A Model of Formation of Profit Expectations of Theodore Judah and the Expected Private Profitability of the First Transcontinental Railroad

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Abstract

An empirical model of formation of profit expectations of Theodore Judah, an entrepreneur promoting the first U.S. transcontinental railroad in 1860, is formulated in this article. The structure of the model is developed following the analysis of the investment opportunity performed by Judah. The parameters of the model are fitted using publicly available information before construction. The model focuses on *ex-ante* methods and public information and makes possible to estimate expected profits for the average entrepreneur and investor. Findings indicate i) market incentives were high enough to promote private construction of the railroad and entrepreneurs were right to expect profits and ii) building ahead of demand cannot justify subsidies in the form of loans and lands granted by the Pacific Railroad Act.

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In 1859 Nevada experienced a gold rush. Theodore Judah, a California railroad engineer-entrepreneur, predicted a boom in demand for transportation and consequently searched and found a route to build the first stage of the first transcontinental railroad between Sacramento and the Washoe mining district in Nevada. He proposed the second stage as a railroad from Nevada to Omaha, Nebraska, passing close to the gold mines of Pikes Peak, Colorado. Judah expected the railroad to be profitable. His efforts led to the incorporation of the Central Pacific Railroad Company in 1861 and the passing of the Pacific Railroad Act of 1862. The Act created the Union Pacific Railway Company and granted loans and lands to the Central Pacific and the Union Pacific to build the largest American public work in the 19th century. The first transcontinental railroad was built by these two companies and inaugurated in 1869.[1]

Were Judah's profit expectations shared by other entrepreneurs and investors? Were market incentives high enough to induce construction of the railroad to profit exclusively through provision of transport services? The purpose of this article is to provide an answer to these two related questions.

Developing an estimate of profits expected by entrepreneurs and investors is not simple. Direct measures of profit expectations are rarely collected in the kind of datasets used by economists.[2] A more conventional approach to assess profit expectations is to use revealed preference analysis on ex-post capital market information to infer ex-ante preferences and expectations.[3] The highly distorted period during which the railroad was built makes it impossible to perform this approach. The key information, in the form of quotations of the railroad's stock and bonds, is not available until summer 1867, when construction of the railroad was well advanced. The Civil War and reconstruction led to an 18-fold expansion of public expenditure that generated high inflation, crowded out private entrepreneurs from the local capital market, and effectively closed the international capital market to American entrepreneurs. The railroad also faced a political economy conflict complicating even more inference of ex-ante preferences and expectations from capital market data.

Consequently, conclusions regarding investors expectations based on revealed preference analysis are unwarranted. i) Failure of investors to buy the company's bonds in the middle of the Civil War does not necessarily imply that they did not expect the railroad to be profitable, as

[1] Judah "*Central Pacific*", "*Memorial of the Central Pacific*", "*Report of the Chief Engineer*"
[2] I am not aware of any dataset on entrepreneurs' profit expectations. Manski *"Measuring expectations"* reviews a recent stream of analysis directly collecting measures of expectations on future occupational status and income.
[3] Samuelson "A note", "Consumption theory" presents the idea on which revealed preference analysis is based. The application of the idea is not without complications, see Manski *"Measuring expectations"*.

Robert Fogel concluded.[4] ii) The fact that the project received subsidies does not necessarily imply that entrepreneurs and capital markets did not expect the railroad to be profitable; that the railroad was premature or built ahead of demand as Joseph Schumpeter, Robert Fogel, Lloyd Mercer and Albert Fishlow have argued.[5]

I develop a new measure of profit expectations using reports written by Judah and other entrepreneurs who promoted construction of the railroad, 1845-1860. In the 1850s the key piece of information required to promote a railroad in America was the report on the preliminary survey. The standard report contained the engineering survey and market research for the project. Judah and other entrepreneurs wrote these reports, which cast light on how entrepreneurs formed profit expectations.

The analysis follows two steps. In the first, I examine the reports written by Judah and the other groups of entrepreneurs and identify the entrepreneur's stated expected profits before the project was executed. These declared expectations, however, may differ from the entrepreneur's true beliefs because they may have had incentives to lie.

The second step of the analysis develops a more reliable estimate of expected profits. I use the preliminary survey reports written by Judah, the other transcontinental railroad entrepreneurs and other 1850s successful railroad entrepreneurs, as well as civil engineering textbooks and bond prospectuses to identify the method to analyze a railroad investment opportunity in the mid 19th century. Since the same method is used in all reports, textbooks and prospectuses examined, it is taken to be common knowledge. In turn, the method identified is used to develop the structure of a model of formation of profit expectations. The model's parameters are inferred using information publicly available before construction of the railroad. Thus, the model of formation of profit expectations is anchored to the historical methods and information sources typically used by 1850s railroad entrepreneurs and investors. The model makes it possible to develop a counterfactual scenario of *ex-ante* profit expectations for the average entrepreneur and investor, where profits come only from operation of the railroad. The counterfactual scenario controls for the negative effects the Civil War and the political economy of the project had over private investment. Next the model is used to deduce a historically plausible and more reliable estimate of profits expected by entrepreneurs and the average investor.

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[4] Fogel *"The Union Pacific"* pp. *75-86.* Appendix 1 discusses limitations of revealed preference analysis.
[5] Schumpeter *"Business Cycles"* p. 328, Fogel *"The Union Pacific"* p. 18, Fishlow *"American Railroads"* p. 204, and *"Internal"* p. 585 , Mercer *"Rates of Return"* p. *604, "Railroads and Land Grant"* pp. 28, 67. Fleisig *"The Union Pacific"* and *"The Central Pacific"* examines whether expected profits with loan subsidy but not land grants were high enough to induce entry, a different question than the one addressed here. Historians have indicated that government intervention was indispensible (see appendix 1).

The results indicate that several entrepreneurs considered construction of the first transcontinental railroad to follow transport demand derived from the China and California trades, from the late 1840s onwards. All entrepreneurs stated that they expected the railroad to be profitable. The analysis of the model of formation of profit expectations indicates that these expected profits for the single stage railroad project were unlikely. However, once the 1859 Nevada gold rush was experienced, the entrepreneurs divided the project into two consecutive stages. The first stage followed transport demand derived from the mining traffic. The second stage followed transport demand derived from the China and California trades. The model indicates that both of these stages should have been expected to be profitable. Contrary to existing studies that focus on expansion of the agricultural frontier and suggest the first transcontinental railroad was expected to be premature or built *ahead* of demand, results presented here emphasize the role of mining and the California and China trade and show that it was expected to be built *following* demand.[6]

Results, in turn, have important implications over our view of the role of government in the construction of this project. Judah's profit expectations were credible because after the Nevada gold rush transport demand and prices were high enough to induce entry and private construction of the first transcontinental railroad. Additionally, the benefit of hindsight has shown the first transcontinental was ex-post profitable - the unaided private ex-post rate of return of the railroad was higher than the opportunity cost.[7] Thus, the railroad was expected to be profitable, and it was actually profitable. It was built *following* demand. The normative analysis of public policy implies that building ahead of demand cannot justify the loans and lands granted by the Pacific Railroad Act.

The next section provides the historical context for the paper. The third section points out the advantages of using entrepreneur reports to measure profit expectations. The fourth presents the entrepreneurs' stated expectations. The fifth section introduces the model of formation of profit expectations. The sixth section presents results and the seventh section concludes.

THE FIRST TRANSCONTINENTAL RAILROAD

During the second half of the 1840s and most of the 1850s trade with the Pacific Ocean boomed. China opened to trade and California experienced a gold rush and was annexed by the

[6] See existing studies by Schumpeter *"Business Cycles"*, Fogel *"The Union Pacific"*, Fishlow *"American Railroads"* and *"Internal"* and Mercer *"Rates of Return"* and *"Railroads and Land Grant"*.
[7] Fogel *"The Union Pacific"* pp. 75-82 and Mercer *"Railroads and Land Grant"* pp. 108-12

United States.[8] Entrepreneurs and governments in different parts of the world competed to provide transportation improvements reducing journey time to the Pacific Ocean. British, French and Austrian entrepreneurs launched canal or rail projects to traverse Canada, Central America, the Suez or the Ottoman Empire.[9] Meanwhile American entrepreneurs developed Clipper ships and a railroad across the Isthmus of Panama.[10]

American entrepreneurs also developed projects for a transcontinental railroad. The first of these was proposed on January 28 1845. The planned route, like any possible route for such a railroad, crossed the federal territories between the Mississippi river and the Pacific Ocean. Consequently, any project to build the railroad was obliged to request the right of way from Congress and faced intense political conflicts over the distribution of the project's costs and benefits. For instance, a northern route would facilitate development of northern territories, while southern territories would lag and some southern states would experience trade diversion. In turn, economic development of northern territories would also lead to these territories claiming state status earlier, disrupting the delicate political equilibrium of America's antebellum Congress. Thus, any project promoting a northern route was opposed by southern states and any project proposing a southern route was blocked by the northern states, leading to a political deadlock.[11] As a result, the projects proposed in 1845-1853 by four different groups of entrepreneurs failed to pass in Congress (see appendix 2).

In 1853 Congress requested the army to perform an engineering survey of six different routes to determine the most appropriate one. In 1855 the results were published. Four of the six routes were found practicable, but the political deadlock prevented any bill from going through Congress. Entrepreneurs continued promoting the project, but with no success.[12]

In 1859 gold was discovered in Nevada. Reacting to the subsequent gold rush, Theodore Judah, a California based engineer-entrepreneur, convinced Sacramento merchants to invest in surveying the route and incorporating the Central Pacific to build the first transcontinental railroad in two stages. As explained above, the first stage was a railroad between Sacramento and the Nevada mines, and the second was a railroad between Nevada and Omaha. Next the Central Pacific was incorporated on June 28 1861. By 1861 Abraham Lincoln, who favoured construction

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[8] Whitney *"A Railroad to the Pacific"* p.2 and Russel *"Improvement of Communcation"* pp. 56-61.
[9] Marlowe *"The Making"* pp. 241-63, Farnie *"East and West"* pp. 83-84, Russel *"Improvement of Communication"* , Wilson *"The Suez"* pp. 44-45.
[10] Hutchins *"The American"* pp. 287-96, Evans *"Without Regard"* pp. 33-34 and Russel *"Improvement of Communication"* p. 76, chs. 5 and 6.
[11] Putnam's Magazine Vol. II July-Dec. 1853 p. 506, Southern Literary Messenger Vol. XX Sept. 1854 p. 553, American Railroad Journal July 21 1855, Judah *"A Plan"* pp. 5-7, Haney *"A Congressional"* ch. 4, Fogel *"The Union Pacific"* p. 22, Klein *"Union Pacific"* pp. 10-11, and Bain *"Empire Express"* p. 43-44.
[12] Davis *"Reports of Explorations"* , and Judah *"A Plan"*.

of the railroad, had been elected president, the southern states had seceded, and the Civil War had started. In turn, political conflict in Congress over the project declined. Judah went to Congress and requested the right of way and subsidies to build the road.[13]

The Pacific Railroad Act promoting construction of the first transcontinental railroad was passed on July 1 1862. The Act and its modifications granted the right of way for two companies to build the road and operate it under a long term lease. The Central Pacific was to build the first stage, from California to Nevada, and the Union Pacific (incorporated on October 29 1863) the second stage, from Nebraska to Nevada. The Act granted a subsidized construction loan and land grants to both companies. The Act also set up a construction race between the two companies. The Central Pacific won the race as it managed to build the whole first stage and continue building east of Nevada into Utah, gaining the right to also lease and operate that part of the track. The two companies' rails met in Promontory Point, Utah, on May 10 1869 and completed the first transcontinental railroad.

The cost of the first stage to Nevada was $14.1 million, and that of the whole railroad was $64.6 million (1860 dollars).[14] It was the largest project supported by the federal government in the 19th century, with a subsidized loan of more than $37 million (1860 dollars) and more than 5.5 million acres granted to the railroad companies.[15]

Robert Fogel and Lloyd Mercer carried out social savings (cost-benefit) analysis of the railroad companies. The average unaided private rate of return ranged from 8% to 13.7%, higher than the opportunity cost. The estimates for the minimum social rate of return ranged from 19% to 29.9%. Taking a normative approach to evaluating public policy, Fogel and Mercer concluded that, based on results of the ex-post social savings analysis, subsidies should not have been granted.[16] However, as explained above, Fogel and Mercer noted that the information appropriate to perform this evaluation is the ex-ante or expected private rate of return, and that ex-ante, the railroads were not expected to be profitable, they were built ahead of demand or premature.[17]

PRELIMINARY SURVEY REPORTS AS EVIDENCE OF PROFIT EXPECTATIONS

[13] Judah *"Central Pacific"*, *"Memorial of the Central Pacific"*, *"Report of the Chief Engineer"*.
[14] Cost estimate from Mercer *"Railroads and Land Grant"* p. 154, 164, $1.6 billion in 2008 dollars.
[15] Nimmo *"Report on the Internal"* p. 42, p. 44, deflated with David and Solar CPI index. Loan was at 3% interest, implying subsidy as railroads normally floated bonds at a coupon rate of 4-7% Mercer *"Railroads and Land Grant"*.
[16] Fogel *"The Union Pacific"* pp. 94-103 and Mercer *"Railroads and Land Grant"* pp. 75-82, 108-12.
[17] Fogel *"The Union Pacific"* and Mercer *"Railroads and Land Grant"* p. 28.

The profit expectations of the first transcontinental entrepreneurs and investors cannot be identified using revealed preference analysis of ex-post capital market data (see appendix 1). Preliminary survey reports are an alternative source of evidence to identify their profit expectations.

The appraisal of a railroad project in the 1850s was usually contained in a document titled “report of the chief engineer on the preliminary survey”, produced before or just after incorporation of the railroad. The report was composed of an engineering survey and market research. The information included in the report was used next by the entrepreneurs to communicate formally with investors, as it was the basis of the stock and bond prospectuses. The report thus contains the key public information used by investors to make their decisions on purchasing the project’s stock and bonds (see appendix 3).

The preliminary survey reports may be used in three different ways to identify profit expectations. First, the reports include statements made by the entrepreneurs explicitly indicating whether they expected the railroad to be profitable. Generally, entrepreneurs’ statements are not to be taken at face value. In the case of the first transcontinental, the conventional problems associated with asymmetric information in the operation of capital markets (adverse selection and moral hazard) are exacerbated by the political conflict over the distribution of the benefits and costs generated by the road. Entrepreneurs have incentives to overstate profit expectations to capital markets and to overstate social benefits and understate profits to Congress. Although it is possible to infer the sign of the effect that each of these problems has on the entrepreneurs’ stated expected profits, it is not possible to infer the overall sign or magnitude of these effects. Hence, I will simply report the entrepreneur’s profit statements and not attach additional value to these statements.

Second, performance and publication of a preliminary survey or of its results in a stock or bond prospectus is itself an indication of expected profits. A preliminary survey was an expensive activity, costing close to $30,000.[18] Although this sum would have been sufficient to build only three miles of relatively cheap railroad track, it was more than twice the annual sales of the average 1850s manufacturing establishment in the United States and represented a sunk investment.[19] Thus, performance, publication and use of a preliminary survey to develop a stock or bond prospectus reveals profit expectations (in the same way as the performance of an R&D project reveals expectations of profiting from future economic activity based on innovation).

[18] Davis *“Reports of Explorations”* , Judah *“A Plan”*, and Williams *“A Great”* pp. 36-7.
[19] http://fisher.lib.virginia.edu/collections/stats/histcensus/php/start.php?year=V1860 retrieved 17/05/2008.

Third, the reports explain the method used to evaluate the investment opportunity presented by the first transcontinental railroad. The method is exactly the same one used by other successful railroad entrepreneurs of the 1850s (see appendix 2). It may be described as the standard way to appraise a railroad investment project in the 1850s by *entrepreneurs and investors*, and is therefore common knowledge. Using the intuition behind this method, it is possible to develop a model of formation of expectations. Using publicly available information to estimate the parameters of the model, it is possible to develop a simulation model of formation of profit expectations.

The model's results are estimates of profit expectations that have several advantages. i) The estimates are less likely to be biased (than the entrepreneurs' stated expectations) in the sense that they are based only on a method that is common knowledge and public information, both generated ex-ante construction. ii) The model also allows testing the sensitivity of the profit estimates to specific data or assumptions. iii) The preliminary surveys indicate the method used to analyze railroad investment opportunities. A model building on this method provides a counterfactual setting where incentives to build the railroad depend exclusively on the profits derived from the operation of the railroad. Incentives to profit from construction or corruption play no role in the model. Thus, the estimated profit expectations are suitable for testing a normative question such as whether subsidies were required to promote private construction of the first transcontinental.

The main caveat is that developing profit expectations in this way does not utilize private information that may have been available to investors at the time. This caveat is not crucial when the purpose is to determine whether an average entrepreneur or investor should have expected profits.

Used in this way, the preliminary survey reports provide evidence on the first transcontinental entrepreneurs' and investors' expected profits. The way in which the reports are used makes it possible to overcome the conventional objections that entrepreneurs may not (necessarily) have provided in these reports information identical to their true beliefs, that entrepreneurial expectations may be different than investors' expectations, and that these statements cannot be subject to tests determining whether a hypothesis may be rejected or not.

PROFIT EXPECTATIONS AS STATED BY ENTREPRENEURS

The entrepreneurs initially proposed to build the first transcontinental as a single stage project (1845-59) and, after the Nevada gold rush the plan was to divide the project into two stages (1859-69). The single stage project was proposed by at least six different groups of entrepreneurs.[20] Entrepreneurs in all cases stated that they expected to make a profit and to prefer to use private funds to build the railroad; but they also requested subsidies (see appendix 3).

Theodore Judah promoted the railroad as a two stage project, and performed a preliminary survey in 1861. This included a detailed engineering survey of the first stage and calculated the expected construction cost as $13.3 million. The route proposed by Judah made it possible to reduce construction cost by more than 50% compared to the route indicated in the army surveys. The report also included market research. Market size was measured using the observed equilibrium in the wagon transport market across the Sierra Nevada, $5.7 million per annum. Next entrepreneurs promised to set the rail price lower than the observed price, and stated expected demand, and operational costs. Expected profits were $3.7 million per annum. Following the 1855 army surveys, the technical feasibility of the project was argued by comparing the technical standards of the proposed route to those of the Baltimore and Ohio Railroad, and showing that the proposed road was less demanding. If the Baltimore and Ohio was built and operated profitably, a technically less demanding railroad, like the first stage, was also expected to be profitable. The cost of the preliminary survey of the first stage was $35,000.[21] The information contained in the preliminary survey, if it is correct, indicates that entrepreneurs were careful in their analysis of the first stage as an investment opportunity and had good reason to expect profits.

The preliminary survey performed in 1861 also contained information on the second stage, but this was not as detailed. The preliminary survey for the second stage was completed by the Central Pacific and the Union Pacific between 1864 and 1866, while the first stage was being built. Construction cost was expected to be 33%-50% lower than the $86.7 million predicted in the army surveys.[22] The market research identified market size as the observed equilibrium in the transport market for sailing ships and Panama steamers to and from California and China, $31 million per annum. Next entrepreneurs promised to set the rail route price higher than the observed price for ships around Cape Horn, forecasted rapid growth in market size and stated the railroad's expected market share; expected revenues were deduced. Operational costs were assumed to be 50% of expected revenues. Expected profits were $27.6 million per annum. The cost of the surveys is not known, but the level of detail is comparable to the typical preliminary

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[20] 1) Whitney *"A Railroad"*, *"Project for a Railroad"*, 2) Degrand, Derby and Fisk *"Proceedings"*, 3) Judah *"A Plan"*, 4) McDougall *"Speech"* and projects by 5) Carver in 1847 and 6) Bayard and Company in late 1840s (see appendix 3).

[21] Project details come from Judah *"Memorial of the Central Pacific", "Report of the Chief Engineer"*

[22] Judah *"Memorial of the Central Pacific"* pp. 22-38, Durant *"Report of the Organization"* appendix 1 p. 8, Dodge *"Report of General"* pp. 12 13, and 17.

survey of the 1850s. The information contained in the preliminary survey for the second stage also revealed clearly that entrepreneurs expected to make a profit.[23]

A MODEL OF FORMATION OF PROFIT EXPECTATIONS OF THEODORE JUDAH

The model of formation of profit expectations of Theodore Judah formulated in this section, together with public information, makes it possible to estimate expected profit for each of the two stages of the first transcontinental railroad in the next section.

The model follows the intuition underlying the analysis of the railroad investment opportunity as illustrated by the market research in the preliminary survey (appendix 3). As explained in section 3, it makes it possible to estimate the profit expected by the average entrepreneur and investor, and is more accurate than measures calculated using revealed preference analysis of ex-post capital market information or the entrepreneurs' stated profit expectations.[24]

The model focuses on measuring a downward biased estimate of profit expectation derived from operation of the railroad. The estimate is downward biased because if it is found to be positive (profitable), then it is most likely that the average entrepreneur and investor would have expected the railroad to be profitable.

The model also develops a counterfactual scenario where the entrepreneurs face the decision to enter into the transport market induced only by operational profits. Thus, it is necessary to assume that i) entrepreneurs may buy the right of way for a fixed fee L – the project did not generate any political conflict in Congress and ii) entrepreneurs face an elastic capital supply at interest rate r – the Civil War did not affect funding for the railroad.

The first assumption excludes from the analysis the perverse incentives that entrepreneurs faced when in Congress to request the right of way. Entrepreneurs may have behaved opportunistically by lobbying, overstating or understating operational profits to facilitate the project's passage through Congress. Assuming it is possible to buy the land for a fixed fee

[23] Dodge *"Report of General"*, Fisk and Hatch *"Railroad Communication"* and Cisco *"The Union Pacific"*.

[24] The 1850s methods are used in preference to a more sophisticated modern approach. The emphasis of this article is on re-creating the investment decision of the 1850s entrepreneur. It is only what 1850s entrepreneurs and investors could have thought that matters for their profit expectations. The main difference between the two approaches is connected to the modern emphasis on the probability of an outcome. Entrepreneurs in the 1850s were just observing the beginning of the adoption of probabilistic and statistical analysis to business decisions in the insurance business. In the railroad industry entrepreneurs tried to use conservative estimates for the underlying variables in their models to compensate for their inability to allocate probabilities to events. The approach developed here follows the 1850s approach but also performs robustness checks on the probability of occurrence of the events studied.

without going to Congress makes it possible to focus on profits derived from the operation of the railroad. The value for L is set using the share of land acquisition costs in total construction cost for eastern railroads (see appendix 4 for a detailed discussion of this assumption).

The purpose of the second assumption is to exclude the possibility that capital markets may fail. The point is not so much to argue that the international capital market of the 1850s did not fail, but to highlight that i) the size of each of the stages was no larger than projects funded earlier in the international capital market and ii) technical uncertainty faced was within the range of existing railroads. Construction cost of the first stage was comparable to that of eastern railroads including the Michigan Southern, the Michigan Central and the Pennsylvania Company, funded in the domestic and international capital markets. Construction cost of the second stage was comparable to that of the Suez Canal. Additionally, neither stage of the first transcontinental implied any technical challenges requiring innovative solutions to build the railroad. The 1855 army surveys had determined that a similar route was feasible. The entrepreneurs improved the route located by the army by surveying the territory extensively in the early 1860s. Actual construction of the railroad indicates that the entrepreneurs identified correctly the difficulties involved, as construction was carried roughly as planned, as measured by cost, technical specifications and time. Crucially, entrepreneurs predicted no need to deviate from standard construction practices, and the actual construction experience gives no indication that construction techniques were improved or new ones developed. In short, once the first transcontinental railroad was divided into two stages, the characteristics of each of the two stages do not indicate any good reason why the capital market would be more likely to fail for this railroad than for other railroads that had already obtained funding in the capital market. The interest rate used here is about 30% higher than the typical 1850s railroad bond coupon to obtain a conservative profit expectation estimate (see appendix 4 for details on this assumption).

Theodore Judah started his analysis of the investment decision (whether to build the first transcontinental railroad) like all the other railroad entrepreneurs, by identifying market size, defined by the N submarkets in which he expected the railroad to operate. Each submarket is defined by a pair of origin i and destination j locations.

<u>Construction cost:</u> The next step was to describe the most appropriate route between origin i and destination j and present the estimated construction cost. Expected total construction cost, $\tilde{C}$, is the sum of the of the fixed fee for the right of way, L, and the flow of construction cost, $\tilde{c}$, discounted at discount rate r: $\tilde{C} = L + \sum_{t=1}^{T} (\tilde{c}_t/(1+r)^t)$

The next step was to estimate the annual flow of expected operational profits. The procedure was first to identify the observed transport demand (revenue). Judah then stated a pricing policy and (implicitly) an expected elasticity of demand, and deduced the expected transport demand (revenue). The operational costs observed for eastern railroads were then used to proxy for those of the first transcontinental. Operational profits were computed next.

Observed transport demand: The market research always starts by identifying the equilibrium observed in a relevant submarket, observed price, P_{ij}, and traffic, q_{ij}.

Expected transport demand: Judah considered how the introduction of the railroad might change the demand for transportation. Consider the case of transportation on one of the key first transcontinental railroad submarkets, between Canton and New York. The observed equilibrium is given by sailing ships following the all-sea route around Cape Horn and transporting q_{ij} tons per annum at an average price P_{ij} (see route AS in figure 1).

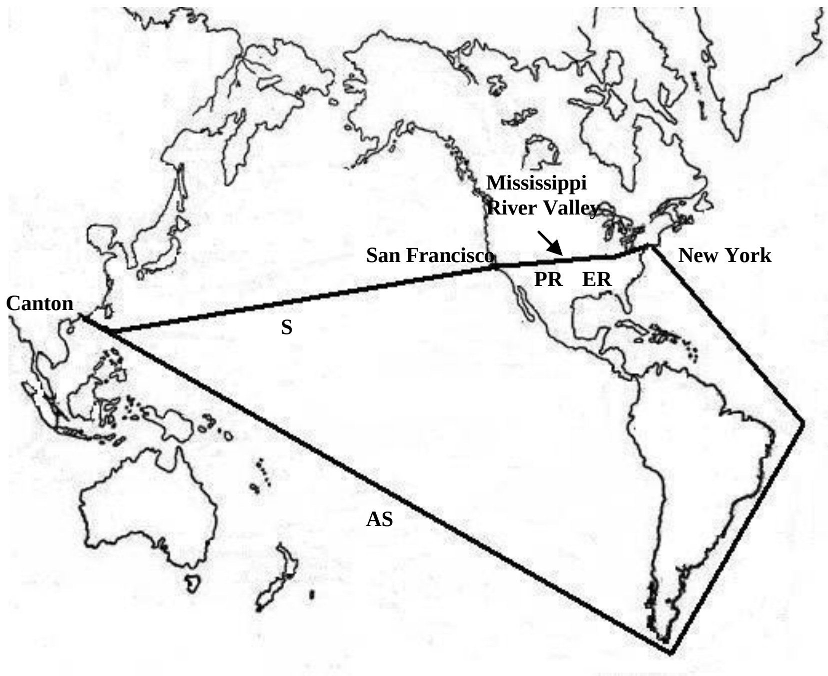

Figure 1
Journey from Canton to New York City via the all-sea and sea-rail routes

Source: Whitney (1849) Appendix. I have added the all-sea and sea-rail routes.
Note: AS: All-sea sail ship route; S: Sail ship segment of first transcontinental route; PR: First transcontinental railroad segment of first transcontinental route; ER: Eastern railroad network segment of first transcontinental route.

The reports indicate that after the introduction of the railroad merchants could use an alternative route between Canton and New York. The new route consists of sea transport from Asia to San Francisco (S), then by the first transcontinental railroad to the Mississippi Valley (PR), and finally by the eastern railroad network to the east coast (ER).[25] The expected demand of the new route is given by the trade that merchants are willing to take over the new route given the expected freight price of the new route. Let us define expected demand for transport over the new route for a given origin-destination pair *ij*, $\tilde{q}_{ij}$, as:

$$(1) \qquad \tilde{q}_{ij} \quad \begin{cases} \tilde{q}_{ij} = \tilde{h}_{ij} - \tilde{a}_{ij}\,\tilde{P}_{ij} \ \text{ if } & \tilde{P}_{ij} \leq P_{ij} + B_{ij} \\ \tilde{q}_{ij} = \tilde{u}_{ij} - \tilde{b}_{ij}\,\tilde{P}_{ij} \ \text{ if } & \tilde{P}_{ij} > P_{ij} + B_{ij} \end{cases}$$

where ~ denotes expectation. $\tilde{P}_{ij}$ is the expected price of transportation on the first transcontinental route. In turn $\tilde{P}_{ij}$ is defined as $\tilde{P}_{ij} = (f^{S} d^{S}_{ij} + f^{PR} d^{PR}_{ij} + f^{ER} d^{ER}_{ij})$ where f^{PR} is the expected average freight rate per ton-mile that the entrepreneur sets for the first transcontinental (e.g. the entrepreneur's decision variable); f^{S} and f^{ER} are the expected average freight rate for the S and ER segments of the route; and d^{S}_{ij}, d^{PR}_{ij}, d^{ER}_{ij} are the distances over the S, PR, and ER segments, respectively.[26] At this stage it is also convenient to note that d^{PR}_{ij} and d^{ER}_{ij} are constant across origin-destination pairs, and therefore their *ij* sub-indices may be dropped, simplifying notation.[27] Parameters $\tilde{a}_{ij}$ and $\tilde{b}_{ij}$ give the sensitivity of traffic to expected price. Parameters $\tilde{h}_{ij}$ and $\tilde{u}_{ij}$ are each a constant specific to each *ij* pair and associated with the economic size and other relevant origin-destination pair specific effects of the trade partners. Parameter B_{ij} is the value in dollars of non-transport trade costs saved by the new route. In the case of the Canton-New York rail route, since the rail route reduces transport time it also saves the merchants part of the expenses on insurance and working capital costs.

The intuition behind the demand function is that as distance or freight rates per ton-mile decline (and, thus, freight price between the two trading partners falls), transport demand increases. Also note that the expected demand function is identical to the observed demand when evaluated at the observed price; hence $\tilde{h}_{ij} = q_{ij} + \tilde{a}_{ij}\,(P_{ij}+B_{ij})$ and $\tilde{u}_{ij} = q_{ij} + \tilde{b}_{ij}\,(P_{ij}+B_{ij})$.

[25] Whitney *"Project for a Railroad"* p. 59
[26] The first transcontinental railroad route may imply trans-shipments not necessary by the all sea route. In the example of trade between Canton and New York the trans-shipments would take place in San Francisco and in the Mississippi region. The trans-shipment costs may be easily included, but for simplicity have been excluded from the analysis at this stage. They will be considered below in section 6.
[27] See appendix 4 for explanation of the reason why d^{PR} and d^{ER} are constant across origin-destination pairs.

The demand function is defined over two different ranges of transport prices to allow for two different types of decision problem without constraining the price elasticity of demand to be identical. The first decision problem is when entrepreneurs indicate that the rail route is expected to experience a cost advantage compared to the alternative transport mode and the entrepreneur considers a price ceiling, $\tilde{P}_{ij} \leq (P_{ij} + B_{ij})$, in his pricing decision. Judah thought about the first stage in this way (rail competes with wagon on prices).[28]

The second decision problem is when entrepreneurs indicate that the rail route offers some new good attributes compared to the alternative route. The relevant range to consider is $\tilde{P}_{ij} > (P_{ij} + B_{ij})$. The reports claimed that the first transcontinental railroad was expected to offer the California and China trade greater safety, a drier and more stable climate (as it avoided crossing the tropic twice), and reductions in transport time. Goods would arrive at their destination in better shape and goods not traded before would be traded (for example green fruits). The decision problem proposed is therefore one in which the rail route offers transportation with new good attributes. And the reports and bond prospectuses indicate that the entrepreneurs expected to set prices higher than the observed price, P_{ij}, and still capture a substantial part of the market share.[29] Note that this decision problem implies the entrepreneurs and investors must develop a forecast of willingness to pay for transport attributes not traded before, the expected demand for transport with new good attributes.

The survey reports and bond prospectuses indicate the entrepreneurs' promised price (once the railroad route was running) and the expected traffic at that price. However, the reports do not provide the explicit method used to determine the promised price or the expected traffic. Only the expected equilibrium ($\tilde{P}_{ij}$ and $\tilde{q}_{ij}$) is indicated in the reports and prospectuses.

The method used here to identify the expected demand function is based on the observation that during the 1850s there was diversity in the quality of transportation. In their reports, entrepreneurs identified the price for "normal" transport and for "higher quality" transport. The observed equilibrium was given by a price for "normal" transportation that, by definition, does not account for the new good attributes. The "high quality" price was observed, but the traffic associated with this price was not available. Moreover, the "high quality" price also was used to set a price ceiling.[30] The logic is that if passengers and merchants paid high transport prices for transport quality improvements that are less than those expected for the first

[28] See Judah *"Memorial of the Central Pacific"*
[29] See Cisco *"The Union Pacific"* p. 23.
[30] Whitney *"Project for a Railroad"* p. 37 used tea as an example of the kind of goods expected to be transported. Clipper ships and Central American steamships charged a premium over Cape Horn normal ships for their shorter journey time (see Lubbock *"The China Clippers"*, American Railroad Journal, Saturday, July 21, 1855, p. 451, Cisco *"The Union Pacific"*).

transcontinental route, it is then reasonable to assume that passengers and merchants will be willing to pay those prices for the transport improvements offered by the first transcontinental.[31]

The method proposed to identify a linear demand function uses two points in the demand schedule $q_{ij} = \tilde{u}_{ij} - \tilde{b}_{ij} \tilde{P}_{ij}$. The first point is the "normal quality" observed equilibrium, P_{ij} and q_{ij}. The second point is given by a "high quality" transport price observed by the entrepreneurs before construction, max P_{ij}. At a price max P_{ij} it is assumed only one ton or one passenger demands transportation, q_{ij}=1. Note that this is a conservative assumption, as more than one ton or one passenger were transported at this price, and leads to underestimating expected profits.[32] After identifying the two points on the demand schedule, it is possible to identify $\tilde{b}_{ij}$ such that it allows expected demand to be equal to q_{ij} (traffic observed in 1860) when $\tilde{P}_{ij} = (P_{ij} + B_{ij})$ and equal to 1 when $\tilde{P}_{ij} = \max P_{ij}$.

Alternative methods to infer the demand function exist. The literature on identification of the welfare effects of new goods offers a different approach. Loosely speaking, and assuming perfect competition to keep matters simple, this approach uses data revealed after the new good has been introduced and a certain functional form for preferences to identify the price elasticity of demand for the new good. It is then possible to integrate the demand function to estimate the area below the demand curve and above the old good's price representing the welfare gains by consumers. The robustness of this approach rests on the researcher demonstrating that the elasticity estimated and the functional form used do not generate an upward bias on the demand function. More precisely, the litmus test is that the virtual price at which the estimated demand function predicts demand is 0 is not unreasonably high.[33]

It is, however, difficult to use this approach in the case of the first transcontinental. The only option is to use a given functional form and solve for the values of the elasticity that allow for expected profits.[34] I undertook this assessment, but the results were highly sensitive to the choice of functional form and it is not possible to connect them to the information available to entrepreneurs in the 1850s.[35]

[31] Note the similarity in the intuition of the argument and a loosely specified hedonic price equation.
[32] For instance, the Panama steamers allocated on average 40% passenger capacity to cabin (luxury) traffic.
[33] See Tratjtenberg *"The Welfare Analysis"*, Hausman *"Valuation of New Goods"*, Petrin *"Quantifying the Benefits"* and Greenwood and Kopecki *"Measuring the Welfare"*.
[34] Estimating the price elasticity of demand for a good before it appears in the market place is not feasible because no market price data exist.
[35] A constant elasticity demand function was assumed and results indicate that if the price elasticity of demand is within the range 1-1.17 expected profits are positive. Two problems arise with this result. First, it is difficult to argue these elasticity values were the ones the entrepreneurs or investors actually expected. Entrepreneurs did implicitly think in terms of elasticity, but simply did not write using this language. Second, the results indicate that the asymptotic nature of the constant elasticity demand function leads the virtual price to be unrealistically high when quantity is 0.

The approach proposed here is theoretically less elegant than that proposed in the new goods literature approach, but it has two advantages in the context of evaluating ex-ante willingness to pay. First, it relies on price information only; prices were available to entrepreneurs and the reports indicate that they used them to inform their decision making. Second, note that at $\tilde{P}_{ij}$ = max P_{ij}, expected demand is $\tilde{q}_{ij} = 1$. This implies that the maximum price the railroad route may charge is the maximum price observed ex-ante. Thus, this assumption guarantees that any solution identified using this method is within a reasonable price range.

Operational costs: Judah used eastern railroads' observed cost statistics to derive expected operational costs. Constant average cost per passenger-mile or per ton-mile was frequently used in the 1850s to describe operational costs, $\tilde{o}$. The expected operational costs are given by $\tilde{O} = \tilde{o}\, d^{PR}\, \tilde{q}_{ij}$ with d^{PR} as the distance over the first transcontinental segment and $\tilde{q}_{ij}$ expected passenger or freight traffic.[36]

Operational profits: The expected operational profits, $\tilde{\pi}_{ij}$, are given by $\tilde{\pi}_{ij} = (f^{PR} - \tilde{o})\, d^{PR}\, \tilde{q}_{ij}$. The first part of the function is the profit per passenger-mile or ton-mile transported. The second part is distance times the number of passengers or freight transported (passengers/tons moved one mile), or quantity transported.

Maximization problem: As explained above, the decision problem faced by the entrepreneurs may be framed in two different ways. First, Judah considered that the first stage rail route would experience cost advantage compared to the alternative transport mode (wagon). The problem is to maximize profits subject to a price ceiling. The entrepreneur chooses an optimal expected freight rate, f^{PR*}, maximising expected operational profits subject to expected transport price being equal to or less than $(P_{ij}+B_{ij})$. Note that $(P_{ij}+B_{ij})$ acts as a strict price ceiling imposed by competition with the alternative transport mode. More formally, the entrepreneur's problem is:

$$(2) \qquad \underset{f^{PR}}{Max}\, \tilde{\pi}_{ij} = (f_{ij}^{PR} - \tilde{o})\, d^{PR}\, (\tilde{h}_{ij} - \tilde{a}_{ij}\, \tilde{P}) \qquad \text{st} \qquad \tilde{P}_{ij} \le P_{ij} + B_{ij}$$

[36] Note that the operational cost function does not allow for economies of scale, scope or density. These are important characteristics of the operational cost function in many transport industries. However, the reports do not indicate that entrepreneurs considered these issues when developing their expected outcomes. Additionally, since these economies lead to lower operational costs and higher profits, the profits estimated by the model will be downward biased and consistent with the research strategy.

Second, when the entrepreneur considers that the second stage rail route is expected to offer some new good attributes compared to the alternative route (sail ships), he faces the following problem:

(3) $$\underset{f^{PR}}{Max}\,\tilde{\pi}_{ij} = (f_{ij}^{PR} - \tilde{o})d^{PR}(\tilde{u}_{ij} - \tilde{b}_{ij}\,\tilde{P}_{ij})$$

The solution to both maximization problems is presented in appendix 4 part 7. The reports then present the expected operational profits for each of the *N* submarkets. Total operational profits, $\tilde{\eta}$, is the sum of operational profits in all *N* submarkets and assumes that operational profits in each submarket are identical for each period *t* of operation.

<u>Entry decision</u>: The reports then compare the expected construction cost, $\tilde{C}$, with the flow of expected operational profits, $\tilde{\eta}$, and derive the entry condition for the entrepreneur to decide whether to build the road or not. The entry condition is defined as follows:

(4) $$\sum_{t}^{T}\frac{\tilde{\eta}_t}{(1+r)^t} \geq L + \sum_{t}^{T}\frac{\tilde{c}_t}{(1+r)^t}$$

where *T* is the total lifetime of the project. For the entrepreneur to decide to build the railroad the sum of the expected discounted stream of total operational profits must be higher than the sum of the expected discounted stream of construction costs.[37]

RESULTS AND DISCUSSION

In this section the model of formation of expectations formulated in the previous section is used to derive an estimate of the profit expectation of an average entrepreneur or investor after Judah presented his project to build the first transcontinental railroad in two stages. The exercise presented here takes as given the technical information and construction cost estimates included in the engineering part of the report of the preliminary survey. The analysis focuses on performing the market research part of the reports using the model formulated in section 5 and information publicly available before construction. The idea is to anchor the model firmly to the historical context, continuing with the *ex-ante* spirit of the exercise. The purpose is to use the model as a counterfactual scenario focused exclusively on expected profits derived from the

[37] The 1850s contemporary entry condition was operational profits over construction cost ratio of 15%. The baseline results for the first and second stage presented below both pass this test.

operation of the railroad. It enables the calculation of an estimate of expected profits less biased than that obtained using revealed preference analysis of ex-post capital market data or simply taking at face value the expected profits as stated by entrepreneurs. Also recall that the objective is to construct a downward biased estimate of profit expectation, and therefore a conservative value will be used for each parameter.

To focus on Judah's project, the plan was to build first a mining railroad from California to the mining district of Washoe, Nevada – the first stage. Then, if, and only if, the first stage was successful, the plan was to build a railroad from Nevada to Omaha, Nebraska, to transport the California and China trades – the second stage. Judah's project was to build sequentially the first and second stages of the first transcontinental railroad. The second stage only makes economic sense if the first stage is successfully built. (see figure 2)

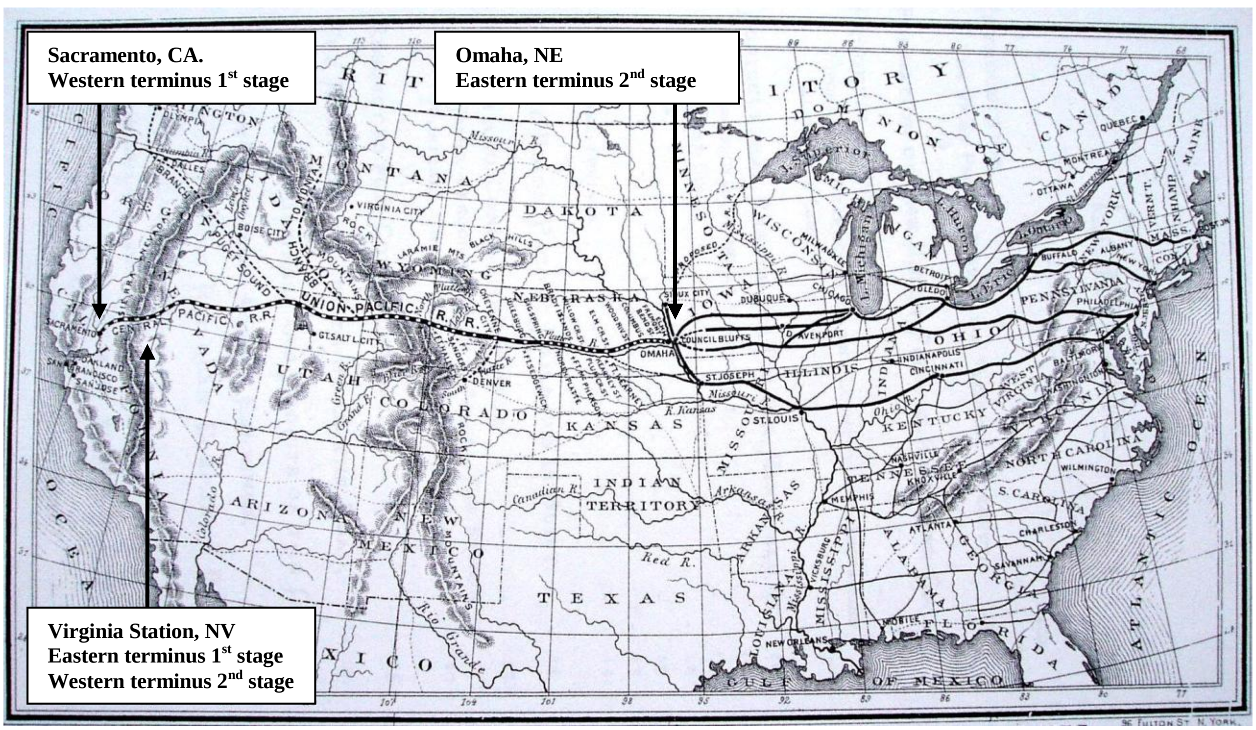

Figure 2
MAP OF THE TWO STAGES OR THE FIRST TRANSCONTINENTAL RAILROAD

Source: Cisco (1868)

Decision to enter into the first stage

Judah's first stage of the first transcontinental is a railroad from Sacramento to Virginia Station, Nevada in the Washoe mining district (see figure 2). The reports indicate that construction was expected to take five years and cost $13.3 million (all values are expressed in 1860 dollars), well within the $10-$22 million range of railroads built in the 1850s in America. Costs are spread evenly over the first five years. Earnings from transportation start in the sixth year and continue until the project's life ends, in year twenty five. The parameters characterizing construction costs, observed demand, expected demand and operational costs are drawn from public sources including specialized press or government reports, sources frequently used by entrepreneurs in the 1850s, see table 1.

Parameter/Variable	Value	Source & comment
Expected construction cost	$13.3 million	Judah (1861)
Expected railroad distance	155 statute miles	Judah (1861)
Construction period	5 years	Actual construction 4.75 years (09/1863-06/1868)
Land fixed fee	1% construction cost	Fishlow (1965)
Project's life	25 years	Fogel (1960), Mercer (1982)
Discount rate	9%	Mercer (1982) Higher than 5-7% typically offered by railroad bonds
Observed freight traffic	43,800 tons/year	Judah (1862) 15%-39% lower than alternative info
Observed passenger traffic	13,505 passenger/year	Judah (1862) In line with alternative info
Observed freight price	$120	Judah (1862) In line with alternative info
Observed passenger price	$30	Judah (1862) In line with alternative info
$\tilde{a}_{ij}$ (expected sensitivity of traffic to price)	Calibrated (see text)	
$\tilde{h}_{ij}$ (trading partners characteristics)	Calibrated (see text)	
Expected freight operational cost	1.18 cents ton-mile	Poor (1860) 136% higher than entrepreneur info
Expected passenger operational cost	0.88 cents per pass-mile	Poor (1860)

Table 1
PARAMETER VALUES AND SOURCES FOR FIRST STAGE

Sources: See appendix 4 for details

Judah considered that the railroad had technological advantage in competing with wagon roads across the Sierra Nevada. The entrepreneur's decision problem is given by equation (2) where the entrant faces a price ceiling equal to the observed price. Although the railroad would certainly offer shorter travel time and more comfort than travel by wagon, there is no evidence entrepreneurs considered these potential transport quality improvements when formulating their profit expectations for the first stage. Note that B_{ij}, $f^S d^S{}_{ij}$ and $f^{ER} d^{ER}{}_{ij}$ are all equal to 0, and the constraint in the maximization problem given by equation (2) is substituted by $\tilde{P}_{ij} \leq P_{ij}$.

Scenario	**Submarket**	**P**	**Q**	**P*Q**	**C**	**Profit**	**NPV**
		$	**Tons or passengers**	**$**	**$**	**$**	**$ m**
Baseline scenario	Freight	120	43,800	5,256,000	80,110	5,175,890	24.5
	Passenger	30	13,505	405,150	18,421	386,729	
Construction cost up 3.15 times	Freight	120	43,800	5,256,000	80,110	5,175,890	0
	Passenger	30	13,505	405,150	18,421	386,729	
Traffic & prices down by 43.2%	Freight	68	24,878	1,695,712	45,503	1,650,209	0
	Passenger	17	7,671	130,711	10,463	120,248	
Operational cost up*	Freight	120	43,800	5,256,000	3,492,805	1,763,195	0
	Passenger	30	13,505	405,150	405,150	0	
Discount rate up by 2.76 times	Freight	120	43,800	5,256,000	80,110	5,175,890	0
	Passenger	30	13,505	405,150	18,421	386,729	
Project's life down to 8.5 years	Freight	120	43,800	5,256,000	80,110	5,175,890	0
	Passenger	30	13,505	405,150	18,421	386,729	
Earnings delayed 9.6 years	Freight	120	43,800	5,256,000	80,110	5,175,890	0
	Passenger	30	13,505	405,150	18,421	386,729	
Combination of negative events 1	Freight	90	32,850	2,956,500	75,103	2,881,397	2.1
	Passenger	23	10,129	227,897	17,270	210,627	
Combination of negative events 2	Freight	96	35,040	3,363,840	76,906	3,286,934	2.3
	Passenger	24	10,804	259,296	17,684	241,612	
Combination of negative events 3	Freight	120	43,800	5,256,000	120,165	5,135,835	1.1
	Passenger	30	13,505	405,150	27,631	377,519	
Combination of negative events 4	Freight	96	35,040	3,363,840	76,906	3,286,934	0
	Passenger	24	10,804	259,296	17,684	241,612	

Table 2
BASELINE SCENARIO AND SENSITIVITY ANALYSIS - FIRST STAGE

Note: P: Profit maximizing price; Q: Total quantity of output in tons per annum; P*Q: Revenue; C: Operational cost; Profit: Operational profit; NPV: Net Present Value. Changes in parameters calculated to make NPV = 0. * Operational cost of freight service up 43.6 times and of passenger up 21.9 times. Combination 1: Construction cost, operational cost and discount rate up by 25%, and traffic & prices down by 25%. Combination 2: Construction cost and operational cost up by 20%, traffic & prices down by 20% and project's life down to 15 years. Combination 3: Construction cost and operational cost up by 50%, earnings delayed by 2 years and project's life down to 15 years. Combination 4: Construction cost and operational cost up by 20%, traffic & prices down by 20%, earnings delayed 1 year, and project's life down to 15 years.

The market for transportation is composed of two submarkets: freight and passenger traffic (both ways) between Sacramento and Virginia Station. The baseline equilibrium is calculated under a range of values for $\tilde{a}_{ij}$, the sensitivity of traffic to changes in expected transport price. For values of $\tilde{a}_{ij}$ rendering a price elasticity of demand equal to or lower than 1 the profit maximizing solution to the model is trivial: the entrepreneur should set a rate for the first transcontinental such that the expected price is equal to the observed price. The entrepreneur gains nothing from reducing the expected price because traffic will grow less than proportionally to the expected price reduction, leading to lower earnings and higher operational costs. The profit maximizing price and quantity are identical to the observed equilibrium. Freight profits should have been expected to have been $5.2 million per annum and passenger profits $387,000 (see table 2, baseline scenario). For values of $\tilde{a}_{ij}$ leading to a price-elasticity higher than 1 the solution has also been calculated. The results indicate that profits should be expected to have increased with $\tilde{a}_{ij}$, the parameter driving the price-elasticity of demand (see appendix 4).

Once expected operational profit for the first stage is calculated, it is possible to compute the entry condition given by equation (4). The expected net present value (NPV) of the project is $24.5 million (see table 2, baseline scenario). The baseline scenario (using only the information available by 1862) indicates that the average entrepreneur and investor should have expected the first stage of the first transcontinental railroad to be profitable.

In order to determine more precisely the robustness of the finding above, sensitivity analysis is performed. The maximum change to each single parameter making the expected NPV equal to 0 reveals that the project is still profitable even after very large changes in the parameters (see table 2). The project is still profitable even after total construction cost increases 3.15 times, or observed traffic and prices for both freight and passenger submarkets go down by 43% for the whole project's life, or operational cost increases by up to 43 times for freight and 21 times for the passenger submarket, or the discount rate goes up 2.76 times, or the project's life is reduced from 25 to 8.5 years, or earnings are delayed entirely by up to 9.6 years.

Note that the project was not highly sensitive to changes in the baseline scenario, and even the typical forecasting mistakes in large projects, underestimation of construction costs or overestimation of future demand, could have been easily accommodated. Construction was carried out roughly along the lines of the proposed project with the help of additional surveying to reduce the length of tunnelling and the use of nitro-glycerine explosives. Construction cost was $14.1 million. But even if entrepreneurs had not performed the surveys leading to the reduction of tunnelling or had not used nitro, the cost over-run would have been at most an additional $1 million, a modest over-run compared to the maximum one of $28.6 million allowing NPV to equal 0 (see appendix 4).[38] On the demand side, the mining boom peaked in 1876 and production

[38] The Sierra Nevada tunnels and the Summit tunnel, especially, have been identified as causing the greatest difficulties in construction of the Central Pacific (and more generally the first transcontinental) because of

by 1880 was at least three times higher than in 1861.[39] But even if Nevada's silver boom had gone bust rapidly, as long as the 1860 demand had been experienced for only 3.5 years after construction finished, the project's NPV is positive.

The project's expected profit is positive even after a varied combination of negative events. All parameters of the model can change (at the same time) in the direction against profits up to 28.4% and the NPV of the project is still positive. Entry of a competing railroad may also be accommodated with NPV still positive (see appendix 4).

In sum, the average entrepreneur and investor should have expected the first stage of the first transcontinental railroad to be profitable. The railroad should have been perceived as an attractive investment opportunity given the methods used to evaluate railroad investments in the 1850s and the information publicly available by 1862. Evidence indicates that the technological challenge of building the road was relatively well predicted. The project based its competitive advantage on its technological advantage over wagon transportation and on booming demand.

Decision to enter into the second stage

The second stage, as proposed by Judah is a railroad from Virginia Station, Nevada, to Omaha, Nebraska (see figure 2).[40] Because Judah proposed to build the two stages sequentially, when the decision to build the second stage is considered, it is already known that the first and technically more difficult stage has been successfully finished, its construction cost has been reduced by half, and it operates profitably.

Construction was expected to cost $57.2 million and take about 5 years.[41] Note that construction of the second stage was simpler than that of the first stage and the credibility of expected construction cost reduction must have been high, as construction cost for the first was actually halved.[42] Uncertainty about construction cost must have been relatively low.

The second stage project's life starts in year 6 of the project as a whole and ends in year twenty five. Construction costs are evenly spread over years six to ten. The market for transportation is composed of three submarkets: freight traffic in both directions between

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the harsh weather and the hardness of the granite walls in the Sierra. Evidence does not suggest that any technical break-through was achieved or even attempted during construction of the tunnel (see appendix 4).

[39] Lord *"Comstock Mining"* p. 416.

[40] Construction cost and time also includes the track segment between Sacramento and San Francisco, completing the full railroad to the Pacific Ocean and connecting directly with ships to and from China.

[41] Judah *"Memorial of the Central Pacific"* pp. 22-38, Durant *"Report of the Organization"* appendix 1 p. 8, Dodge *"Report of General"* pp. 12 13 and 17. See section 4.

[42] The second stage had lower grades and three short tunnels, while the first stage had higher grades and fifteen long tunnels.

California and the eastern United States (California trade), freight traffic in both directions between China and the eastern United States (China trade), and passenger traffic in both directions between California and the eastern United States (California passenger traffic). Earnings begin in year eleven and continue until the end of the project's life. The parameters characterizing construction costs, land values, observed demand, expected demand and operational costs are drawn, as for the first stage, from public sources and are presented in table 3.

The preliminary survey reports, and particularly the Union Pacific bond prospectuses, indicate that entrepreneurs also expected the railroad to provide transportation with new good attributes.[43] The entrepreneur's decision problem is given by equation (3). Recall that the demand function is inferred using the observed "normal quality" price and the "high quality" price. The "normal quality" transport price corresponds to the average sailing ship price for freight and average steerage price for passengers. The "high quality" transport price corresponds to the average fast steamer price for freight and average first cabin price for passengers (both via Panama).

The reports also indicate that market size was predicted to grow quickly, doubling soon after completion of the road.[44] Expectation on market size growth is implemented by allowing average traffic for the 15 years of operation of the second stage to vary pseudo-randomly between the observed level in 1860 and twice this level following a uniform distribution – the expected traffic beliefs probability distribution. The idea is that few investors would have expected market size to decline during the next 15 years as California grows and integrates into the eastern United States and China also grows and integrates into the world economy. Thus, the lower bound of the expected traffic must have been the observed market size. On the other hand, entrepreneurs may have been optimists and over-estimated expected growth, setting the upper bound on expected traffic. Consequently, the interval of the expected traffic beliefs probability distribution reflects the range of expectations the average entrepreneur and investor may have held. No prior assumption about the probability distribution describing expected traffic beliefs exists; hence the uniform probability distribution is adopted for the baseline scenario and sensitivity analysis using other distributions is performed.

[43] Cisco *"The Union Pacific"* pp. 23-24.
[44] Cisco *"The Union Pacific"* p. 23-24.

Parameter/Variable	**Value**	**Source & comment**
Expected construction cost	$57.2	Judah (1861) p. 29.
Expected railroad distance	1,845 statute mile	Judah (1861) p. 29 In line with entrepreneurs
Construction time	5 years	Actual construction 4.75 years (Virginia City to Promontory Summit 06/1868-05/1869 and Omaha-Promontory Summit 07/1865-05/1869)
Land fixed fee	1% construction cost	Fishlow (1965) 4
Observed traffic freight – NY-SF	147,392 tons/year	Berry (1984), Nimmo (1885) 50%-65% lower than entrepreneur info
Observed traffic freight – NY-Shanghai	79,849 tons/year	Report on Navigation (1856-60) 50%-65 lower than entrepreneur info
Observed traffic passenger – NY-SF	44,102 passengers/year	Nimmo (1885) 60%-78% lower than entrepreneur info
Observed sail ship freight price – NY-SF	$16.83	SF Press (1856-60) In line with entrepreneur info
Observed maximum freight price – NY-SF and NY-Shanghai	$140.00	Otis (1860)
Observed sail ship freight price – NY-Shanghai	$17.49	SF Press (1856-60) In line with entrepreneur info
Observed steerage passenger fare – NY-SF	$50	Kemble (1943) In line with entrepreneur info
Observed maximum passenger fare – NY-SF	252.60	Kemble (1943)
$\tilde{b}_{ij}$ (expected sensitivity of traffic to price)	Calibrated (see text)	
$\tilde{u}_{ij}$ (trading partners characteristics)	Calibrated (see text)	
Expected eastern railroad distance	850 statute miles	Mean distance between Omaha and 16 major eastern cities
Expected eastern railroad freight price – Omaha-average eastern city	$20.50	Poor (1860) 140% higher than entrepreneur info
Expected eastern railroad passenger fare - Omaha-average eastern city	$14.96	Poor (1860)
Expected sea distance – Shanghai-SF	6,210 statute miles	
Expected sea freight price	$6.83	SF Press
Expected freight operational cost	$0.0118 ton-mile	Poor (1860) 136% higher than entrepreneur info
Expected passenger operational cost	$0.0088 per pass-mile	Poor (1860)

Table 3
PARAMETERS AND VALUES AND SOURCES FOR THE SECOND STAGE

Sources: See appendix 4 for details

Next a Monte Carlo experiment is performed using the model formulated in section 5, the observed information contained in table 3, and a draw from the expected traffic beliefs probability distribution. The result of the experiment is an estimate of profit expected by the average entrepreneur or investor for the second stage of the first transcontinental railroad. The experiment is repeated 2,000 times, resulting in an estimated probability distribution of profit expected for the second stage.

The results of the Monte Carlo experiment are presented in table 4. The baseline results indicate that entrepreneurs should have expected profits from all three submarkets and a positive NPV for the second stage. The profit maximizing average freight price is $70 and the average passenger price is $128; and predicted traffic is about 135,000 tons freight and almost 40,000 passengers per annum. Average annual profit for the California trade is $4.3 million, for the China trade $2 million, and for the California passenger submarket $4.4 million. The average NPV (proxy for the expected utility criteria) is $7.8 million. The probability of positive NPV is 95.6%. The sum of the NPV of the first and second stages is $32.3 million. Note that since the NPV of the second stage is $7.8 million and the expected construction cost of the first stage present value is $10.8 million, the single stage should not have been expected to be profitable.

How sensitive are results to the specific parameter values? They do not seem particularly sensitive to specific values of key variables (see table 4). Freight maximum observed prices may go down by 18.5% and the NPV is still positive. Passenger maximum observed prices may go down by 57.4% (the level at which the profit maximizing price is equal to the observed price) and the NPV is $0.7 million. The upper bound of the expected traffic beliefs probability distribution may be reduced by 68% - observed traffic growing by up to 42% instead of 100% - and the NPV is still positive. Thus, the specific assumptions imposed on the maximum price and the upper bound of the probability distribution of expected traffic beliefs are not only closely based on the entrepreneurs' declared expectations and data on observed willingness to pay revealed in the 1850s, but may also change moderately in the direction against profits and the railroad should still have been expected to be profitable.

The baseline scenario is also robust to moderate changes in the other parameters of the model (see table 5). The Monte Carlo experiment was performed again, now changing each of the other parameters of the model until the average NPV became 0. Construction cost may increase by 24.3% and the average NPV is still positive – note that construction cost was $50.5 million, lower than the entrepreneur's moderate estimate of $57.2 million.[45] Entrepreneurs invested in surveying the region intensively and succeeded in reducing construction costs. The new good

[45]Construction cost includes $6.5 million repairs required by the government, Snow *"Preliminary Report".*

attributes of the rail route create monopoly power insulating the first transcontinental from competition posed by the all-sea route. The all-sea route price may fall down to $0 and the average NPV is still positive - the sail ship price can go down to 0 and cannot compensate the merchant for the improve quality benefits lost. The "normal quality" sailing ship must give the merchant at least $53.17 for the merchant to prefer to use sail ($70-$16.83). The complementary price (the price for rail service between the Mississippi and the eastern destination of traffic and the price of the Canton to San Francisco sea trip) may go up by 61.3% and the average NPV is still positive. An alternative interpretation of the previous result is that the cost of trans-shipment on the sea-rail route at Omaha (and San Francisco for the China trade) may go up to $12.5 per ton and the transcontinental railroad's average NPV is still positive – the typical transhipment cost was about 30 cents per ton.[46] The operational costs may go up by 57.6% or the discount rate up by 31.7% and the average NPV is still positive. When all parameters in the model change (at the same time) in the direction against profits by 5.2%, the average NPV of the project is still positive.

Scenario	**Submarket**	**P**	**Q**	**PQ**	**C**	**Profit**	**NPV 2nd stage**	**NPV full**
		$	**Tons or passengers**	**$**	**$**	**$**	**$ m**	**$ m**
Baseline scenario	Cal. freight	72	89,574	6,409,016	2,113,937	4,295,079	7.8	32.3
	China freight	68	45,124	3,074,518	1,064,917	2,009,602		
	Cal. Passenger	128	39,857	5,087,460	701,491	4,385,969		
Baseline & max. observed freight down by 18.5%	Cal. freight	59	83,597	4,898,784	1,972,882	2,925,902	0	24.5
	China freight	55	40,912	2,257,751	965,526	1,292,225		
	Cal. passenger	128	39,857	5,087,460	701,491	4,385,969		
Baseline & max. observed pass. price down by 57.4%	Cal. freight	72	89,574	6,409,016	2,113,937	4,295,079	0.7	25.2
	China freight	68	45,124	3,074,518	1,064,917	2,009,602		
	Cal. passenger	55	66,169	3,641,378	1,164,573	2,476,805		
Baseline & expected traffic upper bound down by 40.8%	Cal. freight	72	71,985	5,150,519	1,698,835	3,451,683	0	24.5
	China freight	68	36,233	2,468,787	855,109	1,613,678		
	Cal. passenger	128	32,098	4,097,080	564,930	3,532,150		
Baseline & expected construction cost by up 24.3%	Cal. freight	72	89,574	6,409,016	2,113,937	4,295,079	0	24.5
	China freight	68	45,124	3,074,518	1,064,917	2,009,602		
	Cal. passenger	128	39,857	5,087,460	701,491	4,385,969		

Table 4
BASELINE SCENARIO AND SENTISITIVITY ANALYSIS - SECOND STAGE

Note: P: Profit maximizing price; Q: Total quantity of output in tons per annum; P*Q: Revenue; C: Operational cost; Profit: Operational profit; NPV: Net Present Value. Baseline scenario is Monte Carlo experiment for traffic varying pseudo randomly between observed level in 1860 and twice that level. Changes in parameters calculated to make average NPV = 0.

[46] Fishlow *"American Railroads"* p. 66

Scenario	Submarket	P	Q	PQ	C	Profit	NPV 2nd stage	NPV full
		$	Tons or passengers	$	$	$	$ m	$ m
Baseline scenario	Cal. freight	72	89,574	6,409,016	2,113,937	4,295,079	7.8	32.3
	China freight	68	45,124	3,074,518	1,064,917	2,009,602		
	Cal. passenger	128	39,857	5,087,460	701,491	4,385,969		
Baseline & observed price down to $0	Cal. freight	72	78,464	5,614,155	1,851,761	3,762,394	1.3	25.9
	China freight	68	39,338	2,680,351	928,389	1,751,962		
	Cal. passenger	128	31,291	3,994,066	550,725	3,443,341		
Baseline & observed complementary prices up by 61.3%	Cal. freight	65	76,821	4,972,168	1,812,984	3,159,184	0	24.5
	China freight	61	38,207	2,342,430	901,684	1,440,746		
	Cal. passenger	123	38,053	4,667,577	669,734	3,997,843		
Baseline & operational costs up by 57.6%	Cal. freight	78	76,877	6,023,075	2,859,326	3,163,748	0	24.5
	China freight	75	38,237	2,865,189	1,422,173	1,443,016		
	Cal. passenger	133	38,022	5,045,841	1,054,625	3,991,216		
Baseline & discount rate up by 31.7%	Cal. freight	72	89,574	6,409,016	2,113,937	4,295,079	0	24.5
	China freight	68	45,124	3,074,518	1,064,917	2,009,602		
	Cal. passenger	128	39,857	5,087,460	701,491	4,385,969		

Table 5
BASELINE SCENARIO AND SENSITIVITY ANALYSIS - SECOND STAGE

Note: P: Profit maximizing price; Q: Total quantity of output in tons per annum; P*Q: Revenue; C: Operational cost; Profit: Operational profit; NPV: Net Present Value. Baseline scenario is Monte Carlo experiment for traffic varying pseudo randomly between observed level in 1860 and twice that level. Changes in parameters calculated to make average NPV = 0.

Finally, the second stage baseline scenario result is also robust to various robustness checks. Various forms of formation of expectations about future market size growth and construction cost do not change the qualitative results. The baseline scenario result is also robust to different market structures on the Panama route, if the Panama route average long run freight cost is $60-$70 per ton-trip and $50 per passenger-trip. Ex-ante and ex-post productivity data indicates that there is little reason to think the entrepreneurs should have been concerned about technological change in the steamship industry eroding the rail route's market power. The baseline scenario results also predict moderately well the observed outcome in 1870-84 (see appendix 4).

Summing up, utilizing the conventional way entrepreneurs used to frame railroad investment opportunities in the 1850s and publicly available information to model the formation of expectations of the first transcontinental entrepreneurs reveals that the entrepreneurs and the average investor should have expected the second stage of the road to be profitable. Entrepreneurs anticipated high traffic growth, high transport prices, and likely construction cost reductions. The model of formation of profit expectations suggests that the entrepreneurs were right to expect the railroad to be profitable under these assumptions. The results are even stronger when one considers that they are a lower bound of expected profits. Including in the analysis price discrimination, economies of scale, scope and density, or other sources of earnings not included in the analysis (such as traffic from Colorado's mining or Japan's trade) should lead to even higher expected profits.

Discussion: Expected profits, subsidies and methods

The findings above have important implications for the debates on the desirability of federal subsidies to promote construction of the first transcontinental. Once silver was found in the Washoe region and entrepreneurs divided the project into two stages, the project's profitability becomes highly likely. The evidence indicates that when the Pacific Railroad Act was passed in Congress in 1862, entrepreneurs had already privately carried out the surveys necessary to take the first stage of the project to the capital market. The project's size and expected profits were comparable to or better than those of the typical 1850s railroad project. Thus, the evidence strongly suggests that the first stage of the first transcontinental could have been built privately.

The engineering survey for the second stage had not been completed in detail by 1862. It is likely that entrepreneurs would explore and learn about the construction cost of the second stage while building the first stage (as actually happened with the Central Pacific entrepreneurs). Thus, entrepreneurs should have acquired the information necessary to realize that the construction costs had been overestimated by the army surveys. Once entrepreneurs expect i) rapid traffic growth in the California and China trades, ii) that rail users value highly time savings and transport quality improvements, and iii) reduced construction cost, the second stage should have been expected to be profitable. Thus, in the counterfactual scenario presented here, the average entrepreneur and investor should have expected the first transcontinental to be profitable.

Contrary to conventional belief (as expressed by Schumpeter, Fogel, Mercer, and Fishlow), the first transcontinental railroad was not built ahead of demand.[47] Under a pure market scenario (controlling for the negative effects the Civil War and the political economy of the project had on private investment) pecuniary incentives were high enough to induce private

[47] Schumpeter *"Business Cycles"* p. 328, Fogel *"The Union Pacific"* p. 18, Fishlow *"American Railroads"* p. 204, and *"Internal"* p. 585 , Mercer *"Rates of Return"* p. 604, *"Railroads and Land Grant"* p. 28, 67.

construction. The first transcontinental railroad was built *following* demand. Consequently, building ahead of demand cannot be a justification for subsidies in the form of loans and lands granted by the Pacific Railroad Act.

The results above do not imply that the Pacific Railroad Act was entirely ineffective or unnecessary. First, the positive profit expectations identified by the declared expectations and the model of formation of expectations refer to a project building the two proposed stages of the first transcontinental railroad sequentially. The first stage needs to be finished before the second may be considered. The Pacific Railroad Act, by dividing ownership into two companies and setting up a construction race between the Central Pacific and the Union Pacific, promoted simultaneous construction. In this way it accelerated the arrival of the social benefits associated with the full first transcontinental. The point is important for several reasons. It is possible that the second stage might not have been built immediately after the first stage was finished. It is also possible the second stage might have been divided into more stages to reduce its size, delaying arrival of the social benefits. Note that this point does not justify the subsidies component of the Pacific Railroad Act.

Second, subsidies might have been appropriate for entrepreneurs to overcome the difficulties imposed by the Civil War and reconstruction. The Civil War crowded out private investment in the local capital market, effectively closed access to the international capital market, and brought uncertainty about the future of the entrepreneurs' property rights over the railroad. Subsidies might have been a substitute for a highly distorted and dysfunctional capital market during the Civil War.

The model of formation of profit expectations and the findings reported above raise two important methodological issues. First, a broader literature on the evaluation of small scale and frequent government interventions has developed experimental or quasi-experimental approaches to evaluate the effects of policy over private behaviour.[48] Experiments, quasi-experiments, or "matching observations" approaches are not feasible in the case of large scale projects of historical importance, such as the transcontinental railroads, dams or nuclear energy plants, because of their size and small numbers. The approach presented here, examining carefully the ex-ante period, particularly the methods and information entrepreneurs used to form their expectations, may offer an alternative to simply assuming that a high social rate of return is sufficient evidence to indicate that a specific policy was justified to promote a given project.

Second, this article presents a method – the model of formation of profit expectations - that makes possible to control many of the potential biases of entrepreneur reports (or any

[48] Angrist and Krueger *"Empirical Strategies"* and Heckman, Lalonde and Smith *"The Economics"*

subjective declaration of expectation of an economic outcome). The use of these reports (or declarations) is frequently challenged on the grounds that the entrepreneurs have incentives for opportunistic behaviour and therefore may write in these reports information different from what they truly believe. An economic historian who needs to determine the reliability of an item of information contained in these reports normally examines archival material looking for a letter from a friend, a relative or a business partner not exposed to the entrepreneur's opportunistic behaviour and mentioning the relevant information piece. The economic historian may use the approach proposed here, focusing on the methods the entrepreneurs used to produce the relevant information, and complement the archival research results. More over, even when archival research is not successful, it is possible to substitute for it, and still consider the research question at hand. Thus, the method proposed here provides a new tool of analysis for economic history. Equally important, the new method allows the economic historian to distinguish clearly between an expectation and an outcome, a difference that has become standard in economic theory but is frequently blurred in empirical studies using revealed preference analysis.

CONCLUSIONS

In 1859 the Washoe region in Nevada experienced a gold rush. Reacting to the news, Theodore Judah, a railroad entrepreneur, proposed to build the first transcontinental railroad in two stages. The first stage would profit from transporting the mining traffic in the Washoe region. The second stage would profit from transporting the California and China trades. Judah found a route whose construction cost was substantially lower than any alternative one, and performed a preliminary survey. The survey for the first stage was complete and indicated that the railroad was expected to be profitable. The survey for the second stage was completed during construction of the first stage and was also promising. This article examines whether Judah's profit expectations were credible to other entrepreneurs and investors.

The difficulty in answering this question is to derive a reasonable estimate of profits expected by the average entrepreneur or investor. The approach adopted is to focus on the method used by 1850s railroad entrepreneurs and investors to form *ex-ante* their profit expectations. Examination of preliminary survey reports, bond prospectuses and civil engineering textbooks revealed that all entrepreneurs and investors used the same method to evaluate a railroad investment opportunity. The method may therefore be regarded as common knowledge and may be used to develop the structure of a model of formation of profit expectations. The parameters of the model are estimated using public information released before construction of the railroad to maintain the *ex-ante* spirit of the exercise. The result of the model is an estimate of the profit the average entrepreneur or investor may have expected. The approach and methods presented in this article provide new tools for economic historians to take seriously the important analytical distinction between expectations and outcomes and to overcome the difficulties and limitations imposed by archival research.

The model's results support the analysis performed by Theodore Judah. The first stage of the first transcontinental railroad should have been perceived by the average entrepreneur or investor as very likely to be profitable. The improved route, the technological advantage of a railroad across the Sierra Nevada over the wagon road, and the booming mining transport demand made the first stage an attractive investment. The second stage should also have been expected to be profitable. The high willingness to pay for transport quality improvement, the rapidly growing traffic of the California and China trades, and improvements in the location of the route leading to substantial construction cost reductions should have made investment in the second stage attractive to the average entrepreneur or investor.

The findings have important implications for our view of the role of government in the construction of America's largest public work in the 19th century. Since the average entrepreneur and investor expected the railroad to be profitable, market incentives were high enough to induce its private construction. Contrary to the view of several economic historians, the railroad was *not* built ahead of demand or premature, and subsidies and lands granted by the Pacific Railroad Act to promote construction of the first transcontinental were unnecessary in the context of a market scenario. The Act did promote faster construction by dividing ownership into two companies and setting up a construction race between the two. Additionally, in the context of the Civil War and reconstruction, subsidies probably played a positive role in allowing entrepreneurs to overcome the crowding out generated by government military expenditure and the closing of the international capital market.

In sum, analysis of *ex-ante* information performed here indicates that entrepreneurs and investors were right to expect the first transcontinental railroad to be profitable after 1859, when the project was divided into two stages. The key sources for profits identified are: i) technological advantage of rail over wagon roads for the first stage, ii) rapid transport demand growth on the back of mining booms, growth of international trade and integration between the eastern and western United States, iii) new good attributes of the rail route generating market power and making it possible to charge high prices to transport goods and passengers to and from the Pacific Ocean, and iv) rapid accumulation of knowledge of the topography of the West, improving the location of the route and substantially reducing construction cost.

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