	666	786	0.85
Baltimore	Atlanta	577	690	0.84

Notes: Table compares straight-line (geodesic) distances and all-rail shipping distances between the points shown. Shipping distances from Ripley (1913).

With a limited sample of routes – and particularly, with origins all in the northeast and destinations in Georgia and Alabama – one might be concerned that the sample does not exhibit sufficient variation in distance to identify this source of heterogeneity. Table A.3 lays this concern to rest, showing that across the 52 routes in the sample, distance varies from 500 to 1,100 miles, with a 25th-75th percentile spread of over 300 miles.

Table A.3: Descriptive Statistics: Distribution of Route Distances

	N	**Min**	**p10**	**p25**	**p50**	**p75**	**p90**	**Max**
Route Distance (mi.)	52	501.0	585.8	661.1	749.5	889.0	971.7	1111.8

Notes: Table summarizes the distribution of routes in the sample by straight-line (geodesic) distance between northern origins and southern destinations. See Table A.1 for a list of origins and destinations, and Figure 2 for a map.

Other Data

I also collect data from annual volumes of Poor's Manual of Railroads (1868) to confirm the scale of the gauge change. The Poor's Manual was an annual compendium of railroads in the U.S. and Canada that provides railroads' location, mileage, information on their financial performance (when available) – and conveniently, their gauge. These volumes allow me to calculate annual mileage by region and gauge for the universe of U.S. railroads, and thereby observe both the growth of the network and the standardization of gauge across the country.

To do so, I recorded the name, total mileage, and principal gauge of every railroad in five Poor's Manual volumes: 1882, 1883, 1886, 1888, and 1890 (which provide data from 1881, 1884, 1885, 1887, and 1889).[2] I also recorded the region in which each railroad had principal operations: New England (ME, NH, VT, MA, RI, CT); Middle Atlantic (NY, NJ, PA, DE, MD); Central Northern (OH, IN, IL, MI, WI); South Atlantic (VA, WV, NC, SC, GA, FL); Gulf and Mississippi Valley (KY, TN, AL, MS, LA); Southwestern (MO, AR, TX, KS, CO, NM); Northwestern (WY, NE, IA, MN, Dakota Territory); and Pacific (CA, OR, WA, NV, AZ, UT). In two of the sampled volumes, railroads are sorted alphabetically by these regions; in two other volumes, by state; and in one volume, at the national level. Where available, I use the Poor's Manual-designated region or state as a railroad's location. For the volume with national sorting, I infer each railroad's location from previous or later volumes, or from the address of its principal office (if not otherwise available). There was of course a great deal of new construction and consolidation over this period, but all of it is accounted for in these volumes – indeed, each volume concludes with a table listing all mergers and acquisitions since the first volume in the series was published in 1868.

The collection of the Poor's Manual data proved to be a painstaking process that required significant attention to detail, as many railroads owned subsidiary lines that were listed twice (alone and under the owner), and many railroads leased lines that were listed twice (alone and under the owner). All subsidiary and leased lines were therefore cross-checked against the entered to data to ensure they were not double-counted. The volumes also included railroads under construction, and every

[2] Please contact the author at dgross@hbs.edu if you would like to make use of these data. I extend a hearty thanks to the Historical Collections team at HBS Baker Library for providing access to the Poor's Manual volumes, and to Mary Vasile for her help in compiling the data.

effort was made to count only completed mileage – though this count includes railroads which were complete but not yet (or no longer) in operation. In a few cases, a gauge was not provided – when this occurred, I inferred the gauge from previous or later volumes, from separately-listed parents or subsidiaries, or from information obtained through Internet searches. There were also a few railroads which listed multiple gauges, and I count these railroads as standard-gauge roads of one of the listed gauges is standard gauge. Finally, in each volume there are a handful of railroads for which the gauge could not be determined, and these railroads are omitted from all analysis, as the cumulative mileage with unknown gauge in any given year is less than 0.1% of the network. In Table 1, I sum railroad mileage by year, region, and gauge, consolidating the Poor's regions into five super-regions: New England, Mid-Atlantic, Midwest, South, and West.

I also make use of mapping data from two sources. I use the NHGIS state boundary shapefiles to sketch states east of the Mississippi River, and Atack's (2015) Historical Transportation Shapefiles to map the railroad network. The Atack (2015) railroad shapefile includes railroads constructed between 1826 and 1911; within this file, individual segments are identified by owner and gauge through the Civil War, but this identifying information is not available for later periods. Given the importance of this information to mapping the network by gauge, I restrict attention to set of railroads in operation by 1861. I use these data to illustrate the diversity of gauge in 1861 and then the standardization that took place through 1881 and 1891, leveraging the Poor's Manual data to identify later gauges of railroads in the Atack (2015) shapefile.

To perform the stock price event study in Section 6, I have also collected daily stock prices from the *New York Times* for stocks traded on the New York Stock Exchange between January 1 and October 31, 1886. The stock quote tables in the *New York Times* report opening, closing, high, and low prices and estimated trading volume for stocks traded each trading day. Stocks that did not trade on a given day are not reported in the daily stock quote table, and I treat their price as unchanged from their previous trading day.

Appendix references not in paper:

Ripley, William Z. *Railway Problems*, Boston: Ginn and Company, 1913.

B Vertical Structure of Freight Shipping

Long-distance freight shipment in the 19th century had an inherent vertical character: to get from origin to destination, traffic had to traverse the tracks of multiple, separately-owned connecting lines. Frictions in the vertical transactions required for through shipment were the source of decades of holdup, and led to the formation of numerous innovative contractual relationships, which could be the subject of an entire separate paper – and indeed are the focus of a large contemporary and historical academic literature. For the purposes of this paper, a better understanding of vertical contracting arrangements is both useful context and important to evaluating the model used to estimate demand and supply and simulate competitive conduct.

B.1 How were long-distance shipments priced?

To fix terms, freight shipments borne by multiple, connecting carriers were known as "through" shipments, typically traveling long distances. Shipments which could be delivered by the originating carrier were "local" shipments. There were two approaches to pricing through shipments: the most primitive method was a combination of local rates, whereby a shipment from point A to point C would be charged the first carrier's local rate from A to B plus the second carrier's local rate from B to C, which were independently determined. Given the number of local rates that had to be considered on routes with many connections, and the frequency of rate changes, predicting the cost of shipping under combination rates was a formidable challenge for shippers.

To simplify pricing, railroads began to set joint rates (also/more often termed as "through rates"), which were point-to-point freight rates set jointly by carriers involved in the route, with a negotiated division of revenue. By the dawn of the regulatory era, through rates were by far the most common means of pricing through traffic. However, while there's abundant discussion of the definition and applications of through rates in historical records, there's unfortunately remarkably little coverage of how through rates were set, and how revenue was divided among carriers.

With effort, it was possible to unearth some contemporary references to the issue, which consistently point to prorating of through revenue according to the distance of each carrier's leg in the journey. Proportions were determined by the "constructive mileage" of each leg, which is derived from true distances but allows adjustments (Haney 1924). For example, in Congressional testimony in 1874, the P.A.L. general manager claimed to prorate through revenue with the water lines with which it connects (U.S. Congress 1874, p. 401), with ocean steamships prorating 3 miles for every 1 railroad mile. In the same Congressional record, a representative of the Green Line (a fast freight line, see next subsection) stated that all railroads in the organization received the same rate per mile from through revenue (p. 786). Division *pro rata* thus appears to have been the norm, although there were exceptions in the form of "arbitrary divisions", which often applied to the use of bridges or terminals, compensated carriers for a shipment's fixed costs such as loading and unloading, and were allocated before the remaining revenue was prorated (Haines 1905). It is unclear whether arbitraries were used to compensate carriers for the cost of breaks in gauge – and because joint rates came into use around the same time that the gauge was being standardized, no contemporary references to the precise question could be located.

Joint pricing was not the only means of contracting around vertical transfers of shipments. Trackage rights were also common, which gave an originating carrier rights to travel freely over a connecting carrier's tracks. An alternative was vertical integration via merger or acquisition, which was also occurring at a rapid pace during and after the Reconstruction era.

B.2 Who owned/controlled the rolling stock?

Vertical transfers of rolling stock were an entirely different contracting problem that was resolved in a distinct way. While not as important to the paper as the process determining rates, it is useful to understand how rolling stock was transferred across railroads, and who maintained ownership and control, as freight traveled the tracks of multiple carriers along its route.

The root of the problem is that, to send shipments over long distances on the same car, originating railroads had to (i) send their rolling stock across connecting lines, and (ii) get it back. Conversely, intermediate railroads had to host the rolling stock of their connections. The moral hazard problems arise in several places: not only does the originating carrier have to relinquish control over its rolling stock, but it also retains liability for damage or loss of its shipments on connections. Moreover, different railroads might have different quality cars and different maintenance practices, and a low-quality or poorly-maintained car could damage the tracks it traveled. As a result, until the 1860s, freight had to be unloaded, unregistered, reregistered, and reloaded every time one line ended and another began, imposing enormous costs and delays on through traffic.

To address these issues, railroads around the country formed "fast freight lines" in the 1860s and 1870s, which were joint ventures between connecting railroads which pooled their freight cars into a shared rolling stock. The largest of these in the South was the Green Line fast-freight company, established in 1868. Under the agreement, members of the Green Line submitted rolling stock to the common pool in proportion to their total track mileage, and members were paid 1.5 cents per car-mile when other carriers used their cars. Ordinary maintenance was performed by the railroad operating the car and charged to its owner, but if a railroad damaged another carrier's car, it would be responsible for repairing or replacing it – though enforcement of this latter provision was inherently challenged by the difficulty of determining the party at fault.[3,4]

[3] When asked by Congress "How do you know whether it is the fault of the road or ... the car?" a Green Line agent responded that the issue was an ongoing source of contention (U.S. Congress 1874, p. 788).

[4] For more information on the Green Line, see the following sources: Sindall (1886, pp. 680-861), Joubert (1949, pp. 31-40), Taylor and Neu (1956, pp. 67-76), and Puffert (2009, p. 134).

B.3 What was the vertical structure in the South?

Though these contracting innovations were being developed around the country during Reconstruction, the key question for this paper is ultimately what vertical contracting arrangements were in place in the South around the time of the gauge change, to evaluate whether the model of industry conduct is appropriate. The fundamental issues are (i) whether SRSA freight rates were for end-to-end North-South freight traffic, (ii) whether they applied to both railroads and steamships, and (iii) whether they were determined in coordination with Northern carriers (which comprised half of each all-rail route) and how revenue from each shipment was divided. If the answer to any of these questions is in the negative, or if revenue division was endogenous, the model of the market could require nonstandard features such as bargaining or a vertical dimension.

Information on the SRSA's vertical contracting arrangements is thin, but a few key details are available from the cartel's records. What is clear from these records is that the cartel rates were through rates, from origin to destination, and that these rates applied to all lines in the cartel. However, the records yield no insight into what role Northern railroads played in price-setting. My understanding from cartel documents and later accounts is that the SRSA fundamentally controlled prices on shipments into and out of the South – in part due to its outsize influence over these routes, and in part because Southern traffic was relatively unimportant to Northern carriers in volume and value – and it is thus appropriate to model the SRSA as a price-setter.[5] The cartel's records also make clear that revenue division was negotiated outside of the cartel, and typically *pro rata*, following industry norms – such that revenue division is orthogonal to price-setting and would not enter or affect the cartel's profit-maximization problem.

Appendix references not in paper:

Haney, Lewis H. *The Business of Railway Transportation*, New York: Ronald Press Company, 1924.

U.S. Congress. *Reports of the Select Committee on Transportation Routes to the Seaboard*, Washington: Government Printing Office, 1874.

[5]Total railroad tonnage in the New England, Mid-Atlantic, and Great Lakes regions was over 10x that in the South in 1880, and the difference in ton-miles even greater (U.S. Department of Interior 1883).

C Contemporary Accounts of the Gauge Change

The gauge change received broad coverage in contemporary railroad periodicals and Southern newspapers. The *Atlanta Constitution* reported on the SRSA's gauge change convention as it was underway (Figure B.1), and the *Louisville Courier-Journal* reported several weeks later on the planning, preparations, and procedure for converting 13,000 miles of track in one day (Figure B.2). Though not widely covered in the North, the impending gauge change was nevertheless reported in a lengthy article in the *Commercial and Financial Chronicle* on May 29, where the paper acknowledges that "the matter is hardly attracting the attention it deserves," and the *New York Times* reported on May 31 that the Louisville and Nashville – the only Southern railroad of real importance to Northern shippers and investors – had completed its changeover that day, with no mention of the other railroads simultaneously converting to standard gauge (Figures B.3 and B.4).

Contemporary accounts were not limited to reporting on the mechanics of the gauge change: some newspapers speculated on the effects it might have, or was already having, on the Southern economy. For example, the *Wilmington Morning Star* wrote in April 1886 that to date, "very little lumber [goes] North by rail, for the reason that Southern roads [have] a different gauge from the Northern roads," and that "Southern lumber ports are bound to suffer a considerable loss of business" following the gauge change (Figure B.5) – a prediction consistent with this paper's results.

A year after the gauge change, in July 1887, *The Railroad Gazette* and other railroad journals published a detailed postmortem analysis (Figure B.6) – covering the history of Southern gauge and its "burden [on] both railroads and shippers," the SRSA's gauge change convention in February 1886 and the decision to convert to a 4' 9'' gauge on June 1, the plans and procedures for the day of the conversion and the months leading up to it, the engineering challenges, and even estimates of the aggregate expense of converting the rails and the rolling stock. For those interested, this article is the best source for understanding how 13,000 miles of railroad track could be converted to standard gauge in just 36 hours, and confirmation that it was.

Figure B.1: Report of the Gauge Change Convention (*Atlanta Constitution*, February 3, 1886)

THE NEW GAUGE.

AN IMPORTANT CONVENTION OF RAILROAD OFFICIALS.

A Large Meeting of General Managers ., eral Superintendents, and the Heads of the Transportation, Roadway and Motive Power Departments of Southern Roads.

One of the most important conventions of railroad officials ever held in the south met here yesterday. It was a meeting of the general managers and heads of the transportation roadways, and machinery departments of nearly all of the broad gauge (five feet) roads east of the Mississippi and south of the Ohio river.

The meeting was held in rooms 102 and 104 of the Kimball, and was called for the purpose of fixing the day and arranging all details for the changing of the gauge of the railroads in the territory named H. S. Haines, general manager of the Savannah, Florida and Western railroad, was called to the chair and F. K. Huger requested to act as secretary. The following

REPRESENTATIVES WERE PRESENT.

H. S. Haines, general manager, R. G. Fleming superintendent, George Riley master mechanic, Savannah, Florida and Western railroad: C. S. Gadsden, superintendent, J. W. Craig, master of roadway and master of transportation C. & S. railroad; Wm. Rogers, general superintendent, W. W. Starr, master of transportation, T. D. Kline, superintendent Southwestetn railroad, Georgia Central. J. W. Thomas, general manager, Nashville, Chattanooga and St. Louis: J. W. Green, general manager, John S. Cook, master mechanic, Hamilton Wilkins road master, Georgia railroad: J. W. Green, general manager, P. R. & A. J. T. Hanahan, general manager, R. Montfort, engineer, R. Wells, assistant to president Louisville and Nashville; J. B. Beck, general manager, J. H Averell, master of transportation, D. E. Maxwell, general superintendent Florida railway and Navigation company South Carolina railroad: Cecil Gabbott, general manager, J. F. Worwick, master mechanic Atlanta and West Point, Western railway of Alabama, Cincinnati, Selma and Mobile railway; C. H. Hudson, general manager, F. K. Huger, superintendent, W. H. Thomas, superintendent motive power East Tennessee, Virginia and Georgia; S. B. Thomas, general manager, Peyton Randolph, assistant general manager, W. H. Green superintendent Richmond and Danville division Superintendent Berkeley, Air-Line division Richmond and Danville railroad R. D. Wade, superintendent motive power, C. M Bolton, engineer, C. P. Hammond, road master, T. W. Gentry, master mechanic, Rome and Dalton: A B. Andrews, president, Frank Coxe, vice president, V. C. McBee, superintendent, G. W. Gitis, master mechanic, Western of North Carolina: Joseph H. Sands, general manager, Frank Huger, superintendent, W. W. Coe, chief engineer, S. B. Haupt, superintendent M. P., Norfolk and Western; G. R. Talcott, superiendent, Thos. Bernard, assistant engineer, Charlotte, Columbia and Augusta, Joseph H. Green, master mechanic Charlotte, Columbia and Augusta; G. R. Talcott, superintendent Columbia and Greenville; H. Walters, general manager Atlanta and Charlotte Air-Line: B. R. Dunn, engineer master mechanic Atlanta and Charlotte Air-Line; William R. Mims, road master Atlanta and West Point; R. Southgate, assistant engineer Columbia and Greenville: G. M. D. Riley, master of road way Sav., Florida and Western: H W. Reed, master of roadway Savannah, Florida and Western; I. Y. Sage, general superintendent Georgia Pacific railroad; J. F. Alexander, division master Georgia Pacific railroad: H. R. Duval, receiver Florida railway and navigaiion company; W. R. Kline, master mechanic Brunswick and Western railroad, J. N. Brown, road master Brunswick and Western railroad, R. A. Bridges, road master Columbus and Western: A. L. Koutz, assistant superintendent Pullman palace car company J. F. Divine, general superintandent Atlanta and Charlotte; W. T. Newman, master mechanic, Georgia Pacific; R. A. Anderson, superintendent, A. B Bostwick, assistant superintendent; M. H. Dooly, road master; M. L. Collier, master mechanic, Western and Atlantic.

Mr. Haines upon taking the chair, briefly stated to the convention the object for which the meeting had been called, and announced that it would be necessary to appoint several committees to take in hand and arrange all the details of the work, and submit reports to the convention showing how every detail connected with change in the gauge must be arranged, so that the work would be accomplished easily and satisfactory.

The convention listened to him attentively and when he had concluded authorized him to appoint the committees and put them at work.

Chairman Haines then appointed the following committees:

Committee on date of change of gauge—E. B. Thomas, chairman; J. T. Horroban, C. H. Hudson, Wm. Rogers, H. R. Duval, Henry Walters, R. G. Fleming, J. W. Thomas, J. W. Green, J. H. Sands, R. A. Anderson, J. B. Peck, Cecil Gabbett, W. R. Kline.

Committee on transportation—J. F. Devine, chairman; J. H. Averill, D. E. Maxwell, F. K. Huger, Peyton Randolph, A. B. Andrews, Frank Coxe, V. E. McBee, Frank Huger, C. S. Gadsden, W. W. Starr, I. Y. Sage, A. B. Bostwick, W. H. Green, J. C. Gault.

Committee on roadway—W. W. Coe, chairman, C. P. Hammond, M. H. Dooly, William Mims, H. W. Reade, J. N. Brown, R. Muilfort, Hamilton Wilkins, G. R. Talcott, C. M. Bolton, Thomas Bernard, B. R. Dunn, R. Southgate, J. T. Alexander, R. A. Bridges, J. W. Craig, E. Burkley, B. R. Swoop.

Committee on machinery—Reuben Wells, chairman; F. D. Kline, R. D. Wade, S. B. Haupt, Joseph H. Greene, G. M. D. Riley, J. S. Cook, M. L. Collier, W. H. Thomas, T. W. Gentry, G. W. Gates, J. E. Worswick, W. T. Newman.

The convention then, by unanimous consent, adopted the Pennsylvania standard gauge for the track and trucks.

The meeting then adjourned until 4 p. m., so as to allow the committees to get to work and prepare their reports to presented at that hour for consideration. At that hour the convention again assembled. The committees made reports, which were read and discussed.

A number of changes in the reports were suggested, and they were recommitted, so that these changes could be properly considered and acted upon. The convention then adjourned to meet at 11 o'clock this morning.

Figure B.2: Preparations and Procedures for Conversion (*Louisville Courier-Journal*, March 23, 1886)

CHANGE OF GAUGE.

How the Work of Altering Nearly 13,000 Miles of Track is to Be Accomplished.

The Foresight and Preparation Necessary—Force to Be Employed—Estimated Cost.

At a meeting of the General Managers, Superintendents, and heads of the transportation, roadway and motive power departments of Southern roads, held at the Kimball House, Atlanta, Ga., Feb. 2 and 3, 1886, called for the purpose of fixing date and arranging details for change of gauge, the following resolution, offered by Mr. E. B. Thomas, of the Richmond and Danville, was adopted:

That 4 feet 9 inches is hereby adopted as the standard gauge of the roads represented in this convention, and that in changing gauge from 5 feet it shall be to 4 feet 9 inches, and that a committee be appointed which shall communicate with the leading railways which are 4 feet 8½ and 4 feet 9 inch gauge to agree upon a wheel gauge which shall be suitable for both gauges, and that said committee report at an early day to an adjourned meeting of this convention.

It appears that all of the standard gauge roads north of the Ohio river except the Pennsylvania, whose gauge is 4 feet 9 inches, have a gauge of 4 feet 8½ inches, and the committee's important duty was to fix upon a wheel gauge which would for all time be interchangeable with all of the roads in the country. At the adjourned meeting of the convention held in Atlanta, February 16, the committee made its report. Circulars had been sent out to all the leading railroads in the country asking their experience in running 4 feet 8½ inches gauged cars over 4 feet 9 inches gauge track, or vice versa. The answers received demonstrated that no trouble was experienced, and the committee recommended that 4 feet 5⅜ inches, allowing a variation of ⅛ of an inch either way, be adopted as a standard gauge between flanges. After hearing this report the convention adjourned, having previously arranged the date for the change, and adopting all the important committee reports, especially that of the Roadway Committee. This latter outlined the preparations that were necessary, designating the proper tools, organization, methods, etc. This report recommends that the roadway forces should all be increased thirty days prior to the change, so that on the day of change they shall be double the usual number. On the day, or days, of change the force must equal not less than three men to the mile. The organization for eight-mile sections laid down is as follows:

Four men drawing inside spikes, 8 men driving outside spikes, 4 men driving inside spike, 4 men throwing rail, 1 man with 5-foot gauge pole car, 1 man with standard gauge lever car, 2 men extra, 24 men total.

The changing of the gauge of the track from five to four feet nine inches will be done by moving one rail in three inches without disturbing the other rail at all. The preparations for changing the road-bed will be commenced about one month ahead. This preparation will consist in adzing or cutting the tie to a smooth and even surface with the rail and clearing away any obstructions even with the top of the tie for a space of not less than five inches from the rail that is to be moved in, so that when the change is made the bearing of the track will not be destroyed. All spikes not absolutely necessary will be drawn out beforehand. The rail is fastened to each crosstie by two spikes, one on the inside and the other on the outside. All inside spikes will be drawn except the spikes in every third crosstie on tangents and every other tie on curves.

By means of a template to measure the distance that the rail is to be moved a great deal of valuable time will also be saved by driving the inside spikes beforehand. Inside spikes will be set with templates in every third tie, and will project sufficiently above the surface of the tie to receive the base of the rail. When the change actually takes place, therefore, all that will be necessary to be done will be to draw the few inside spikes that have been left to keep the rail in position, shove the base of the rail under the spikes that have already been driven on the inside of the new gauge, and then secure it by driving in the outside spikes, leaving the old outside spikes to be drawn at leisure. This arrangement will also save the necessity for measuring the gauge and arranging bearing on the day of the change.

Monday, May 31, and Tuesday, June 1, have been designated as the days for general change of gauge. The following lines will change on Monday May 31: Louisville and Nashville, Nashville, Chattanooga and St. Louis, Memphis and Charleston, Alabama Great Southern, Cincinnati Southern railway, Cincinnati, Selma and Mobile, Montgomery and Eufala, Southwestern of Georgia, Pensacola and Alabama, Florida Railway and Navagation Company. All other main lines will change on Tuesday, June 1.

The change will take place on almost every railroad south of the Ohio and Potomac rivers, extending over about 13,128 miles of railway, made up as follows: South Carolina, 1,320 miles; North Carolina, 960; Georgia, 2,413; Florida, 1,250; Alabama, 1,808; Mississippi, 776; Louisiana, 313; Kentucky, 1,118; Tennessee, 1,886, and Virginia 951 miles.

The Southern gauge has been an endless source of trouble, expense and inconvenience, and its abandonment has for a long time been regarded as a certainty, and all that was needed was for some one road to start the ball rolling. This the Mobile and Ohio did and the others are prompt to follow suit. When the work is completed all the important systems in the United States will correspond sufficiently to have the running gear throughout the country alike and transferable everywhere. As an illustration of the cumbersome obstacle the five feet gauge presented to easy and rapid transportation, a general statement will suffice. It is estimated that sixty per cent. of the freight business going south over the L. and N. through Louisville at present has to be actually transferred from car to car at South Louisville, the remaining forty per cent. going through the hoist and requiring a change of trucks. The cost of hoisting each car is placed at about fifty cents, for transferring from car to car between $2 and $3. These same figures, it is supposed, apply to the terminus of the Southern gauge at other points.

This gigantic undertaking has already caused an immense amount of labor and forethought on the part of those to whose care it has been intrusted. The burden falls upon the heads of the operating departments. A COURIER-JOURNAL reporter in quest of some of the matter connected with the change, sought Mr. Reuben Wells, second assistant to the President of the Louisville and Nashville, and chief of that large and important branch—the operating department. Mr. Wells' desk was piled to overflowing with printed instructions to the different shops, divisions, etc., which he had just completed after two months' labor. The instructions, if combined, would comprise a quarto volume of no mean proportions, a reading of which, the writer ventures to predict, would guarantee a headache or dyspepsia to any but an iron constitution. This latter all railroad men, and especially those attached to five-foot guage system, are supposed to enjoy. As a matter of fact, however, and illustrative of the wide divergence in matters of taste from a newspaper reporter, the division superintendents, superintendents of machinery, etc., are said to have already so thoroughly digested their respective portions of Mr. Wells' instructions, as to be able to recite them from memory, including commas, necessary claw bars, spike mauls, lining bars, track-wrenchers, adzes, water-buckets, tin cups, engine truck wheels, new wide tires, oil-box bolts, brake-head bolts, hydraulic jacks, etc. A pretty hearty meal, but such is one of the exigencies of a railroad career; and then, too, the number of freight and passenger cars have also to be digested without regard to contents.

Seriously, though, Mr. Wells' instructions are a marvel of labor, foresight and comprehensive provision for minutiae. The manner in which every detail is considered and fully provided for, can not but excite admiration and wonder. The instructions, too, are written in a clear, direct style that enables the unprofessional, as well almost as those to whom it is directed to understand.

The instructions comprise "general instructions for changing gauge of rolling-stock," "general instructions for change of gauge," separate instructions to the different shops, and separate instructions to the different divisions. The instructions for the change of rolling stock at Louisville give as near as can be estimated the number of cars and engines to be changed here, the amount of labor required, the extra material that must be on hand, the tools and appliances necessary, etc.

The instructions to the first division are illustrative of those sent out to the other divisions. The first division comprises 152 miles. This includes main and side track. This division, for convenience, is divided up into 17 sections. The instructions to the first section are after this order: Section 1—Main track, 1.5 miles; side track, 10 miles; total miles, 20.5. Men required, 40; hand cars, 1; push cars, 1; claw bars, 14; spike mauls, 14; lining bars, 8; track gauges, 8; track wrenches, 4; adzes, 4; axes, 4; spike maul handles, 8; water barrels, 2; water buckets, 4; tin cups, 4; kegs of spikes, 3.

These are the men, the tools and appliances required in addition to those already in that section of that division.

The total number of men per mile of track, including side track, will be an average of four men on sections having no more than the usual number of curves, and five men on sections having more than the usual number sharp curves. This includes foremen. In addition, there will be one extra man with each gang, to each hand or push car, to carry the water and push the car with the extra tools, supplies, etc. The men assigned to each section will be divided into two gangs, commencing to change as nearly in the middle of the section, as may be decided by the road master to be best, and working from each other, until each meets the gang working towards them from the adjoining sections; the foreman will go with one of the gangs; his standard gauge hand car will follow this gang. His assistant will go with the other gang, and have his push car of five feet gauge pushed ahead of his gang. The work of the two gangs is not to be confined to their section only, but they will continue on beyond its limits (if not met sooner) until they meet the gang from the other section, regardless of section limits, so as to complete the work promptly.

Previous to May 10, twenty-five of the lot of 38 new engines of standard gauge being built by the Rogers works will be received, put together and tested, so far as that is practicable, and be ready for service as soon as the gauge of track is changed. All spare engines will be changed as early as practicable. "Doubling," or having the engines in service do all the running possible, will be resorted to, thus putting out of service as many engines as possible to be changed, and lessen the number to be changed the day the track is changed and afterward.

There will be two new 18-inch cylinder passenger engines and six new consolidation engines put on the line at Henderson the day the track is changed, to be used on the Henderson division, if needed there. If only a part are needed there, the balance will be forwarded for use on the Nashville and Decatur division. There will be put on at Louisville the same day four new passenger, nineteen consolidation and two pushing engines.

The rolling stock to be changed at the several points specified in the instructions has been approximately estimated as follows: Engines, 267; passenger equipment cars, 254; Pullman sleepers, 38; freight cars and cabooses, 7,740.

Some seven to ten days previous to changing the track the work of changing freight cars will begin, and will continue at the rate of 465 per day, in greater number if possible, until the work is completed.

The cost of the change of gauge is estimated by Mr. Wells at about $300,000. When the work is completed in the short time given it will be a triumph of organized labor and intelligent, comprehensive foresight.

Figure B.3: Report on the Conversion (*Commercial and Financial Chronicle*, May 29, 1886)

THE UNIFICATION OF OUR RAILROAD GAUGE.

On Monday and Tuesday next, according to previous arrangement and agreement, an important work will be undertaken and carried through. This is nothing less than the changing of the guage of all Southern roads whose width of track now is 5 feet, to a standard that will bring these lines more closely in conformity with the standard now in use in other parts of the country.

The matter is attracting hardly as much attention as it deserves. It is a task of no little magnitude. Practically it involves the taking up and relaying of one rail over the entire length of all the roads (and in some cases a change in the road bed and of course alteration of the rolling stock) in the territory bounded by the Atlantic Ocean on the one side and the Mississippi and Ohio Rivers on the other, and comprising the States of Virginia, West Virginia, Kentucky, Tennessee, Mississippi, Alabama, Georgia, Florida and North and South Carolina. Some of the newer systems in these States, like the Chesapeake & Ohio and its accessories, and the Louisville New Orleans & Texas, are of the standard Northern gauge, and so is the Southern Line of the Illinois Central, while the Mobile & Ohio was last year also altered to conform to this standard. But the vast bulk of the mileage in the Southern States at the present moment has a track width of five feet, and it is estimated that next week's operations will embrace fully 14,000 to 15,000 miles, from which one can judge of the dimensions of the work. And as already said, not only will the track have to be changed, but the rolling stock—locomotives and cars—will have to be adjusted to the new guage (where it has not previously been done) the latter being really the most difficult part of the undertaking. All the preliminaries, however, have been completed, preparations for the event having been in progress for several months, and much of the equipment having been already altered, so when on the 31st of May and 1st of June the 14,000 or 15,000 miles of track are simultaneously changed (some branches and minor pieces will be changed a day or two earlier), everything will be in readiness, and the business and operations of the roads proceed as if nothing had happened, while the means of intercourse between the different sections of the country will have been improved and our transportation interests benefited.

The new gauge will not be precisely the same as the commonly accepted standard, but it will be so nearly so as to be equivalent to the same thing. It will be 4 feet 9 inches, whereas the prevailing width is 4 feet 8½ inches. The Pennsylvania, however, has a gauge of 4 feet 9 inches, and the Southern lines have adopted the same figure. In reality, though, the difference—half an inch—is so small that the rolling stock of the one can and is being freely used upon the track of the other, so that for all practical purposes the two gauges are identical. Moreover, these two gauges embrace together the greater part of the railroad mileage of the country—the Southern roads with their five foot gauge forming the only important exception. According to the Census Report of 1880, of the total track in the country at that time (July 1) 66·3 per cent belonged to the roads with 4 ft. 8½ in. gauge, and 11·4 per cent belonged to those of the 4 ft. 9 in. gauge, making together 77·7 per cent, while of the 5-foot gauge (almost exclusively Southern roads and now to be changed) there was 11·4 per cent more, giving in the aggregate over 89 per cent of the total track in the country. The remaining 10 per cent was distributed chiefly between roads with the 6-foot gauge, some of which have since been changed to the standard, and narrow gauge roads with the 3-foot gauge, the most of which contemplate changing where they have not already changed. It follows, then, that after next week the mileage of the United States will be substantially of one and the same gauge, the exceptions of a wider or narrower gauge being so few as merely to emphasize the rule.

The step which the Southern roads have taken is of course an important one, both in its immediate effects in entailing an exceptional outlay in making the change, and in its ultimate effects in bringing Southern lines in closer communication with Northern and Western systems. In the latter particular the importance of the move can hardly be overestimated. The free interchange of traffic which a common standard will permit, we need hardly say will be of benefit to all interests concerned. The shipper will be saved delays, the railroad will be able to cheapen the cost of handling the traffic, and the mercantile and financial community generally will feel the effects in the increased stimulus that this gives to the development of trade and industry between the different sections. Hitherto the South has been in a measure shut off from the rest of the country by this lack of uniformity. On the north, the Ohio River marked the limit beyond which Southern freight could not go without a transfer of the contents of the car, or at least a change of trucks, and on the West the Mississippi River also formed a dividing line, for Texas and Arkansas roads are of standard gauge. After the change however, this barrier will no longer exist, and traffic can then be moved to the North or West without breaking bulk. Aside from the saving of expense that this will involve, good results may be expected to follow from the fact that the equipment of Northern and Western roads will be placed at the service of Southern roads, which may prove of considerable advantage to these, especially during the months when the cotton movement is most active. And upon the sections themselves the effect of such an interchange in bringing the people closer together, is not to be lightly dismissed. It should even help to attract attention to the South as a field for the profitable employment of capital. That section has been comparatively neglected heretofore. Tnere has of course been growth in recent years—very decided growth indeed,—but as compared with the West and Northwest, the South has not gained as much as the inducements she offers warrant. The flood of immigration especially has passed her by. It is unnecessary to inquire into the causes of this. It is sufficient to know that the change of gauge will make the union between the sections more complete, and in connection with the new industrial development now making such rapid progress, ought to tend to give greater prominence to that section hereafter.

As to the cost of the change on such an extensive body of roads, that cannot be stated with any great degree of accuracy till after the work has been accomplished. Reducing the gauge of track is, of course, a simple problem, but the adjusting of engines, equipment, tools and the various paraphernalia connected with the operation of a railroad, is what constitutes the largest proportion of the expense. We have no exact data for estimating the cost of the work, but an approximate idea of the amount required can be gained by using the figures which Mr. William Butler Duncan gives in the report of the Mobile & Ohio for the late fiscal year. The Mobile & Ohio was changed to standard gauge on the 8th of last July, and an itemized statement in the report places the expenditures on that account up to the close of August at $66,329, of which $11,069 was paid out directly for labor and $25,260 for the necessary material. This included all the track, engines, cars, tools, bridges, etc. We infer, however, that it does not comprise the whole charge involved in the work, for in his remarks we find Mr. Duncan saying that the total cost, which had been originally estimated at $95,777, would probably be less than $80,000. The Mobile & Ohio has 527 miles of main line and branches, and on the basis of $80,000 for the whole the cost of effecting the change (including rolling stock and everything else) *per mile of road* would be a little over $150. On the same basis, the 14,000 miles now to be changed would involve an outlay of $2,100,000, showing that the work is not only one of importance, but one also involving in the aggregate a great expense. The roads on which this burden of cost will chiefly fall are of course the larger systems like the Louisville & Nashville, the Richmond & Danville, the Cincinnati New Orleans & Texas Pacific, the East Tennessee, the Norfolk & Western, and the Central R.R. of Georgia; but the minor roads all over the South will also have their expenses increased on the same account.

It is interesting to note how completely the standard gauge of 4ft. 8½in. and 4ft. 9in. has supplanted all other gauges. Only a few years ago, when hardly enough could be said by the advocates of the 3 foot gauge in favor of the narrow guage plan, it seemed as if a new and dangerous rival were about to arise. But a short trial has served to demonstrate that the advantages claimed for the narrow guage system were largely illusory, and the three-foot gauge has now fallen into pretty general disrepute, while nearly all the companies that had built their lines on that guage have become discredited, and are in the hands of the officers of the law. The Toledo Cincinnati & St. Louis was to be the most brilliant exponent of the new theory, "the grandest narrow guage enterprise on the Continent," but alas! there never was a road so deeply involved in financial and other difficulties as this, and when it finally succeeds in getting out of the dilemma in which it now finds itself, the road will be widened to the standard guage. Then there is the Texas & St. Louis, which also has an extensive narrow guage mileage, now to be changed to standard width. The Denver & Rio Grande is the only narrow guage system of consequence remaining, and there the mountainous character of the country renders a comparison with other sections out of the question. For short distances and special kinds of traffic the narrow guage sometimes answers very well, and there are some pieces of this character that pay, but on any large or extensive scale, and with ordinary kinds of traffic, experience seems to have demonstrated that the narrow guage does not meet the requirements called for, and most of the companies of this kind formed in recent years have, as already said, met with disaster.

As to the old broad guage, that has long since gone out of fashion. The Erie was constructed on that pattern, but was changed to standard in 1878. Its principal connection—the Atlantic & Great Western—was also of six foot guage, and this was changed in 1880. We may remark that the Canadian system is likewise of standard guage. There were varying gauges in Canada at first, but in 1873 a common movement was made towards the adoption of the standard, and since then that has been generally followed. The Mexican Central (El Paso to City of Mexico) is also of 4ft. 8½in. gauge, and so is the Mexican Railway (Vera Cruz to City of Mexico), though the Mexican National is narrow gauge. Practically, therefore, it may be said that the whole railroad system of the North American Continent is of standard gauge. And elsewhere this gauge also chiefly prevails, that being the usual width in Great Britain and other European countries. In fact the experience of the world seems to have settled in its favor as offering a maximum of service at a minimum of cost.

Not the least significant feature about the change now to be made on Southern roads, is that it is undertaken voluntarily and without any external pressure whatever. In this it is like the adoption of a uniform time standard, effected not so very long ago. The roads are yielding simply to the demands of necessity. They find that a gauge at variance with that of the roads in most other sections of the country is an impediment which interferes greatly with the free operation and full development of their business. So they determine to remove the impediment. But there is no force or compulsion—no law except the natural law of trade, in obedience to which they make the change. They are exercising their own volition entirely. Nevertheless, the agreement between them is unanimous. Is there not in that a lesson to those who never weary in calling for legal enactments and Government intervention to accomplish this or that? When the necessity for an important step is clear and imperative—and who can be a better judge of this than those most directly concerned—railroad managers take that step (whether it be a reduction of rates or a change of custom or condition) promptly and without hesitation or complaint. In fact in this way the laws of trade and the instinct of self preservation effect reforms and improvements that all the legislative bodies combined could not accomplish, as is so evident in the present case.

Figure B.4: Report on the Conversion (*New York Times*, May 31, 1886)

CHANGING THE GAUGE.

WORK ON THE LOUISVILLE AND NASHVILLE COMPLETED—OTHER SOUTHERN ROADS.

LOUISVILLE, Ky., May 30.—The great work of changing the gauge of the Louisville and Nashville Railway from wide to standard is completed. Eight thousand men were scattered over the divisions of the main stem at daylight this morning, and at sundown the track was standard all along the line, and test trains had been run over the different divisions and switches, and reports had been sent in to General Manager Harahan, in this city, pronouncing the work complete and everything in good shape. Some of the divisions were completed as early as 9:30 o'clock this morning, and the great bulk of the work was finished by noon, everything being finished up in proper shape by the middle of the afternoon. The day was propitious, the elements offering no interference at any point except Memphis, where thunder storms interrupted the work to some extent. But in spite of that the Memphis division was finished before noon. No trains were run out last night or to-day, but at midnight to-night the regular schedule will be resumed and the rolling stock of the Louisville and Nashville will have only been treated to a Sunday's rest. The following branches were changed yesterday: Pensacola and Atlantic Railway, Metumpka branch; Birmingham Mineral Railway, both branches; Owensborough and Nashville, Madisonville branch; Elkton and Guthrie, Glasgow branch, Bardstown branch. The following are the roads changed to-day: Main stem, first and second divisions, Knoxville Division, Evansville, Henderson and Nashville Division, Memphis Line, Nashville and Decatur Division, South and North Division, Mobile and Montgomery Division, New-Orleans and Mobile Division, and Pensacola Railroad.

Figure B.5: Example of Anticipated Effects (*Wilmington Morning Star*, April 16, 1886)

A THREATENED LOSS OF BUSINESS.

Savannah News.

The change of gauge on Southern railroads, which, it is expected, will be made in July next, will bring about some important changes in the lumber business in the South. Southern lumber now reaches the Northern markets by sea. It is transported from the mills to the nearest ports, and sent by sailing vessels to the Northern distributing points.

This way of getting lumber from the producer to the consumer is rather slow. It has to be handled several times—once at the mills, once, and sometimes twice, at the port of shipment, generally twice at the port of its destination, and, finally, once at the place of consumption. It has to be insured against the of the sea, and frequent handlings often cause considerable breakage. Another drawback to shipments by sea is the long time required for lumber to reach the Northern markets after it has been shipped.

Very little lumber has gone North by rail for the reason that Southern roads having a different gauge from the Northern roads, it is rather troublesome and somewhat expense to change the trucks.

Southern lumbermen say, however, that when the gauge of the Southern roads is changed they will be able to ship lumber without breaking the bulk direct from their mills in Georgia, Florida or any other Southern State to any point in the country, and that the difference between the cost of rail and water transportation will be more than overcome by the saving that will be effected in insurance, handling and breakage.

While much of the lumber will continue to be shipped by sea, there is no doubt that a great deal of it will not seek the seaboard for transportation to market when it can be transported as cheaply and much more quickly by rail, and Southern lumber ports are bound to suffer a considerable loss of business. Other kinds of business, however, will doubtless take the place of whatever part of the lumber business that may be lost to them.

Figure B.6: Technical Summary of the Gauge Change (*Railroad Gazette*, October 14, 1887)

The Change of Gauge of Southern Railroads in 1886.*

When Horatio Allen recommended a 5-ft. gauge for the South Carolina Railroad, he little thought that half a century later an expenditure of over a million dollars would be required to undo his work. He did not expect an extension of the iron rails, within that time, from ocean to ocean, nor that necessities would arise for running cars from one extreme of the country to the other. His successors, in later years, were little wiser. Time, however, has shown that prompt and economical transportation requires that our car, once loaded, shall go to its destination without transfer. To this end, the 6-ft. lines attempted to extend their wide gauges to distant centres of trade; while the 4 ft. 8½ in. and 4 ft. 10 in. gauges tried to compromise their troubles by changing the tread of their wheels from the 3½ in. of the early lines to 5 in., that they might run on both gauges. This was not altogether satisfactory, and another attempt was made to harmonize matters by the use of a compromise gauge of 4 ft. 9¼ in. This did better, and in time the 4 ft. 10 in. or "Ohio" gauge, was changed to this or its successor, the 4 ft. 9 in. The 5 ft. 6 in. gauge became a thing of the past, and the 6 ft. either became "standard" or laid a third rail, so that either "wide" or "narrow" trains could be run, and all equipment be kept in use until it was narrowed, when the third rail could be taken up. It became possible to run a car from the Atlantic to the Pacific, north of the Ohio River and west of the Mississippi River. South of the Ohio and east of the Mississippi, however, the universal gauge, save a few roads in Virginia, was 5 ft. Interchanges of cars were not thought necessary, and all freight to and from this section had to be transferred from car to car. This burden was realized by both railroads and shippers, and arrangements were made to exchange trucks, till not a prominent point could be found on the border without its "hoist" and acres of extra trucks. This was expensive, both in time and "plant," and a change of gauge, which would do away with these "hoists" and the time and labor required to operate them began to be talked of. Few, however, had the courage to think of it as a thing of the near future.

The Illinois Central Railroad was the first line east of the Mississippi to meet the question and make its southern end conform in gauge to its northern, which it did in 1884, giving a continuous 4 ft. 8½ in. line from New Orleans to Chicago. Under the pressure of competition, the Mobile & Ohio Railroad followed, and in July, 1885, changed to 4 ft. 8½ in. The most direct competitors of the Mobile & Ohio Railroad, the Louisville & Nashville and Cincinnati Southern systems, saw that they, too, must change, or be at a disadvantage, and determined so to do. Other large systems realized that they could delay no longer, but must move with the Louisville & Nashville and Cincinnati Southern. The smaller roads had no choice in the matter, but must join the ranks.

At a meeting of the Executive Committee of the Southern Railway and Steamship Association (presidents of the various lines) held in the summer of 1885, a committee of general managers of the principal lines was appointed to take up the matter, formulate plans and fix dates, that there might be harmonious working and the least possible delay and discomfort to the public. This committee met in New York in October, 1885, but nothing like a general or satisfactory discussion was had. The more the managers looked into the matter, the more they were impressed with its magnitude, and the need for co-operation. Our chairman was requested to call a meeting of the managers of all lines interested, with the request that the heads of their Transportation, Machinery and Maintenance of Way departments be present to aid in the consideration of the question. This convention was held at Atlanta, Ga., Feb. 2 and 3, 1886, with 70 representatives, of various grades, of 30 roads. Tuesday, June 1, was fixed upon as the day for the general change, though some 6 or 8 roads, for local reasons, were to change on Monday, May 31. It was also agreed that branch lines might be changed at such other times as best suited the owners, the general change being so conducted as to best promote the interests of the through lines. Committees were appointed on Transportation, Roadway and Machinery, to discuss in detail matters pertaining to the various departments and to report to the convention for final action.

The matter of the proper gauge to which we should change was taken up by the convention itself, and a lengthy discussion followed. It was urged by one important line, whose business was mostly with Northwestern roads, that 4 ft. 8½ in. was the true gauge to be used. The greater parts of the roads changing, however, had their largest interchange of business with the east and northeast, and consequently with the Pennsylvania Railroad system. There must necessarily be a large interchange of cars with that road, and it would follow that the gauge used should readily admit Pennsylvania Railroad cars, and that our cars must be acceptable to that road. It is true that the Pennsylvania Railroad cars do run on the Northwestern, or 4 ft 8½ in. roads; but it was the experience of several who had worked both gauges, that to haul a given number of cars upon a 4 ft. 8½ in. track required more power than upon a 4 ft. 9 in. track, because of the greater friction between the wheels and the rails; the flanges in one case clearing the rail by three-fourths of an inch, while in the other the clearance is one-fourth of an inch, and sometimes less, especially when the track men have the track gauged a little too close; not an uncommon thing to find. Again it is not an unusual thing for a wheel to be carelessly put on, and be too wide. It was the writer's experience, a few years ago, while connected with a 4 ft. 8½ in. road, to send some Pittsburgh, Ft. Wayne & Chicago cars to the Mississippi River loaded. They were undoubtedly a little too wide and the track in the yard where they went was a little too narrow. The inspector found something wrong, and actually took the trucks out from under the cars and replaced them with narrow trucks, upon which he sent the cars to Chicago, while he loaded the wide trucks upon flats and returned them home in that way. One road in Ohio, formerly a 4 ft. 10 in. "Ohio" gauge, changed to 4 ft. 8½ in., and after a few months experience again changed to 4 ft. 9 in., and found that it was freed from many trials due to small clearance between flange and rail. It was at last decided that we would make 4 ft. 9 in. our gauge. This discussion brought out a special committee on wheel gauge who were to take up that question in connection with other roads of both gauges and report at an adjourned meeting on the 16th of February.

The Transportation Committee reported upon the transportation feature of the problem, which chiefly pertained to the handling of loaded and the return of foreign cars prior to the change, in order that each road might have only its own cars on the day of change, or the fewest possible cars of other roads.

The Machinery Committee treated upon the matter of changing cars from a general stand-point, in order that the work upon those away from home, or upon foreign roads, should be done in the manner desired by the road owning the cars. Beyond that, they left each road to do its own work in its own way.

The Committee on Roadway went more into detail, and based upon the experiences of the Mobile & Ohio, and such other information as they could obtain, reported as follows:

[The instructions issued by the General Superintendent of the Mobile & Ohio for the change of gauge on that line July 8, 1885, were printed in the *Railroad Gazette* May 14, 1886, and we published those of the Superintendent of the East Tennessee, Virginia & Georgia in 1886, June 4, 1886. These cover essentially those prepared by the Committee, which, therefore, are not reprinted here.—Ed.]

Feb. 16, the convention met, pursuant to adjournment, to receive and consider the report of the Committee on Wheel Gauge. This Committee sent circulars, upon the subject of wheel gauge, to a large number of roads, both 4 ft. 9 in. and 4 ft. 8½ in. gauge, in order to get their ideas and experience. At the same time a sub-committee was started upon a tour of investigation, to learn what they could upon the matter. They visited a large number of roads and saw the practical workings, and consulted with the most experienced car-builders in the country. After a careful examination of the information thus obtained the Committee reported:

"We recommend that 4 ft. 5⅜ in., allowing variations of ⅛ of an inch either way, be adopted as a standard gauge between flanges, and further recommend that the limit gauge of the Pennsylvania Railroad be adopted, that is, the smallest distance between flanges be 4 ft. 5 in., and the smallest distance from out to out of the tread of wheel be 5 ft. 4 in. Any wheels measuring less than allowed by these limits to be rejected."

This was exactly what the Master Car-Builders had fixed upon as the proper gauge for wheels, but which had only stood as a recommendation, never having been accepted as a standard by any roads. The following statement shows the gauge, distance between flanges and lateral play of a number of large systems:

Gauge track. Ft. In.	Name of road.	Distance between flanges. Ft. In.	Lateral play In.
4 9	Pennsylvania	4 5¼	¾
4 8½	Illinois Central	4 5⅜	⅜
4 8½	C., B. & Q.	4 5⅝	½
4 8½	L., N. A. & C.	4 5⅜	..
4 8½	N. Y. C. & H. R. R.	4 5⅝	..
4 8½	Missouri Pacific	4 5¼	¼
4 8½	L. S. & M. S.	4 5¼	¾
4 9	Rich., Fed. & P.	4 5⅜	¾
4 8½	Balt. & Ohio	4 8¼	½
4 8½	C., M. & St. P.	4 5⅝	⅝
4 8½	C. & N. W.	4 5⅝	⅝
4 8½	St. P., M. & M.	4 5⅝	¾
4 9	Ches. & Ohio	4 5½	¾
4 8½	Pitts. & L. E.	4 5⅛	¼

It will be seen that the report was based upon the practice of many roads, and would undoubtedly give satisfaction to all. It was adopted by the convention.

The general plan has now been blocked out, and individual work could commence with reasonable assurance that it would be in harmony with that of other roads. The various officers had studied the problem to some extent before the meeting, and had worked out many details in their own minds. They were thus enabled to compare notes, and avail themselves of the thoughts of others, and gain much valuable information. Some prepared and printed very elaborate instructions, intending to cover the minutest detail of the work, so nobody could possibly err, only to find that the practical man on the track or in the shop discerned "snags" unthought of by the formulator of the instructions, and also found ways to overcome the difficulties, and in many cases was able to do his work in a better and cheaper way than was pointed out in the instructions. The more general way was to print and issue only the general instructions, leaving much to department heads to work out according to the conditions surrounding them. Frequent and full personal consultations were found to be useful. The work was of an extent and character, all things considered, never before undertaken, and must be done at the time selected. There would be no chance to wait and see what others did, or to correct mistakes; it must be done and the public served. The work of preparation was spread over several months, and in fact was much more of a problem than the mere moving of the one rail three inches. The engines and cars were of varied construction and conditions, and the facilities varied with the various roads and localities. A rule which would work well in one place, would not of necessity be the best in another. A process which would be good in one place, might not be the most economical in another. So the officers of each road tried to look at their problems, with their surroundings, and decide for themselves how much of the general plan they could follow.

I give briefly some of the plans and methods in both track and machinery matters, showing how details were handled. While several roads had changed gauge, the conditions varied much from these we now had to meet. In former cases there were plenty of neighbors or connections, from whom cars could be borrowed to keep their traffic moving, while in ours everybody had to look out for himself, and could not help his neighbor if he would. We must take care of our traffic and change our cars at the same time. To do this we must withdraw a part of our equipment from service, and change it prior to the change of the track, giving us something to use as soon as the track was changed. Necessarily, this would inconvenience the public somewhat; but there was no other way out of the trouble, though a loss of earnings would follow.

It was argued by some that the proper way would be to provide entire new sets of wheels and axles, so that, at the change, the least possible time would be used in the transfer. The general idea, however, was that it would be very expensive and unwise. When we consider that with 13,000 miles of main track and 1,500 miles of side track, there were 1,800 engines and 40,000 cars, we see the great cost of that plan, 327,000 new wheels and 163,000 axles could not be thought of, even if we did have nearly as many wheels and axles left over to be used in repairs. We must withdraw our cars, and if possible get half of them changed before the first of June. Cars so changed would be "parked" upon tracks, which would be prepared for the purpose, near the shops where the change was made. When the day of change came it would be necessary to gather in all the remaining broad gauge cars at the same points and "park" them upon these tracks, unless the road should be fortunate enough to have a large surplus of broad gauge tracks that were not needed for traffic. Very few Southern roads had this, and the extra tracks were, as a rule, laid. A system with 5,000 cars would need about 30 miles.

Just how much would be needed at each point was a matter of conjecture, as no one could tell in advance how many cars would be changed at any one point, or how many broad gauge cars would be hauled there at the last minute. Storage tracks as a rule could not be built very near the shops where the change of trucks were made, so that tracks had to be laid connecting them with the shop tracks.

The shop tracks were so arranged that both wide and narrow gauge trucks would run upon them. This was, as a rule, done by putting some guard rails inside the 5-ft. track, 4 ft. 5 in. out to out, so that the tread of a wheel of the narrow truck would be kept on the rail of the 5-ft. track, fig. 1. Some were laid with the outer rails 4 ft. 11¼ in. apart, and without guard rail. This, however, did not give good satisfaction, as the bearing surface was so small that a slight imperfection in the rail, or a curve that let the wheel run to one side, would cause a wheel to drop in and give trouble and delay. The tracks from storage yards to shops were sometimes laid with a guard rail, fig. 1, and at others with two

FIG. 1

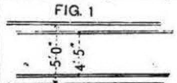
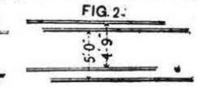


FIG. 2.



separate tracks on the same ties, as shown in fig. 2. This last was most satisfactory. Several ingenious devices were used to switch from one track to another, all temporary in character and inexpensive. Expensive frogs in some way were avoided, where two tracks or rails were crossed and compound frogs ordinarily used.

In changes heretofore made full sets of bridles for switches had in some cases been provided and "Wharton" switches thrown out, plain stub switches being put in their places. This seemed expensive, and would take up much valuable time on the day of change.

We have various kinds of bridles. The old-fashioned one for the stub switch, that clasped the base of the rail, as shown in fig. 3, was cut near its centre and had one end lengthened: each part being at least 2 ft. 9 in. long. Three holes were either punched or drilled through the bars near the end, the outer one 2 ft. 7½ in. from the inside of the rail head, the next one 3 in. inside of that. This made the bars all alike, and no care had to be used to pick "rights" and "lefts."

These were put on the 5-foot gauge by placing the outer hole of one bar over the second hole in the other; a bolt was

FIG. 3.

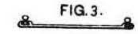


FIG. 5.

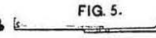


FIG. 4

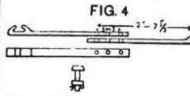


FIG. 6

then put through, a nut put on the bolt, and a spring cotter put in a hole which had been drilled through the bolt. Another bolt through the other holes, and the bar was secure. On the day of change the bolts were easily removed, the bars moved 3 in., the bolts replaced, and our track was 4 ft. 9 in. Fig. 4 shows the bars as changed and ready to be put together. Fig. 5 shows a bar which took hold of the flange of the switch rail, treated in the same way. Fig. 6 shows another kind, and the manner of its treatment is readily seen by the sketch. A hole is drilled 3 in. back from the one through which the original rivet or bolt was put.

With the "Wharton" there was more trouble, as the bars could not easily be removed to be prepared for change. It was found however, that a casting could be made that could

FIG. 7

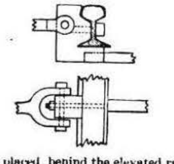
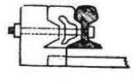


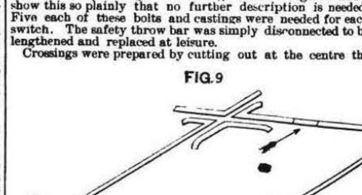
FIG. 8



be placed behind the elevated rail, which would hold it in 3 inches securely, a longer bolt being needed. Figs. 7 and 8 show this so plainly that no further description is needed. Five each of these bolts and castings were needed for each switch. The safety throw bar was simply disconnected to be lengthened and replaced at leisure.

Crossings were prepared by cutting out at the centre the

FIG. 9

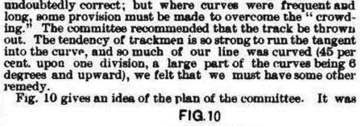


requisite length, and then keeping the piece in place by splice bars till the day of change, when the cut pieces were taken out and one side moved up to proper gauge, see fig. 9.

It was decided that the "gauge" rail was the one to be moved. On lines without curves, or with very few, this was undoubtedly correct; but where curves were frequent and long, some provision must be made to overcome the "crowding." The committee recommended that the track be thrown out. The tendency of trackmen is so strong to run the tangent into the curve, and so much of our line was curved (45 per cent. upon one division, a large part of the curves being 6 degrees and upward), we felt that we must have some other remedy.

Fig. 10 gives an idea of the plan of the committee. It was

FIG. 10

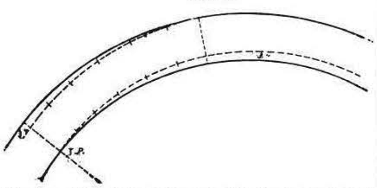


claimed that we could cut rails so as to leave room; but our grades were high, and we felt that in the days that would elapse between any such preparation and the day of change our track would "run," as in fact it did constantly. We thought June 1 would be hot, and thus any gap we might calculate upon surely be closed up. All this, of course, where the outside rail was the one to be moved. It seemed better to us to change sides, and in all cases to move the inside rail. To do this we would change the "gauge" rail up to the tangent point the regular 3 in., the joint first beyond the tangent point (which we will assume at a joint nearest the actual T. P.) we will throw in 2⅓ in., while the other rail will come in ⅓ in.; the second joint in same way will go in 2 in., while the opposite rail comes in 1 in.; at third joint the distances will be 1⅓ and 2⅓ in.; at the fourth joint, 1 and 2 in.; at the fifth joint, ⅓ and 1⅓ in.; at the sixth joint our outside rail will not move at all, while the inside rail will come in the full

* By C. H. Hudson, member of the Western Society of Engineers, reprinted from the *Journal of the Association of Engineering Societies*.

3 in.; we continue to move the inside rail till within six joints of the next tangent point, when we commence to reverse the process. In the process of preparation spikes have been driven at each of the points mentioned. Fig. 11 shows

FIG. 11

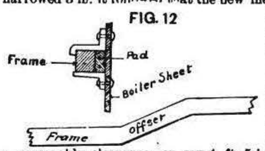


this plan. The outside or elevated rail is the one usually used as the line rail upon a curve, so we were following the plan on which we started, viz.: to move the "gauge" rail. The wisdom of the plan was shown when the day of change came and curves changed on this plan were found to be in better line than those changed by any other method. We tried all three plans spoken of.

In the matter of locomotives the conditions varied much. Of the engine builders, the Baldwin Locomotive Works had probably been the most far-seeing. For twenty years they had looked forward to this change, and had during that time so constructed their frames and fire-boxes that, by using new driving wheel centres, the change could be made without changing other parts. Few other builders had, until comparatively recently, given the matter any thought, and, as a result, many engines were found that could be changed only by moving the frames in, and not unfrequently the fire-box had to be altered; this meant a new fire-box and heavy expense. Many engines were thrown out of service by the fact of the great cost of changing them.

The 5-ft. engines measured between flanges of drivers (and other wheels as well) 4 ft. 8⅞ in. As the gauge was narrowed 3 in. it followed that the new measurement would be 4 ft. 5⅞ in., and this in fact was the measure fixed upon by the convention, with a limit of variation of ⅛ in. either way; so the frames must be enough less than this from out to out to give

FIG. 12



a reasonable clearance, or say 4 ft. 5 in. I think all our Baldwins was within this limit; but we found other engines wider from out to out of frames, the frames being set out from the fire-box and a "pad" placed between them; see fig. 12. The "pad" could be cut out and the frame set in against side of the fire-box; but to do it, this frame had to be offset, as shown in fig. 12. This was done behind the rocker arm and in front of the pedestal or "jaw" thus rendering unnecessary the changing of machinery, but enabled us to set in the boxes and wheels or tires to the proper width without cutting into the frame.

To get proper information about all the engines, accurate measurements were taken of width of fire-box, width between frames, from out to out frames, between hubs, between inside of tires, between rims of wheels, sizes of boxes and wedges, thickness of hubs, rims of wheels, etc. Blue print diagrams were prepared upon which were placed all these measurements with the number of the engine. From these the head of the machinery department could see at a glance what was required for each engine. It was expected at the start that new driving wheel centres would be required for all engines; but examination of our blue prints showed that upon our lines, at least in a majority of cases, this was not necessary.

FIG. 13

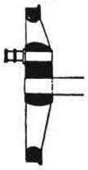
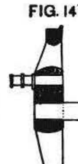


FIG. 14



Some few engines, notably some of the old Rogers, had wheels that were dished to such an extent that by pressing them off and putting on again, with the outside face inside, an inch and a half could be gained and the tire could go on as originally placed, squarely upon the wheel. See fig. 13 as originally, and fig. 14 as turned. It was found in practice that a new crank pin had to be put in. In many cases we found that we had thick hubs and heavy flanges to both driving boxes and wedges, so that by taking from ⅛ to ⅝ of an inch from the insides of the hubs, and ⅛ to ¼ from the box and wedge flanges, we could gain at least one inch, and in some cases did more. This left not to exceed half an inch for the tire to project over the wheel centre on the inside, neither an unreasonable nor an unusual projection. This change was a trifling one and done at a cost per engine of about $130.67, including new crank pins. A new set of wheel centres, finished and in place, including pins, which would probably be needed, would cost $264.46. When changes were decided upon, and an engine was in the shop, they were made, and the tires were then put on at the old gauge, projecting outside the centres. They

FIG. 15

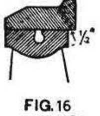


FIG. 17

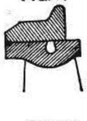


FIG. 19

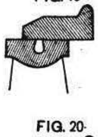


FIG. 16

FIG. 18

FIG. 20

were used in this way without trouble until the day of change came; fig. 15, original; fig. 16, changed. Some of the more recent engines had their wheel centres built expressly with a view to changing. They were placed upon the axle, and would be required with the new gauge; but the rim projected outwardly an inch and a half more than usual, so that the tire could be placed for the 5 ft. gauge and still have its full support. See fig. 17. When the tire was eventually moved to the narrow gauge this outward rim would be turned off. Of course, we were not able to take all our engines into the shop and press in their wheel centres, and had to be satisfied with some temporary arrangements that would give us the use of the engine until such time as it could be taken into the shop. We decided to set tires in, leaving the centres unchanged. This gave an inside projection of 1½ in., plus what little projection there might have originally been. When the rim was solid, there was no trouble in this (fig. 18), provided the tire was not too thin. We fixed upon 2 in. as a limit safe beyond doubt. When the coring was in the middle and not large this was still safe, see fig. 19. We sometimes, however, found very large cores, and at one side (see fig. 20), which gave us a very small hold for our tire, and it was not deemed safe for road service. To overcome this danger we purchased a few new tires 6¾ in. wide with the outer corner cut away, as shown in fig. 21. This gave us a bearing over the entire rim of the wheel, and was safe, no matter how large or in what position was the core. The corner was cut off to save material, and at the same time, to save the bad effects of a wide tire upon frogs and switches. The edge was left 1 in. thick. At some future time when the engine goes into the shop and has new centres put on, or the old ones pressed in, this extra width of tire can be turned off.

As to engine trucks: The frames had, in many cases, been made of the proper width for the narrow gauge, and the wheels had been built with a heavy hub projecting an inch and a half inward (fig. 22), so that it would bear against

FIG. 21

FIG. 23

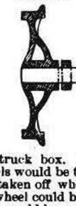


FIG. 24

FIG. 25

FIG. 22

the truck box. It was expected that these wheels would be taken out and 1½ in. of the hub taken off when the change came, so that the wheel could be pressed on the new gauge. This would have taken too much time, so the inch and a half extra hub was left off of all new wheels, but a cast iron collar or washer 1½ in. thick was placed upon the axle inside each wheel and between it and the box (fig. 23). When the day of change came a few blows of the hammer upon a cold chisel split this collar off and we were ready to press the wheel the needed inch and a half upon the axle.

Many of the wheels that were still in use with the long hub were put into a lathe and a groove was cut an inch and a half back from the face, leaving our cast collar; which was easily split off as before. (Fig. 24.)

With tender wheels, as with our car wheels, the case was different. Originally, the axle for the 5-ft. gauge was longer than for the 4 ft. 9 in.; but latterly the 5-ft roads had used a great many Master Car-Builders' axles for the 4 ft. 9 in. gauge, namely, 6 ft. 11¼ in. over all, thus making the width of the truck the same as for 4 ft. 9 in. gauge. To do this a dished wheel, or rather a wheel with a greater dish by 1½ in. than previously used was needed, so that the tread of the wheel could be at its proper place; see fig. 25. There were, of course, many of the wheels with small dish and long axles still in use. Their treatment, however, when the day of change came, did not vary from that of the short axles. It had been the rule for some years that all axles should be turned back 1½ in. further than needed; but unfortunately the rule had not been closely followed, and many were found not to be so turned. To make the matter worse, quite a number of the wheels were found to have been counterbored about ½ in. deep at the back end, and the axle turned up to fit this counterbore; a good idea to prevent the running in, in case the wheel worked loose, but bad from the standpoint of a

FIG. 26

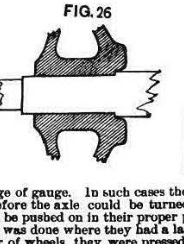


FIG. 27

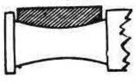
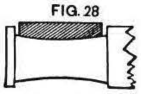


FIG. 28



change of gauge. In such cases the wheels had to be started off before the axle could be turned back, so that the wheels could be pushed on in their proper position. (Fig. 26.) If the work was done where they had a lathe large enough to swing a pair of wheels, they were pressed off but half an inch, the wheels swung in the lathe, the axles turned back 1½ in., and the wheels then pressed on 2 in. or 1½ in. inside of their first position. Where no large lathe was in use, the wheels came entirely off before the axles could be turned back. The work in the former case was both the quicker and the cheaper. Where the large lathes were used they were either set down into the floor, so a pair of wheels would easily roll into place, or a raised platform was put before the lathe, with an incline up which the wheels were rolled and then taken to the lathe. These arrangements were found much quicker and cheaper than to hoist the wheels up, as is usually done. In pressing the wheels on, where the axles had previously been turned back, much trouble was at first experienced because of the rust that had gathered upon the turned part behind the wheel, forming a ridge over or upon which the wheel must be pushed. Some of the roads, at the start, burst 10 or 15 per cent. of the wheels so pressed on. By saturating this surface with coal oil, however, it was found that the rust was easily removed and little trouble was had. It was found, sometimes, that upon axles newly turned back a careless workman would leave a ridge at the starting point of the turning. Frequently, also, the axles were a little sprung, so that the new turning would be a little scant upon one side when compared with the old surface, and upon the opposite side a little full. As an indication that these difficulties were overcome as they appeared, I will say that upon our line only 202 wheels burst, out of nearly 27,000 pressed on, an exceedingly small percentage.

After the change upon the early roads they were troubled for weeks with hot boxes, caused, as we believed, by the changing of brasses. A brass once fitted to a journal will work upon it without trouble; but when placed upon some other journal will probably not fit. If the journal had been worn hollow (and it was surprising to see how many were so worn), the brass would be found worn down to fit it. See fig. 27, exaggerated of course. The next wheel may have an axle worn little or none, as in fig. 28. Now, if these brasses are exchanged, we have the conditions, as shown in figs. 29 and 30, and we must expect they will heat. The remedy was simply to keep each brass upon its own journal. To do this the brasses were fastened to the axle by a piece of small wire, and went with it to the lathe and press. When its truck was reached, the brass was there with its journal. Worn

FIG. 29

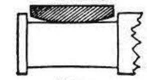


FIG. 30

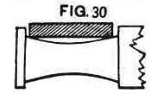
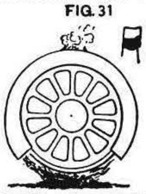


FIG. 31

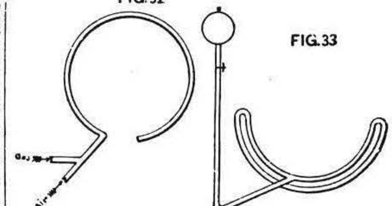


out brasses, of course, could not be put in, and new ones were substituted. The little trouble from that source that followed the change showed the efficacy of the remedy.

The manner in which the tires of engines were to be changed, when the final day came, was a serious question. The old fashioned fire upon the ground could not be thought of. The Mobile & Ohio had used a fire of pine under the wheel, which was covered by a box of sheet iron, so arranged that the flame and heat would be conveyed around the tire, and out at an aperture at the top; fig. 31. Many thought this perfect, while others were not satisfied, and began experiments for something better. A device for using gas had been patented, but it was somewhat complicated, as well as expensive, and did not meet with general favor. A very simple device was soon hit upon. A two-inch pipe was bent around in a circle a little larger than the outer rim of the wheel. Holes $\frac{1}{10}$ inch in diameter and 3 or 4 inches apart were drilled through the pipe on the inside of the circle. To this pipe was fastened another with a branch or fork upon it. To one branch or fork was connected a gas-pipe from the meter, while to the other was

FIG. 32

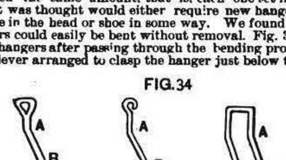
FIG. 33



connected a pipe from an air-pump. With the ordinary pressure of city gas upon this pipe it was found that the air-pump must keep an air-pressure of 40 lbs., that the air and gas might mix properly at the branch or fork, so we could get the best combustion and most heat from our "blow-pipe," for such it was. See fig. 32. We were able to heat a tire so it could be moved in ten to twenty minutes, and the machine may be said to have been satisfactory. Gas, however, was not to be had at all places where it would be necessary to change tires, and the item of cost was considerable. To reach a result as good, if possible, experiments were begun with coal oil (head-light oil). They were crude and unsatisfactory at first, but soon success was reached. A pipe was bent to fit the lower half of a wheel pretty closely, and then turned back under itself about the diameter of the pipe distant from it. This under part had holes $\frac{1}{10}$ in. in diameter and 3 or 4 in. apart, drilled upon its upper side, or under the upper pipe. Connected with the upper pipe at its centre was a pipe which ran to one side and up to the can containing the kerosene. Between the can and the pipe under the wheel was a stop-cock by which the flow of oil could be controlled. To use the device, open the cock and let a small amount of oil flow; apply fire to the pipe under the wheel, and the oil in the upper pipe is converted into gas, which flows out of the small holes in the lower pipes, takes fire and heats not only the tire, but the upper pipe, thus converting more oil into gas. We had here a lot of blue flame jets and the same result as with gas, but at less cost. We had also a machine that was inexpensive and easily handled anywhere. Boxes were placed over the upper part of the wheels, that the heat might pass close to the tire. This device was extensively used by our people, and with great satisfaction. Care had to be taken that in starting the fire it did not smoke and cover the tire with carbon or "lampblack," which is a non-conductor of heat. Experiments were made with air forced through gasoline, and with oil heated in a can to form gas. There was more danger in either of these than with our blow-pipe device, and no better results were obtained, though the cost was greater.

With the change of the wheels, the brakes had to be changed the same amount, that is, each one set in 1½ in. This it was thought would either require new hangers, or a change in the head or shoe in some way. We found that the hangers could easily be bent without removal. Fig. 34 shows three hangers after passing through the bending process. A short lever arranged to clasp the hanger just below the point

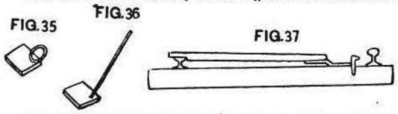
FIG. 34



A was the instrument. A forked "shore" is now placed, with the fork against the point *A*, and the other end agains the car sill; press down on the lever and you bend the hang er at *A*; lower the lever to a point just below *B*, reverse the process and you have the bend at *B*; the whole thing taking less than two minutes per hanger. A new bolt hole, of course, has been bored in the brake beam 1½ in. inside the old bolt. It takes but a short time after this to change the position of the head and shoe.

Before the day of change, a portion of the spikes were drawn from the inside of the rail to be moved, and a spike set 3 in. inside of the rail. As a rule two spikes were drawn and the third left. At least every third spike was set for the new gauge, and in some cases every other one. There were several devices with which to set the spike. A small piece of iron 3 in. wide was common, and answered the purpose well. This had a handle, sometimes small, just large enough for the hand to clasp, while others had a handle long enough for a man to use it without stooping down. See figs. 35 and 36. Another device is shown in fig. 37, so arranged that the measurements were made from the head of the other rail. This was liked best, and, it is thought, gave the best results, as the moved rail was more likely to be in good line than when the

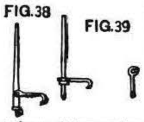
FIG. 35 FIG. 36 FIG. 37



measurements were taken from the flange. It was intended that great care should be taken in driving the spikes, that they were in the proper place, square with the rail, and left sticking up about an inch. The ties, of course, were all adzed down before the day of change.

Hand-spikes were originally used to throw the rails, as were lining bars. We found, however, that small cant-hooks were more easily handled and did better work. The first were made like fig. 38, with a spike in the end of a stick, while the hook was fastened with a bolt about 10 or 12 in. above the foot. We afterward made them of a 1¼ in. rod, 3½ feet long, pointed at one end, with a ring shrunk on 1 foot from the bottom. Then the hook was made with an eye, as shown in fig. 39, which slipped down over the top of the main rod. This was simple and cheap, and the iron was to be used for repair purposes when this work was done.

FIG. 38 FIG. 39



Upon the system with which the writer was connected we had some branches where we could experiment upon the moving of the rail. Between Selma and Lauderdale the traffic was light, and at Lauderdale it connected with the Mobile & Ohio Railroad, which was narrow, and to which all freight had to be transferred, either by hoisting the cars, or by handling through the house. By changing our gauge we would simply change the point of transfer to Selma. Here was a chance to experiment upon one hundred miles and cause little trouble to traffic. We could see the practical workings of our plans, and, at the same time, leave less to do on the final day. Upon the 20th of April we did this work. It had been our plan to do it somewhat earlier, but floods prevented. Most of the rail was old chair iron, short, and consequently more time was used in making the change than would have been required had our work been on fish plate rail. Our sections here were about eight miles long, and we arranged our men on the basis blocked out by the committee, viz.: 24 to 26 men to the section, consisting of 6 spike pullers, 4 throwing rails, 12 spikers, 2 to push the cars and carry water.

We soon found 5-ft. cars useless and threw them into the ditch to be picked up at some future time.

The men were spread out so as not to be in each other's way, and, when the organization was understood and conformed to, it worked well. One gang changed 5 miles in five hours and ten minutes, including a number of switches. We found, however, and it was demonstrated still more strongly on later work, that after 5 or 6 miles the men began to lag. We believed we had the best results when we had sections of about that length. It was arranged that two sections, alternately, commenced work together at one point, working from each other and continuing until the force of another section was met, working from the opposite direction.

The foreman in charge was expected to examine the work and know that all was right. The push car which followed was a good test as to gauge. A work train was started from each end with a small force (20 or 25 men) to run over the changed track. This train, of course, had been changed on a previous day to be ready for this work. If a force was overtaken by this train with its work not done, the men on the train were at once spread out to aid in its completion. This done, the train ran on. Not until this was done was a traffic train allowed to pass over the track. The same rule was followed upon all the work. Upon the final day it was required that upon all high trestles and in tunnels the track should be full spiked before being left, or a train let over. This took extra time and labor, and possibly was not necessary; but it was a precaution on the side of safety.

Upon the day of the change of the Alabama Central Division (Selma to Lauderdale), superintendents of other divisions, with their road masters, supervisors, master mechanics and many section foremen, were sent over to see the organization and work and the preparations that had been made. Many of them lent a helping hand in the work. They saw here in practice what had only been theory before. About a week before the general change that portion of the road between Rome, Ga., and Selma, Ala., about 200 miles, was changed, and again men from other divisions were sent to see and aid in the work; so when the final day came the largest possible number of men were able to work understandingly.

On the last day of May the Memphis & Charleston, Knoxville & Ohio, and North Carolina Branch were changed, and on June 1 the line from Bristol to Chattanooga and Brunswick. Other roads changed their branch lines a day or two before the 1st of June; but the main lines, as a rule, were changed on that day.

It was no small matter to take care of the cars and arrange the train service so there should be no hitches. It was not expected that connections would move freight during the 48 hours prior to the change, and these days were spent in clearing the road of everything, and taking the cars to the points of rendezvous. All scheduled freight trains were abandoned on the day prior to the change, and only trains run *to* such points. Upon the East Tennessee system these points were Knoxville, Rome, Atlanta, Macon, Huntsville and Memphis, and to these points all cars must go, loaded or empty, and there they were parked upon the tracks prepared for the purpose. Passenger trains were run to points where it had been arranged to change them, generally to the general changing point. Most of the Southern roads have double daily passenger service; upon all roads one of these trains, upon the day of change, was abandoned, and upon some, all. Some, even, did not run till next day. We were able to start the day trains out by 10 o'clock or 11 o'clock a. m., and put them through in fair time. Of course, no freights were run that day, and the next day was used in getting the cars which had been changed, out of the parks and into line. So our freight traffic over the entire South was suspended practically three days.

The work of changing was to commence at 3:30 a. m., but many of the men were in position at an earlier hour and did commence work as soon as the last train was over, or an hour or so before the fixed time. Half-past three a. m., however, can be set down as the general hour of commencement. For five or six hours in the cool morning the work went on briskly, the men working with much more than ordinary enthusiasm; but the day was warm, and after 9 or 10 a. m. it began to lag. All was done, however, before the day was over, and safe, so that trains could pass at full speed. The men all received $1.50 for the work, whether it was finished early or late in the day, and were paid that afternoon as soon as the work was done. Tickets were given the men, which the nearest agent paid, remitting as cash to the treasurer.

On some lines it was deemed best to offer prizes to those who got through first. Reports showed some very early finishes; but the facts seem to have been that under such encouragement the men were apt to pull *too many* spikes before the change and put *too few* in while changing. They were thus reported through early, but their work was not done, and they took great chances. It was by most considered unwise to offer such prizes, preferring to have a little more taken and be sure that all was safe. Such lines seemed to get their trains in motion with as much promptness as others. This, with freedom from accident, was the end sought.

It was found after the work had been done that there had been little inaccuracies in driving the gauge spike, to which the rail was thrown, probably from various causes. The rail to be moved may not always have been exactly in its proper place, and then the template in the hurry may not have been accurately placed, or the spike may have turned or twisted. Whatever was the cause, it was found that frequently the line on the moved side was not perfect, and, of course, many spikes had to be drawn and the rail lined up and re-spiked. The more careful the work had been done, the less of this there was to do afterward. With rough track this was least seen. The nearer perfect the more noticeable it was.

Of course, we all planned to get foreign cars home and have ours sent to us; but when the interchange stopped, we found we had many foreign cars, which, of course, had to be changed. This subject had come up in convention and it had been voted to charge $3 per car when axles did not need turning, and $5 where they did. By comparison with the cost of changing, as shown in this paper, it will be seen that to our company, at least, there was no loss at these figures.

The following statements will explain the work done upon the Louisville & Nashville, and East Tennessee, Virginia & Georgia systems.

It is to be regretted that the writer has not at hand information regarding other roads that fuller statements and comparisons might be made and the showings be of greater value.

The figures of the Mobile & Ohio are added, having been compiled from the annual report of that road.

MOBILE & OHIO RAILROAD.
(Compiled from Annual Report.)

	Number changed.	Cost of labor.	Cost of material.	Total cost.	Average cost.
Engines and tenders	47	$8,031.42	$7,276.86	$15,308.28	$325 70
Pass., bag. and ex. c's	55	438.37	104.25	542.62	9.87
Freight c's, 1,361 … Fre't tr'ks, 107½ …	1,468½	5,719.03	739.57	6,458.60	4.40
Lever and push cars	143	1,427.55	476 93	1,904.48	13.32
Track (including sidings)	583.5 Miles.	17,109.53	7,275.14	24,384.67	41.79
Bridges	.....	1,896.60	190.00	2,086.60	3.58
Track tools	....	170.72	1,405.74	1,576.46	2.70
Shop tools	.....	419.70	2,982.90	3,402 60	5.83
Temporary side tracks	12.09	1,958 94	372.37	2,331.31	192 83
Switch'g cars	......	1,398.18	16.50	1,414.68	......
Car hoists	......	2,499.38	4,419.34	6,918.72	......
Total cost		$41,060.42	$25,259.60	$66,320.02	
Total average cost per mile					$113 68

LOUISVILLE & NASHVILLE RAILROAD.
(Compiled from Annual Report.)

Main line, 1,893.7; side track, 196.3; total, 2,090 0.

Track:		Cost per mile.
Section labor	$67,910.21	$32 49
Carpenter labor	3,799.19	1.82
Spikes	20,873.70	9 99
Switches	6,331.85	3.03
Tools	2,749.50	1.31
Hand cars and sundries	5,691.39	2.72
Total	$107,355 84	$51.36

Equipment:	Number.	Total	Average cost.
Locomotives	264	$53,480.98	$202.58
Cars (300 of these passenger—3.5 per cent.)	8,537	49 577 20	55.81
Total cost		$210,414.02	
Total average cost per mile			$100.67

EAST TENNESSEE, VIRGINIA & GEORGIA SYSTEM.

	Number changed.	Cost of labor.	Cost of material.	Total cost.	Average cost.
Engines and tenders	180	$8,227.47	$2,904.30	$11,131.77	$61.82
Pass., bag. and mail cars	168	734.93	59.67	794 60	4 73
Freight cars and cabo's	5,175	17 425.57	1,224.08	18,649.65	3.60
M. of W. cars	439	2,038.44	549.47	2,587.91	5.89
	Miles.				
Track (inc. sidings)	1,532.7	27,718.17	40,912.09	68,630.26	44.78
Bridges	1,532.7	1,808.57	200.00	2,008 57	1.31
Track tools	1,532.7	194.48	2,573.83	2,768.31	1.80
Storage tr'ks, inc. taking up	37.02	9,825.41	1,481.59	11,307.00	305.44
Shop tools	....	472.20	2,728.30	3,200.50	.....
Total cost		$68,445.24	$52,633.33	$121,078.57	
Total average cost per mile					$79.06

Axles condemned	577
Wheels condemned	754
Wheels burst	202
New axles used	1,102
New wheels used	2,783
Axles turned back	8,316
Wheels pressed on without turning axle	23,952
New brasses used	10,723
Cars narrowed (not including lever or push cars)	5,343
Engines narrowed	180
Average cost of new centres and crank pins, etc.	$164.46
Average cost of cutting off hub and pressing wheels and new pins	130.67
Average cost of pressing old tires on old centres	29.08
Average cost of pressing old tires on broad centres	31.83
Average cost of labor putting on new tires	22.94

COMPARATIVE STATEMENT OF AVERAGE COST OF VARIOUS ITEMS OF WORK.

	M. & O. R. R.	L. & N. R. R.	E. T., V. & G. R. R.	Average.
Engines and tenders, per engine	$325.70	$202.58	$61.82	$196.70
Pass., bag. and Ex. cars, per car	9.87	*5.81	4.73	6 80
Freight cars, per car	4 40	†5.81	3 60	4.60
M. of W. cars, per car	13.32	2.72	5.89	7.31
Track (inc. sidings, bridges, etc.), per mile	45.37	47.33	46.09	46.26
Track tools, per mile	2.70	1.31	1 80	1.94
Temporary side tracks, per mile	192.83	....	305.44	249.13
Total per mile of track, inc. sidings	$113.68	$100.67	$79.06	$97.80

*Expense not divided as between passenger and freight cars.
†3.5 per cent. passenger, baggage and express cars; 96.5 per cent. freight cars.

Since the preparation of this paper the general manager of the Norfolk & Western Railroad has kindly furnished the following items of expense for that line:

	No.	Cost.	Average cost.
Engines and tenders	95	$37,730.00	$397.16
Cars (all kinds)	3,615	37,994.65	10.51
Track, miles (including sidings)	597.5		
Labor		25,296,96	
Tools and supplies		3,581.12	
Changing M. of W. equipment		813.13	
Switches		571.67	
Spikes		508.22	
Total track		$38,721.10	64.80
Total		$114,445.75	
Total average cost per mile			$191.53

And the superintendent of the Savannah, Florida & Western has also furnished the expenses for that road:

	No.	Average cost
Engines and tenders	75	$76.31
Cars (passenger)	95	4.67
" (freight)	1.133	3.88
Track, including sidings	601.76	44.49

Nothing was said about shop or other tools, storage tracks or changing of maintenance of way equipment.

COMPARATIVE STATEMENT OF AVERAGE COST OF LABOR OF VARIOUS ITEMS OF WORK.

	M. & O. R. R.	L. & N. R. R.	E. T., V. & G. R. R.	Average.
Engines and tenders	$170.88	Not divided.	$45.71	$108 20
Pass. bag. and ex. cars	7.97		4 38	6 17
Freight cars	3.89		3 36	3.62
M. of W. cars	9.98		4.64	7 31
Miles track (inc. sidings, bridges, etc.)	32.57	34.31	19.26	28.71
Track tools per mile	.30	No	.13	.21
Temporary tracks	162.03	divided.	265.40	213.71
Total per mile of track	$70.38	Not divided.	$44.72	$57.55

COMPARATIVE STATEMENT OF AVERAGE COST OF MATERIAL OF VARIOUS ITEMS OF WORK.

	M. & O. R. R.	L. & N. R. R.	E. T. V. & G Ry.	Average.
Engines and tenders	$154.82	Not divided.	$16.11	$85 46
Pass. bag. and ex. cars	1 90		.35	1.12
Freight cars	.51		.24	.37
M. of W cars	3.34		1.25	2.30
Miles track (inc. sidings, bridges, etc.)	12 80	13.02	26.83	17.55
Track tools per mile	2.40	Not	1.67	2.03
Temporary tracks	162 03	divided.	40.04	101 03
Total per mile of track	$44 30	Not divided.	$34.34	$38.82

SUMMARY OF STATEMENTS OF L. & N. AND E. T., V. & G. RAILWAYS.

The mileage changed of the L & N. and E T., V. & G. systems combined aggregates	3,622 miles
The total cost of these two roads	$331,492.59
Or an average per mile of	91.52
Total miles changed was about	14,500 miles.
Which would give total cost, at same rate	$1,327 040

We should really add to this a large sum for the great number of new locomotives which were purchased to replace old ones that could not be changed, except at large cost, and which, when done, would have been light and undesirable.

Upon the basis of the work done upon the Louisville & Nashville and East Tennessee, Virginia & Georgia systems, which combined cover about one-fourth the mileage changed, we have made the following estimates, which will perhaps convey a better idea of the extent of the work than can be obtained in any other way

Miles of track changed, about	14 500
Locomotives changed, about	1,800
Cars (pass. and freight) changed, about	45 000
New axles used, about	9 000
New wheels used, about	20,000
Axles turned back, about	75,000
Wheels pressed on without turning axles, about	220,000
New brasses used, about	90,000
Kegs of spikes used, about	50,000
Cost of material used, about	$600,000
Cost of labor, about	730,000
Total cost of work, about	1,330,000
Amount expended on equipment, about	650,000
Amount expended on track, about	680,000
Amount expended on track on day of change in labor, about	140,000

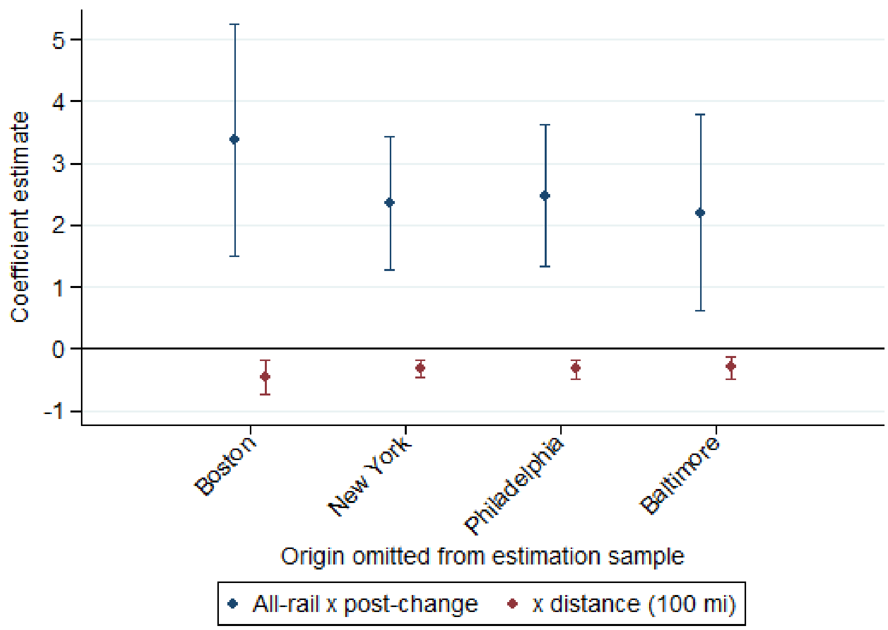
The work was done economically, and so quietly that the public hardly realized it was in progress. To the casual observer it was an every-day transaction. It was, however, a work of great magnitude, requiring much thought and mechanical ability. That it was ably handled is evidenced by the uniform success attained, the prompt changing at the agreed time, and the trifling inconvenience to the public.

D Sensitivity Checks

D.1 Sensitivity Checks: Dropping Origins

The tables in this section evaluate the sensitivity of the main results in Tables 3 and 5 to dropping observations with a given origin. Figure D.1 illustrates the stability of the results, plotting the focal coefficient estimates from a specification of log quantities with route-year fixed effects, omitting the given origin. The 95% confidence interval for each parameter is also provided. The plotted estimates come from Column (5) of Tables D.1, D.3, D.5, and D.7.

Figure D.1: Focal coefficient estimates, omitting the given origin



Notes: Figure plots focal coefficient estimates (and 95% confidence intervals) from a regression of log quantities with route-year fixed effects, omitting the given origin. Estimates from Column (5) of the All-Rail Traffic estimation tables shown below.

Table D.1: Change in All-Rail Traffic, omitting Boston

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	3.342***	3.362***	3.363***	3.412***	3.368***	3.455***
	(0.827)	(0.780)	(0.782)	(0.801)	(0.955)	(0.983)
* distance (100 mi)	-0.460***	-0.470***	-0.470***	-0.474***	-0.469***	-0.478***
	(0.122)	(0.115)	(0.115)	(0.118)	(0.141)	(0.144)
Breakeven distance	727.1	715.7	715.8	720.3	717.7	722.9
	(31.3)	(27.3)	(27.4)	(28.9)	(33.4)	(35.5)
N	777	777	777	777	777	777
R^2	0.34	0.69	0.69	0.72	0.71	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with an origin of Boston. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.2: Share of Traffic, omitting Boston

	(1)	(2)
All-rail x post-change	3.369***	3.471***
	(0.691)	(0.734)
* distance (100 mi)	-0.481***	-0.487***
	(0.102)	(0.107)
Breakeven distance	701.0	712.1
	(23.4)	(26.0)
N	507	507
R^2	0.29	0.48
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with an origin of Boston. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.3: Change in All-Rail Traffic, omitting New York

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.314***	2.313***	2.310***	2.367***	2.358***	2.430***
	(0.460)	(0.449)	(0.449)	(0.469)	(0.548)	(0.590)
* distance (100 mi)	-0.301***	-0.308***	-0.307***	-0.314***	-0.313***	-0.321***
	(0.057)	(0.057)	(0.057)	(0.060)	(0.070)	(0.075)
Breakeven distance	767.7	752.0	751.5	754.5	754.0	755.8
	(41.0)	(39.1)	(39.1)	(39.5)	(46.7)	(47.9)
N	777	777	777	777	777	777
R^2	0.28	0.67	0.67	0.71	0.70	0.73
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with an origin of New York. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.4: Share of Traffic, omitting New York

	(1)	(2)
All-rail x post-change	2.155***	2.275***
	(0.424)	(0.452)
* distance (100 mi)	-0.293***	-0.305***
	(0.055)	(0.057)
Breakeven distance	735.6	746.8
	(38.7)	(39.8)
N	507	507
R^2	0.14	0.37
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with an origin of New York. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.5: Change in All-Rail Traffic, omitting Philadelphia

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.487***	2.466***	2.458***	2.502***	2.472***	2.519***
	(0.489)	(0.485)	(0.484)	(0.495)	(0.585)	(0.606)
* distance (100 mi)	-0.323***	-0.327***	-0.327***	-0.332***	-0.327***	-0.334***
	(0.060)	(0.061)	(0.061)	(0.062)	(0.074)	(0.076)
Breakeven distance	770.6	753.6	752.7	754.0	755.9	754.8
	(37.3)	(35.4)	(35.4)	(35.0)	(43.3)	(42.3)
N	777	777	777	777	777	777
R^2	0.34	0.68	0.68	0.74	0.70	0.77
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with an origin of Philadelphia. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.6: Share of Traffic, omitting Philadelphia

	(1)	(2)
All-rail x post-change	2.320***	2.396***
	(0.455)	(0.472)
* distance (100 mi)	-0.313***	-0.321***
	(0.057)	(0.059)
Breakeven distance	740.3	746.2
	(35.2)	(34.7)
N	507	507
R^2	0.13	0.50
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with an origin of Philadelphia. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.7: Change in All-Rail Traffic, omitting Baltimore

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.133***	2.108***	2.102***	2.196***	2.203***	2.325**
	(0.653)	(0.644)	(0.645)	(0.676)	(0.807)	(0.870)
* distance (100 mi)	-0.289***	-0.293***	-0.292***	-0.304***	-0.302***	-0.318***
	(0.075)	(0.076)	(0.076)	(0.079)	(0.095)	(0.101)
Breakeven distance	737.9	719.5	718.8	723.3	728.6	731.9
	(55.3)	(54.0)	(54.2)	(53.4)	(63.6)	(63.1)
N	777	777	777	777	777	777
R^2	0.34	0.68	0.68	0.73	0.71	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with an origin of Baltimore. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.8: Share of Traffic, omitting Baltimore

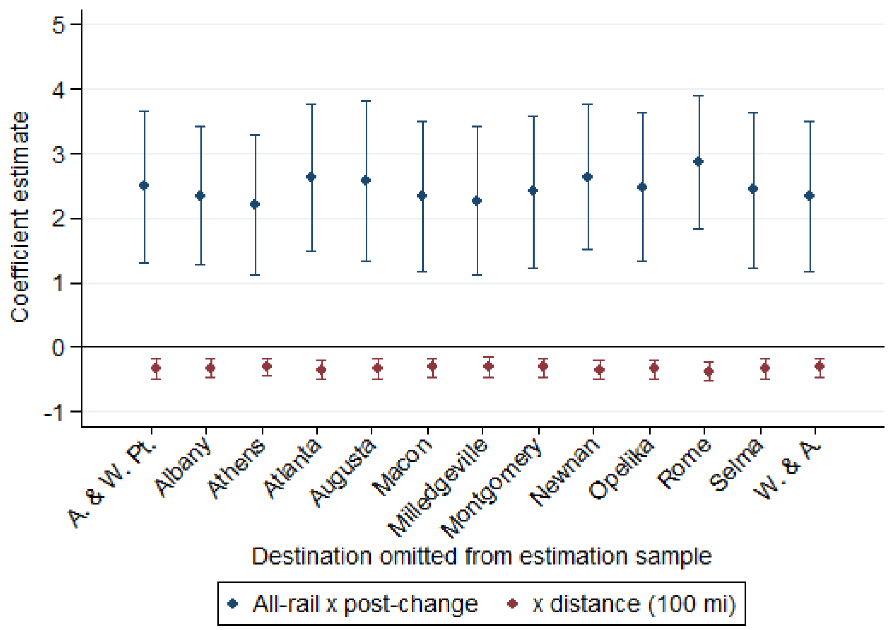
	(1)	(2)
All-rail x post-change	1.905***	2.088***
	(0.611)	(0.658)
* distance (100 mi)	-0.273***	-0.293***
	(0.071)	(0.076)
Breakeven distance	697.7	712.5
	(58.2)	(55.8)
N	507	507
R^2	0.03	0.36
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with an origin of Baltimore. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

D.2 Sensitivity Checks: Dropping Destinations

The tables in this section evaluate the sensitivity of the main results in Tables 3 and 5 to dropping observations with a given destination. Figure D.2 illustrates the stability of the results, plotting the focal coefficient estimates from a specification of log quantities with route-year fixed effects, omitting the given destination. The 95% confidence interval for each parameter is also provided. The plotted estimates come from Column (5) of Tables D.9, D.11, D.13, D.15, D.17, D.19, D.21, D.23, D.25, D.27, D.29, D.31, and D.33.

Figure D.2: Focal coefficient estimates, omitting the given destination



Notes: Figure plots focal coefficient estimates (and 95% confidence intervals) from a regression of log quantities with route-year fixed effects, omitting the given destination. Estimates from Column (5) of the All-Rail Traffic estimation tables shown below.

Table D.9: Change in All-Rail Traffic, omitting Albany

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.298***	2.288***	2.281***	2.328***	2.348***	2.405***
	(0.458)	(0.449)	(0.448)	(0.462)	(0.542)	(0.569)
* distance (100 mi)	-0.311***	-0.316***	-0.316***	-0.319***	-0.322***	-0.327***
	(0.058)	(0.058)	(0.058)	(0.059)	(0.070)	(0.072)
Breakeven distance	738.8	723.5	722.8	728.9	728.7	735.8
	(34.9)	(33.0)	(33.0)	(34.1)	(39.1)	(41.3)
N	992	992	992	992	992	992
R^2	0.32	0.66	0.66	0.72	0.69	0.74
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Albany. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.10: Share of Traffic, omitting Albany

	(1)	(2)
All-rail x post-change	2.200***	2.306***
	(0.427)	(0.449)
* distance (100 mi)	-0.309***	-0.317***
	(0.055)	(0.057)
Breakeven distance	712.5	726.8
	(32.7)	(34.0)
N	656	656
R^2	0.11	0.44
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Albany. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.11: Change in All-Rail Traffic, omitting Athens

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.199***	2.178***	2.179***	2.247***	2.210***	2.304***
	(0.461)	(0.450)	(0.452)	(0.468)	(0.555)	(0.589)
* distance (100 mi)	-0.301***	-0.305***	-0.306***	-0.313***	-0.308***	-0.319***
	(0.058)	(0.058)	(0.058)	(0.060)	(0.072)	(0.075)
Breakeven distance	731.0	713.2	713.1	717.9	716.6	721.4
	(38.3)	(36.1)	(36.1)	(36.4)	(43.6)	(44.3)
N	956	956	956	956	956	956
R^2	0.33	0.69	0.69	0.74	0.71	0.77
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Athens. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.12: Share of Traffic, omitting Athens

	(1)	(2)
All-rail x post-change	2.034***	2.193***
	(0.426)	(0.464)
* distance (100 mi)	-0.293***	-0.308***
	(0.055)	(0.059)
Breakeven distance	695.3	711.9
	(36.4)	(36.9)
N	624	624
R^2	0.11	0.46
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Athens. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.13: Change in All-Rail Traffic, omitting Atlanta

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.637***	2.587***	2.583***	2.646***	2.632***	2.712***
	(0.475)	(0.467)	(0.468)	(0.478)	(0.574)	(0.597)
* distance (100 mi)	-0.339***	-0.342***	-0.342***	-0.349***	-0.346***	-0.356***
	(0.061)	(0.061)	(0.061)	(0.062)	(0.076)	(0.077)
Breakeven distance	776.8	756.2	755.8	758.3	760.2	761.6
	(35.3)	(33.1)	(33.1)	(33.0)	(40.3)	(40.0)
N	952	952	952	952	952	952
R^2	0.35	0.65	0.65	0.72	0.68	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Atlanta. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.14: Share of Traffic, omitting Atlanta

	(1)	(2)
All-rail x post-change	2.429***	2.562***
	(0.438)	(0.462)
* distance (100 mi)	-0.328***	-0.341***
	(0.057)	(0.059)
Breakeven distance	741.2	751.0
	(32.4)	(32.8)
N	620	620
R^2	0.12	0.47
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Atlanta. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.15: Change in All-Rail Traffic, omitting Augusta

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.634***	2.532***	2.527***	2.594***	2.576***	2.658***
	(0.529)	(0.513)	(0.514)	(0.528)	(0.631)	(0.659)
* distance (100 mi)	-0.341***	-0.337***	-0.337***	-0.344***	-0.341***	-0.352***
	(0.066)	(0.065)	(0.065)	(0.066)	(0.080)	(0.082)
Breakeven distance	772.1	750.8	750.3	753.0	754.6	756.1
	(35.8)	(34.6)	(34.6)	(34.6)	(41.9)	(41.8)
N	952	952	952	952	952	952
R^2	0.33	0.64	0.64	0.70	0.66	0.72
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Augusta. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.16: Share of Traffic, omitting Augusta

	(1)	(2)
All-rail x post-change	2.358***	2.490***
	(0.485)	(0.514)
* distance (100 mi)	-0.321***	-0.334***
	(0.061)	(0.064)
Breakeven distance	734.5	744.3
	(34.7)	(35.0)
N	620	620
R^2	0.10	0.42
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Augusta. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.17: Change in All-Rail Traffic, omitting Macon

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.353***	2.354***	2.351***	2.362***	2.340***	2.348***
	(0.471)	(0.481)	(0.482)	(0.487)	(0.588)	(0.598)
* distance (100 mi)	-0.318***	-0.319***	-0.319***	-0.322***	-0.317***	-0.321***
	(0.060)	(0.062)	(0.062)	(0.063)	(0.077)	(0.077)
Breakeven distance	740.2	738.5	737.9	734.0	739.1	731.5
	(36.3)	(36.3)	(36.3)	(35.8)	(44.8)	(43.6)
N	964	964	964	964	964	964
R^2	0.30	0.66	0.66	0.71	0.68	0.74
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Macon. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.18: Share of Traffic, omitting Macon

	(1)	(2)
All-rail x post-change	2.253***	2.244***
	(0.454)	(0.462)
* distance (100 mi)	-0.309***	-0.311***
	(0.059)	(0.059)
Breakeven distance	729.8	721.8
	(35.5)	(35.6)
N	632	632
R^2	0.12	0.43
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Macon. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.19: Change in All-Rail Traffic, omitting Milledgeville

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.218***	2.231***	2.228***	2.296***	2.271***	2.358***
	(0.478)	(0.479)	(0.480)	(0.493)	(0.590)	(0.617)
* distance (100 mi)	-0.297***	-0.305***	-0.305***	-0.313***	-0.309***	-0.320***
	(0.061)	(0.062)	(0.062)	(0.063)	(0.076)	(0.078)
Breakeven distance	745.9	730.4	730.1	733.6	734.6	736.9
	(39.9)	(37.7)	(37.7)	(37.6)	(45.6)	(45.6)
N	952	952	952	952	952	952
R^2	0.32	0.66	0.66	0.72	0.69	0.74
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Milledgeville. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.20: Share of Traffic, omitting Milledgeville

	(1)	(2)
All-rail x post-change	2.047***	2.193***
	(0.444)	(0.473)
* distance (100 mi)	-0.289***	-0.303***
	(0.057)	(0.060)
Breakeven distance	709.2	722.6
	(37.5)	(37.9)
N	620	620
R^2	0.12	0.45
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Milledgeville. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.21: Change in All-Rail Traffic, omitting Montgomery

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.343***	2.366***	2.362***	2.428***	2.407***	2.496***
	(0.489)	(0.481)	(0.482)	(0.493)	(0.596)	(0.619)
* distance (100 mi)	-0.303***	-0.314***	-0.314***	-0.321***	-0.318***	-0.329***
	(0.064)	(0.064)	(0.064)	(0.064)	(0.079)	(0.081)
Breakeven distance	774.1	753.8	753.4	755.8	757.2	757.8
	(39.2)	(35.7)	(35.7)	(35.4)	(43.6)	(42.7)
N	952	952	952	952	952	952
R^2	0.30	0.68	0.68	0.73	0.70	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Montgomery. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.22: Share of Traffic, omitting Montgomery

	(1)	(2)
All-rail x post-change	2.230***	2.350***
	(0.455)	(0.475)
* distance (100 mi)	-0.303***	-0.315***
	(0.060)	(0.062)
Breakeven distance	736.2	746.7
	(34.6)	(34.9)
N	620	620
R^2	0.10	0.45
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Montgomery. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.23: Change in All-Rail Traffic, omitting Newnan

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.590***	2.598***	2.595***	2.655***	2.640***	2.718***
	(0.469)	(0.467)	(0.468)	(0.479)	(0.576)	(0.600)
* distance (100 mi)	-0.346***	-0.353***	-0.353***	-0.360***	-0.357***	-0.367***
	(0.059)	(0.060)	(0.060)	(0.060)	(0.074)	(0.076)
Breakeven distance	748.9	735.3	735.0	737.6	739.0	740.6
	(34.4)	(32.5)	(32.5)	(32.5)	(39.4)	(39.4)
N	952	952	952	952	952	952
R^2	0.33	0.67	0.67	0.73	0.69	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Newnan. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.24: Share of Traffic, omitting Newnan

	(1)	(2)
All-rail x post-change	2.448***	2.572***
	(0.440)	(0.464)
* distance (100 mi)	-0.340***	-0.353***
	(0.056)	(0.058)
Breakeven distance	719.2	728.8
	(32.0)	(32.5)
N	620	620
R^2	0.12	0.47
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Newnan. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.25: Change in All-Rail Traffic, omitting Opelika

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.440***	2.443***	2.438***	2.498***	2.485***	2.559***
	(0.481)	(0.477)	(0.477)	(0.486)	(0.589)	(0.608)
* distance (100 mi)	-0.328***	-0.336***	-0.335***	-0.342***	-0.340***	-0.349***
	(0.063)	(0.063)	(0.063)	(0.064)	(0.078)	(0.079)
Breakeven distance	743.1	727.1	726.7	729.7	730.8	732.8
	(35.3)	(32.7)	(32.7)	(32.9)	(39.7)	(39.9)
N	952	952	952	952	952	952
R^2	0.32	0.68	0.68	0.74	0.71	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Opelika. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.26: Share of Traffic, omitting Opelika

	(1)	(2)
All-rail x post-change	2.291***	2.414***
	(0.451)	(0.470)
* distance (100 mi)	-0.323***	-0.335***
	(0.060)	(0.061)
Breakeven distance	709.9	720.1
	(32.0)	(32.5)
N	620	620
R^2	0.13	0.46
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Opelika. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.27: Change in All-Rail Traffic, omitting Rome

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.835***	2.828***	2.823***	2.898***	2.863***	2.958***
	(0.438)	(0.426)	(0.427)	(0.436)	(0.524)	(0.548)
* distance (100 mi)	-0.364***	-0.370***	-0.370***	-0.378***	-0.373***	-0.385***
	(0.058)	(0.058)	(0.058)	(0.059)	(0.072)	(0.074)
Breakeven distance	779.2	763.9	763.4	765.9	767.4	768.4
	(30.6)	(27.9)	(27.8)	(27.4)	(34.4)	(33.5)
N	952	952	952	952	952	952
R^2	0.30	0.68	0.68	0.73	0.70	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Rome. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.28: Share of Traffic, omitting Rome

	(1)	(2)
All-rail x post-change	2.658***	2.817***
	(0.402)	(0.419)
* distance (100 mi)	-0.355***	-0.371***
	(0.055)	(0.056)
Breakeven distance	748.7	759.2
	(27.0)	(26.7)
N	620	620
R^2	0.13	0.43
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Rome. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.29: Change in All-Rail Traffic, omitting Selma

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.378***	2.405***	2.403***	2.469***	2.438***	2.529***
	(0.504)	(0.497)	(0.498)	(0.508)	(0.613)	(0.635)
* distance (100 mi)	-0.310***	-0.321***	-0.321***	-0.329***	-0.324***	-0.336***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.082)	(0.084)
Breakeven distance	766.9	748.3	747.8	750.2	752.2	752.9
	(38.7)	(35.2)	(35.2)	(34.9)	(43.1)	(42.3)
N	952	952	952	952	952	952
R^2	0.29	0.67	0.67	0.72	0.69	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of Selma. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.30: Share of Traffic, omitting Selma

	(1)	(2)
All-rail x post-change	2.264***	2.385***
	(0.469)	(0.489)
* distance (100 mi)	-0.310***	-0.322***
	(0.063)	(0.064)
Breakeven distance	731.4	741.7
	(34.1)	(34.4)
N	620	620
R^2	0.09	0.43
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of Selma. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.31: Change in All-Rail Traffic, omitting A. & W. Pt.

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.442***	2.447***	2.441***	2.500***	2.489***	2.560***
	(0.488)	(0.482)	(0.482)	(0.492)	(0.597)	(0.616)
* distance (100 mi)	-0.319***	-0.326***	-0.326***	-0.332***	-0.331***	-0.340***
	(0.063)	(0.063)	(0.063)	(0.063)	(0.078)	(0.079)
Breakeven distance	766.1	749.4	748.9	751.9	752.3	754.1
	(37.8)	(35.2)	(35.2)	(35.2)	(42.7)	(42.6)
N	952	952	952	952	952	952
R^2	0.33	0.69	0.69	0.74	0.71	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of A. & W. Pt.. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.32: Share of Traffic, omitting A. & W. Pt.

	(1)	(2)
All-rail x post-change	2.287***	2.410***
	(0.453)	(0.476)
* distance (100 mi)	-0.312***	-0.325***
	(0.059)	(0.061)
Breakeven distance	732.7	742.5
	(34.6)	(35.1)
N	620	620
R^2	0.13	0.45
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of A. & W. Pt.. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.33: Change in All-Rail Traffic, omitting W. & A.

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.298***	2.300***	2.294***	2.354***	2.342***	2.416***
	(0.485)	(0.480)	(0.480)	(0.491)	(0.593)	(0.616)
* distance (100 mi)	-0.307***	-0.314***	-0.314***	-0.321***	-0.318***	-0.328***
	(0.062)	(0.062)	(0.062)	(0.063)	(0.077)	(0.078)
Breakeven distance	748.1	731.8	731.1	734.2	735.8	737.5
	(39.4)	(37.0)	(37.0)	(37.0)	(44.7)	(44.9)
N	952	952	952	952	952	952
R^2	0.33	0.68	0.68	0.74	0.71	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations with a destination of W. & A.. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.34: Share of Traffic, omitting W. & A.

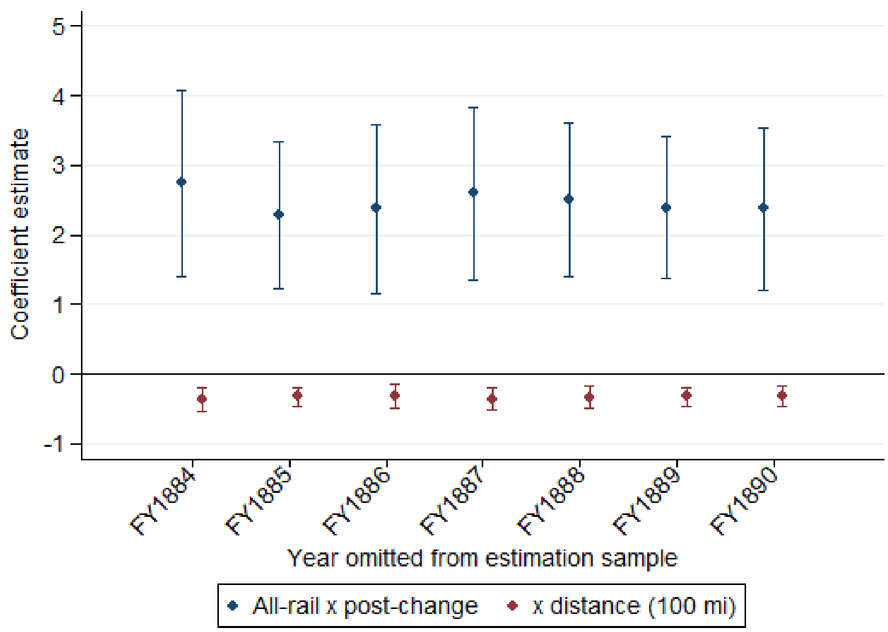
	(1)	(2)
All-rail x post-change	2.143***	2.253***
	(0.453)	(0.471)
* distance (100 mi)	-0.300***	-0.311***
	(0.059)	(0.060)
Breakeven distance	713.6	723.6
	(36.8)	(37.2)
N	620	620
R^2	0.10	0.44
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations with a destination of W. & A.. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

D.3 Sensitivity Checks: Dropping Years

The tables in this section evaluate the sensitivity of the main results in Tables 3 and 5 to dropping observations in a given year. Figure D.3 illustrates the stability of the results, plotting the focal coefficient estimates from a specification of log quantities with route-year fixed effects, omitting the given year. The 95% confidence interval for each parameter is also provided. The plotted estimates come from Column (5) of Tables D.35, D.37, D.39, D.41, D.43, D.45, and D.47.

Figure D.3: Focal coefficient estimates, omitting the given year



Notes: Figure plots focal coefficient estimates (and 95% confidence intervals) from a regression of log quantities with route-year fixed effects, omitting the given year. Estimates from Column (5) of the All-Rail Traffic estimation tables shown below.

Table D.35: Change in All-Rail Traffic, omitting 1884

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.730***	2.712***	2.704***	2.777***	2.746***	2.837***
	(0.567)	(0.560)	(0.558)	(0.573)	(0.683)	(0.707)
* distance (100 mi)	-0.350***	-0.355***	-0.354***	-0.363***	-0.357***	-0.368***
	(0.072)	(0.072)	(0.072)	(0.073)	(0.088)	(0.090)
Breakeven distance	780.5	764.2	763.5	765.5	769.7	770.1
	(37.8)	(36.0)	(35.9)	(35.8)	(44.4)	(43.7)
N	888	888	888	888	888	888
R^2	0.32	0.67	0.67	0.73	0.69	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations in 1884. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.36: Share of Traffic, omitting 1884

	(1)	(2)
All-rail x post-change	2.563***	2.685***
	(0.532)	(0.545)
* distance (100 mi)	-0.341***	-0.354***
	(0.069)	(0.069)
Breakeven distance	751.8	758.9
	(35.9)	(35.6)
N	580	580
R^2	0.12	0.45
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations in 1884. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.37: Change in All-Rail Traffic, omitting 1885

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.291***	2.274***	2.272***	2.330***	2.277***	2.354***
	(0.455)	(0.447)	(0.448)	(0.465)	(0.537)	(0.572)
* distance (100 mi)	-0.318***	-0.323***	-0.323***	-0.330***	-0.321***	-0.331***
	(0.056)	(0.056)	(0.057)	(0.058)	(0.068)	(0.071)
Breakeven distance	721.3	704.3	704.0	706.3	710.3	711.8
	(35.6)	(34.0)	(34.0)	(34.2)	(41.6)	(42.1)
N	888	888	888	888	888	888
R^2	0.32	0.67	0.67	0.73	0.70	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations in 1885. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.38: Share of Traffic, omitting 1885

	(1)	(2)
All-rail x post-change	2.084***	2.182***
	(0.411)	(0.445)
* distance (100 mi)	-0.303***	-0.314***
	(0.052)	(0.055)
Breakeven distance	687.1	694.8
	(35.3)	(36.1)
N	580	580
R^2	0.13	0.47
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations in 1885. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.39: Change in All-Rail Traffic, omitting 1886

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.297***	2.286***	2.287***	2.338***	2.375***	2.450***
	(0.484)	(0.494)	(0.495)	(0.508)	(0.621)	(0.651)
* distance (100 mi)	-0.300***	-0.305***	-0.305***	-0.310***	-0.317***	-0.325***
	(0.065)	(0.067)	(0.067)	(0.068)	(0.084)	(0.087)
Breakeven distance	765.9	749.4	749.3	753.5	749.4	753.3
	(39.4)	(37.2)	(37.2)	(37.9)	(43.0)	(44.3)
N	892	892	892	892	892	892
R^2	0.32	0.67	0.67	0.73	0.69	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations in 1886. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.40: Share of Traffic, omitting 1886

	(1)	(2)
All-rail x post-change	2.197***	2.329***
	(0.480)	(0.512)
* distance (100 mi)	-0.300***	-0.312***
	(0.065)	(0.068)
Breakeven distance	731.4	745.5
	(34.3)	(36.3)
N	584	584
R^2	0.13	0.46
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations in 1886. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.41: Change in All-Rail Traffic, omitting 1887

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.561***	2.571***	2.566***	2.623***	2.595***	2.669***
	(0.512)	(0.515)	(0.516)	(0.534)	(0.631)	(0.664)
* distance (100 mi)	-0.346***	-0.356***	-0.356***	-0.361***	-0.358***	-0.366***
	(0.065)	(0.066)	(0.066)	(0.068)	(0.081)	(0.085)
Breakeven distance	740.7	721.9	721.7	726.1	724.8	728.6
	(35.9)	(33.7)	(33.7)	(34.5)	(40.6)	(41.8)
N	892	892	892	892	892	892
R^2	0.32	0.68	0.68	0.73	0.70	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations in 1887. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.42: Share of Traffic, omitting 1887

	(1)	(2)
All-rail x post-change	2.406***	2.533***
	(0.489)	(0.522)
* distance (100 mi)	-0.341***	-0.353***
	(0.063)	(0.066)
Breakeven distance	705.5	717.0
	(33.9)	(34.7)
N	580	580
R^2	0.12	0.45
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations in 1887. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.43: Change in All-Rail Traffic, omitting 1888

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.483***	2.477***	2.473***	2.532***	2.496***	2.567***
	(0.471)	(0.461)	(0.462)	(0.473)	(0.563)	(0.588)
* distance (100 mi)	-0.321***	-0.327***	-0.327***	-0.334***	-0.328***	-0.338***
	(0.062)	(0.062)	(0.063)	(0.063)	(0.076)	(0.078)
Breakeven distance	774.2	757.6	757.1	758.4	761.3	759.8
	(36.8)	(33.7)	(33.7)	(33.6)	(41.7)	(41.2)
N	884	884	884	884	884	884
R^2	0.31	0.67	0.67	0.73	0.70	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations in 1888. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.44: Share of Traffic, omitting 1888

	(1)	(2)
All-rail x post-change	2.318***	2.440***
	(0.433)	(0.457)
* distance (100 mi)	-0.312***	-0.325***
	(0.059)	(0.061)
Breakeven distance	742.2	749.9
	(32.4)	(33.2)
N	576	576
R^2	0.11	0.43
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations in 1888. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.45: Change in All-Rail Traffic, omitting 1889

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.353***	2.352***	2.348***	2.405***	2.389***	2.454***
	(0.423)	(0.423)	(0.422)	(0.434)	(0.520)	(0.541)
* distance (100 mi)	-0.310***	-0.317***	-0.317***	-0.324***	-0.322***	-0.331***
	(0.054)	(0.055)	(0.055)	(0.055)	(0.068)	(0.068)
Breakeven distance	757.7	741.1	740.6	741.7	742.5	740.8
	(34.5)	(32.3)	(32.3)	(32.1)	(38.7)	(38.5)
N	884	884	884	884	884	884
R^2	0.31	0.67	0.67	0.73	0.70	0.76
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations in 1889. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.46: Share of Traffic, omitting 1889

	(1)	(2)
All-rail x post-change	2.214***	2.327***
	(0.397)	(0.417)
* distance (100 mi)	-0.306***	-0.319***
	(0.052)	(0.053)
Breakeven distance	722.5	730.3
	(31.0)	(31.4)
N	576	576
R^2	0.11	0.44
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations in 1889. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.47: Change in All-Rail Traffic, omitting 1890

	(1)	(2)	(3)	(4)	(5)	(6)
All-rail x post-change	2.351***	2.329***	2.326***	2.387***	2.380***	2.455***
	(0.497)	(0.488)	(0.489)	(0.502)	(0.593)	(0.622)
* distance (100 mi)	-0.311***	-0.312***	-0.312***	-0.319***	-0.317***	-0.326***
	(0.064)	(0.063)	(0.063)	(0.064)	(0.077)	(0.080)
Breakeven distance	755.0	745.7	744.9	748.1	750.2	753.9
	(37.0)	(36.5)	(36.6)	(36.5)	(43.7)	(44.2)
N	888	888	888	888	888	888
R^2	0.32	0.67	0.67	0.73	0.69	0.75
Route FE		X	X			
Mode FE			X			
Year FE			X			
Route-mode FE				X		X
Route-yr FE					X	X

Notes: This table is a robustness check on the results in Table 3, omitting observations in 1890. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

Table D.48: Share of Traffic, omitting 1890

	(1)	(2)
All-rail x post-change	2.185***	2.310***
	(0.454)	(0.480)
* distance (100 mi)	-0.299***	-0.311***
	(0.059)	(0.061)
Breakeven distance	730.2	743.2
	(36.3)	(36.6)
N	580	580
R^2	0.10	0.45
Route FE		X

Notes: This table is a robustness check on the results in Table 5, omitting observations in 1890. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by route in parentheses.

E Structural Estimates under Alternative Assumptions

The tables below provide the results of the supply and demand estimation under alternative assumptions for the total latent market size for each route-year, and the implied effects of the gauge change in a Nash-Bertrand competitive equilibrium. Tables E.1 and E.4 reproduce Table 9 (parameter estimates) and Table 11 (counterfactual), where the assumption is that the total potential shipments in each route-year is twice the observed traffic. Tables E.2/E.5 and E.3/E.6 are based on an assumption of 3x and 4x the observed traffic, respectively.

The key results are Tables E.4 to E.6 (the reproduction or counterparts to Table 11 in the paper), which compare prices, quantities, and profits in a competitive market with versus without the gauge change. The range of outcomes across these tables suggests that with competition, average all-rail freight rates would have declined by 5-10%, all-rail traffic would have grown by 30-36%, and total traffic would have grown by 6-9% as a result of the gauge change – effects which stand in contrast to realized history, where prices and quantities were not affected.

Table E.1: Supply and Demand Estimates (Market Size = 2x)

Demand Parameters		*Marginal Costs ($ per 100 lbs.)*	
Break in gauge	-3.42***	Break in gauge	0.079***
	(0.71)		(0.027)
* distance (100 mi)	0.43***	Transshipment	0.207***
	(0.09)		(0.088)
Rail dummy	4.54***	Distance, rail	0.044***
	(1.11)		(0.008)
Steam dummy	6.41***	Distance, steam	0.042***
	(1.13)		(0.009)
Price ($ per 100 lbs.)	-8.98***	N	244
	(1.54)	Mean R^2	0.77
Breakeven distance	792.7		
	(95.7)		
N	488		
R^2	0.62		
1st-stage F-stat	222.5		
Instrument	Distance		

Notes: Table shows estimates from the joint estimation of demand and supply for freight traffic, assuming total latent market size to be 200% of realized traffic. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Bootstrapped SEs are provided in parentheses.

Table E.2: Supply and Demand Estimates (Market Size = 3x)

Demand Parameters		*Marginal Costs ($ per 100 lbs.)*	
Break in gauge	-3.42***	Break in gauge	0.049***
	(0.71)		(0.021)
* distance (100 mi)	0.43***	Transshipment	0.266***
	(0.09)		(0.055)
Rail dummy	3.85***	Distance, rail	0.063***
	(1.11)		(0.005)
Steam dummy	5.72***	Distance, steam	0.040***
	(1.13)		(0.005)
Price ($ per 100 lbs.)	-8.98***	N	244
	(1.54)	Mean R^2	0.68
Breakeven distance	792.7		
	(95.7)		
N	488		
R^2	0.62		
1st-stage F-stat	222.5		
Instrument	Distance		

Notes: Table shows estimates from the joint estimation of demand and supply for freight traffic, assuming total latent market size to be 300% of realized traffic. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Bootstrapped SEs are provided in parentheses.

Table E.3: Supply and Demand Estimates (Market Size = 4x)

Demand Parameters		*Marginal Costs ($ per 100 lbs.)*	
Break in gauge	-3.42***	Break in gauge	0.039**
	(0.71)		(0.019)
* distance (100 mi)	0.43***	Transshipment	0.286***
	(0.09)		(0.045)
Rail dummy	3.44***	Distance, rail	0.069***
	(1.11)		(0.005)
Steam dummy	5.31***	Distance, steam	0.040***
	(1.13)		(0.003)
Price ($ per 100 lbs.)	-8.98***	N	244
	(1.54)	Mean R^2	0.63
Breakeven distance	792.7		
	(95.7)		
N	488		
R^2	0.62		
1st-stage F-stat	222.5		
Instrument	Distance		

Notes: Table shows estimates from the joint estimation of demand and supply for freight traffic, assuming total latent market size to be 400% of realized traffic. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Bootstrapped SEs are provided in parentheses.

Table E.4: Post-Period Competitive Outcomes: Without vs. With Gauge Change (Market Size = 2x)

	Average price ($ per 100 lbs.)		**Freight Traffic (million lbs.)**			**Carrier Profits (thousand $s)**			**Gross Margins**	
	Rail	**Steam**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**
No gauge change	0.55	0.69	72.9	104.8	177.8	$69.7	$136.1	$205.8	20%	20%
Gauge change	0.49	0.68	99.1	94.9	194.0	126.8	123.1	249.9	29%	20%
Percent difference	-10%	-1%	36%	-9%	9%	82%	-10%	21%		

Notes: Table provides a summary of counterfactual competitive prices, quantities, profits, and margins in the post-period (1887-1890) without versus with a uniform gauge, generated from demand and supply parameters estimated under the assumption that total latent market size to be 200% of realized traffic.

Table E.5: Post-Period Competitive Outcomes: Without vs. With Gauge Change (Market Size = 3x)

	Average price ($ per 100 lbs.)		**Freight Traffic (million lbs.)**			**Carrier Profits (thousand $s)**			**Gross Margins**	
	Rail	**Steam**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**
No gauge change	0.64	0.71	53.2	121.7	174.9	$34.5	$121.2	$155.7	12%	15%
Gauge change	0.60	0.71	71.1	115.7	186.8	54.4	117.7	172.0	15%	15%
Percent difference	-7%	0%	33%	-5%	7%	58%	-3%	11%		

Notes: Table provides a summary of counterfactual competitive prices, quantities, profits, and margins in the post-period (1887-1890) without versus with a uniform gauge, generated from demand and supply parameters estimated under the assumption that total latent market size to be 300% of realized traffic.

Table E.6: Post-Period Competitive Outcomes: Without vs. With Gauge Change (Market Size = 4x)

	Average price ($ per 100 lbs.)		**Freight Traffic (million lbs.)**			**Carrier Profits (thousand $s)**			**Gross Margins**	
	Rail	**Steam**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**	**Total**	**Rail**	**Steam**
No gauge change	0.67	0.72	46.9	128.0	174.9	$28.1	$114.0	$142.1	11%	13%
Gauge change	0.64	0.71	61.1	124.0	185.2	40.5	112.2	152.8	12%	13%
Percent difference	-5%	0%	30%	-3%	6%	44%	-2%	8%		

Notes: Table provides a summary of counterfactual competitive prices, quantities, profits, and margins in the post-period (1887-1890) without versus with a uniform gauge, generated from demand and supply parameters estimated under the assumption that total latent market size to be 400% of realized traffic.

F International Railway Agreements

This appendix provides more background on the persistence of breaks in gauge around the world today, accompanying the discussion in Section 7 on what these results might teach us regarding the value of standardizing railway gauge in the present. Though countries in North America and Western Europe have adopted a common standard, gauge breaks are prevalent in underdeveloped regions, including most of Asia, Africa, and South America.

To focus attention, I invoke two examples: Asia and the European periphery. Table F.1 shows the principal gauges currently used in countries in South and Southeast Asia. This diversity precluded an agreement to unify domestic railways into a transcontinental railway network for over 50 years, and the problem of incompatibility was never fully resolved: when the Trans-Asian Railway Network Agreement (UNTC 2006) was ratified in 2006, they skirted the issue, instead opting to continue using adapters at border crossings, which were enumerated in the agreement itself.

Similarly, when European countries agreed to unify their railway networks in 1991, no uniform standard was specified. Though much of Western Europe was on standard gauge, breaks persisted in various places. Table F.2 lists the interchange stations enumerated in the European Agreement on Important International Combined Transport Lines (UNTC 1991, p. 38), as well as the means of interchange at each station – which are (shockingly) the same technologies that were in use 100 years prior. These breaks are present mostly along the eastern periphery, though there are also two junctions where French and Spanish tracks of incompatible gauge meet.

To make the problem more concrete, Figures F.1 and F.2 illustrate the diversity in gauge in Asia and around the world. The former figure is from Wikipedia and shows a map of the world which color-codes countries by their principal gauge. The latter figure is taken from supporting documentation for the Trans-Asian Railway Network Agreement and maps the major lines in Asia, as of 2006, color-coding by gauge. Both figures make it visually obvious just how much of a problem breaks in gauge continue to be, especially in less-developed parts of the world.

Table F.1: Railway Gauge of Trans-Asian Railway Members at Time of Agreement (2006)

1,000 mm (3' 3.375")	1,067 mm (3' 6")	1,435 mm (4' 8.5")	1,520 mm (6' 0")	1,676 mm (6' 6")
Bangladesh	Indonesia	China	Armenia	Bangladesh
Laos		North Korea	Azerbaijan	India
Malaysia		South Korea	Georgia	Nepal
Myanmar		Iran	Kazakhstan	Pakistan
Singapore		Turkey	Kyrgyzstan	Sri Lanka
Thailand			Mongolia	
Vietnam			Russia	
			Tajikistan	
			Turkmenistan	
			Uzbekistan	

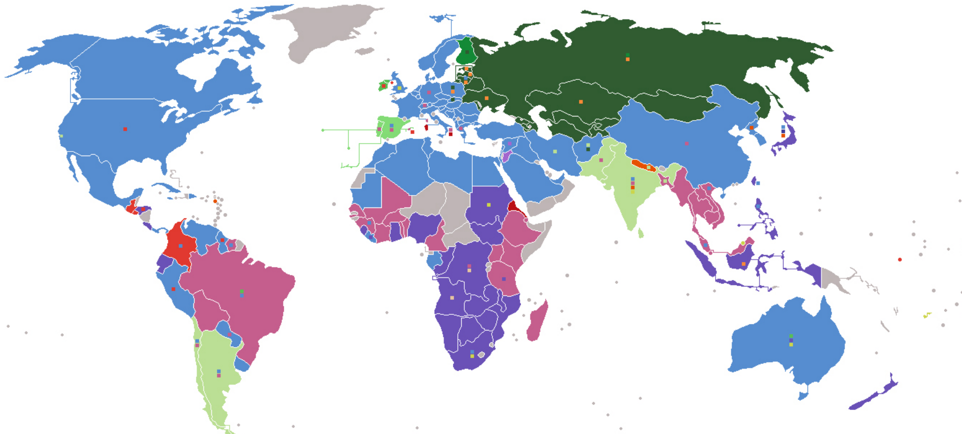
Notes: Table lists the varying railroad gauge standards of the countries that were party to or affected by the Intergovernmental Agreement on the Trans-Asian Railway Network at the time of ratification (November 21, 2006). Data from text of the agreement (UNTC 2006).

Table F.2: Gauge Interchanges on European Country Borders at Time of Agreement (1991)

		Means of Interchange	
Countries	**Number of Interchanges**	**Change of wagon axles/bogies**	**Transshipment by crane or other equipment**
Hungary-Ukraine	2	X	X
Romania-Moldova	2	X	X
Romania-Ukraine	2	X	X
Spain-France	2	X	X
Poland-Belarus	1	X	X
Poland-Lithuania	1	X	X
Poland-Ukraine	1	X	X
Russia-North Korea	1	X	X
Russia-China	1	X	X
Kazakhstan-China	1	X	X
Slovakia-Ukraine	1		X

Notes: Table counts number of gauge interchange stations on the border between country pairs, and the means of interchange used to transfer freight across gauges, at the time of the European Agreement on Important International Combined Transport Lines and Related Installations (February 1, 1991). Data from text of the agreement (UNTC 1991).

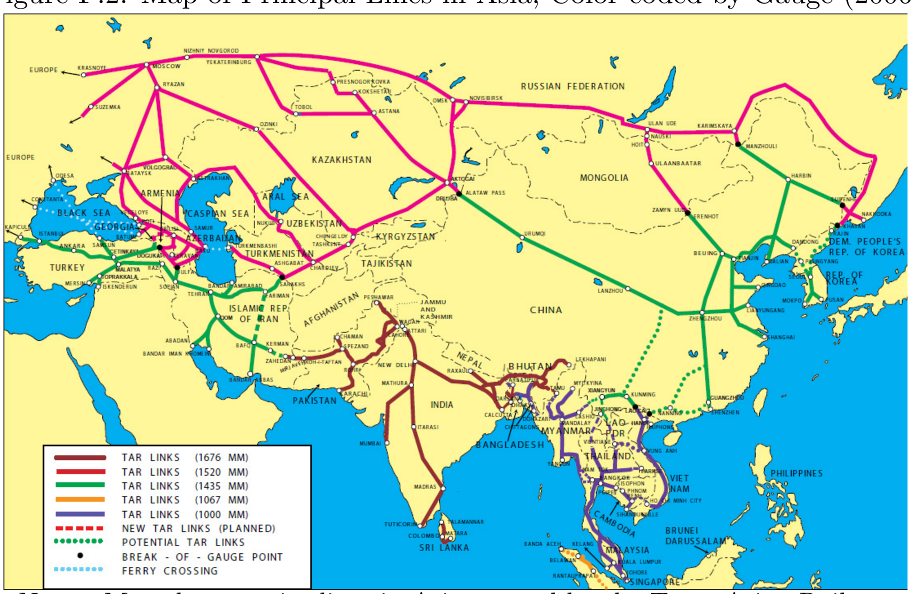
Figure F.1: World Map, Color-coding Countries by Principal Gauge



mm	1676	1668	1600	1524	1520	1435	1372	1067	1050	1000	950	914	762	750	610	600
ft in	5'6"	5'5.67"	5'3"	5'	4'11.8"	4'8.5"	4'6"	3'6"	3'5.3"	3'3.4"	3'1.4"	3'	2'6"	2'5.5"	2'	1'11.6"

Notes: Map illustrates the principal gauge of individual countries around the world, color-coding each country by gauge, thereby making the prevalence of breaks visually apparent. Figure obtained from Wikipedia, available at https://upload.wikimedia.org/wikipedia/commons/1/1f/Rail_gauge_world.jpg.

Figure F.2: Map of Principal Lines in Asia, Color-coded by Gauge (2006)



Notes: Map shows major lines in Asia covered by the Trans-Asian Railway Network Agreement (UNTC 2006), as well as links planned under the agreement, color-coding by gauge. Figure published in 1999 and available as part of the supporting documentation for the TAR.