Railroads and Economic Growth in the Antebellum United States

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Abstract

We measure the overall impact of railroad investment on economic growth in the antebellum period in the United States using a bivariate dynamic time series methodological approach, based on the use of a vector autoregressive (VAR) model. We find bidirectional causality between railroad infrastructure investment and GDP. Our estimates suggest that railroad investment had a substantial impact on economic growth in the antebellum United States. The elasticity of output with respect to railroad investment is 0.048 with a corresponding marginal product of 4.2. The marginal product figure indicates that one dollar invested in railroads yields a $4.2 accumulated increase in GDP over the long-term. This corresponds to a 7.5% rate of return when considering a 20–year lifetime for railroad capital. While the bulk of the estimated effect of railroad infrastructure investment, nearly two thirds of the total, stems from supply side effects, the short run demand side effects of these investments are substantial.

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1. **Introduction**

It is a well-established fact that the railroad played a major role in the development of the antebellum United States.[1] The availability of an expanding railroad infrastructure revolutionized the dynamics of the US economy, shattering traditional time and space barriers. Transportation of people and goods overland became faster, more reliable, safer, and hence more economical.

There are literally thousands of books and pamphlets and hundreds of thousands of newspaper and journal articles that extol the virtues or discuss the many and varied impacts of the antebellum railroad.[2] Yet very few of these were scientific. Many were intended specifically for the promotion of the sale of railroad bonds and the expansion of the rail network. More recently, economic historians have tried to specify carefully and measure statistically these impacts.

George Rogers Taylor's (1951) descriptive work has stood the test of time. Taylor linked the coming of the railroad directly to falling transportation costs, which in turn stimulated increased agricultural output, expanded domestic and foreign commerce, and ultimately, industrialization. "Improved roads, canals, and steamboats made their contribution, but they were not entirely effective in loosening the bonds which fettered the agrarian, merchant-capitalist economy of the early nineteenth century. The United States encompassed vast distances, difficult mountain barriers, virgin forests, and great unsettled plains. Only a method of transportation by land – cheap, fast, and flexible – could meet the pressing needs of agriculture and industry. The steam railroad, surely one

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[1]Whether or not railroads, as opposed to transportation in general, were "indispensable" for economic growth has long been debated by economic historians. See Fishlow (1965, pp. ix-x), for a positive view, and Fogel (1964, pp. 10-16), for a negative view.

[2]Miner (2010) used digital databases to examine newspapers, magazines, pamphlets, and books of the era. "For some single years in the 1850s, the databases turned up more than 30,000 articles for the search term 'railroad' or its spelling variants" (p. xiv).

of the most revolutionary inventions of all time, provided the solution" (p. 74). But what exactly were its effects?

Two seminal works analyzing the broad economic impact of the railroad were published closely together: Robert Fogel's *Railroads and American Economic Growth* (1964) and Albert Fishlow's, *American Railroads and the Transformation of the Antebellum Economy* (1965). These analyses were based on defining the social savings of railroads as the difference between the actual costs of shipping goods and the costs of employing a shipping alternative to the railroad, principally canals (Fogel, 1979). The social savings approach is "designed to set an upper bound on the resource savings brought about by an improvement in transportation technology" (Fogel, 1979, p. 5). This stems from the assumption of inelastic demand for transportation services and that the alternative transportation service options available are perfect substitutes. Fogel calculated the impact of the railroad to be less than 5% of gross national product in 1890 (p. 223). Fishlow calculated a social saving of roughly the same magnitude, 4%, for 1859, but he argued that if this were extrapolated to 1890, it would represent a social saving of at least 15% of GNP (pp. 52, 57).

In addition to providing estimates for the contribution of railroads to economic conditions in the antebellum period, Fishlow tested Schumpeter's hypothesis of construction ahead of demand and finds that they tended to be built incrementally into areas that already had been settled (Fogel, 1979). Atack, Bateman, Haines and Margo (2010) further reinforce this conclusion in their analysis of investment, population density, and urbanization patterns between 1850 and 1860. These concerns support the need to examine and accommodate the possibility of reverse causality between railroad investment and economic growth in understanding the effects of railroad construction.

The railroad was a large enterprise, necessitating a managerial hierarchy, it was a large employer of labor, and it was a large consumer of capital, reaching 15-20% of total capital investment in the U.S. by the 1850s. This is suggestive of the possibility of a Keynesian stimulus to

economic activity at the time brought about by the construction of the railroad as spending on material inputs and railroad workers wages rippled throughout the economy supporting local industries. The heart of the social savings approach, however, rests with the idea that lower transportation costs are the central component in understanding the contribution of railroads to economic growth. Indeed one criticism of the social savings approach is that it is equipped to measure only these direct gains and not any indirect benefits stemming from demand side effects (Leunig, 2010). There is scant evidence on how the effects of railroad investment may be decomposed between short-term – demand side effects and long term – supply side effects.

In this paper we estimate the overall impact of railroad investment on gross domestic product (GDP) in the antebellum period in a way that addresses the three questions above. Namely, 1) Did railroad investment follow or precede economic growth in the antebellum United States? 2) What were the effects of railroad investment on GDP during this time? And 3) How can these effects be decomposed into short-run, contemporaneous effects and long run effects?

We adopt the methodological approach, initially developed in Pereira and Flores (1999) and Pereira (2000, 2001), that has now became standard in the evaluation of the impact of infrastructure investment [see Pereira and Andraz (2013) for a literature survey]. This approach has also been employed in examining infrastructure investment and economic development in the Netherlands between 1853 and 1913 [see Groote et al., 1999] and in Spain between 1850 and 1935 [see Herranz-Loncan (2004, 2007)].

We use a multivariate dynamic time series methodological approach, based on the use of vector autoregressive (VAR) models. This approach addresses several criticisms levied against the social savings approach to evaluating the impact of railroad investment. First, we accommodate, at every step of the analysis, the possibility of structural change over the relevant time period. Second, this approach gives direct consideration to issues of causality and, in particular, the possibility of

reverse causality, that is, economic conditions serving as a driving force in railroad investment. Third, this methodological approach allows us to measure the short-term and long-term impact of railroad investment and thus goes beyond the direct gains from lower transportation costs.

The remainder of this paper is organized as follows. Section 2 describes railroad construction and expansion in the antebellum United States. Section 3 presents the data sources and provides preliminary statistical analyses of the data series. Section 4 presents our methods for evaluating the effects of innovation in railroad investment. Section 5 presents the main results of our analysis. Section 6 examines the contribution of railroad infrastructures to economic conditions between 1828 and 1860 and section 7 concludes.

2. Railroads in the Antebellum United States

In this section we present the data on railroad infrastructure investment in the Antebellum United States. We provide a discussion of the historical context in which these investments took place. This allows for an analysis of the conditions at the time that are important in understanding investment dynamics and the potential for structural breaks in the period under consideration.

2.1. The Data

One of Fishlow's (1965) greatest contributions was the meticulous collection of data on antebellum railroads. He constructed data on output, disaggregated by region and between freight and passenger traffic. Important for our purposes, Fishlow constructed annual capital formation estimates, in both nominal and real terms, and gross and net of depreciation. Data for net railroad capital formation for the years from 1828 to 1860 are from this Fishlow (1965) series. Annual data for real GDP in the United States are from Williamson (2014). Both variables are measured in millions of constant 1860 dollars.

Table 1 presents the average growth rate of real GDP, net railroad capital formation and net railroad capital formation as a percent of GDP by decade for the sample period between 1828 and 1860. Figure 1 presents time series plots of investment levels and growth over the sample period.

2.2.   Railroad Construction and Expansion between 1828 and 1860

Ground was broken in Baltimore and the "cornerstone" laid on July 4, 1828 for the first major (a projected two hundred miles) railroad line in the United States, the Baltimore and Ohio Railroad. Two difficult years later, in 1830, thirteen miles of track were placed in operation, and a new era in transportation had begun. The Baltimore and Ohio entered into direct competition with the Chesapeake and Ohio Canal, but it was clear that the future belonged to the railroad (Fishlow, 1965, p. 3; Taylor, p. 77). [3] The three decades that followed marked tremendous growth in investment in railroads.

Between 1828 and 1860, real GDP grew at an average annual rate of 4.6 percent while railroad infrastructure grew at the rate of 17.2 percent per year (9.9 percent per year if the first two years of the sample are excluded). Between 1830 and 1839, investment in railroads grew at an average annual rate of 31.45 percent, rising from 0.2 percent of GDP in 1830 to just above 0.9 of GDP in 1839. Investment continued to grow strongly through the 1840s at 8.4 percent per year, slowing somewhat during the decade that followed. Between 1950 and 1959 railroad investment volumes were substantial and amounted to 1.7 percent of GDP. Investment levels reached their maximum levels in 1854 at 2.6 percent of GDP. [4]

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[3]Typical for the 1820s the company needed a charter from the state legislature in order to operate. This they obtained in 1827. The charter contained many interesting provisions. The company was to be capitalized at $3 million with shares at $100 each. Ten thousand shares were reserved for the State of Maryland and 5,000 for the City of Baltimore. Fifteen thousand shares were to be available to the public. In the twelve days the subscription books were open, the shares were vastly oversubscribed and had to be prorated. This all was before ground was broken. The railroad could have been fully financed with private capital. In addition, the company obtained a provision that exempted it from paying any taxes to the State of Maryland forever. Hungerford (1928, Ch. I-III).

[4]As Atack, Bateman, Haines, and Margo (2010) note, the Unites States by 1860 "had more miles of railroad than the rest of the world combined" (p. 172).

Fishlow noted that it is the great surge in railroad mileage in the 1850s that grabs our attention. By 1860 it was possible to travel from New York to Chicago and St. Louis by an all-rail route. Farm products could be sent from Illinois to Boston without having to be transshipped. Manufacturers could send their goods from the East to the West with few interruptions. Impediments remained, however. The cars were small and there were only a few bridges over the major rivers. There were no time zones, so that every locality was on its own time, making scheduling difficult, and engines still were not very powerful. But an economic transformation had begun. Manufacturing establishments supplying the railroad directly, foundries, rolling mills, and locomotive producers began to settle in the Midwest. Urbanization was stimulated and agricultural output, while growing absolutely, fell relative to manufacturing output, although it was agriculture, according to Fishlow (p. 303) that that may have benefitted most from the coming of the railroad.

2.3. Financing Railroad Construction between 1828 and 1860

Many of the early railroads were largely privately financed through the sale of corporate securities to the merchants, manufacturers, farmers, and other citizens that lived along the proposed routes. Fishlow notes that the internal rate of return on railroads was high enough to justify private investment. However, there was insufficient private capital to finance the railroad building boom that began in the 1830s and continued, with interruptions, into the 1840s and 1850s. National, state, and local governments supplemented and supported railroad construction enterprises throughout the period. Railroads were granted liberal charters, grants of land were made by both the national government and by state governments, some railroads were granted banking and lottery privileges, and in some cases, states and even cities actually built and managed railroads (Taylor, 1951, ch. 5).

In addition, one of the most important components of government aid was direct financial support. Such support generated a substantial amount of state debt, although this debt was not

uniformly distributed.[5] There were many who believed that the economic growth, particularly growth in land values, stemming from these infrastructure investments would ultimately increase state revenues sufficient to make these debts essentially self-financing, as had been the case in the 1820s with the Erie Canal.

The dual Panics of 1837 and 1839 led ultimately to an economic recession and massive defaults on state bonds, for which the Federal government would not provide a bailout, as it had in 1790 in the aftermath of the Revolutionary War[6]. The crisis, however, led more than half of the states to rewrite their state constitutions in the 1840s to require balanced budgets (Wallis, 2005; Sargent, 2012). This, together with the weak economic conditions of the early 1840s had a substantial effect on railroad investment volumes, which fell through 1843.

The national government attempted to ameliorate the situation somewhat by providing land grants first to the states, and then to railroads directly. The State Selection Act of 1841 granted to most midwestern, southern, and newly-admitted states 500,000 acres of land to be sold, with the proceeds to be used for internal improvements. This, of course, was a time consuming process. The Federal Land Grant Act of 1850 provided a stimulus to railroad investment by promoting a railroad that would run from the Great Lakes to the Gulf of Mexico. This generated a substantial increase in investment volumes across Illinois, Indiana, Ohio, and Michigan as lines (the Illinois Central, Ohio Central, and Michigan Central) grew to accommodate expansion to the south and west.

The early to mid-1850s was a time of expansion. Generally rising prices, increased speculation by opportunistic investors, particularly with regard to the effect of railroad investment on land values, aggravated by the land grants, however, contributed, in part, to the Panic of 1857

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[5]Taylor (1951, p. 92) notes that a census report from 1838 concluded that state debts totaling $43 million could be attributed to railroads. That is roughly $1billion in 2014 dollars using the consumer price index to adjust or $450 billion using the equivalent share of GDP to adjust. CPI from Officer and Williamson (2014).

[6]By 1842 eight states and the Territory of Florida were in default on interest payments. Two states ultimately repudiated their debts and three states partially repudiated. Total state debts in 1841 were $190 million (roughly $5.6 billion in 2014 dollars using the consumer price index to adjust). Eight states had no debt (Wallis, 2005; Measuring Worth).

and the collapse of several banking institutions.[7] The railroads themselves may not have been responsible for the panic. As one contemporary noted, "Up to August 1857, our commercial affairs were generally prosperous. The local journals throughout the country represented business as in a wholesome condition. High prices were said to have enriched the farmer, stockgrower, and the planter. Trade and mechanical industry flourished with corresponding success. In estimating probabilities for the future, great stress was laid on the fact, that the madness of railroad building was arrested" (Gibbons, 1859, p. 343).

3. Preliminary Statistical Analysis

This section provides a preliminary statistical analysis of the time series properties of the investment and GDP series employed here. We further discussion model specification issues and address the important issued of granger causality between railroad investment and GDP growth in the antebellum United States.

3.1. Univariate and cointegration analysis

In order to determine the order of integration of the variables, we use the Augmented Dickey-Fuller (ADF) t-test to test the null hypotheses of a unit root. We use the Bayesian Information Criterion (BIC) to determine the optimal number of lagged differences to be included in the regressions, and we include deterministic components in the regressions if they are statistically significant. The possibility of a structural break is considered at every stage of the analysis.

Table 2 and Table 3 present unit root test results, both the Augmented Dickey Fuller test results and the Zivot-Andrews test results, which accommodate the possibility of an endogenously

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[7]Between 1850 and 1857 the national government granted just over 32 million acres of land to states or companies to be used for internal improvements, the vast majority of which were for construction of railroads. It granted another 126 million acres between 1862 and 1871. The Panic of 1857 halted this land policy temporarily and the Credit Mobilier scandal of 1873 ended it once and for all. Details can be found in Donald (1911).

determined structural break. Unit root test results suggest that both GDP and railroad investment are non-stationary in levels but stationary in growth rates around a deterministic constant. Now that we have established that both series are I(1), we test for cointegration. Table 4 and Table 5 present the Engle Granger and Gregory Hansen cointegration test results. These test results suggest a failure to reject the null hypothesis of no cointegration. This is to be expected due to the rather incipient nature of the technology and resulting inability to reach and maintain a stable equilibrium ratio.

3.2.   VAR specification and Estimation

We have now determined that both variables are I(1) and that they are not cointegrated. Given the non-stationarity of the variables, we follow the standard procedure in the literature and determine the specifications of the VAR models using first differences of log levels, i.e. growth rates of the original variables.

The candidates for potential breakpoints are determined empirically by selecting the break in the constant for each equation in the VAR that yields the largest t-statistic among all possible breakpoints (excluding 15 percent of the beginning and the end of the sample from consideration). Our results suggest a break point in 1851 (see Figure 2). This period marks also the start of legislation facilitating substantial federal land grants to rail holdings and the start of westward expansion via the transcontinental railroad.

The specification of the VAR structure, in terms of the order of the VAR and the deterministic components are determined by the BIC. The model selection leads to the choice of a VAR(1) with a constant and a break in 1851 (see Table 6). The estimated system is presented in Table 7. The Portmanteau test for joint residual autocorrelation yields a Chi-squared test statistic of 69.9663 with corresponding p-value of 0.1778 indicative, through the failure to reject the null of no serial correlation, that the dynamics of the model are adequately specified. The multivariate

generalization of the Jarque Bera tests based on the skewness and kurtosis in the residuals allows us to conclude that normality for the residuals appears to be a valid assumption given the joint p-value of 0.4160. These considerations suggest that the VAR system is well specified.

The variance decomposition indicates that 21.36% of the 20-step ahead forecast mean squared error (MSE) for the growth rate of GDP is due to the growth in railroad investment, which provides a preliminary view of the importance of railroad infrastructure to economic growth in the antebellum United States.

3.3.   Granger Causality

The issue of causality is particularly important in identifying the effects of railroad infrastructure on economic performance, that is, did railroads induce or follow economic growth? It is certainly plausible, given the high internal rates of return reported for infrastructure investment, and the participation of the public sector in this endeavor, that patterns of railroad investment may have been responsive to economic conditions, an idea that would also suggest a degree of reverse causality. Expansionary economic conditions may increase the availability of private capital and, by expanding tax bases, increase the capacity for the public sector to provide support for railroad construction. In addition, the expansion of the network may have been designed to serve the needs of regions where migration and subsequent growth in activity manifested sufficient demand for these transportation services to justify their construction.

The VAR framework here employed allows us to further examine this relationship directly by testing for Granger causality between economic growth and railroad infrastructure investment during the antebellum period

The significance of lagged railroad investment in the output equation and lagged output in the railroad infrastructure investment supports bidirectional causality between railroad infrastructure

investment and GDP. That is, railroad infrastructure granger caused growth from a time series perspective while the reverse is also true, economic growth also stimulated an increase in railroad investment. This is consistent with a casual observation of the graphs in Figure 1 were it seems indeed that sometimes growth of the GDP leads growth in railroad investment. These dynamic feedbacks are consistent with bi-directional causality made possible by the expansionary effects of railroad infrastructure investment on incomes and tax revenues and in the expansion of the rail network into new areas following the movement of people and activities.

This immediately addresses the first question we pose: Did railroad investment precede or follow economic growth? The answer, naturally, is that railroad investment did stimulate growth while at the same time was responsive to economic conditions. In response to this question, Fishlow (1965) notes that railroads were not built "ahead of demand." They tended to be built incrementally into areas that already had been settled. Atack, Bateman, Haines and Margo (2010) further reinforce this conclusion in their analysis of 1850-1860 investment and population density and urbanization patterns. These considerations highlight the need to examine the effects of railroad investment in a dynamic framework that explicitly addresses bi-directional causality between the variables.

4. Identifying and Measuring the Effects of Innovations in Railroad Investment

This section describes the methodological approach employed to estimate the effects of railroad infrastructure on economic growth. These effects are based on identifying the effects of innovations in railroad investment in a dynamic context based on our orthogonalization strategy for the variance covariance matrix of the VAR residuals. We also describe the approach to calculating the accumulated elasticities and marginal products for railroad investment.

4.1.   Identifying the Effects of Innovations in Railroad Investment

We use the impulse-response functions associated with the estimated VAR models to examine the effects of railroad infrastructure investment on economic performance. In this context our methodology allows dynamic feed-backs among the different variables to play a critical role. This is true in both the identification of innovations in the railroad investment variables and the measurement of the effects of such innovations.

The central issue for the determination of the effects of railroad infrastructure investment on the economic variables is the identification of shocks to railroad infrastructure investment that are not contemporaneously correlated with shocks in these variables, i.e., shocks that are not subject to the reverse causality problem. In dealing with this issue we draw from the approach typically followed in the literature on the effects of monetary policy [see, for example, Christiano, Eichenbaum and Evans (1996, 1998), and Rudebusch (1998)] and adopted by Pereira (2000) in the context of the analysis of the effects of infrastructure investment.

Ideally, the identification of shocks to railroad infrastructure investment which are uncorrelated with shocks in other variables would result from knowing what fraction of investment in each period is due to purely non-economic reasons. The econometric counterpart to this idea is to imagine a policy function which relates the rate of growth of railroad infrastructure investment to the relevant information set; in our case, the past and current observations of the growth rates of output. The residuals from this policy function reflect the unexpected component of the evolution of railroad infrastructure investment and are uncorrelated with other innovations.

In the central case, we assume that the relevant information set for the policy function includes past values but not current values of the economic variables. This is equivalent in the context of the standard Choleski decomposition to assuming that innovations in railroad investment

lead innovations in GDP. This means that while innovations in railroad infrastructure investment affect economic output contemporaneously, the reverse is not true.

We have three reasons for making this our central case. First, it seems reasonable to believe that the economy reacts within a year to innovations in infrastructure investment decisions. Second, it also seems reasonable to assume that the relevant economic agents are unable to adjust railroad investment decisions to innovations in the economic variables within a year. This is due to the time lags involved in information gathering and public decision making. Finally, the opposite orthogonalization strategy implies that railroad investment has no effect on GDP on impact.

4.2.   Impulse Response Functions

We present the impulse response function and accumulated impulse response function for railroad infrastructure investment during the antebellum period together with 95% confidence bands. The impulse response functions and the accumulated impulse-response functions as well as the corresponding confidence bands that characterize the likelihood shape are presented for railroad infrastructure investment during the antebellum period in Figure 3. These figures show the cumulative effects of shocks to investment based on the historical record of 31 years of data as filtered through the VAR and the reaction function estimates described above. The accumulated impulse response function converges within a very short time period suggesting that most of the growth rate effects occur within the first few years after the shocks occur. Accordingly, we present the accumulated impulse response results for only a twenty-year horizon.

The error bands surrounding the point estimates for the accumulated impulse responses convey uncertainty around estimation and are computed via bootstrapping methods. Evidence exists that nominal coverage distances may under represent the true coverage in a variety of situations (Kilian, 1998). Thus, the bands presented are wider than the true coverage would suggest. The error

bands for our accumulated impulse response functions suggest a high degree of precision in our estimates for the effect of railroad investment on output and significant short-term effects, that is effects on impact or demand side effect.

4.3. Measuring the Effects of Innovations in Railroad Investment

Our analysis of the effects of railroad infrastructure investment on economic activity is based on the analysis of the elasticities and marginal product figures computed from the information provided by the impulse response function. However, these concepts are used in a way that departs from conventional definitions because they are not based on *ceteris paribus* assumptions, but include all the dynamic feedback effects among different variables.

Table 9 presents the elasticity of output with respect to railroad investment. The long-term accumulated elasticity is interpreted as the total accumulated percentage point long-term change in GDP, for each one-percentage point accumulated long-term change in railroad investment. That is to say, the elasticity indicates the extent to which each GDP changes as a result of an unexpected one percentage point increase in the growth rate of railroad investment in a specific year. This estimated elasticity takes into account not only the impact of railroad investment on impact but all subsequent feedbacks through time during which railroad investment and economic conditions responded to that initial shock. Because railroad investment is an endogenous variable, the variations produced in GDP will also affect its growth rate, and this variation will, in turn, affect investment levels. This process will continue until the effects of the initial shock in the growth rate of railroad investment are completely diluted and will no longer affect the evolution of the GDP.

Therefore, the accumulated elasticity of GDP with respect to railroad investment will be calculated by dividing the accumulated change in output by the accumulated variation in railroad investment. Thus,

$$\varepsilon_{GGDP,GPINV} = \frac{dGGDP/GGDP}{dGPINV/GPINV} = \frac{dGGDP}{dGPINV}\frac{GPINV}{GGDP},$$

Table 9 presents the marginal product for output with respect to railroad infrastructure investment. The long-term accumulated marginal product of railroad infrastructure investment measures the dollar change in output for each additional dollar of investment in railroads during the antebellum period. The marginal product figures are obtained by multiplying the average ratio of output to railroad investment levels, over the sample, by the corresponding elasticity:

$$dGGDP = \varepsilon_{GGPD,GPINV}\frac{GGDP}{GPINV}dGPINV,$$

Using the average ratio of output to the level of railroad investment allows the marginal product figures to reflect the relative scarcity of the railroad infrastructures without letting these ratios be overly affected by business cycle factors. We further assess the evolution of the marginal product over time by considering the ratio of output to railroad investment levels for ten-year periods between 1828 and 1860.

Finally, the annual rate of return is calculated from the marginal product figures by assuming a useful life schedule for railroad capital assets consistent with its observed implicit depreciation rate. The rate of return is the annual rate at which an investment of one dollar would grow over the lifetime of the asset to yield its accumulated marginal product,

$$dGGDP = (1+r)^t.$$

5.   On the Impact of Railroad Investment in the Antebellum United States

5.1.   On the Overall Long-term Effects of Railroad Investment

Our estimates suggest that railroad investment had a substantial impact on economic growth in the antebellum United States. Results are presented in Table 9. The elasticity of output with respect to railroad investment is 0.048 with a corresponding marginal product of 4.2[8]. The marginal product figure indicates that one dollar invested in railroads yields a $4.2 accumulated increase in GDP over the long-term.

These economic effects correspond to a 15.5% rate of return when considering a 10–year lifetime for railroad capital. Rails in the antebellum period were typically built of wood and iron. The weakness in these materials quickly became apparent with some sources suggesting a replacement period of less than 5 years. By the 1860s iron was largely replaced with steel rails. Table 10 presents the rate of return for alternative assumptions regarding the lifetime of the capital stock.

5.2.   Short Term versus Long Term Effects

Railroad investment has fundamentally two important contributions to economic conditions. First, the construction of the rail lines requires the allocation of resources which can stimulate demand. This stems from the employment of labor in the construction of the railroad and subsequent spending induced by payments to workers. In addition, railroad construction required the purchase of raw materials that supported iron foundries, rolling mills and machine shops which prepared iron and other metals required to furnish the rails, spikes, sills, frogs, levers and switches needed to lay track. Over the long run, however, the importance of the railroad in accessing regions distant from waterways and the network spillovers manifest by the presence of the railroad are

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[8] The estimated elasticity under the alternative, and somewhat less plausible, orthogonalization is approximately 42.8% as large, 0.02073, with an equivalent reduction in the marginal product.

another important driver in the positive impact of railroad investment on economic growth and in lower transportation costs. Thus, we can decompose the effect of railroad investment into contemporaneous effects as well as those that result from the dynamics of the process accumulated over time. These results are presented in Table 9. The immediate short-term effects are to be interpreted as essentially demand-side effects induced by the construction of the railroad itself while the accumulated long term effects include also the supply side impact over time as the effects of railroad investment reverberate through the economy.

Our results also show that about one-third of the overall effect of railroad infrastructure investment occurs contemporaneously. This corresponds to a marginal product of $1.6. The interpretation of this effect is that a one dollar increase in railroad investment stimulates a $1.6 dollar increase in GDP within the first year. These effects are naturally dominated by demand side innovations and the short-term stimulus to economic activity stemming from construction efforts and associated industries. Thus the bulk of the estimated effect, nearly two thirds of the total effect of railroad infrastructure investment, stems from network effects that contribute towards the reduction in transportation costs.

5.3. On the Evolution of the Marginal Product

The marginal product of output with respect to railroad investment is computed using the ratio of GDP to the stock of capital and the ratio of the stock of capital to investment volumes for the entire sample horizon. This period is chosen to reflect the impact of railroad investment from its inception until just prior to the Civil War and to ensure that the results are not overly affected by business cycle fluctuations.

To assess the effects of scarcity on the marginal products during the antebellum period, we present the marginal product of output with respect to railroad capital using alternative time periods

for the computation of the ratio of GDP to railroad investment. In particular, we consider the 10-year moving average for the two ratios beginning in 1828 which reflects the evolution of the relative scarcity of railroad infrastructure over the time period under consideration.

Figure 4 presents the marginal products for output with respect to railroad infrastructure investment using different periods for the ratio of GDP to railroad investment. The information provided here is particularly useful in depicting the diminishing marginal productivity of railroad investment. This diminishing marginal return is consistent with economic theory and suggests that with a more developed stock of infrastructure incremental additions through investment will have progressively smaller economic effects. We would expect a general pattern of a decreasing marginal product as the stock of railroad infrastructure increased time. Indeed, we observe that the marginal product was initially very high, around 8 to 9 dollars but that it decreased over time reaching a low of between 2 and 3 dollars when only the 40s and 50s are considered in the computations of the marginal product.

6. Contribution of Railroad Infrastructure Investment to the Antebellum Economy

In order to assess the contribution of railroad infrastructure investment to economic growth we must accommodate the dynamics of the relationship as well as the fact that our estimates for the elasticity and marginal product reflect the accumulated effect of railroad investment once the dynamic feedbacks between railroad investment and GDP are accounted for.

We proceed in two steps. First, we isolate innovations in railroad infrastructure investment that are not due to momentum driven by investment in previous years. To this effect we use the information from the impulse response functions to identify changes in investment that are not driven by the initial shock. Once we have identified the volume of investment in each year that is

exogenous to the system, we decompose the marginal product figure on an annual basis, by interpreting the change in output relative to the initial contemporaneous change as incremental growth in output stemming from the dynamic process. This allows us to estimate, on an annual basis, the percent of output due to exogenous investments in railroad investment while taking into account the relative scarcity of the infrastructure stock.

The results of this historical analysis suggest that 2.54% of GDP between 1828 and 1860 can be attributed to investment in railroads. This effect varies substantially over time due to both varied investment volumes as well as the evolution of the marginal products through time. The largest effects are measured in the early 1850s, which, despite somewhat small marginal products reflective of the already substantial accumulated investment invest, where the years during which railroad investment reached its maximum levels over the sample period. Between 1848 and 1854, railroad investment, in these and in preceding years, contributed to 4.31% of GDP. Overall, the 1850s are the period in which railroad investment had the most substantial contribution to economic conditions, 2.93% of GDP, relative to 2.51% during the 1840s and 2.49% during the 1830s, driven by the much larger investment volumes during the period.

It is useful to compare these estimates to those obtained by Fishlow and by Fogel following the social savings approach. Based on a hypothetical second-best transportation system with no railroads, Fogel (1964) calculated the impact of the railroad to be less than 5% of GNP in 1890. Fishlow (1965) calculated a social saving of roughly the same magnitude, 4% of GNP, for 1859, but he argued that if this were extrapolated to 1890, it would represent a social saving of at least 15% of GNP. To put these figures in perspective, our estimates of the total contribution of railroad infrastructure investment to economic growth between 1828 and 1860 based on the estimated marginal product suggest that 2.9% of GDP over this period can be attributed to railroad infrastructure investment.

7. Concluding Remarks

This paper is motivated by the desire to answer three fundamental questions regarding railroad investment in the antebellum United States using state of the art time series econometric methods. The three questions we are concerned with are 1) Did railroad investment follow or precede economic growth in the antebellum period? 2) What were the effects of railroad investment on GDP during this time? And 3) How can these effects be decomposed into short-run, contemporaneous effects and long run effects?

We estimate the effect of railroad investment on economic growth in the antebellum period using a bivariate dynamic time series methodological approach. The VAR framework here employed has allowed us test directly for Granger causality between economic growth and railroad infrastructure investment during the antebellum period and support bidirectional causality between railroad infrastructure investment and GDP. This conclusion supports the assertions made by Fishlow (1965) and Atack et al. (2010) and suggests that the identification of the effects of railroad investment requires direct accommodation of the bidirectional causality between railroads and economic conditions.

Furthermore, our estimates suggest that railroad investment had a substantial impact on economic growth in the antebellum United States. The marginal product figure we estimate indicates that one dollar invested in railroads yields a $4.2 accumulated increase in GDP over the long-term. This corresponds to a 15.5% rate of return when considering a 10–year lifetime for railroad capital or 10.1% with a 15-year lifetime implied by a 7% depreciation rate. To put these figures in perspective, Fishlow (1965) estimates that the social rate of return on antebellum railroads was 15-20% per annum based on a 7% depreciation rate.

We can decompose the effect of railroad investment into contemporaneous effects as well as those that result from the dynamics of the process accumulated over time. The immediate short-

term effects are to be interpreted as essentially demand-side effects induced by the construction of the railroad itself while the accumulated long term effects include also the supply side effects reflective of the reduction in transportation costs. Our results also show that about one-third of the overall effect of railroad infrastructure investment occurs on impact. The short-term demand effects are, therefore, substantial. The bulk of the estimated effect, however, nearly two-thirds of the total effect, stems from the long-term, supply side effects.

Our results further allow us to capture the diminishing marginal productivity of these investments as the stock increases. We observe that the marginal product was initially very high, around 8 to 9 dollars but that it decreased over time reaching a low of between 2 and 3 dollars when only the 40s and 50s are considered in the computations of the marginal product.

Our estimates of the total contribution of railroad infrastructure investment to economic growth between 1828 and 1860 based on the estimated marginal product suggest that 2.9% of GDP over this period can be attributed to railroad infrastructure investment. Fogel (1964) calculated the impact of the railroad to be less than 5% of GNP in 1890. Fishlow (1965) calculated a social saving of roughly the same magnitude, 4% of GNP, for 1859, but he argued that if this were extrapolated to 1890, it would represent a social saving of at least 15% of GNP. Therefore, our results are somewhat lower than those indicated by Fishlow (1965) and support Fogel's (1979) assertion that the social savings approach is designed to provide an upper bound.

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Table 1 Average Growth Rate for Real GDP and Railroad Investment by Decade, 1828-1860

	1828-60	**1830-39**	**1840-49**	**1850-59**
Growth Rate of Real GDP	4.58	4.45	4.22	5.53
Growth Rate of Net Railroad Capital Formation	17.24	31.45	8.43	1.84
Net Railroad Capital Formation (% of GDP)	0.94	0.60	0.68	1.72

Note: Geometric mean growth rates presented.
Source: Johnston and Williamson (2008), Fishlow (1965) and Authors' Calculations

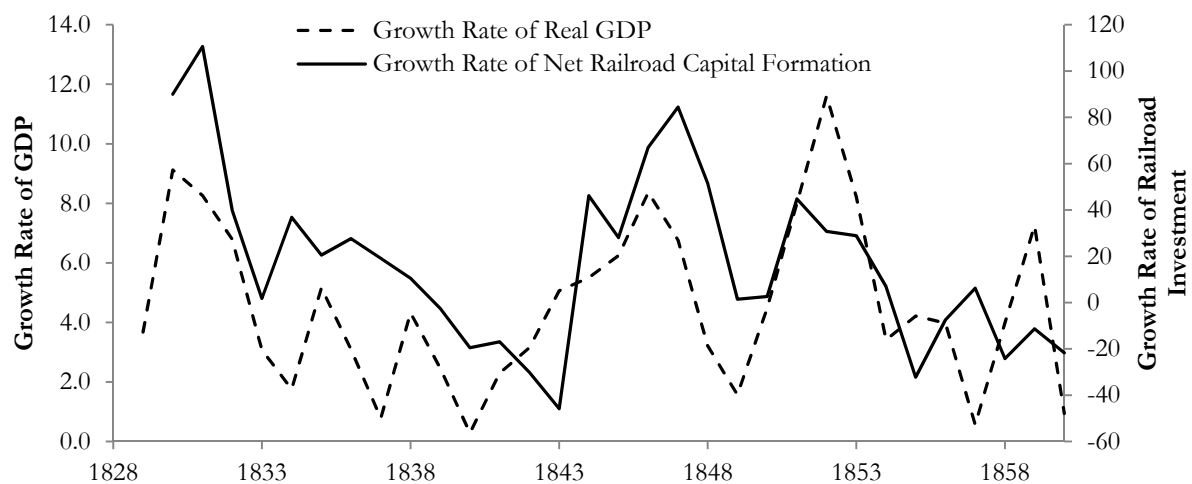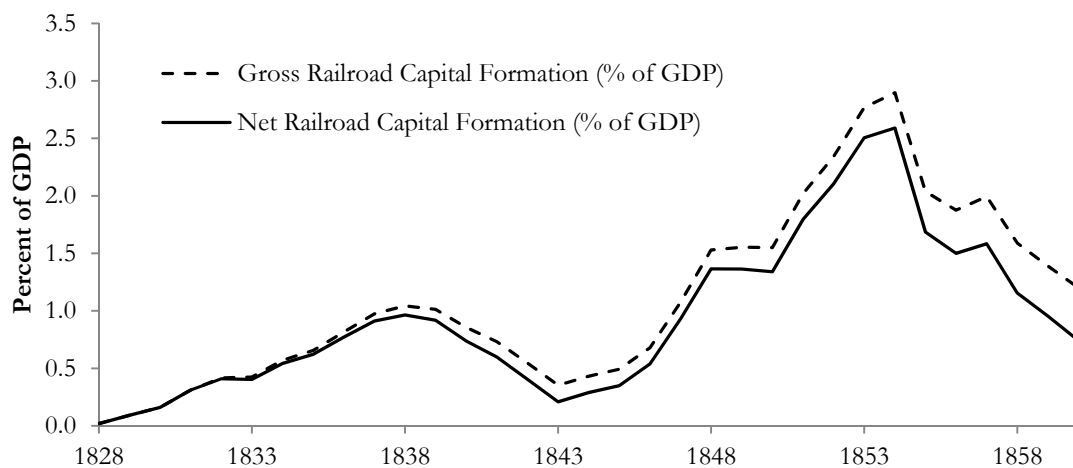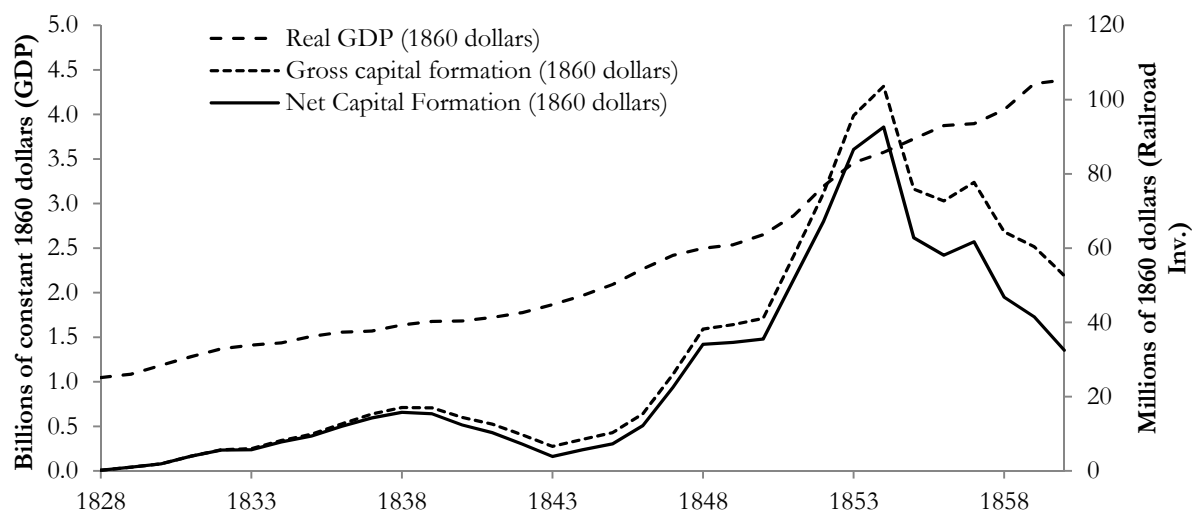*Figure 1 Railroad investment in the United States between 1828 and 1860*

Table 2 Augmented Dickey Fuller Unit Root Test

Variable	Deterministic Components	Lags	ADF Test Statistic
Growth Rate of GDP	Constant	1	-3.858
Growth Rate of Railroad Investment	Constant	1	-3.153

Critical Values - 1%: -3.716; 5%: -2.986; 10%: -2.624

Table 3 Zivot Andrews Unit Root Test

Variable	Break	Date of Break	Lags	Zivot-Andrews Test Statistic
ln(GDP)	Constant and Trend	1839	1	-4.160
ln(Railroad Investment)	Constant and Trend	1846	1	-2.589

Critical Values - 1%: -5.57; 5%: -5.08; 10%: -4.82

Table 4 Engle Granger CointegrationTest

Endogenous Variable	Deterministic	Lags	Test Statistic
ln(GDP)	Constant and Trend	1	-1.640
ln(Railroad Investment)	Constant and Trend	1	-1.257

Critical Values - 1%: -4.845; 5%: -4.090; 10%: -3.724

Table 5 Gregory Hansen Cointegration Test

Endogenous Variable	Break	Date of Break	Lags	Test Statistic (ADF)
ln(GDP)	Constant	1855	0	-2.61
ln(Railroad Investment)	Constant	1855	0	-3.99

Critical Values - 1%: -5.13; 5%: -4.61; 10%: -4.34
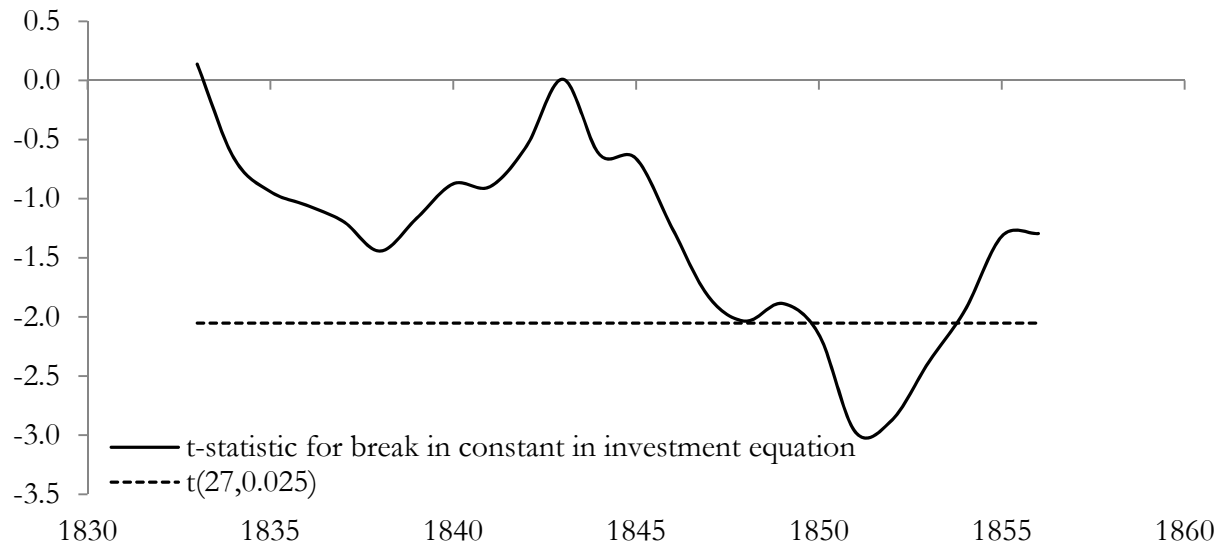
Figure 2 Endogenous Determination of Break in the Constant

Table 6 Model Selection (BIC)

Deterministic Components	Order	No Breaks	One Break (1851)
None	1	-9.82	-10.10
Constant	1	-10.13	**-10.38**
Constant and Trend	1	-10.29	-10.34
None	2	-9.77	-9.89
Constant	2	-10.10	-10.26
Constant and Trend	2	-10.13	-10.19

Table 7 Vector Auto-regression Equation Estimates

	Output	**Gross Investment in Railroads**
$Output_{t-1}$	0.348	6.515**
	(0.173)	(1.794)
$Railroad\ Investment_{t-1}$	0.0135*	0.209**
	(0.00620)	(0.0643)
1851 *Indicator*	0.00949	-0.227*
	(0.0102)	(0.106)
Constant	0.0227*	-0.125
	(0.00908)	(0.0942)
N	31	31
R^2	0.318	0.579

Standard errors in parentheses; * $p<0.05$, ** $p<0.01$

Table 8 Forecast Error Variance Decomposition for the Growth Rate of GDP

	Percent due to Railroad Investment
Period 0	0.15594
Period 1	0.19761
Period 2	0.20841
Period 3	0.21185
Period 4	0.21299
Period 5	0.21337
Period 20	0.21357

Figure 3 Impulse Response Functions

Impulse Response Function

Accumulated Impulse Response Function
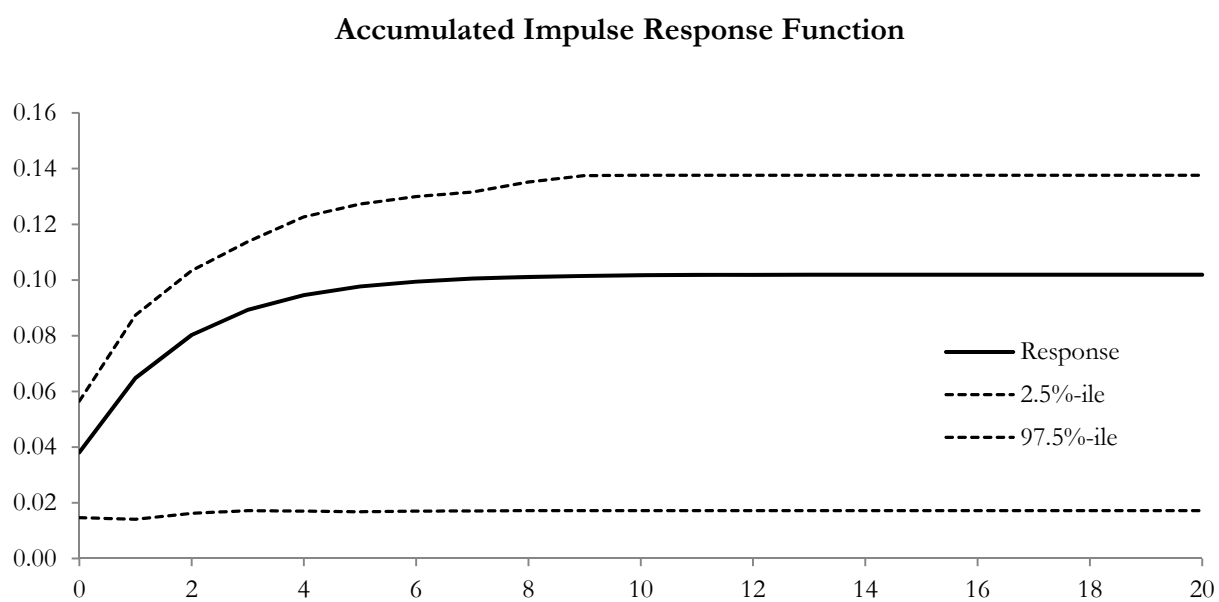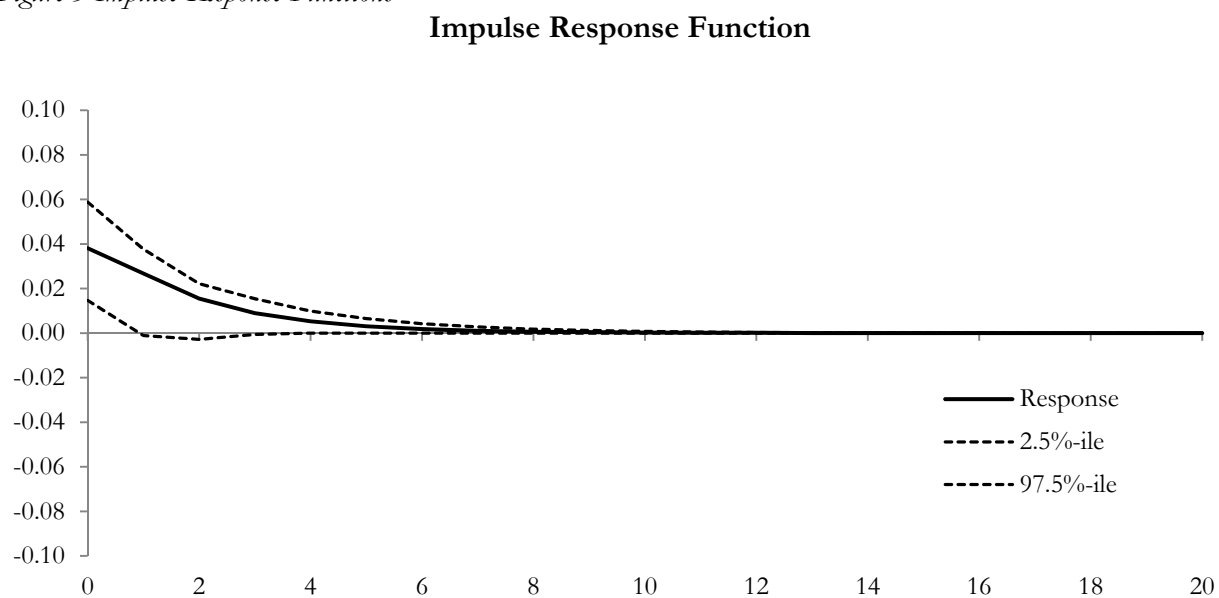
Table 9 Effects of Railroad Infrastructure Investment

	Elasticity	**Marginal Product**
Railroad Investment – Total long-term effect	0.04847	4.22
Railroad Investment – Short-term effect	0.01810	1.57
Ratio of Contemporaneous to Long Term Effects	37.3%	

Table 10 Rate of Return to Railroad Infrastructure Investment in the Antebellum United States

Lifetime of the Capital Asset	**Rate of Return**
5	33.4
10	15.5
15	10.1
20	7.5
25	5.9

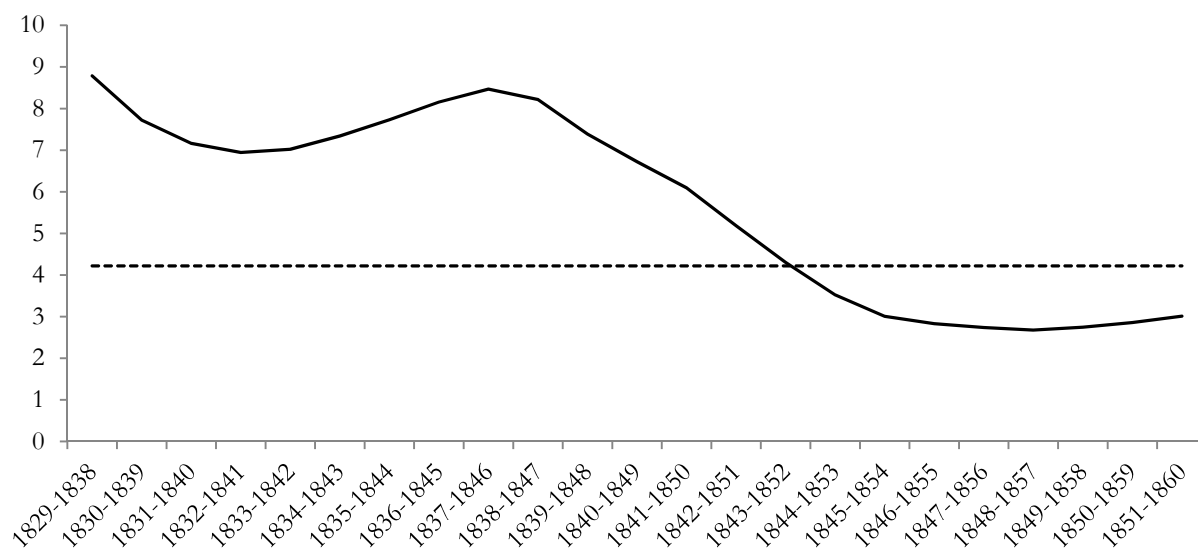*Figure 4 Marginal Product for Railroad Investment in the U.S. by Decade*

Figure 5 Effect of Railroad Infrastructure in the Antebellum United States