

Formation of expectations and the expected private profitability of the first transcontinental railroad

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Abstract

Discovering how economic agents form their expectations is critical to our understanding of many economic outcomes. As a unique example of how expectations are formed, the first U.S. transcontinental railroad, which received substantial construction subsidies but also was highly profitable, is studied. Did entrepreneurs expect such profits ex-ante? The approach uses detailed information from entrepreneurial reports written before construction to reveal their expectations. Stated expectations could be different from the entrepreneurs' true beliefs. Hence, I develop an empirical model of formation of expectations to evaluate the plausibility of the declared expectations. I find that entrepreneurs expected profits ex-ante and the empirical model confirms their economic logic. Formation of forward looking expectations regarding the railroad's "new good" attributes and demand growth are critical for these results. Observed market outcomes indicate entrepreneurs anticipated relatively well the ex-post scenario, confirming that entrepreneurs were right to expect the railroad to be profitable. Market incentives were high enough to promote private construction.

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1. Introduction

How do agents' form their expectations? Although economists have long recognized the importance of the relationship between agents' expectations and subsequent economic outcomes, the body of empirical knowledge developed by economics on how agents' form their expectations is little. Probably the main reason for this is that identifying and measuring an agent's expectation is difficult. Direct measures of expectations are rarely collected in the kind of datasets used by economists.¹ A more conventional approach to assess profit expectations is to use revealed preference analysis on ex-post market information to infer ex-ante preferences and expectations.² The purpose of this paper is to propose an alternative way to measure expectations and apply it to solve an important historical puzzle: the introduction of the first transcontinental.

The construction of the first transcontinental railroad is an important event in American economic history and also provides the key evidence used here to develop a measure of expected profits. The first transcontinental railroad is one of the largest railroads ever built in the United States and the largest publicly funded work during the 19th century. In May 10th 1869 the railroad was inaugurated, and it became a symbol of the nation's union after the Civil War, facilitated westward expansion, and generated high positive externalities. However, the ex-post cost-benefit and social savings analysis of the railroad indicates the unaided private rate of return was higher than the opportunity cost.³ Assuming a normative approach to the analysis of public policy leads to asking: Was the first transcontinental railroad (the venture that received the largest federal government subsidies in the 19th century) expected to be privately profitable. Or put another way, would the railroad have been built without subsidies by 1869 anyway?

The issue is even more puzzling when it is considered that theory and empirical evidence indicate that most frequently we observe entrepreneurs being optimists, entering a market, and rapidly realizing the market or their productivity is not as expected and exiting the industry.⁴ If

¹ Manski (2004) reviews a recent stream of analysis collecting directly measures of expectations.

² Samuelson (1938 and 1948) presents the idea on which revealed preference analysis is based. The application of the revealed preferences analysis is not without complications. If agents' face a decision with access to only partial information, different combinations of preferences and expectations may lead to identical observed choices, limiting our ability to identify the original set of expectations using ex-post choice data. The most frequently used solution to overcome this problem is to assume agent's form rational expectations, and the ex-post probability distribution of events is used as the one expected by the agent (Manski (2004) presents the argument in detail).

³ Fogel (1960) and Mercer (1982). Some readers may also be aware the first transcontinental was associated to the most visible corruption scandal of the 19th century, the Credit Mobilier scandal, making the issue of legitimacy of subsidies even more sensitive.

⁴ Brunnermeier and Parker (2005) Jovanovic (1982), and Camerer and Lovo (1999) explain optimism and excess entry. Dunne, Roberts and Samuelson (1988) provide empirical evidence of excess entry.

the first transcontinental entrepreneurs failed to anticipate the railroad's high profits it would be a striking finding.

Answering this question is not simple. It is not possible to identify the expectations of the first transcontinental entrepreneurs or investors by performing a revealed preference analysis of ex-post capital market data. The railroad faced a complicated political economy problem and was built during very convoluted times generating important distortions and perverse incentives to private investment. Consequently, it is not possible to infer that entrepreneurs expected the project to be profitable because it was profitable ex-post, that entrepreneurs or capital markets did not expect the road to be profitable because the project received subsidies, or that investors did not expect the road to be profitable because they did not buy the company's bonds in the middle of the Civil War.

In this paper, I develop an alternative approach to identify and measure profit expectations. Several different groups of entrepreneurs promoted construction of the first transcontinental railroad. Each of these groups wrote the standard report on the preliminary survey of the railroad (project report). Some of these reports have survived and are available, and represent a window into how entrepreneurs form profit expectations.

In the first part of the analysis, I study these reports and identify their stated expected profits before the project is executed. These declared expectations, however, may differ from the entrepreneurs' true beliefs because they may have incentives to lie.

The second part of the approach develops a more reliable estimate of expected profits. The preliminary survey reports written by 1850s successful railroad entrepreneurs' and civil engineering textbooks are used to identify the intuition behind the analysis of railroad investment opportunities in the mid 19th century. This intuition is common knowledge. In turn, the intuition identified is used to build a simple 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 on the historical methods and information sources typically used by 1850s railroad entrepreneurs and investors, and allows developing a counterfactual scenario were profits come only from operation of the railroad (excluding potential profits from construction activity or corruption, and the negative effects of political uncertainty and war on investment). Next the model is used to deduce a historically plausible and more reliable estimate of profits expected by entrepreneurs and the average investor.

The results indicate that several entrepreneurs began considering construction of the first transcontinental railroad from the late 1840s. All these entrepreneurs stated to expect profits. The

analysis of the empirical model of formation of profit expectations indicates that expected profits for the single stage project were unlikely to be positive. However, once the 1859 Nevada gold rush was experienced, the entrepreneurs divided the project into two consecutive stages. The model indicates both stages should have been expected to be profitable. The first stage baseline equilibrium may be subject to major parameters all varying randomly at the same time and in the direction against profits up to 62.9% of their baseline value and expected average profit is still positive. The second stage baseline equilibrium profits, considering forward looking expectations, may be subject to major parameters all varying randomly at the same time in the direction against profits up to 8.3% of their baseline value. The model's predictions are roughly in line with the observed market outcomes, strengthening the idea of positive expected profits. Hence, entrepreneurs declared to expect the railroad to be profitable and the model confirms their economic logic.

The paper contributes to several literatures. First, the paper uses the preliminary survey reports to identify how entrepreneurs for their profit expectations. Entrepreneurs identify the observed equilibrium in the market of transportation. Next, entrepreneurs consider how the introduction of the railroad may change the observed equilibrium. The entrepreneurs provide the new expected equilibrium, but do not indicate explicitly the method used to calculate the value of the new good attributes of the railroad route to passengers and merchants. A simple method using the type of information the entrepreneurs included in their reports is proposed. The method is that entrepreneurs used price differences observed ex-ante to infer the demand curve. The idea is analogous to that used in the literature on the welfare analysis of new goods, but instead of estimating an elasticity of demand after the innovation has been introduced, the approach uses price differences observed ex-ante to infer willingness to pay for the new good attributes to identify the demand curve.⁵

Second, the paper sheds light on the normative question whether subsidies were required to promote private construction of the first transcontinental railroad.⁶ Entrepreneurs expected the road to be profitable and, after 1859, the model's results confirm their economic logic. Assuming a normative approach, it is possible to conclude that under normal market circumstances government's subsidies promoting private construction of the railroad were unnecessary. However, there are two caveats to this finding. Government intervention, dividing ownership of the route into two companies and setting up a construction race (not subsidies), organized

⁵ The literature on new goods includes Tratjtenberg (1989), Hausman (1996), Hausman (1997), Hausman (1999), Petril (2002) and Greenwood and Kopecki (2009).

⁶ Schumpeter (1939), Carstensen (1962), Fishlow (1972 and 2000), Fogel (1960), Mercer (1982), and Fleisig (1974 and 1975),

simultaneous construction rather than sequential construction of the first and second stage of the railroad. Externalities probably arrived faster under this institutional arrangement than under a pure market one. Additionally, it is likely the subsidies allowed entrepreneurs to overcome the intense crowding out and property rights uncertainty experienced by private investment during the Civil War and Reconstruction.

Third, this study also points out that it is important for conventional ex-post cost-benefit analysis of large infrastructure projects to carefully analyze the ex-ante period. Since the entrepreneurs faced a political economy conflict over the distribution of the project's costs and benefits it is possible there is also a positive political economy explanation for the subsidies. Thus, particularly when the ex-post cost-benefit analysis indicates the unaided private rate of return is higher than the opportunity cost, it is necessary to carefully identify entrepreneurial expectations to perform a complete evaluation of the efficiency of government intervention. Given the high level of resources allocated to this kind of projects, the issue is important.⁷

Fourth, the intuition guiding railroad investment decision making during the mid 19th century was identified. The evidence presented indicates entrepreneurs performed procedurally rational analysis of investment opportunities by identifying the observed market equilibrium, considering the potential market power for the railroad, and using forward looking information to identify expected outcomes. This finding provides *direct* evidence of a relatively high level of economic rationality (in the procedural sense) of 19th century economic agents that complements the indirect evidence that already exists.⁸

The next section provides the historical context for the paper. The third examines the use of ex-post data to identify profit expectations, while the fourth section points out the advantages of using entrepreneur reports to measure profit expectations. The fifth presents the entrepreneurs' stated expectations. The sixth section introduces the model of formation of profit expectations. The seventh section presents results. Finally, conclusions are put forward.

2. 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 after the Opium War, California and Australia experienced a gold rush and California was annexed by the United States.⁹ Entrepreneurs and governments in

⁷ For instance, close to 20% of World Bank lending was allocated to transportation (World Bank (2007))

⁸ The distinction between procedural and outcome rationality follows the one suggested by Simon (1978). See Fishlow (1965) and Rothenberg (1981) for examples of indirect evidence of rationality of economic agents during the first half of the 19th century.

⁹ Whitney (1845) p.2 and Russel (1948) pp. 56-61.

different parts of the world competed to provide transportation improvements leading to transport time reductions. British, French and Austrian entrepreneurs launched canal or rail projects to cross over Canada, Central America, the Suez or the Ottoman Empire.¹⁰ Meanwhile American entrepreneurs developed Clipper ships and a railroad through the Isthmus of Panama.¹¹

American entrepreneurs also developed projects for a transcontinental railroad. The first one was proposed by an entrepreneur in January 28 1845. The proposed route, as 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 road was obliged to request the right of way to 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 earlier state status, disrupting the delicate political equilibrium of America's antebellum congress. Thus, any project promoting a northern route was rejected by southern states and any project for a southern route was rejected by the northern states, leading to a political deadlock.¹² As a result, all projects proposed during the late 1840s and 1850s by four different groups of entrepreneurs failed to pass in congress.¹³

In 1853 congress requested the army to perform an engineering survey of six different routes to determine the most appropriate one to build the railroad. In 1855 the results were published. Four out six routes were found practicable, but the political deadlock prevented any bill to go through congress. Entrepreneurs continued promoting the project, but with no success.¹⁴

In 1859 Nevada experienced a silver rush. Reacting to this event, California based entrepreneurs incorporated the Central Pacific to build the first transcontinental railroad in two stages. The first stage was a railroad between Sacramento and the Nevada silver mines. The second stage a railroad between Nevada and Omaha. By 1861 Lincoln, who included the first transcontinental in his presidential election platform, had been elected president, the southern states had seceded, and the Civil War started. The intensity of political conflict in congress over

¹⁰ Marlowe (1964) pp. 241-63, Farnie (1969) pp. 83-84, Russel (1948), Wilson (1977) pp. 44-45.

¹¹ See Lubbock (1916) pp. 36-102, Hutchins (1941) pp. 287-96, and Evans (1964) pp. 33-34 for Clipper ships and Russel (1948) p. 76 and chapters 5 and 6 for the Panama railroad.

¹² The political economy conflict is described by contemporary sources as Putnam's Magazine (1853), Southern Literary Messenger (1854), American Railroad Journal (1855), Judah (1857), and secondary sources as Haney (1910) ch. 4, Fogel (1960) p. 22, Klein (1987) p. pp. 10-11, and Bain (1999) p. 43-44.

¹³ Whitney (1845 and 1849), Degrand, Derby and Fisk (1849), and projects by Carver in 1847 and Bayard and Company in late 1840s (see Cleveland and Powell (1909) pp. 269-71)

¹⁴ Davis (1855), and Judah (1857 and 1859)

the project declined, entrepreneur's perceived it and requested the right of way and subsidies to build the road.¹⁵

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 and operate the first stage of the first transcontinental railroad, from California to Nevada, while the Union Pacific (incorporated in 1863) was to do it for the second stage, from Nebraska to the 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 operate and lease that part of the track. The two companies' rails met in Promontory Point, Utah, May 10 1869 and completed the first transcontinental railroad.

Once completed the road was almost 2,000 miles long and crossed the Rockies and the Sierra. Construction cost of the first stage to Nevada was \$14.1 million, and the whole road was over \$64.6 million 1860 dollars.¹⁶ The road was the largest project supported by the federal government in the 19th century, with a subsidized loan of more than \$37 million and more than 5.5 million acres granted to railroad companies.¹⁷

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%.¹⁸ Taking a normative approach to evaluating public policy Fogel and Mercer conclude that, based on the results of the ex-post social savings analysis, subsidies should not have been

¹⁵ Judah (1860), Judah (1861) and Judah (1862).

¹⁶ The cost has been calculated using Mercer (1982) p. 154 and 164 total construction cost 1863-1869 and deflated with David and Solar (1977) CPI index. The equivalent value in 2008 dollars is \$1.6 billion dollars.

¹⁷ The subsidy information comes from Nimmo (1885) p. 42 and p. 44 and the loan value was deflated with David and Solar (1977) CPI index. The loan was at 3% interest and implied a subsidy as railroads normally floated bonds at a coupon rate of 4-7% (Mercer (1982))

¹⁸ Fogel (1960) pp. 94-97 estimated the average rate of return for the Union Pacific was 11.6%, compared to an average 5%-7% yield of the best corporate bonds. Mercer (1982) pp. 75-82 estimated the private rate of return for the Central Pacific and the Union Pacific (after excluding additional earnings derived from land sales and reduced interest payments) was 8%-13.2% and 8.9% and 13.7% respectively. Both railroad companies experienced returns higher than alternative investment opportunities in most of the scenarios considered. The minimum social rate of return is 19%-29.9% and comes from Fogel (1960) pp. 97-103 and Mercer (1982) pp. 108-12.

granted.¹⁹ However, they also note that the appropriate information to perform this evaluation is the ex-ante or expected private rate of return, not the ex-post one.²⁰

3. Profit expectations and revealed preference analysis using ex-post information

Several scholars have indicated their belief that entrepreneurs' were not interested in the first transcontinental railroad project.²¹ Fogel is the first and so far the only scholar to address the issue of profit expectations explicitly.²² His approach is to perform a revealed preference analysis of capital market data to infer the investor's profit expectations profits for the Union Pacific. Since there are no capital market quotations until summer 1867, Fogel uses information released in 1873 by a member of the board of the Union Pacific during a congressional investigation for corruption in the construction of the Union Pacific. The member of the board declared that before 1867 the Union Pacific first mortgage bonds could only be sold at a discount of 50%-60% on their face value. Fogel suggests that under these circumstances, rather than selling the bonds to the public at high discounts, the entrepreneurs developed a scheme to profit from construction activity. The Union Pacific contracted construction with the Credit Mobilier (created and owned by the Union Pacific entrepreneurs). The Union Pacific paid the Credit Mobilier with cash (derived from government subsidies) and discounted stock and bonds. The cash payments were not enough to build the road. The entrepreneurs acquired personal loans at 19% interest to finance construction by the Credit Mobilier and charged to the Union Pacific a high mark-up. The entrepreneurs kept the stock and bonds expecting stock and bond prices to increase soon and enough for them to complete the road and profit. Following Fogel's argument, luck struck the entrepreneurs when they found an easy pass over the Rocky Mountains in 1866. The obstacles to construction had been overcome, the public's risk perception changed radically, and the Union Pacific bonds were sold in large portions and with low discounts.²³

The accuracy of some of Fogel's calculations may be improved. The effects of construction cost savings (due to the new pass) on the bond's face value discount levels and expected profit may be calculated; the revealed preference analysis may control for the effects of crowding out experienced by private investment during the Civil War and Reconstruction to determine if a 50% discount was high relative to other transport projects

¹⁹ Fogel (1960) p. 97 and Mercer (1982) p. 77 and p.81.

²⁰ Mercer (1982) p. 28.

²¹ See Schumpeter (1939) p. 328, Fishlow (1965) p. 204, and Mercer (1982) p. 28 and 67.

²² Fleisig (1974 and 1975) provides an estimate of the profit insiders may have expected given the legislation included in the Pacific Railroad Act 1862.

²³ Fogel (1960) pp. 75-81 and 85-6.

during the period; and revealed preference analysis of capital market quotations of the railroad's competitors and complements may be performed.²⁴ But even if the accuracy of Fogel's calculations was improved, the approach faces several important difficulties.

First, using revealed preference analysis on the exactly the same data used by Fogel also indicates the opposite conclusion: entrepreneurs expected the road to be profitable from operating transport services. Note that for entrepreneurs to borrow at 19% while taking Union Pacific stock and bonds as payment for construction they must have believed the railroad was going to be perceived by the public as profitable, so stock and bonds could be sold at a profit.

Second, and most important, the nature of the venture and its coincidence with the Civil War make identification of profit expectations from operating the railroad using revealed preference analysis of capital market information highly unlikely. i) The first transcontinental was in its project stage until 1863, and no capital market quotations exist until late 1867. ii) The political conflict over the distribution of the project's costs and benefits and the Civil War generated high uncertainty regarding the strength and stability of property rights over the returns to investment on the first transcontinental. In turn, obligation to go to Congress to request the right of way, the political conflict, the Civil War and the uncertainty over property rights imply that entrepreneurs have the opportunity and incentives to lobby for subsidies and to develop schemes to profit from construction (as they actually did, as the Credit Mobilier scandal suggests) rather than building the railroad to profit only from its operation. Once one accepts these incentives, one leaves the realm of normative analysis of government action and enters the realm of positive political economy. Thus, the scenario actually observed is one where subsidies are endogenous. It is not possible to infer that because bond discounts were high even as late as 1866, it must have been the case that the public did not expect the road to be profitable. War and Reconstruction activities may have looked more profitable or the public feared the risk of government's expropriation of the road for political reasons. It is not possible either to infer that

²⁴An alternative avenue (to Fogel's analysis) to identify investor's profit expectations using capital market data is to perform revealed preference analysis on the market quotations of the businesses affected by entry of the first transcontinental. On the announcement of the Pacific Railroad Act of 1862, competitors (sea transport) should experience a fall in stock prices relative to a transportation stock price index while complements (eastern railroads transporting from Omaha to the east) should experience a rise. The results indicate no clear effect of the Act on these stock prices. The stock of the Pacific Mail Steamship Company and the Panama Railroad (competitors) increased relative to the transport index after 1861, just before the Act passed in congress. The steamship company stocks continued rising up to 1865 and then declined up to 1870, when they stabilized. The railroad company stocks continued rising up to 1869, when the stocks fall and stabilize in 1873. The New York Erie railroad (complementary) stock price rises between 1859 and 1869 and then falls. The Chicago Rock Island railroad (complementary) stock price is flat until 1865 and underperforms the transportation index between 1865 and 1871. Data from NYSE historical project, Cowles Foundation, Yale University

because subsidies were granted expected profit from operation of the railroad must have been negative.

Still, even if subsidies were endogenous, the normative question is an important one. The size of government intervention implied important opportunity costs. The only way to answer the question whether subsidies were required to induce private construction of the first transcontinental is to set a counterfactual scenario under which the motive to build the road are expected profits coming only from operation of the railroad. Note this is precisely the question addressed in this paper. Moreover, it is proposed here that a more effective way to infer profit expectations under these circumstances is to explore alternative sources of information during period before the Civil War and subsidies had been granted, and to use these sources to develop a counterfactual scenario were expected profits only come from operation of the road.

4. Preliminary survey reports as evidence on profit expectations

Preliminary survey reports are an alternative source of evidence to identify profit expectations. The appraisal of a railroad project in the 1850s was contained in a document frequently named “report of the chief engineer on the preliminary survey”. The document was produced before incorporation of a railroad company or just after incorporation. The report was composed of an engineering survey and a market research. The information included in the report was used next by the entrepreneurs to communicate formally with investors, as it was the basis to prepare the stock and bond prospectuses. The report thus contains the key public information used by investor’s to make their decisions regarding buying or not the project’s stock and bonds.²⁵

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 road to be profitable. Generally, entrepreneur’s statements are not to be taken at face value. In the case of first transcontinental, the conventional problems associated to asymmetric information and 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 face incentives to overstate profit expectations to capital markets and

²⁵ A sample of railroad project reports and contemporary engineering “textbooks” was collected to determine the appraisal methods and level of accuracy of the measurements involved. The sample shows that the same investment appraisal methods were used in different parts of the United States and England, and that it shares many features with techniques to evaluate modern transportation projects (see appendix 1). The two classic sources in railroad finance at the early 20th century (Cleveland and Powell (1909) and Ripley (1915)) also identify the preliminary survey report (or instrumental survey, as they call it) as the key stage in railroad promotion activities.

overstate social benefits and understate (or even in some circumstances overstate) profits to congress. Although it is possible to infer the sign of the effect 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, the entrepreneur's profit statements will be simply reported and no additional value will be attached to it.

Second, performance and publication of a preliminary survey or of its information in a stock or bond prospectus is itself an indication of expected profits. A preliminary survey was an expensive activity, costing close to \$30,000.²⁶ Although \$30,000 was only enough to build 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 a sunk investment.²⁷ Thus, performance, publication and use of a preliminary survey to develop a stock or bond prospectus reveals profit expectations (in the same way performance of an R&D project reveal expectations of profiting from future economic activity).

Third, the reports explain the method used to evaluate the first transcontinental railroad investment opportunity. The method is exactly the same one used by other successful railroad entrepreneurs of the 1850s (see appendix 1). Therefore, the method may be described as the standard way to appraise a railroad investment project, also accepted by investors, and common knowledge in the 1850s. 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 on a method that is common knowledge and public information only. ii) The model also allows testing how sensitive are the profit estimates to specific data or assumptions. iii) The preliminary surveys indicate the method used to analyze railroad investment opportunities, and in this sense 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 for profiting from construction or corruption play no role in the model. Thus, the estimated profit expectations are suitable for testing such a normative question as whether subsidies were required to promote private construction of the first transcontinental.

²⁶ Davis (1855), Judah (1857), and Williams (1988) pp. 36-7.

²⁷ Railroad surveys cost \$30,000-\$35,000. In comparison the average annual revenue per manufacturing establishment was \$13,500, \$17,700 and \$8,000 in Illinois, New York and California respectively (Manufacturing number of establishments, sales, wage, and employment data comes from US Census Browser <http://fisher.lib.virginia.edu/collections/stats/histcensus/php/start.php?year=V1860> retrieved 17/05/2008).

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 operational profits. The reports are used in a way allowing 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 if a hypothesis may be rejected or not.

5. The first transcontinental railroad preliminary survey reports

The entrepreneurs proposed two different types of projects to build the first transcontinental railroad. Initially the plan was to build it as a single stage (1845-59) and, after the Nevada gold rush the plan was to divide the project into two stages (1859-69) (see appendix 1).

The single stage project was proposed by at least by six different groups of entrepreneurs.²⁸ Among these entrepreneurs were Asian trade merchants, New England railroad promoters, and railroad engineers. The reports for three of the projects and a note in congress regarding a fourth one have been found, while the reports on the remaining two are still missing. The reports proxy market size by identifying the observed equilibrium in the transport market for sail ships around Cape Horn (traffic X transport costs plus other trade costs (including insurance, working capital, non-insured losses, food expenses and foregone income while travelling)). Market size ranged from \$50 to \$78 million per annum. Construction costs were expected to be close to \$100 million, a figure obtained in a superficial manner using the reports of western explorers, one reconnaissance survey, and, after 1855, the army surveys. Operational costs, when provided, were close to 13 million. Profits were not explicitly calculated.²⁹ Entrepreneurs in all cases stated to expect profits (even though all the necessary information had not been collected and presented) and to prefer building the road privately; but they also requested subsidies. The investment involved in producing the market research described above was probably small compared to the cost of the detailed engineering survey required to produce a reliable construction cost estimate; but some entrepreneurs did perform significant investments to

²⁸ 1) Whitney (1845 and 1849), 2) Degrand, Derby and Fisk (1849), 3) Judah (1857 and 1859), 4) McDougall (1854) and projects by 5) Carver in 1847 and 6) Bayard and Company in late 1840s (see Cleveland and Powell (1909) pp. 269-71).

²⁹ Whitney (1849), Degrand (1849) and McDougall (1854).

promote the project in front of the public, press and congress. Asa Whitney successfully developed a publicity campaign, at a cost of \$23,000.³⁰ Entrepreneurs stated clearly to expect profits; but it is not possible to perform a simple and clear-cut interpretation of whether these statements were close to their true belief.

The group of entrepreneurs promoting the two stage railroad project performed a reconnaissance survey in 1860 and a preliminary survey in 1861 (before incorporating the Central Pacific later that year, and before the Pacific Railroad Act granted the right of way and subsidies in July 1862). The report on the preliminary survey included an engineering survey for the first stage describing the route, grades, curves, tunnels, bridges, and calculated expected construction cost as \$13.3 million. The route proposed by the entrepreneurs allowed reducing construction cost by more than 50% compared to the route indicated in the army surveys. The report also included market research identifying market size by using the observed equilibrium in the transport market for wagon across the Sierra Nevada (traffic X transport price) as \$5.7 million per annum. Next entrepreneurs promised rail price to be set lower than observed price, and stated expected demand, and operational costs. Expected profits were \$3.7 per annum. 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 proposed road was less demanding. If the Baltimore and Ohio was built and operated profitably, the Central Pacific was also expected to be profitable. The cost of the preliminary survey was \$35,000. The information contained in the preliminary survey for the first stage, if it is correct, indicates that entrepreneurs analyzed the investment opportunity carefully and had sound basis to expect profits.³¹

The preliminary survey performed in 1861 also contained information on the second stage, but it 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, as construction of the first stage was performed and subsidies had already been granted. Construction cost was expected to be up to 50% lower than the \$86.7 million predicted in the army surveys. The market research identified market size as the observed market equilibrium in the transport market for sail ships and Panama steamers to and from the California and China trades (traffic X transport price), \$31 million per annum. Next entrepreneurs promised to set rail price higher than the observed price, forecasted rapid market size growth and stated the railroad's expected market share, allowing deducing expected revenues. Operational costs were assumed to be 50% of expected revenues. Expected profits were \$27.6 million. The cost of the surveys is not known, but the detail of the

³⁰ Bancroft (1890) p. 498

³¹ Judah (1861)

engineering survey and the market research is comparable to the typical preliminary survey of the 1850s. The information contained in the preliminary survey for the second stage also revealed clearly entrepreneurs stated to expect profits.

6. A model of formation of expectations for the first transcontinental railroad

A model of formation of profit expectations is presented in this section. The model, together with public information, allows developing an estimate of expected profits for the first transcontinental railroad.

The model follows the intuition underlying the analysis of the railroad investment opportunity as illustrated by the market research part of the preliminary survey. Essentially, this intuition reflects the way 1850s entrepreneurs and investors framed the decision to build a railroad and enter into a given transport market. The information included in the preliminary survey was then used as the basis for the elaboration of stock and bond prospectuses. In turn, prospectuses provided key information for investors to decide whether to buy stocks or bonds or none. Since all railroad preliminary survey reports use the same intuition to appraise railroad projects, it is possible to infer that this intuition was common knowledge to entrepreneurs and investors (see appendix 1).³² In this way it is possible to use entrepreneur reports to develop more accurate measures of expected profitability by entrepreneurs and investors than those measures provided by the revealed preference analysis of ex-post capital market information (section 3) or the entrepreneurs' stated profit expectations (section 5).

The model focuses on measuring expectations of profits derived from operation of the railroad (as opposed to profits derived from construction or corruption). The point is to develop a counterfactual scenario where the entrepreneurs face the decision to enter into a pure marketplace. Only under these circumstances the normative question whether subsidies were necessary to promote construction may be answered. Consequently, it is assumed i) entrepreneurs may buy the right of way for a fixed fee L and ii) entrepreneurs face an elastic capital supply at interest rate r .

³² The 1850s methods rather than a more sophisticated modern approach is used. The emphasis of this article is on re-creating the 1850s entrepreneur and investment decision. It is only what 1850s entrepreneurs and investors could have thought that matters for their profits 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. Outside the insurance 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.

The first assumption abstracts the perverse incentives entrepreneurs may face when in congress to request the right of way. Entrepreneurs may have lobbied to build coalitions, to get subsidies or more generally behaved opportunistically by overstating or understating operational profits to facilitate the project's process through congress. Assuming it is possible to buy the land for a fixed fee without going to congress allows focusing 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.

The second assumption abstracts the fact that some good projects may not receive funding (or some bad projects may receive funding) in the capital market as a result of market failure. However, the assumption does allow including some other features of capital market failure. For instance, adverse selection models indicate that equilibrium interest rate under market failure is higher than that socially optimal.³³ The interest rate used here is about 30% higher than the typical 1850s railroad bond coupon to accommodate some features of market failure. An elastic capital supply also implies the capital market is large enough to finance the projects and no substantial technical uncertainty. Details on the relevance of these two assumptions are discussed in the next section.

A. A model of formation of profit expectations

An entrepreneur considers whether to build a railroad to enter the market for transportation in N submarkets. Each submarket is defined by a pair of origin i and destination j locations. The preliminary survey reveals the process to make the decision. First, the most appropriate route is located and construction cost estimated. Second, the annual flow of expected operational profits is forecasted. Third, expected construction cost is compared to the flow of operational profits and the decision whether to enter the market is made.

Expected construction costs: The report always starts by describing the most appropriate route located between origin i and destination j pair and presents an estimate of construction cost. Expected total construction cost, \tilde{C} , is given by the sum of the of the right of way fixed fee, L , and the flow of construction cost, \tilde{c} , and discounted at discount rate r : $\tilde{C} = L + \sum_{t=1}^T (\tilde{c}_t / (1+r)^t)$

Expected operational profits: Next the preliminary survey presents information to evaluate expected operational profits. The starting point is always to identify the equilibrium observed in

³³ Stiglitz and Weiss (1981).

each of the N submarkets. Next the report considers how demand may change due to the characteristics of the road, the expected demand function. After this, expected operational costs are estimated based on the operational costs of eastern railroads. The expected demand and expected operational costs are used to derive a pricing policy, and it is then possible to deduce expected operational profits.

Observed transport demand: The preliminary survey reports always start the market research part by identifying the equilibrium observed in a relevant submarket. The report normally includes information on the observed prices, P_{ij} , and traffic, q_{ij} .

Expected transport demand: Next the preliminary report considers how introduction of the railroad may change 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 sail 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).

The reports indicate after introduction of the railroad merchants could use an alternative route between Canton and New York. The new route consists of 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).³⁴ 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:

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

where \sim denotes expectation. \tilde{P}_{ij} is the expected price of transportation on the first transcontinental route. In turn \tilde{P}_{ij} is defined as $\tilde{P}_{ij} = (f^S d_{ij}^S + f^{PR} d_{ij}^{PR} + f^{ER} d_{ij}^{ER})$ 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_{ij}^S , d_{ij}^{PR} , d_{ij}^{ER} are the distances over the S, PR, and ER

³⁴ Whitney (1848) p. 7 and Whitney (1849) p. 59

transport modes, respectively.³⁵ 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, facilitating notation.³⁶ Parameters \tilde{a}_{ij} and \tilde{b}_{ij} give the sensitivity of traffic to observed price. Parameters h_{ij} and 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 merchants' part of their expenses on insurance and working capital costs.

The intuition behind the demand function is simple: as distance or freight rates per ton-mile decline (and, thus, freight price between the two trading partner's falls), transport demand increases. Also note 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 $\tilde{u}_{ij} = q_{ij} + \tilde{b}_{ij} (P_{ij} + B_{ij})$.

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 the rail route is expected to experience cost advantage compared to the alternative transport mode. The relevant range to consider is $\tilde{P}_{ij} \leq (P_{ij} + B_{ij})$ as it implies a price ceiling. This is the case for the first stage, when the first transcontinental railroad competes with wagons across the Sierra Nevada.³⁷

The second decision problem is when entrepreneurs indicate 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 the first transcontinental railroad was expected to offer California and China trade higher safety, dryer and more stable climate (as it avoided crossing the tropic twice), and transport time reductions allowing goods to arrive in better shape to its destination and for transportation of goods not traded before (green fruits). The scenario proposed is therefore one where the rail route offers transportation with new good attributes. And the reports indicate the entrepreneurs expected to set prices higher than the observed average price, P_{ij} , and still capture a substantial part of the market share.³⁸ Note this second decision problem implies the entrepreneurs and investors must develop a forecast of the willingness to pay for transport

³⁵ The first transcontinental railroad route may imply transshipments not necessary by the all sea route. In the example of trade between Canton and New York the transshipments would take place in San Francisco and in the Mississippi region. The transshipment costs may be easily included, but for simplicity have been excluded from the analysis at this stage. They will be considered below in section 7.

³⁶ See appendix for explanation why d^{PR} and d^{ER} are constant across origin-destination pairs.

³⁷ See Judah (1861)

³⁸ See Cisco (1868) p. 23.

attributes not traded before, and therefore also implies a more forward looking expectation than the first decision problem.

The key issue is how entrepreneurs inferred the demand function. The preliminary survey reports indicate a promised price once the railroad route was introduced 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 is indicated.

The first decision problem, when the entrepreneur considers the railroad route is expected to have cost advantage over the wagon road across the Sierra, does not require inferring the demand function. The reason is that the empirical results presented in section 7 show that the railroad had enough technological advantage compared to wagon roads over the Sierra Nevada to make the first stage of the first transcontinental very likely to be profitable, even if the observed equilibrium did not change as the rail route is introduced. Changes in demand are therefore explored only to test robustness of results using the observed equilibrium expected profits.

The second decision problem, when the entrepreneur considers the railroad will offer new good attributes valued by California and Panama passengers and merchants, does require an explicit method to infer the demand function. The observed equilibrium is given by a price for “normal” transportation that, by definition, does not account for the new good attributes. However, even during the 1850s there was diversity in transport quality. For instance, although most freight took the Cape Horn route on a “normal” sail ship, some merchants preferred to use the faster Clipper ships or the Panama steamer route and pay a premium. In fact, the preliminary survey reports and the press pointed out that Clipper ships and the Panama steamers charged high prices for transportation between the Pacific Ocean and New York. High prices were an indication of passengers and merchants high willingness to pay to reduce transport time to the Pacific Ocean and improve transport quality more generally.³⁹ The method proposed here relies on comparing observed prices for transportation of different quality. The logic is simple: if passengers and merchants paid high transport prices for transport quality improvements that are less than those expected for the first 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.⁴⁰

³⁹ Whitney (1849) p. 37 used the tea as an example of the kind of goods expected to be transported. Clipper ships transporting tea frequently charged a premium on normal ships for their faster transport (Lubbock (1916). The American Railroad Journal indicated that the Panama and Nicaragua routes indicated the railroad was expected to be profitable (American Railroad Journal, Saturday, July 21, 1855, p. 451). The Central American routes charged high transport prices (Cisco (1868)).

⁴⁰ Note the similarity in the intuition of the argument and a loosely specified hedonic price equation,

The method proposed to identify a linear demand function uses two points on demand schedule $q_{ij} = \tilde{a}_{ij} - \tilde{b}_{ij} P_{ij}$. The first point is the observed equilibrium, P_{ij} and q_{ij} . The second point is given by a high transport price observed by the entrepreneurs before construction, $\max P_{ij}$. At a price of $\max P_{ij}$ it is assumed only one ton or one passenger demands transportation, $q_{ij}=1$. After identifying the two points on the demand schedule, it is possible to identify \tilde{b}_{ij} such that 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 $\tilde{P}_{ij} = \max P_{ij}$. Note that the second point on the demand schedule is in line with what entrepreneurs and the press argued during the 1850s.

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. Next it is 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. Robustness of this approach rests on the researcher demonstrating the elasticity estimated and 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 too high.⁴¹

It is, however, difficult to use this approach in the case of the first transcontinental. First, estimating the price elasticity of demand for a good before it appears in the market place is difficult. Second, using a given functional form and solving for the values of the elasticity that allow for expected profits is feasible. The approach was in fact implemented. The results, however, were too sensitive to the choice of functional form and, most important, it was not possible to connect them to the information that entrepreneurs had available in the 1850s.⁴²

⁴¹ See Tratjenberg (1989), Hausman (1996), Hausman (1997), Hausman (1999), Petril (2002) and Greenwood and Kopecki (2009).

⁴² 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 difficulties arise with this result. First, it is difficult to argue these elasticity values were the ones the entrepreneurs actually expected. Entrepreneurs did implicitly think in terms of elasticity, but simply did not write using this language. Second, the results indicate the asymptotic nature of the constant elasticity demand function leads the virtual price to be unrealistically high when quantity is 0. Consequently, the profit maximization solution is at unrealistically high prices and very low quantities. However, examination of other points on the demand curve that are not profit maximizing solutions but do involve positive expected profits reveals many of these points involve realistic price and quantity solutions. Thus, the use of a constant elasticity demand function leads to the disturbing finding that profit maximizing solutions are not realistic while non-profit maximizing solutions are realistic. Detailed results are available upon request.

The approach proposed here is less elegant than 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, and prices were available to entrepreneurs and they acknowledged observing these prices. Second, note that at the maximum observed price the expected demand is $\tilde{q}_{ij} = 1$. This implies the maximum price the railroad route may charge is the maximum price observed ex-ante. Thus, this assumption guarantees any solution identified using this method is within a reasonable price range.

Operational costs: The reports used examples and statistics of the eastern railroads experience 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, similar to a constant marginal cost incurred in the provision of the transport service, \tilde{o} . The expected operational costs are given by $\tilde{O} = \tilde{o} d^{PR} \tilde{q}_{ij}$ with d^{PR} the distance over the first transcontinental segment and \tilde{q}_{ij} expected passenger or freight traffic.⁴³

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 intuition behind the profit function is simple. 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, when the entrepreneur considers the rail route is expected to experience cost advantage compared to the alternative transport mode, 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 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:

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

⁴³ Note 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 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 the rail route is expected to offer some new good attributes compared to the alternative route, he faces the following problem:

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

The solution to both maximization problems is presented in appendix 2.

The reports then present the expected operational profits for each of the N submarkets. Total operational profits, $\tilde{\eta}$, assumes operational profits in each submarket are identical for each period t of operation. Hence, $\tilde{\eta} = \sum_{ij=1} \tilde{\pi}_{ij}$.

Entry decision: 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:⁴⁴

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

where T is the total life time of the project. The intuition is simple. The sum of expected discounted stream of total operational profits must be higher than the sum of expected discounted stream of construction costs for the entrepreneur to decide to build the railroad.

7. Results and discussion

In this section the question whether entrepreneurs and investors expected the first transcontinental railroad to be profitable is answered. The model presented in section 6 is anchored on the historical context by using information publicly available before construction. The purpose of using information publicly available before construction is to continue with the *ex-ante* spirit of the exercise. Additionally, when ever exists doubt about the appropriate value for a specific parameter the criterion is to choose the one that leads to a downward biased estimate of expected profits. The results of the model are therefore downward biased estimates of expected profits derived exclusively from transportation. Thus, the model allows answering whether entrepreneurs expected the railroad to be profitable and therefore provides an appropriate

⁴⁴ The 1850s contemporary entry conditions discussed in the appendix are also used to interpret results.

counterfactual setting to answer the normative question whether subsidies were necessary to promote private construction of the first transcontinental.

The project proposal examined here is that promoted by the Central Pacific entrepreneurs. Recall in this proposal the first transcontinental railroad was divided into two stages. The first stage was a mining railroad between Sacramento and Nevada. The second stage was a railroad from Nevada to Omaha focusing on the California and China trades. The project proposed building the two stages sequentially. Therefore, the first stage is independent of the second stage, but the second stage depends on the successful completion of the first stage. If the road cannot go through the Sierra Nevada it will simply not be possible to run a train between California and the eastern United States. Subsection A presents results for the first stage, subsection B presents results for the second stage, while subsection C discusses results.

A. Decision to enter into the first stage

The first stage of the railroad, as proposed by in the Central Pacific preliminary survey reports, is a railroad from Sacramento to Virginia Station, in the Washoe mining region of Nevada (see figure 2). The exercise presented here takes as given the technical information and construction cost estimates included in the engineering survey part of the reports. The exercise focuses on performing again the market research part of the reports using the model presented in section 6 and publicly available information. The purpose is to use the model as a counterfactual scenario focused exclusively on profits derived from operation of the railroad and allowing obtaining 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. The market research baseline results are then subject to sensitivity analysis. Finally, the ex-ante and ex-post information is compared to evaluate the extent to which technical uncertainty may have existed.

The reports indicate construction is expected to take five years and cost \$13.3 million. Costs are spread evenly over the five years. Earnings from transportation start arriving in the sixth year and continue until the project's life is finished in year twenty five. The parameters characterizing construction costs, observed demand, expected demand and operational costs are drawn from public sources like specialized press or government reports, sources frequently used by entrepreneurs in the 1850s (see table 1). For a detailed description of the data see appendix 3.

Recall the model assumes that capital supply is elastic at a given discount rate. The assumption is justified as follows. First, the discount rate is assumed to be 9%, higher than the interest rate railroad bonds offered usually, 5%-7%. The idea is to account for the premium

investors may charge in the face of market failure caused by asymmetric information – note asymmetric information is a general problem in capital markets, not one specific to the first transcontinental railroad.

Second, market size was large enough to accommodate the first stage of the first transcontinental. The project was not a small one, but certainly was not an unusually large project either. The first stage was expected to cost \$13.3 million or \$2.7 million per annum. Several railroads built privately in the United States in the 1850s were within the \$10-\$22 million construction cost range. More than \$70 million per annum was invested in American railroads, with roughly 50% coming from European countries.⁴⁵ Thus, there is no indication the first stage of the first transcontinental was too large for Americas 1850s capital market.

Third, there is indication that technical uncertainty was not generally perceived as high. i) The entrepreneurs did not consider the project to be one of high technical challenges. Comparing the preliminary survey reports produced to evaluate the first transcontinental railroad to those of other railroads reveals that it implied no engineering challenges requiring important technical innovations.⁴⁶ The reports demonstrate the technical standards of the proposed route for the Central Pacific were within the range of those of the Baltimore and Ohio. If the Baltimore and Ohio is profitable, the Central Pacific can also be profitable under similar technical specifications.⁴⁷ As important, the only person in the team constructing the Central Pacific who had experience building technically challenging railroads in the east was Judah, and he died before construction reached the Sierra Nevada. This suggests the entrepreneurs did not expect major technical challenges during construction. ii) Other influential members of American society did not consider the project to be one of high technical challenge either. During the 1850s the army produced surveys indicating feasibility of construction and operation of the road. The American Railroad Journal expressed positively about the feasibility of building and operating profitably a railroad over the Sierra Nevada.⁴⁸ iii) Even if some members of society had been risk averse and preferred not to invest in the first stage of the first transcontinental, risk averse members do not seem to have prevented the capital market to finance high risk-high return

⁴⁵ See Poor (1860) p. 282 and 472, and Chandler (1977) p. 90, Fishlow (1965) p. 389 and Davis and Cull (2000) p. 751. Engerman (1972) also supports the view that capital market size was not a major limitation for developing the transcontinental.

⁴⁶ The chief engineer reports written by Judah or Montague include no proposed innovation or improvement of any of the building or operating techniques. The chief engineer reports of the Baltimore and Ohio published in 1830 are an excellent example of a report that identified the technical challenges implied by high grades on construction and operation of the road. The engineers building the Baltimore and Ohio even travelled to England in their search to find technical solutions to their problems (Thomas (1830)).

⁴⁷ Davis (1855) and Judah (1861) p. 18-22.

⁴⁸ Davis (1855), American railroad Journal, Saturday 27 1853 p. 546 and Saturday July 21 1855 p. 451.

projects. The Panama Railroad was 47 miles long and it cost \$8 million. A short but expensive road. Panama's jungle was known for its unhealthy environment and associated high mortality rates (and in fact many workers died, some even suggest several thousands died). And there was also the risk of expropriation by a foreign government. Nevertheless the railroad's construction was funded by stock and bond sales, and earnings were high enough to make it one of the most profitable railroads of the mid 19th century and pay the Colombian government an annual royalty for the use of its territory.⁴⁹ Thus, although construction of the railroad was to cross the steep Sierra, was certain to face terrible winters, and people were likely to die in the venture, ex-ante high technical uncertainty or its effects on deterring investment are not evident.

As explained above the preliminary survey reports indicate entrepreneurs considered the railroad had technological advantage over wagon roads. 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 convenience than wagon, there is no evidence entrepreneurs considered these potential transport quality improvements to form their profit expectations for the first stage. Since $B_{ij} = 0$ the constraint in the maximization problem in given by equation (2) is substituted by $\tilde{P}_{ij} \leq P_{ij}$.⁵⁰

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 or lower than 1 the profit maximizing solution to the model is trivial: the entrepreneur should set a rate of the first transcontinental such that the expected price is equal to the observed price. The entrepreneur gains nothing from reducing 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 be close to \$5.2 million per annum and passenger profits close to \$387,000 (see table 2 baseline scenario). For values of \tilde{a}_{ij} leading to a price-elasticity higher than 1 the solution was also calculated. The results indicate profits should have been expected to increase with \tilde{a}_{ij} (or with the price-elasticity of demand).⁵¹

Once expected operational profits for the first stage are calculated it is possible to compute the entry condition. The expected net present value (NPV) of the project is \$24.5 million

⁴⁹ Poor (1872/3) p. 402 and Mack (1944) pp. 149-60.

⁵⁰ Note the first stage implies no need for sea or eastern railroad transport (as opposed to the second stage), and therefore the $f^S d^S_{ij}$ and $f^{ER} d^{ER}_{ij}$ are equal to 0.

⁵¹ See table 1 in appendix 4 for detailed results.

dollars (see table 2 baseline scenario). The entrepreneurs used two measures of expected profitability in the 1850s instead of the NPV. The ratio of operational costs to revenue is an inverse indicator of the average margin per unit. A satisfactory ratio was expected to be lower than 50%. The results indicate the expected ratio for the first transcontinental railroad is less than 5%. The ratio of total operational profits over total construction costs indicates the time in years it takes the entrepreneurs to repay the initial fixed/sunk investment. The minimum satisfactory level for this ratio was 15%-20%. The results indicate the ratio was over 40%. The railroad was expected to generate higher margins and to repay initial investment faster than the standard 1850s railroad investment opportunity. The baseline scenario (using the information available to the entrepreneurs by 1862) indicates the first stage of the first transcontinental railroad should have been expected to be profitable.

In order to determine more precisely the robustness of the finding above sensitivity analysis is performed in three different ways. i) The maximum change to each single parameter making the project's expected NPV equal to 0 is identified, ii) the effects of a series of combinations of negative events over the project's NPV are evaluated, and iii) a Monte Carlo experiment identifying the effects of pseudo-random negative events on the project's NPV is performed.

The maximum change to each single parameter making the expected NPV equal to 0 reveals 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 up 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 24 to 8.5 years, or earnings are delayed entirely up to 9.6 years. Note that these statistics indicate the project is not terribly sensitive to the major uncertainty entrepreneurs may have faced: silver production running down and Nevada's economy collapsing. Traffic may decline substantially or the mining boom may bust rapidly, but as long as booming traffic lasts for at least four years after the first stage's track is completed expected profits are positive. The project's expected profitability is still positive even after a wide combination of negative events (see table 4).

The Monte Carlo experiment allows testing the sensitivity of the baseline results described above and identifying their probability of occurrence. The experiment is as follows. The price elasticity of demand is assumed to be inelastic; therefore the profit maximizing price is

equal to the observed price.⁵² The parameters of the model (construction cost, observed traffic, observed price, operational cost and discount rate) experience a pseudo-random shock in the direction against profits up to a given percentage of the historical value. For example, if the parameters vary by 10%, it means that the freight traffic value used to calculate the optimal expected profits in a given replication is a pseudo-random number between 43,800 tons a year (the historic value reported in table 3) and 39,420 (0.9 X 43,800) drawn from a uniform probability distribution.⁵³ The experiment allows every parameter to vary pseudo-randomly and independently at the same time, and is replicated 2,000 times for any given percentage level of negative shock. The procedure is then repeated for negative shocks of 10%, 20%, 30%, 40% and 50%. The Monte Carlo experiment gives a sample of 2,000 observations of estimated NPV for each given level of negative shock that may then be used to proxy the probability distribution of NPV given the parameters' historical values and a specific level of negative shock. The Monte Carlo method applied in this way allows identifying the probability of the project attaining a certain level of profits, given the assumptions of the model.

The summary results are presented in figure 3.⁵⁴ The qualitative findings above still hold. Since the Monte Carlo experiment allows each parameter to vary independently and each replication is also generated independently of each other, the average NPV for each sample is a statistic consistent with the concept of expected utility (payoff). The average NPV declines as the negative shock increases and reaches roughly \$5 million when the shock is up by 50%. The NPV is 0 when the negative shock is 62.9%.⁵⁵

Finally, it is also possible to learn about the *ex-ante* scenario and the nature of the decision to enter by examining *ex-post* information. Construction activity is briefly examined next. Transport market outcomes cannot be examined as the relevant information is not available.⁵⁶

⁵² The case when the price elasticity of demand is elastic indicates NPV is increasing in the elasticity of demand. Results are thus qualitatively identical.

⁵³ The uniform probability distribution is used because there is no prior about whether a certain outcome for each variable is more likely than another. Additionally, the uniform probability distribution weights heavier the extremely bad outcomes than other probability distributions, a pattern in line with the approach to develop a minimum profit estimate.

⁵⁴ Summary statistics and distributions for each of the five samples of NPV are presented in appendix 4.

⁵⁵ Appendix 4 includes a simple analysis of the threat of entry on the first stage of the first transcontinental.

⁵⁶ The average freight rate and the aggregate tons carried for years 1868 to 1869, when the railroad opened to Washoe, are available. The order of magnitude of the numbers indicates the equilibrium that prevailed in the Sacramento-Washoe submarket was probably one with a price lower than that observed in 1861 and with moderately higher quantities. Given this data and the growth of the Sacramento and Washoe regions it is likely that transport demand was inelastic. If this was the case, entrepreneurs engaged in behavior (reducing prices under an inelastic demand function) that was different from profit maximizing. The information is not detailed enough to determine if this was the case. No passenger rate or traffic

The best *ex-post* construction cost estimate available indicates the first stage construction cost is \$14.1 million, implying a cost over-run of 6% (see table 3). Construction was also achieved within the grade limit of 116 feet per mile emphasized by entrepreneurs, although the distance over which the grade stretched was more than three times longer (up from 2.8 to 9.5 miles) – but still shorter than the Baltimore-Ohio (11 miles), the technical benchmark of the first transcontinental.⁵⁷

The information in table 3 reveals substantial learning about the terrain during the first two years of construction helped to reduce the length of required tunnels.⁵⁸ The savings in construction cost and time derived from less tunnelling are not available. An estimate indicates savings in excavation (the lion's share cost in tunnelling) were between \$0.5 and \$0.9 million dollars.⁵⁹ Also recall the route originally proposed by Judah already saved more than 50% construction cost compared to the route proposed in the army surveys. The evidence indicates it was feasible to rapidly learn about the topography of the region, improve the location of the route and reduce construction costs compared to those estimated by the army surveys.

The *ex-post* evidence suggests the longest tunnel (Summit tunnel) took as long as expected to be excavated, although it was actually longer and more expensive than expected. The entrepreneurs initially did not expect to use nitro-glycerine, but it was actually used to excavate about half of the tunnel, saving about 100 days of excavation work and \$22,000 1860 dollars.⁶⁰ Thus, nitro-glycerine allowed traffic to run between Sacramento and the Washoe region just over three months earlier but had a very modest effect on total construction costs.

Construction was performed 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. But even

information is available as it was aggregated with mails, express, and other services and reported only as aggregate revenue.

⁵⁷ Judah (1861) p. 25.

⁵⁸ See Montague (1865) report for evidence of learning and improvement on the route originally proposed by Judah.

⁵⁹ Assuming the *ex-ante* average cost per foot of tunnelling from Judah (1861) the savings are \$558,250. Assuming the *ex-post* average cost per foot of tunnelling the Summit tunnel (the most difficult and expensive one) from Gilliss (1870) savings are \$908,058.

⁶⁰ Nitro-glycerine had been recently invented in 1847. At the same time nitro was introduced to mining in California, the Central Pacific entrepreneurs explored the possibility of using nitro to excavate the transcontinental railroad tunnels, in 1866. It was actually used in excavation activities after February 9th 1867 (Bain (1999) pp. 272-3, Griswold (1962) pp. 146-8, and Gilliss (1870) p. 162). The excavation savings are computed as the difference between the cost of a 1,659 tunnel at the average cost per foot using no nitro and the estimated actual cost of Summit tunnel (using nitro) as reported by Gilliss (1870).

if entrepreneurs had not performed the surveys leading to reduction of tunnelling length or used nitro, the project's baseline expected profits would have been reduced only modestly.⁶¹

In sum, the first stage of the first transcontinental railroad should have been expected to be profitable. The railroad should have been perceived as an attractive investment opportunity by the entrepreneurs and the average investor given the methods to evaluate railroad investments in the 1850s and the information publicly available by 1862. Evidence indicates the technological challenge of building the road was relatively well predicted by the entrepreneurs and no innovation in construction techniques was required to build the road roughly within the plan proposed by the entrepreneurs. If anything, the experience of the entrepreneurs seems to suggest the technology of construction exhibits important learning economies, particularly in surveying activities. As knowledge of the region's topography is accumulated, the route is improved and construction cost reduced. The entrepreneurs predicted improving the location of the line compared to the army surveys, predicted substantially lower construction costs, and achieved them. The project based its competitive advantage on its technological advantage over wagon transportation and booming demand.

B. Decision to enter the second stage

The second stage of the railroad, as proposed by the entrepreneurs of the Central Pacific, is a railroad going from Virginia Station, Nevada, to Omaha, Nebraska. Recall the first and

⁶¹ The Sierra Nevada tunnels and the Summit one, especially, have been indicated as the key technological difficulty to build the Central Pacific (and more generally the first transcontinental) because of the harsh weather and the hardness of granite in the Sierra. The histories of the first transcontinental railroad have highlighted entrepreneurs' devised creative solutions to overcome these difficulties, as snow tunnels, a shaft in the middle of the Summit tunnel in order to allow excavation of four faces instead of only the two external ones, and the use of nitro-glycerine. However, a report by civil engineer John Gilliss for the American Society of Civil Engineers casts doubt about the level of creativity or innovativeness of these solutions. Gilliss introduced the paper "the track has been completed ... much sooner than thought possible, that the difficulties overcome are apt to be underrated" (p. 153). Next he describes the harsh winter conditions. The solutions to building under these circumstances are identified as snow tunnels and the shaft, as the secondary literature reports. But these solutions are not indicated to be new techniques in railroad construction. No adjectives synonymous of creativity were used. The only novelty highlighted by Gilliss is regarding the use of nitro-glycerine. The novelty, Gilliss points out, is not the manufacture or use of nitro, but the information on performance of nitro in excavating hard rock tunnels (Gilliss (1870) p. 163). The Van Nostrand's Eclectic Engineering Magazine report on Gilliss article and does not include any mention of a novel technique or idea (Van Nostrand's (1870)). The 1855 army reports in fact indicate that the challenge to build railroad tunnels is not so much technology to excavate or the length of the tunnel, but costs (citing the experience of the Baltimore-Ohio with sixteen tunnels) (McClelland (1855) pp. 111-12). Once one considers that the only person involved with the Central Pacific that had experience with railroad construction prior to the project, Theodore Judah, died in 1863 while travelling to New York and before construction into the Sierra started, it is not surprising the project did not advance railroad technology. In short, the evidence indicates that entrepreneurs performed an immense work and investment under harsh climate but did not advance railroad construction or tunneling technology.

second stages were proposed as sequential projects. The exercise performed here assumes the first stage has been successfully completed and takes as given the technical information and construction cost estimates for the second stage included in the engineering survey part of the reports by the Central Pacific and the Union Pacific. The exercise focuses on performing again the market research part of the reports using the model presented in section 6 and publicly available information. The purpose is to use the model as a counterfactual scenario focusing only on operational profits to obtain a less biased estimate of expected profits. The market research baseline results are then subject to sensitivity analysis. Finally, the ex-ante and ex-post information is compared.

The route of the project follows that proposed by Judah in the Central Pacific preliminary survey reports and built by the first transcontinental railroad (see figure 4).⁶² Expected construction cost is drawn from the Central Pacific project report. Construction of the full project was expected to cost almost \$100 million and take about 10 years.⁶³ Since \$13.3 million and 5 years are allocated to construction of the first stage, the remaining \$86.7 million and 5 years are allocated to construction of the second stage (see table 4).⁶⁴ Entrepreneurs also expected to reduce construction cost by 33% to 50%.⁶⁵ Note construction of the second stage was simpler than that of the first stage. Grades were generally smoother and less and shorter tunnels were required (compared to crossing the Sierra). Not only the second stage was simpler but the credibility of expected construction cost reduction must have also increased. Construction of the second stage may only be initiated after the first stage had been completed successfully (because the first and second stages were sequential). Additionally, completion of the first stage also reveals that construction cost has been predicted relatively well. Thus, technical uncertainty about building the simpler second stage must have decreased substantially.

The second stage project's life starts in year 6 of the full project (including the first stage) and ends in year twenty five. Costs are evenly spread over the five years. The market for transportation is composed of three submarkets: freight traffic in both directions between California and eastern United States (California trade), freight traffic in both directions between China and eastern United States (China trade), and passenger traffic in both directions between California and eastern United States (California passenger). Earnings arrive in year 11 and continue doing so for the rest of the project's life. The parameters characterizing construction

⁶² Judah (1861) pp. 1-30.

⁶³ Judah (1861) p. 29. The observed cost was \$58.2 million.

⁶⁴ 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.

⁶⁵ See section 3.C. above.

costs, land values, observed demand, expected demand and operational costs are drawn, as for the first stage, from public sources like specialized press or government reports (see table 4).⁶⁶

The model assumes that capital supply is elastic. As for the first stage, the discount rate is assumed to be 9% to account for the premium investors may charge in the face of market failure. The second stage was a substantially larger project than the first stage or any other infrastructure project undertaken in the United States at the time. About \$70 million per annum was invested in railroad construction and the project would consume the equivalent of 12%-25% this capital (depending on the construction cost estimate used).⁶⁷ However, precisely during the second half of the 1850s and the 1860s the international market allocated substantial resources to the construction of the Suez Canal, a project of comparable scale. The Canal was funded using substantial capital provided mostly by small French private investors, while French investment bankers were excluded from the project and British and German investors boycotted it for political reasons.⁶⁸ Additionally, the first stage should have been capable of generating resources to transfer into the second stage and reducing the need for external financing. Thus, although funding the second stage must have been a tighter affair than financing the first stage, the international capital markets revealed to be large enough to accommodate it.

The data in table 4 indicates the project should not have been expected to be profitable if expectations do not account for the new good attributes of the railroad route and expected market size growth. The use of only observed information cannot have led entrepreneurs to form high expectations about the project's profits. The observed all sea freight price per ton between San Francisco and New York is \$16.83 while just the expected eastern railroad freight price is \$20.50. Sail is about 10 times cheaper per ton-mile than rail (0.11 cents to 1.18 cents), while the railroad route is expected to reduce distance to one fifth of the sail route distance (from 15,300 to 2,850).⁶⁹

The use of observed information on transport and trade costs does not allow expecting the railroad to be profitable either. An estimate of the trade cost savings generated by the project and measured by savings in insurance, interest charges on working capital and foregone income is presented in table 5. The likely average savings the rail route may offer are not high enough to allow freight services to operate profitably. Insurance and working capital savings are on average \$4.30 for the typical ton traded on the California trade. Adding the value of insurance and

⁶⁶ A detailed description of the data and sources included in table 4 is included in appendix 3.

⁶⁷ Fishlow (1965) p. 389 and Davis and Cull (2000) p. 751. Engerman (1972) also supports the view that capital market size was not a major limitation for developing the transcontinental.

⁶⁸ See appendix 1 for details on the Suez canal funding.

⁶⁹ The results for the China trade are analogous. The road does enjoy a small cost advantage for passenger traffic. The advantage is not enough to render the project profitable. Maximum operational profits are \$700,000 dollars, but are not enough to generate a positive net present value.

working capital savings to the all sea route price gives \$21.13. The eastern railroad price is \$20.5. The difference between \$21.13 and \$20.5 is 63 cents, and gives the maximum price the first transcontinental railroad can charge without making the total price of the rail route higher than the all sea route. The implied freight rate per ton-mile is 0.03 cents per ton-mile, substantially lower than the 1.18 cents per ton-mile operational costs. The first transcontinental railroad had no room to enter freight services.⁷⁰ Foregone income savings are high enough for the first transcontinental passenger services to be profitable. The first transcontinental may charge a fare of up to 2.75 cents per passenger-mile. Profit per passenger-mile is 1.87 cents and total through passenger profit is \$1.6 million. Passenger profits alone are not high enough to induce entry of the first transcontinental railroad into the second stage, as the NPV is \$-63 million.

The preliminary survey reports, and particularly the Union Pacific bond prospectuses, indicate entrepreneurs also expected the railroad to provide transportation with new good attributes.⁷¹ The entrepreneur's decision problem is given by equation (3). Recall the demand function is inferred using the observed price and the maximum observed price. The observed price corresponds to an average price for transportation. The maximum price corresponds to the average for fast steamer price (freight) and for first cabin fares (passenger) on the Panama route.

The reports also indicate market size was predicted to grow fast, doubling soon after completion of the road.⁷² 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 idea is that few investors would have expected market size to decline during the next 15 years as eastern United States and California increasingly integrate and China grows and integrates into the world economy. Some must have also expected the growing Japanese trade to go over the rail route. Thus, the lower bound 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 market size growth. Consequently, the interval for market size growth indicates the range of expectations investors may have held. Since indication of the central tendency of investors' expectation does not exist, the uniform distribution is adopted.

Expected construction cost is implemented by allowing construction cost to vary pseudo-randomly between the expected value based on the mid 1850s army surveys (\$86.7 million) and 50% of that value (\$43.4 million) following a uniform distribution. The entrepreneurs declared to

⁷⁰ The results for the China trade are analogous. See table 5.

⁷¹ Cisco (1868) pp. 23-24.

⁷² Entrepreneurs also mentioned the New York and Erie Railroad that originally planned to earn 3 million per annum in the 1830s and by early 1860s earned more than 15 million (Cisco (1868) p. 23-24).

expect construction cost of the second stage to be between 33% and 50% lower than expected in the mid 1850s.⁷³ Again, the construction cost drawn from a uniform distribution represents the range of construction costs the entrepreneurs and investors may have held.

Next a Monte Carlo experiment is performed using the model, the observed information contained in table 4 and the intervals for expected traffic and construction cost indicated above. The experiment is repeated 2,000 times.

Results are presented in table 6. The baseline results indicate 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 average passenger price is \$128; and predicted freight traffic is about 134,000 tons and almost 40,000 passengers per annum. Average annual profit for the California trade is \$4.2 million, for the China trade \$2 million, and for the California passenger submarket \$4.3 million. The average NPV (that proxy the expected utility (payoff) criteria) is \$3.5 million. Positive NPV is likely with 64.2% probability. The operational cost ratio (operational cost/earnings) ranges 14%-35%, well below the maximum 50% suggested by entrepreneurs as acceptable in the 1850s. The annual profit over construction cost ratio is 9%, however, below the 15%-20% indicated by entrepreneurs as satisfactory. The sum of the NPV of first and second stage is \$34.7 million.

Note that the single stage first transcontinental railroad proposed by entrepreneurs during the late 1840s and 1850s could not have been expected to be profitable. The average NPV of the second stage is \$3.5 million while the present value of the expected construction cost of the first stage (\$13.3 million) is \$10.8 million. Dividing the first transcontinental railroad line into stages was indispensable for the venture to be expected profitable.

How sensitive are the results to the specific assumptions? The results do not seem too sensitive to specific values imposed on the range of each of the key variables (see table 6). Freight maximum observed prices may go down by 8.3% or passenger maximum observed prices may go down by 23.9% and the NPV is still positive. The expected market size growth interval's upper bound may be reduced to 1.7 of the observed traffic instead of doubling it and the NPV is still positive. Expected construction cost reduction's interval upper bound may be reduced by a maximum of 35.7% rather than halved and the NPV is still positive.⁷⁴ Thus, the specific assumptions imposed on the upper bound of expected traffic, construction cost reduction, and maximum price are not only tightly based on the entrepreneurs declared expectations and data on

⁷³ See section 3.C. above.

⁷⁴ A simple test on the shape of the demand schedule is also performed. The test indicates the shape may change moderately and the qualitative results remain invariant.

observed willingness to pay revealed in the 1850s, but may also change moderately in the direction against profits and the road should still be expected to be profitable.

The baseline scenario is also robust to moderate changes in the rest of the parameters of the model (see table 7). The Monte Carlo experiment was performed now changing each of the rest of parameters of the model until the NPV became 0. The new good attributes of the rail route create monopoly power insulating the first transcontinental from competition via the all sea route. The all sea route price may decline down to \$8.40 and the average NPV is still expected to be positive. 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 all sea trip) may go up by 26.3% and the average NPV is still positive. An alternative interpretation of the previous result is that the cost of transshipment at Omaha (and San Francisco for the China trade) may go up to \$7 per ton and the first transcontinental should still be expected to be profitable on average. The operational costs may go up by 24.8% or the discount rate up by 13.8% and the average NPV is still positive. Finally, the Monte Carlo experiments allow examining the effects of a negative random shock on the project's expected profitability (following the same method as the Monte Carlo experiment in subsection 7.A.). The baseline scenario may be subject to a random negative shock of up to 8.3% on construction cost, operational cost, all sea price, complementary transport price, and discount rate (all at the same time) and the average NPV is still positive with a probability of 50.3%.

It is also possible to learn about the nature of the results presented above by comparing the forecasted scenario to what was actually observed during the operation of the railroad. The best construction cost estimate available indicates total cost of the second stage was \$50.5 millions and of the full road \$64.6 million.⁷⁵ Construction cost was actually substantially lower than that expected by the army surveys, \$86.7 million. It is remarkable that such an important difference has not been pointed out by the existing literature. Part of the explanation possibly lies in that no previous work on the first transcontinental has identified carefully what the entrepreneurs expected at different times, and therefore cannot identify the surprisingly low cost of construction. The entrepreneurs invested intensively in surveying and learning about the topography over which the road was to be built. They expected the investment to pay-off in the form of substantially lower construction costs. A route with grades lower than 90 feet per mile and substantially lower construction cost was found. Construction cost was actually reduced to

⁷⁵ Construction cost from Mercer (1982) plus necessary repairs for \$6.5 million demanded by government commissioner Snow after evaluating the road to grant last batch of subsidies is 1869 (Snow (1869)).

58% of the army survey's estimate.⁷⁶ Note the cost reduction came from all over the route, including the Central Pacific part, not only the pass over the Rockies, as indicated by Fogel.

The information in table 8 compares the baseline scenario and the average observed market outcomes during operation 1870-84. The baseline scenario predicts the weighted average freight price is \$70 and traffic close to 134,000 tons for the first transcontinental railroad. Predicted passenger price is \$128 and about 39,000 passengers per year. The observed market outcomes indicate an average freight price of \$41 and almost 247,000 tons traffic per annum for the first transcontinental and more than 528,000 tons traffic for the total California and China trades. The passenger fare was \$52 and traffic over 89,000 passengers per year. The baseline scenario predicts higher prices and lower traffic than the observed market outcomes.

There are two main reasons why the baseline scenario predicts higher price and lower traffic. First, when the observed outcomes are compared to the baseline scenario it appears the baseline uses a conservative range for expected traffic and construction cost, while it uses a higher range for expected maximum price. The baseline scenario used an expectation of traffic varying on a range between the level of observed traffic in 1860 and a maximum of twice that level, with a mean expected average traffic of 1.5. The average traffic 1870-84 for the California and China trades was actually 2.3 times the traffic observed in 1860 and 2.19 for California passenger traffic. Construction cost in the baseline scenario varies between the figure suggested in the army surveys and 50% of it, with a mean expected construction cost of 75% of the army surveys. The observed outcome was 58% of the army surveys.

Once the average 1870-84 traffic, the actual construction cost are used, and the observed average price on the Panama route in the 1850s are input the model's predictions come closer to the observed outcomes (see table 8 simulation using observed traffic growth, maximum price and construction cost). The predicted profit maximizing price for freight declines to \$43, and relatively close to the \$41 observed outcome. Predicted freight traffic via rail increases to more than 159,000 tons a year. The profit maximizing passenger price declines to \$92, still higher than the observed average price 1870-84, \$52. Predicted passenger traffic increases to 64,000. The NPV of the second stage under these assumptions is \$1.3 million.

Second, the reports written by the entrepreneurs performed a simplified analysis of the investment opportunity. The framing of the problem abstracted differences between commodities. But once the railroad was built, the entrepreneurs did consider these differences and set different prices for different commodities. Figures 5 and 6 show some of the different prices set by the first transcontinental route San Francisco-New York for different commodities. The price predicted by

⁷⁶ See Dodge (1867) for a description of the advantages of the improved route.

the model is in between the low and high rail route prices. Thus, the entry decision model seems to capture relatively well the aggregate pricing problem the entrepreneurs faced in the 1850s, but its predictions are weakened because it does not consider price discrimination between commodities. An important characteristic of price discrimination pricing is that it may lead to increasing total output.⁷⁷ Thus, price discrimination may also explain why the model predicts a relatively lower level of traffic compared to observed traffic 1870-84.

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 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 the entrepreneurs were right to expect the railroad to be profitable under these assumptions. Additionally, if the *ex-post* market outcomes also provide an indication of the likelihood of the expectations (i.e. the observed outcome is the most likely to occur), entrepreneurs and investors were right to expect higher traffic and prices and lower construction cost. The results are even stronger once one considers these are a lower bound of expected profits. The inclusion of price discrimination, network economies, economies of scale, scope and density or other sources of earnings not included in the analysis should lead to even higher expected profits.

C. Discussion: Expected profits and subsidies

The findings above have important implications regarding 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 likely. The evidence indicates that when the Pacific Railroad Act was passed in Congress in 1862, entrepreneurs had already privately performed the surveys necessary to take the first stage of the project to the capital market. The project's size and expected profits were comparable or better than those of the typical 1850s railroad project. Thus, the evidence strongly suggests 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 entrepreneurs would learn about construction cost of the first stage and explored the terrain for the second stage while building the first stage (as it actually happened with the Central Pacific entrepreneurs). Thus, entrepreneurs should have completed the necessary information to

⁷⁷ Varian (1985)

realize construction cost had been overestimated by the army surveys. Once entrepreneurs expect i) rapid traffic growth in the California and China trades, ii) rail users to value highly time savings, and iii) reduced construction cost, the second stage should have been expected to be profitable. Thus, in the counterfactual scenario presented here, the first transcontinental should have been expected to be profitable by entrepreneurs and the average investor. Contrary to conventional belief (as expressed by Schumpeter, Fogel, Mercer, and Fishlow), under a pure market scenario, subsidies were not necessary to promote private construction of the first transcontinental.

The results above do not necessarily imply the Pacific Railroad Act was a giveaway. Subsidies may have been provided for two different reasons. 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 first transcontinental railroad sequentially. The first stage needs to be finished before the second stage 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 arrival of the social benefits associated to the full first transcontinental. The point is important for several reasons. It is possible the second stage may not have been built immediately after the first stage was finished. It is also possible the second stage may have been divided into more stages, delaying arrival of social benefits.

Second, subsidies may 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 may have been a substitute for a highly distorted and dysfunctional capital market.

8. Conclusions

The examination of the reports written by the first transcontinental entrepreneurs allows learning in three directions. First, the paper presents direct evidence on how entrepreneurs formed their profit expectations in the 1850s. Entrepreneurs first identify the equilibrium observed in the market. Next, they consider changes in demand induced by the introduction of the railroad route and the possibility of that the railroad will experience market power. Market power was expected when the rail route experienced technological advantage over the alternative transport mode, or when the rail route was expected to offer new good attributes. The way entrepreneurs inferred the

demand function and set prices is not explicit in the reports. But judging on the information included in the reports, it is likely the key information used to infer the demand function is diversity in prices associated to different quality of transportation.

Second, this paper presents a method that allows controlling many of the potential biases of entrepreneur reports (or any subjective declaration of expectation of an economic outcome). The use of these reports (or declarations) is frequently challenged on grounds that the entrepreneurs face incentives for opportunistic behaviour and therefore may write in these reports information different than that they truly believe. The method proposed here relies on using the reports and public information ex-ante to develop a simulation model to control for these biases.

Third, the examination of preliminary survey reports and secondary sources on the history of the first transcontinental reveals several important findings. i) Since the late 1840s entrepreneurs were interested in investing and developing the first transcontinental railroad to profit from transporting the booming trade with the Pacific Ocean and its high valuation of transport time reduction. ii) The development of the mining Washoe trade in 1859 allowed entrepreneurs to divide the project into two stages and perform the necessary non-negligible investments to reduce uncertainty of the first stage. iii) The reports for the first stage indicate it was as good or better as the typical 1850s railroad investment. An improved route had been located, its technical specifications were not more challenging than those of existing railroads in the east, and the mining trade boomed and paid high prices for transportation. iv) The activities and reports for the second stage indicate it was a promising railroad investment opportunity based on indications of lower construction costs than initially expected and the potential to profit by charging a high price for reducing transport time to the Pacific Ocean.

The preliminary survey reports and public information allow developing a model of formation of profit expectations illuminating better the incentives 1850s entrepreneurs and investors faced in the counterfactual scenario where the railroad was built privately to profit only from operation in the transport market. The allows controlling for the perverse incentives faced by entrepreneurs in congress and the capital market. The model confirms the intuition the entrepreneurs described in their projects. Once it was possible to divide the project into two stages and it was likely both stages turn out to be profitable. Prices and traffic observed in early 1860s indicate the first stage of the first transcontinental should have been expected to be highly profitable. Entrepreneurs predicted rapidly growing traffic, high willingness to pay for transport time reductions, and construction cost reductions. Given these expectations, the model indicates the second stage should have been expected to be profitable.

In sum, analysis of *ex-ante* information performed here indicates entrepreneurs did expect the first transcontinental to be profitable and they were right to do so after 1859, when the project was divided into two stages. The key sources for profits identified are: i) technological advantage 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 eastern and western United States, iii) new good attributes of the rail route generating market power and allowing to charge high transport prices to transport to and from the Pacific Ocean, and iv) little initial knowledge of the topography of the West and rapid accumulation of this knowledge, allowing to improve the location of the route and substantially reducing construction cost.

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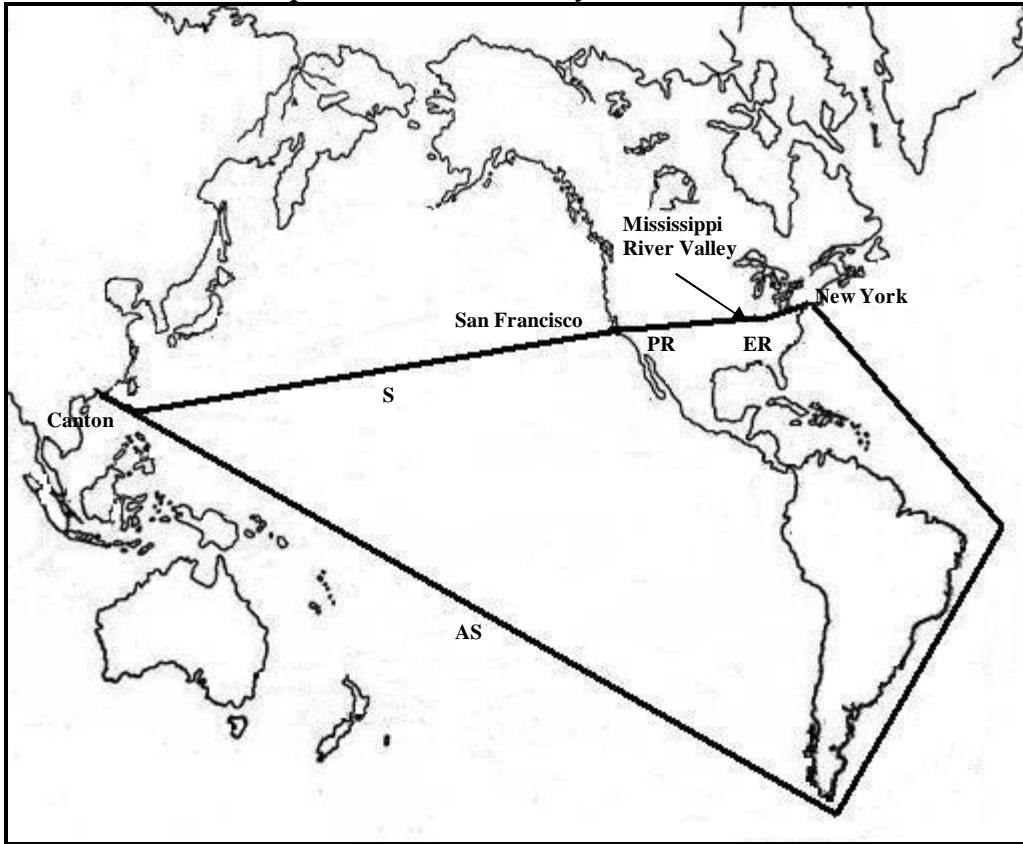
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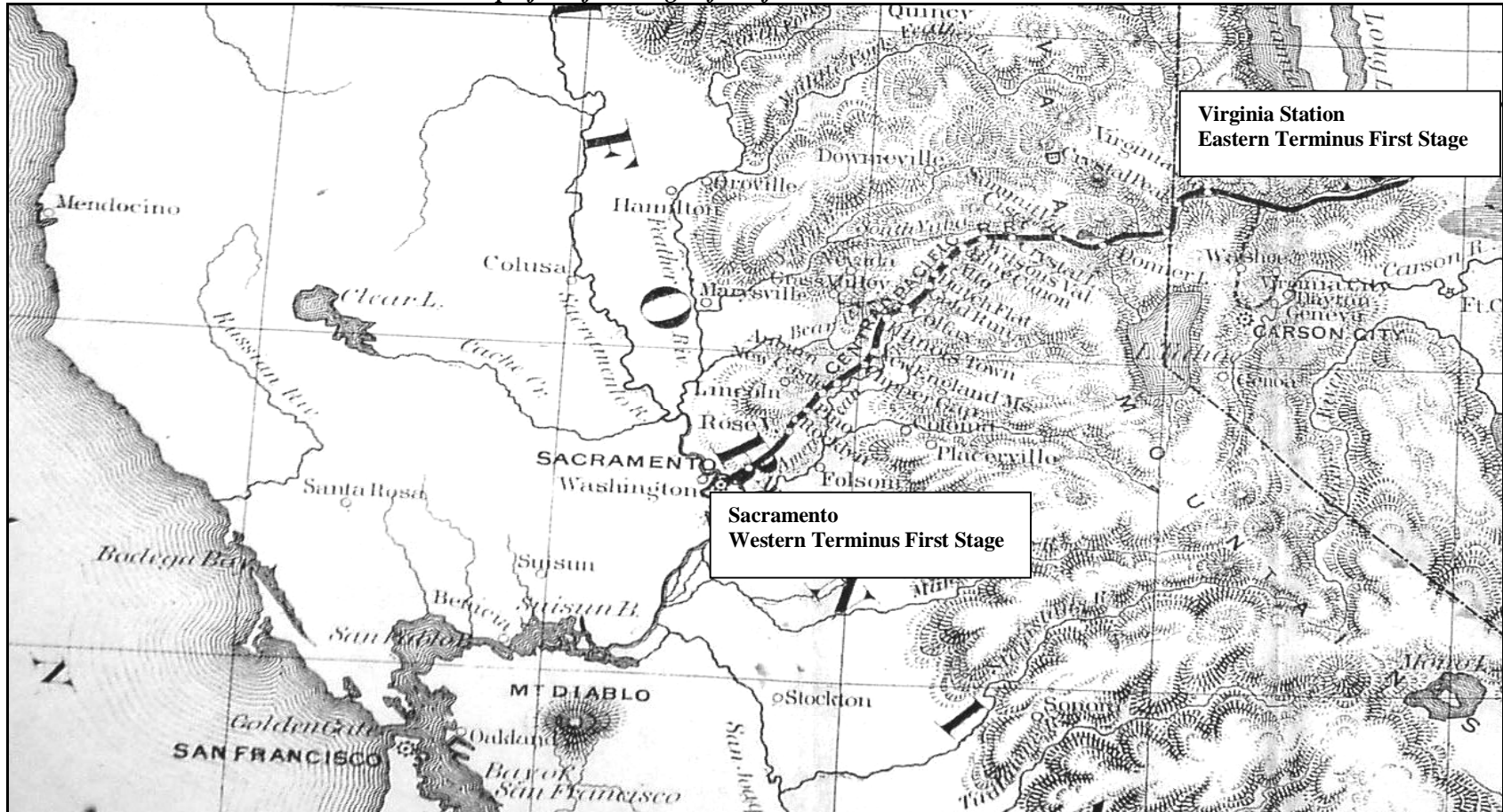
Figure 1.
Trip Canton-New York City via all sea and rail routes



Source: Whitney (1849) Appendix. All sea and first transcontinental routes are own drawing.

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.

Figure 2.
Map of the first stage of the first transcontinental railroad



Source: Judah (1861)

Table 1.
Summary parameter values, sources and comments for first stage

Parameter/Variable	Value	Source & comment
Expected construction cost	\$13.3 million	Judah (1861)
Expected railroad distance	155 statute miles	Judah (1862)
Construction period	5 years	Close to distance of railroad when it was actually built Construction of Sacramento-Virginia Station segment took 4 years and 9 months (09/1863-06/1868)
Land fixed fee	1% construction cost	Fishlow (1965) and land prices in 1850
Project's life	25 years	Average of Fogel (1960) and Mercer (1982)
Discount rate	9%	Mercer (1982)
Observed freight traffic	43,800 tons/year	Higher than 5-8% typically offered by railroad bonds Judah (1862)
Observed passenger traffic	13,505 passenger/year	15%-39% lower than alternative info Judah (1862)
Observed freight price	\$120	In line with alternative info Judah (1862)
Observed passenger price	\$30	In line with alternative info Judah (1862)
\tilde{a}_{ij} (expected sensitivity of traffic to price)	Calibrated (see text)	In line with alternative info
\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)

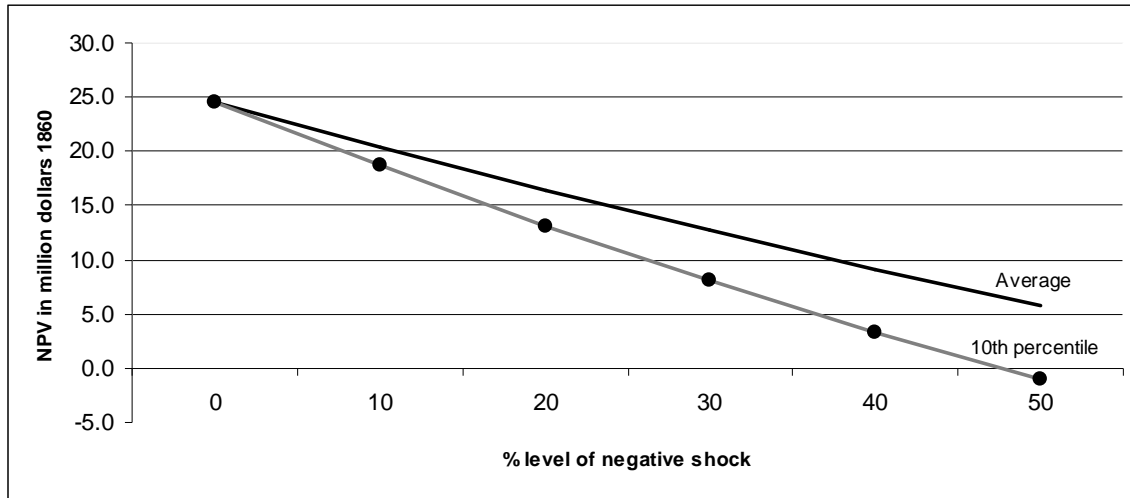
Sources: See appendix 2 for details.

Table 2.
Comparative statics first stage and inelastic price elasticity of demand

Scenario	Submarket	P	Q Tons or passengers	P*Q \$	C \$	Profit \$	NPV \$ mlls	C/P*Q	Profit/CC
Baseline scenario	Freight	120	43,800	5,256,000	80,110	5,175,890	24.5	0.02	0.42
	Passenger	30	13,505	405,150	18,421	386,729		0.05	
Construction cost up 3.15 times	Freight	120	43,800	5,256,000	80,110	5,175,890	0	0.02	0.13
	Passenger	30	13,505	405,150	18,421	386,729		0.05	
Traffic & prices down by 43.2%	Freight	68	24,878	1,695,712	45,503	1,650,209	0	0.03	0.13
	Passenger	17	7,671	130,711	10,463	120,248		0.08	
Operational cost freight up 43.6 times and passenger up 21.9 times	Freight	120	43,800	5,256,000	3,492,805	1,763,195	0	0.66	0.13
	Passenger	30	13,505	405,150	405,150	0		1.00	
Discount rate up by 2.76 times	Freight	120	43,800	5,256,000	80,110	5,175,890	0	0.02	0.42
	Passenger	30	13,505	405,150	18,421	386,729		0.05	
Project's life down to 8.5 years	Freight	120	43,800	5,256,000	80,110	5,175,890	0	0.02	0.42
	Passenger	30	13,505	405,150	18,421	386,729		0.05	
Earnings delayed 9.6 years	Freight	120	43,800	5,256,000	80,110	5,175,890	0	0.02	0.42
	Passenger	30	13,505	405,150	18,421	386,729		0.05	
Combination of negative events 1	Freight	90	32,850	2,956,500	75,103	2,881,397	2.1	0.03	0.23
	Passenger	23	10,129	227,897	17,270	210,627		0.08	
Combination of negative events 2	Freight	96	35,040	3,363,840	76,906	3,286,934	2.3	0.02	0.27
	Passenger	24	10,804	259,296	17,684	241,612		0.07	
Combination of negative events 3	Freight	120	43,800	5,256,000	120,165	5,135,835	1.1	0.02	0.41
	Passenger	30	13,505	405,150	27,631	377,519		0.07	
Combination of negative events 4	Freight	96	35,040	3,363,840	76,906	3,286,934	0	0.02	0.27
	Passenger	24	10,804	259,296	17,684	241,612		0.07	

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 of first stage project; C/P*Q: Operational cost over revenue; Profit/CC: Operational profit over construction cost. 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.

Figure 3.
First stage average and 10th percentile expected NPV in Monte Carlo experiment



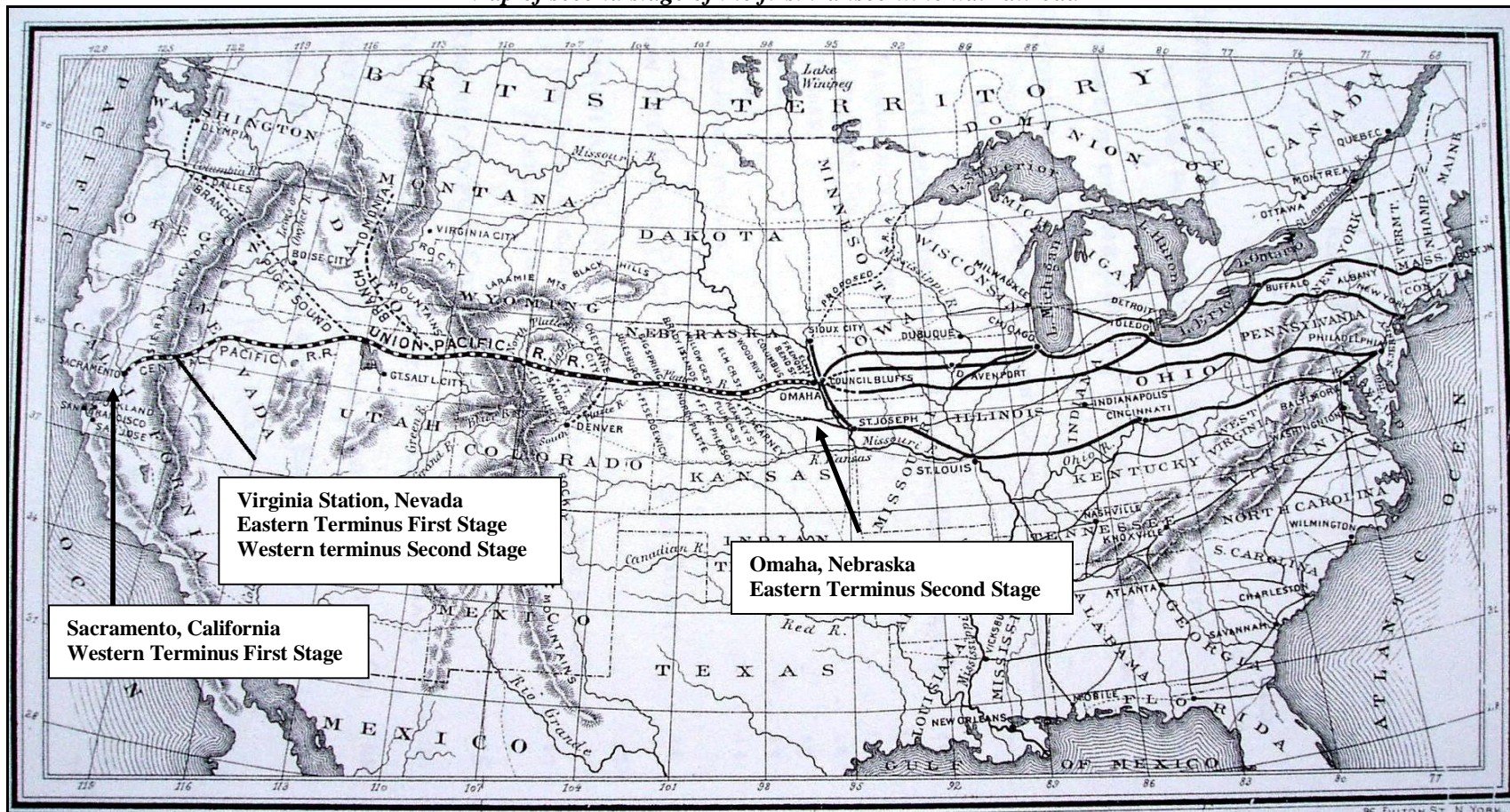
Note: Negative shock on construction cost, observed traffic and prices, and operational costs. Each variable experienced a shock on the direction affecting negatively profits. The shock is defined as a random reduction between 0% and the % level of negative shock indicated in the X axis. The average and the 10th percentile are from a sample of 2,000 replications of the Monte Carlo experiment.

Table 3.
Comparison of ex-ante and ex-post construction activity of first stage

	Unit	Ex-ante	Ex-post
Construction cost	Millions	13.3	14.1
Completion time	Years	More than 2.5 ^(a)	4 years 9 months
Maximum grade	Feet per mile	116	116
Miles of max grade	Miles	2.84	9.5
Number of tunnels	Number	18 12 ^(b)	15
Length of tunnels	Feet	17,410 5,655	6,245
Cost of tunnels	Dollars	870,500	312,250 ^(c) 473,355 ^(d)
Length of longest tunnel	Feet	1,370 1,700 ^(b)	1,659
Time to excavate longest tunnel	Months	13 18 ^(b)	13
Cost of longest tunnel	Dollars	68,500	109,474 ^(d)

Source: Ex-ante information comes from Judah (1861), except (a) that comes from Judah (1860) and (b) that comes from Montague (1865) p. 15. Ex-post construction costs comes from Mercer (1982) p. 154 and 164, completion time, maximum grade and length of maximum grade comes from Report of the Board of Railroad Commissioners (1879) p. 313, number and length of tunnels and time to excavate of longest tunnel comes from Central Pacific (1869) Report of the Engineer's Office to the President and Directors, pp. 32-5. Tunnel construction cost (c) is calculated using the average cost per linear foot of excavation in Judah (1861) and (d) is calculated using the average cost per linear foot of excavation of the Summit tunnel (the most difficult and expensive of the tunnels) using black powder and nitro-glycerine in Gilliss (1870) p. 170.

Figure 4.
Map of second stage of the first transcontinental railroad



Virginia Station, Nevada
 Eastern Terminus First Stage
 Western terminus Second Stage

Sacramento, California
 Western Terminus First Stage

Omaha, Nebraska
 Eastern Terminus Second Stage

Source: Cisco (1868)

Table 4.
Summary of parameters, values, and comments for second stage

Parameter/Variable	Value	Source & comment
Expected construction cost	\$86.7	Judah (1861) p. 29.
Expected railroad distance	1,845 statute mile	Judah (1861) p. 29
Construction time	5 years	In line with entrepreneurs. ⁷⁸ Construction of Virginia City to Promontory Summit (Central Pacific 06/1868-05/1869) and Omaha-Promontory Summit (Union Pacific 07/1865-05/1869) took 4 years and 9 months.
Land fixed fee	1% construction cost	Fishlow (1965) and land prices in 1850
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 Commerce and Navigation (1856-6) 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 sail ship passenger fare – NY-SF	\$50	Chandler (2007) 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	Estimated based on distance between Omaha and 16 large 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)

⁷⁸ See Bancroft (1890) p. 504.

Table 5.
Value of time per ton or passenger in real dollars (1860=100)

	China	Freight California	Passenger California
<u>Time trade costs - via all sea</u>			
Insurance (\$ per ton/trip)	2.21		
Working capital interest (\$ per ton/trip)	2.36		
Foregone earnings (\$ per passenger trip)			25.00
Total costs (\$ per ton/trip)	4.58	4.58	25.00
<u>Time trade costs - via first transcontinental railroad</u>			
Insurance (\$ per ton/trip)	0.34	0.00	
Working capital interest (\$ per ton/trip)	0.65	0.27	
Foregone earnings (\$ per passenger trip)			5.00
Total cost (\$ per ton/trip)	0.99	0.27	5.00
<u>All sea total cost</u>			
Trade cost savings (\$ per ton) (1)	3.58	4.30	20.00
Freight cost (2)	17.49	16.83	50.00
Total cost (3) = (1)+(2)	21.07	21.13	70.00
<u>Maximum first transcontinental railroad price</u>			
ER price (4)	20.5	20.5	14.96
Canton-SF via sea (5)	6.83		
Maximum first transcontinental price (3)-(4)-(5)	-6.26	0.63	55.04

Sources: Average value per ton of trade = (value of exports+value of imports)/(tonnage entered+tonnage cleared). Information for exports to China from series Ee546, imports from China from series Ee554. Value of California trade is not available. The value of a ton of average China trade is assumed to proxy the value of a ton of average California trade. The idea is reasonable in so far both regions trade with eastern United States luxury goods, like gold, salmon, tea and silk. Information on insurance rates and working capital interest rates comes from Whitney (1849) p. 80, McDougall (1854) p. 865, and Nimmo (1885) p. 71. Information on time length of average trip New York-San Francisco comes from Berry (1984) p. 119. Information on expected time length of first transcontinental comes from Whitney (1849) p. 25 and McDougall (1854) p. 865. Information on value of time for passengers comes from Degrand (1849) p. 12 and McDougall (1854) p. 865.

Table 6.
Monte Carlo experiment forward looking expectation of profitability

Scenario	Submarket	P	Q	PQ	C	Profit	NPV 2 nd stage	NPV full	C/P*Q	Profit/CC
		\$	Tons or passengers	\$	\$	\$	\$ mlls	\$ mlls		
Baseline scenario	California freight	72	89,574	6,409,016	2,113,937	4,295,079	3.5	28.039	0.33	0.09
	China freight	68	45,124	3,074,518	1,064,917	2,009,602			0.35	
	California passenger	128	39,857	5,087,460	701,491	4,385,969			0.14	
Baseline & maximum observed freight down by 8.3%	California freight	66	87,269	5,741,074	2,059,555	3,681,519	0	24.562	0.36	0.08
	China freight	62	43,500	2,713,121	1,026,594	1,686,527			0.38	
	California passenger	128	39,857	5,087,460	701,491	4,385,969			0.14	
Baseline & maximum observed passenger price down by 23.9%	California freight	72	89,574	6,409,016	2,113,937	4,295,079	0	24.562	0.33	0.08
	China freight	68	45,124	3,074,518	1,064,917	2,009,602			0.35	
	California passenger	97	43,210	4,209,776	760,502	3,449,274			0.18	
Baseline & expected market size growth down from 100% to 73.8%	California freight	72	81,701	5,845,731	1,928,144	3,917,587	0	24.562	0.33	0.08
	China freight	68	41,144	2,803,402	971,010	1,832,392			0.35	
	California passenger	128	36,385	4,644,180	640,368	4,003,812			0.14	
Baseline & expected construction cost reduction down from 50% to 35.7%	California freight	72	89,574	6,409,016	2,113,937	4,295,079	0	24.562	0.33	0.09
	China freight	68	45,124	3,074,518	1,064,917	2,009,602			0.35	
	California passenger	128	39,857	5,087,460	701,491	4,385,969			0.14	
Baseline & maximum expected market size down from 100% to 73.9%	California freight	72	81,647	5,841,896	1,926,879	3,915,017	0	24.562	0.33	0.08
	China freight	68	41,216	2,808,267	972,695	1,835,572			0.35	
	California passenger	128	36,380	4,643,600	640,288	4,003,312			0.14	

Note: P: Profit maximizing price; Q: Total quantity of output in tons per annum; P*Q: Revenue; C: Operational cost; Profit: Operational profit; NPV 2nd stage: Net Present Value of second stage project; NPV full: Net Present Value of full project; C/P*Q: Operational cost over revenue; Profit/CC: Operational profit over construction cost. Baseline scenario is Monte Carlo experiment for traffic varying pseudo randomly between observed level in 1860 and twice that level, expected maximum price varying pseudo randomly between observed maximum price and expected maximum price using observed value per day of transport time reduction in Clipper ships or Panama route and expected transport time reduction by first transcontinental railroad, construction costs varying pseudo randomly between expected construction cost using army surveys and 50% that level.

Table 7.
Monte Carlo experiment sensitivity of forward looking expectation of profitability

Scenario	Submarket	P	Q	PQ	C	Profit	NPV 2 nd stage	NPV full	C/P*Q	Profit/CC
		\$	Tons or passengers	\$	\$	\$	\$ mlls	\$ mlls		
Baseline scenario	California freight	72	89,574	6,409,016	2,113,937	4,295,079			0.33	
	China freight	68	45,124	3,074,518	1,064,917	2,009,602			0.35	
	California passenger	128	39,857	5,087,460	701,491	4,385,969	3.5	28.039	0.14	0.09
	China freight	68	41,216	2,808,267	972,695	1,835,572			0.35	
	California passenger	128	36,380	4,643,600	640,288	4,003,312			0.14	
Baseline & observed price down by 49.5%	California freight	72	83,735	5,991,252	1,976,142	4,015,110			0.33	
	China freight	68	42,076	2,866,881	992,997	1,873,884	0	24.562	0.35	0.08
	California passenger	128	35,122	4,483,037	618,149	3,864,888			0.14	
Baseline & observed complementary prices up by 26.3%	California freight	69	84,534	5,820,374	1,995,002	3,825,371			0.34	
	China freight	65	41,479	2,677,038	978,916	1,698,123	0	24.562	0.37	0.08
	California passenger	126	39,144	4,919,376	688,941	4,230,435			0.14	
Baseline & operational costs up by 24.8%	California freight	74	84,103	6,263,875	2,477,452	3,786,423			0.40	
	China freight	71	42,156	2,995,796	1,241,816	1,753,980	0	24.562	0.41	0.08
	California passenger	130	39,066	5,071,808	858,222	4,213,586			0.17	
Baseline & discount rate up by 13.8%	California freight	72	89,574	6,409,016	2,113,937	4,295,079			0.33	
	China freight	68	45,124	3,074,518	1,064,917	2,009,602	0	24.562	0.35	0.09
	California passenger	128	39,857	5,087,460	701,491	4,385,969			0.14	

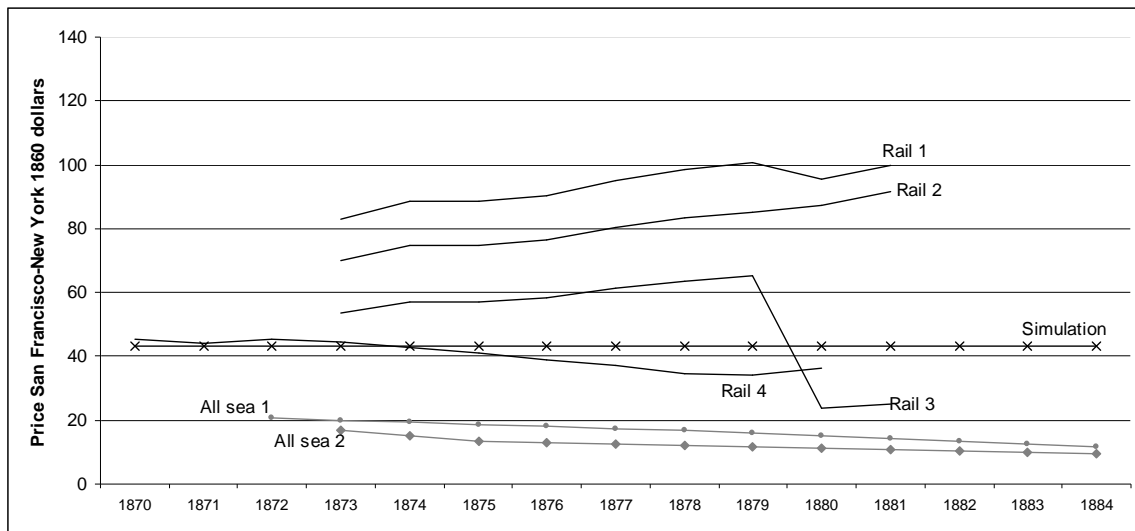
Note: P: Profit maximizing price; Q: Total quantity of output in tons per annum; P*Q: Revenue; C: Operational cost; Profit: Operational profit; NPV 2nd stage: Net Present Value of second stage project; NPV full: Net Present Value of full project; C/P*Q: Operational cost over revenue; Profit/CC: Operational profit over construction cost. Baseline scenario is Monte Carlo experiment for traffic varying pseudo randomly between observed in 1860 and twice that level, expected maximum price varying pseudo randomly between observed maximum price and expected maximum price using observed value per day of transport time reduction in Clipper ships or Panama route and expected transport time reduction by first transcontinental railroad, construction costs varying pseudo randomly between expected construction cost using army surveys and 50% that level.

Table 8.
Comparison of baseline scenario and average observed market outcomes 1870-84

Scenario	Submarket	P	Q	Market share	Profits	NPV 2 nd stage
Simulation - baseline scenario						
	Freight California	72	89,574		4,295,079	
	Freight China	68	45,124		2,009,602	
	Freight total	70	134,697	26	6,304,680	
	Passenger California	128	39,857	41	4,385,969	3,477,113
Simulation - using <i>ex-post</i> traffic, maximum price, and construction cost						
	Freight California	45	109,471		2,292,768	
	Freight China	41	49,590		869,266	
	Freight total	43	159,061	30	3,162,034	
	Passenger California	92	64,500	67	4,804,893	1,378,596
Observed outcome						
	Freight total	41	246,645	47	n.a.	
	Passenger total	52	89,463	93	n.a.	

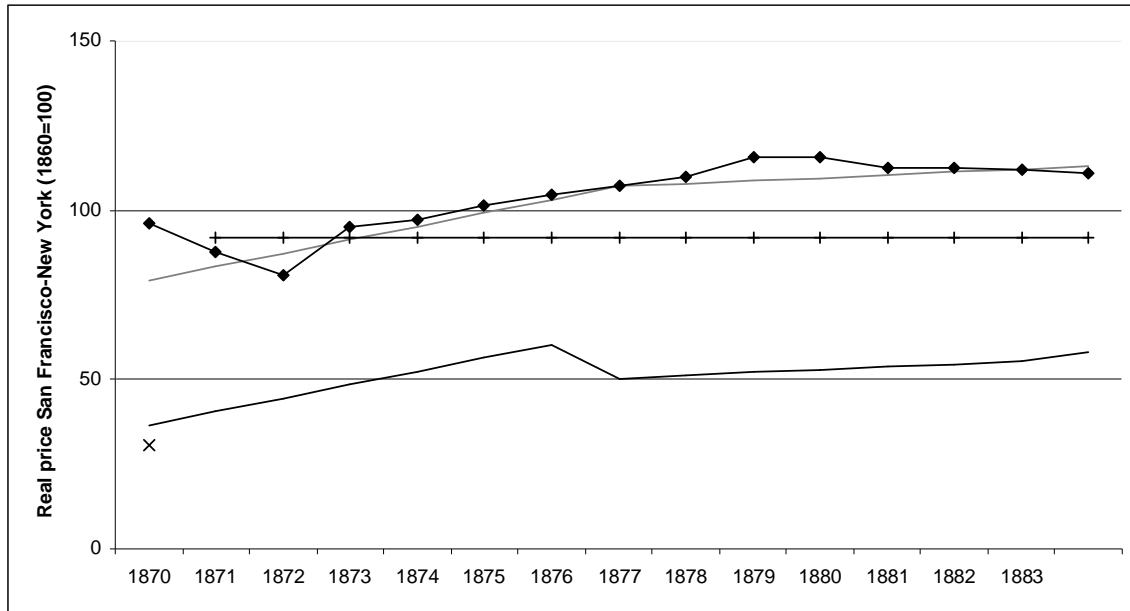
Source: Rail route freight price and traffic from Mercer (1982)

Figure 5.
Freight price for all sea, Clipper ships, Panama route, simulation and first transcontinental railroad



Source: All sea 1: Kaukianen (n.d.) p. 3 of statistical annex for 1873, 1880, and 1885; the series was completed by interpolation. All sea 2: Harley (1988) p. 864 for 1873, 1875, and 1890; the series was completed by interpolation. Rail 1: Aldrich (1893) pp. 593 Dry goods & glass ware. Rail 2: Aldrich (1893) pp. 593 Cotton goods, hides, leather. Rail 3: Aldrich (1893) pp. 593 Canned goods and starch. Rail 4: Mercer (1982) implicit average freight rate.

Figure 6.
Passenger price for all sea, Panama route, simulation and first transcontinental railroad



Source: Panama 5: Nimmo (1885) p. 126, cabin. Panama 6: Nimmo (1885) p. 126, steerage. Rail 1: Nimmo (1885) p. 132, 1st class. Rail 2: Appleton's Railway and Steamship Guide of the United States and Canada (1869), emigrant class. Deflator: CPI index David (1977).