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RAILROAD INFRASTRUCTURE INVESTMENTS AND ECONOMIC DEVELOPMENT IN THE ANTEBELLUM UNITED STATES

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We measure the overall impact of railroad investment on economic development in the antebellum period in the United States using a vector autoregressive approach. Our results can be summarized as follows. First, we find bidirectional causality between railroad infrastructure investment and GDP. Second, we estimate a marginal product of $4.2 for railroad investment which corresponds to a 15.5% rate of return when considering a 10–year lifetime for railroad capital. While about two-thirds of this effect stems from the supply side, short run demand side effects also are substantial. Third, given the low effective tax rates practiced in the 1830s and the magnitude of the effects of railroad investment we estimate, it is very likely that these investments were not self-financing and may, therefore, have contributed to the high levels of public indebtedness observed in the period.

Keywords: Railroad; Infrastructure Investments, Economic Development, Antebellum United States, Vector Auto-Regression
JEL Classification: H54, N71, R42

1. INTRODUCTION

Railroads played a major role in the development of the antebellum United States. 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 became faster, more reliable, safer, and hence more economical. For some time economists and historians have tried to specify and carefully measure these impacts (for recent contributions see, for example, Rousseau and Sylla, 2005; Atack et al., 2008; Atack and Margo, 2011; Donaldson and Hornbeck, 2013; Atack et al., 2014a, 2014b).[1]

* We would like to thank the editor for very helpful comments and suggestions. The usual disclaimers apply.

[1] For recent evidence on the role of railroad investments in early development in other countries see, for example, Herranz-Loncan (2004, 2007), Trew (2008), Donaldson (2010), Tang (2013), Berger and Enflo

And yet, several important questions remain unanswered. First, what was the overall impact of railroad investment on economic development in this period? Second what was the impact of railroad investment in this period on public state budgets?

At the most fundamental level, there is the question of causality. It is often implicitly assumed in measuring the effects of railroad investments that they led to economic development. Yet, the possibility of feedback effects from economic conditions to railroad investment is ignored. But there exists evidence for such effects. Fishlow (1965) tested Schumpeter's hypothesis of construction ahead of demand and finds that railroads tended to be built incrementally into areas that already had been settled (see Fogel, 1979). Atack et al. (2010) further reinforce this conclusion in their analysis of investment, population density, and urbanization patterns between 1850 and 1860.

It is indeed likely, given the high internal rates of return reported for railroad investment and the participation of the public sector in this endeavor, that patterns of railroad investment may have been responsive to economic conditions. Expansionary economic conditions 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. These concerns support the need to accommodate the possibility of reverse causality between economic development and railroad investment when measuring the effects of railroad construction on economic development.

In a more general vein, the heart of the social savings approach traditionally used to measure the economic effects of railroad investment (see Fogel (1964) and Fishlow (1965) for the seminal contributions), rests on the idea that lower transportation costs are the central component of the effects of railroads on economic development. A key criticism of this approach is that it is equipped to measure only these direct gains and not any indirect benefits stemming from demand side effects (see, for example, Leunig, 2010).

Indeed, railroad investment should be expected to have two fundamentally different types of contributions to economic development. First, the construction of the rail lines required the allocation of resources which may stimulate demand. This stems from the purchase of raw materials that supported the iron foundries, rolling mills and machine shops that prepared iron and other metals required to furnish the rails, spikes, sills, frogs, levers and switches needed to lay track. In addition, the employment of labor in the construction of the railroad and subsequent spending induced by payments to workers may contribute to greater levels of output. Over the long run, however, the importance of the railroad in accessing regions distant from waterways and the network spillover effects induced by their presence are an important driver in the positive impact of railroad investment on economic growth and in lowering transportation costs. There is

(2014), and Felis-Rota (2014).

scant evidence on how the effects of railroad investment may be decomposed between short-term – demand side effects – and long term – supply side effects (see, for example, Berger and Enflo, 2014).

Many of the early railroads were privately financed through the sale of corporate securities to the citizens and businesses along the proposed routes. National, state, and local governments supplemented and supported railroad construction enterprises. Railroads were granted liberal charters, grants of land, some were granted banking and lottery privileges, and in some cases, states and even cities actually built and managed railroads (see, Taylor, 1951). In addition, a critical component of government aid was direct financial support, which generated a substantial amount of state debt. Much of this support was justified by the assertion that the economic growth, particularly growth in land values, stemming from these 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. Clearly, an analysis of the fiscal implications of railroad investments rests critically on their effects on economic performance and provides important insights for assessing the contribution of these investments to state debt levels.

In this paper we analyze the impact of railroad investment on GDP in the antebellum United States in a way that addresses three questions directly related to the discussions above. First, did railroad investment follow or precede economic growth? Second, what were the effects of railroad investment on GDP during this time and how can they be decomposed into short-run and long-run effects? And, third, were railroad investments self-financing for the public sector?

To address these questions, we adopt the VAR approach initially developed in Pereira (2000, 2001). This approach has become standard in the evaluation of the impact of infrastructure investment (see Pereira and Andraz (2013) for a literature survey). This methodological approach addresses several criticisms levied against the social savings approach to evaluating the impact of railroad investment. It directly considers the possibility of reverse causality, i.e., economic conditions serving as a driving force in railroad investment. It allows us to measure both the short-term and long-term impact of railroad investment and thus goes beyond the direct gains from lower transportation costs.[2]

[2] This type of methodological approach has recently also been employed in examining infrastructure investment and economic development in the Netherlands between 1853 and 1913 (see Groote et al., 1999), in Spain between 1850 and 1935 (see Herranz-Loncan, 2004, 2007) and for 1850 to 1920 for a panel of thirteen European countries (Felis-Rota, 2014). It was also employed by Rousseau and Sylla, (2005) to show that the expansion of the banking and financial system as these new transportation technologies emerged was instrumental in economic growth between 1790 and 1850.

2. RAILROAD INVESTMENT IN THE ANTEBRLLUM UNITED STATES

We consider the period 1828 to 1860. Annual data for net railroad investment are from Fishlow (1965) while data for real GDP are from Williamson (2014). Both variables are measured in millions of constant 1860 dollars. Summary information is presented in Figure 1 and Table 1.

Ground was broken in 1828 for the first major line, the Baltimore and Ohio Railroad. The three decades that followed marked tremendous growth in investment in railroads. Between 1828 and 1860, GDP grew at an annual rate of 4.6% while railroad investment grew annually at a rate of 17.2%. 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.

Between 1830 and 1839, investment in railroads grew at an average annual rate of 31.5%, rising from 0.2% of GDP in 1830 to above 0.9% in 1839. The dual Panics of 1837 and 1839 led to an economic recession and massive defaults on state bonds. This, together with the weak economic conditions of the early 1840s had a substantial effect on railroad investments, which fell through 1843. The national government attempted to ameliorate the situation by providing land grants first to the states, and then to railroads directly, and investment continued to grow through the 1840s at 8.4% per year.

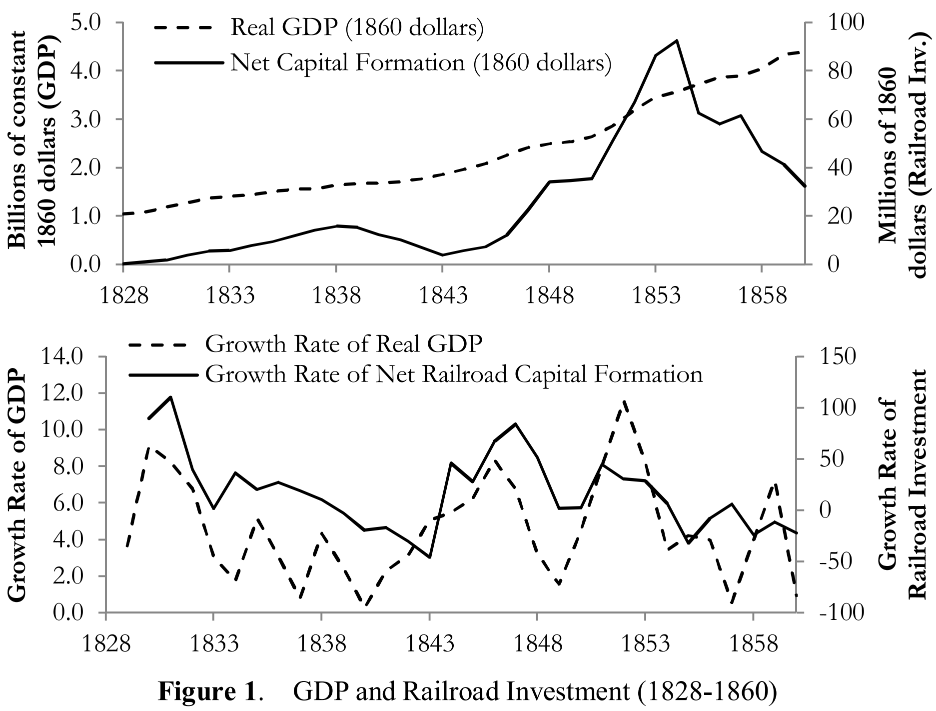

Figure 1. GDP and Railroad Investment (1828-1860)

Table 1. GDP and Railroad Investment (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

Notes: Geometric mean growth rates presented.

Source: Johnston and Williamson (2008), Fishlow (1965) and Authors' Calculations

Between 1850 and 1859 railroad investments amounted to 1.7% of GDP and reached their maximum levels in 1854 at 2.6%. The Federal Land Grant Act of 1850 provided a stimulus by promoting a railroad that would run from the Great Lakes to the Gulf of Mexico. The early to mid-1850s was a time of expansion. Rising prices and increased speculation, particularly with regard to the effect of railroad investment on land values and further aggravated by the land grants, contributed, in part, to the Panic of 1857 and the collapse of several banking institutions.

3. PRELIMINARY STATISTICAL ANALYSIS

3.1. Unit Roots and Cointegration

To address the issues of unit roots and co-integration we use two sets of tests. One set of tests ignores structural breaks – the Augmented Dickey-Fuller unit root test and the Engle-Granger test for cointegration. The other set allows for the endogenous determination of structural breaks – Zivot-Andrews tests for unit roots and the Gregory-Hansen test for cointegration. The use of the second set of tests is motivated by the fact that tests that ignore existing structural breaks tend to be biased in favor of finding non-stationarity. In all cases, 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.

Table 2. Augmented Dickey Fuller Unit Root Test

	Deterministic Components	Lags	ADF Test Statistic	Critical Values		
				1%	5%	10%
Growth Rate of GDP	Constant	1	-3.858	-3.716	-2.986	-2.624
Growth Rate of Railroad Investment	Constant	1	-3.153	-3.716	-2.986	-2.624

Table 3. Zivot Andrews Unit Root Test allowing for an Endogenously Determined Break in the Deterministic Components

	Break	Date of Break	Lags	Zivot-Andrews Test Statistic	Critical Values		
					1%	5%	10%
Logarithm of GDP	Constant and Trend	1839	1	-4.160	-5.57	-5.08	-4.82
Logarithm of Railroad Investment	Constant and Trend	1846	1	-2.589	-5.57	-5.08	-4.82

The Augmented Dickey Fuller and the Zivot-Andrews tests both suggest that GDP and railroad investment are non-stationary in levels but stationary in growth rates around a deterministic constant. Endogenous structural breaks were identified in the GDP series around 1839, the period of the Dual Panics of 1837 and 1839, and around 1846 in the railroad investment series, as investment takes up again in the aftermath of such panics. As both series are I(1), we test for cointegration. The Engle-Granger and Gregory-Hansen tests both indicate the series are not cointegrated. This is not a surprising result as one would not expect at such an early stage of development for these two variables to show any signs of convergence to a fixed ratio.

3.2. VAR Specification and Estimation

In light of the results above, we follow the standard procedure in the literature and estimate a VAR model in first differences of log levels, i.e. growth rates of the original variables. The specification of the VAR structure, the order of the VAR and the deterministic components are determined by the BIC. Structural breaks are determined endogenously following the procedure in Qu and Perron (2007), where the break point is determined by maximizing the likelihood function conditional on the potential breaks under consideration.

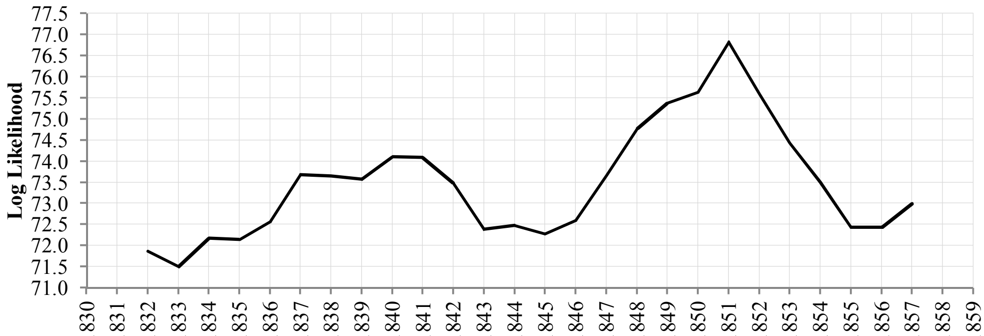

Figure 2. Log Likelihood for the Vector Autoregressive System with a break in the Intercept: Break Point Determination Following Qu and Perron (2007)

Table 4. VAR Estimates

	Output	Gross Railroad Investment
Output_{t-1}	0.376*	6.874***
	(0.176)	(1.688)
$\text{Railroad Investment}_{t-1}$	0.012	0.200**
	(0.006)	(0.060)
1851 Indicator $I(t \leq 1851)$	-0.003	0.304**
	(0.011)	(0.102)
Constant	0.027*	-0.428**
	(0.013)	(0.125)
N	31	31
R^2	0.298	0.629

Notes: Standard errors in parentheses; * p<0.05, **p<0.01

The estimated VAR model is presented in Table 4. The model selection leads to the choice of a VAR of first order with a constant and a break in the constant in 1851. The log-likelihood values for each break point are presented in Figure 2. A likelihood ratio tests indicates that this break point does provide a statistically significant increase in the likelihood.[3] This break point is consistent with the substantial changes in state constitutions precipitated by insolvent budgetary situations stemming from very high levels of public spending and by the Panic of 1837 and 1839. Indeed, between 1842 and 1852, eleven of the 31 U.S. states adopted new constitutions with specific provisions governing the issuance of public debt and therefore support for internal improvement projects such as investments in railroads (see, for example, Wallis, 2005; Sargent, 2012). Furthermore, it is consistent with the inception of the Federal Land Grant Act of 1850 which is associated with a great expansion of the railroad system.[4]

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

[3] We also tested for two breakpoints, for which the years 1850 and 1852 were identified. The likelihood ratio test indicated that these were significant but, due to the proximity of the two dates, one was adopted for reasons of parsimony. The results under this alternative specification of the structural breaks – which are available from the authors upon request - are very close to the results presented here.

[4] It should be pointed out that although the structural breaks identified in the previous section for the individual series and the break here identified for the VAR model do not coincide this does not represent a conceptual or empirical inconsistency. This is because the first set of tests deals with breaks in an individual GDP and railroad investment series while the second deals with breaks in the relationship between the two series. Accordingly, the difference in the two sets of results suggest that the Federal Land Grant Act of 1850 while not affecting each of the two individual series was a game changer in terms of their interaction.

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.

3.3. Granger Causality

The VAR framework allows us to readily test for causality between economic growth and railroad investment during the antebellum period. The significance of lagged railroad investment growth in the GDP equation and lagged GDP growth in the railroad investment equation supports bidirectional Granger causality, i.e., railroad infrastructure leads to improved economic performance but the reverse is also true, improved economic conditions also stimulated railroad investment.

These results are reinforced with Wald tests with test statistics of 4.4815 and p-value of 0.034 for the exclusion of railroad investment from the output equation and a χ^2test statistic of 19.033 with corresponding p-value of 0.000 for the exclusion of GDP from the railroad investment equation. These results are consistent with the assertions of Fishlow (1965) and Atack, et al. (2010). They are also consistent with a casual observation of the graphs in Figure 1 were it seems indeed that, at times, GDP growth leads growth in railroad investment.[5]

4. ON THE IMPACT OF RAILROAD INVESTMENT IN THE ANTEBELLUM UNITED STATES[6]

4.1. Identifying the Effects of Railroad Investment

The central issue for measuring the effects of railroad investment is the identification of shocks to railroad investment that are not contemporaneously correlated with shocks in GDP. 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 et al., 1996; Rudebusch, 1998) and adopted by Pereira (2000, 2001) in the context of the analysis of

[5] From a methodological perspective, these considerations highlight the need to examine the effects of railroad investment on economic performance in a dynamic framework that explicitly addresses bi-directional causality.

[6] Despite the fact that, by construction, our framework allows for consideration of the effects of railroad investments on economic performance as well as the effects of economic performance on railroad investment, the focus of this paper is on the role of railroad investments. As such, the effects of innovations in economic performance on railroad investment are not highlighted. Indeed, the key issue in the literature is to identify how railroad investments affected economic performance and the key point in this paper is to do so while at the same time recognizing and incorporating the existence of feedbacks between the two variables.

the effects of infrastructure investments.

The idea is to estimate a policy function which relates the rate of growth of railroad investment to the relevant information set. The residuals from this policy function, uncorrelated with other innovations, are the unexpected component of railroad investment. We assume that the information set 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 affect economic output contemporaneously but the reverse is not true.[7]

We have several reasons for this assumption. First, it is reasonable to assume that the economy reacts within a year to innovations in railroad investments. Second, it also is reasonable to assume that the relevant economic agents, private and public, 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 alternative strategy has the unreasonable implication that railroad investment has no effect on GDP on impact, that is, there would be no demand side effects from its construction.

4.2. The Impulse Response Functions

The impulse response functions and the accumulated impulse-response functions derived from the VAR estimates and under the procedure discussed above are presented in Figure 3. These functions converge within a short time period suggesting that most of the effects occur within the first few years after the shocks. The 95% error bands surrounding the point estimates for these functions convey uncertainty around estimation

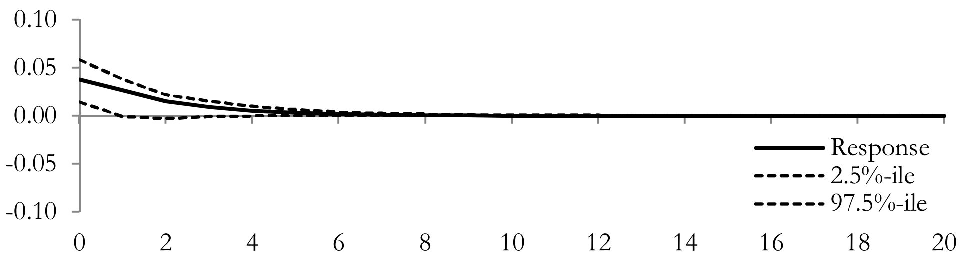

Figure 3. Impulse Response Functions

[7] To be noted, this is completely consistent with the patterns of bi-directional causality identified and discussed above. Indeed, while here the focus is on contemporaneous correlations, meaning interactions within one year, the issue of Granger causality deals with lagged interactions over the time span of one year or more.

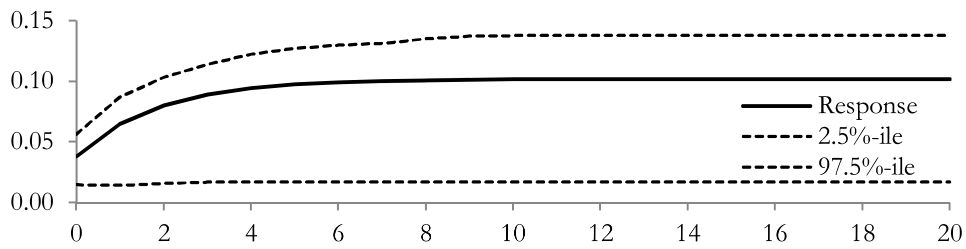

Figure 3. Impulse Response Functions Cont'

and are computed via bootstrapping methods. Evidence exists that nominal coverage distances may under represent the true coverage in a variety of situations (see, for example, Kilian, 1998). Thus, the bands presented are wider than the true coverage would suggest. The error bands we present, therefore, suggest a high degree of precision in our estimates.

4.3. Measuring the Effects of Railroad Investment

Our analysis of the effects of railroad infrastructure investment is based on the estimates of elasticity, marginal product, and rate of return of railroad investments derived from the impulse response function. Results are presented in Tables 5 and 6.

The elasticity is calculated as the total accumulated percentage point long-term change in GDP, for each one-percentage point accumulated long-term change in railroad investment. It takes into account not only the effect of railroad investment on impact but all subsequent feedbacks through time in response to the initial shock.

The marginal product measures the long-term accumulated dollar change in output for each additional dollar of investment in railroads. These figures are obtained by multiplying the average ratio of output to railroad investment levels by the corresponding elasticity. The marginal product is computed using the ratio of GDP to railroad investment 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.

Table 5. Effects of Railroad Infrastructure Investment

	Elasticity	Marginal Product
Railroad Investment – Total long-term effect	0.05	4.23
Railroad Investment – Short-term effect	0.02	1.56
Ratio of Contemporaneous to Long Term Effects	36.9%	

In addition to the long-term accumulated elasticities and marginal products we also consider the short-term elasticities and marginal products. These measure the effects of railroad investment on impact, that is, in the year in which such investments occur. Naturally, and by definition, the long-term accumulated elasticities and marginal products include these effects on impact but also the effects as they accumulate throughout time.

Finally, the annual rate of return is calculated from the marginal product by assuming an economic life for railroad 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 the accumulated marginal product we estimate.

Table 6. Rate of Return to Railroad Investment

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

4.4. On the Long-term Effects of Railroad Investment

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 0.049[8] with a corresponding marginal product of 4.2[9]. The marginal product figure means that in the long term there is a $4.2 accumulated increase in GDP for each dollar invested.

This marginal product corresponds to a 15.5% rate of return when considering a 10–year lifetime or 10.1% with a 15-year lifetime. 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. 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 15-year lifetime or a 7% depreciation rate.

[8] We also estimated the elasticity of industrial production using historical data from Davis (2004). Our estimated elasticity of industrial production with respect to railroad investment is 0.097.

[9] The estimated elasticity under the alternative, and less plausible, orthogonalization assumption is about 42.8% as large, 0.021, with an equivalent reduction in the estimated marginal product.

4.5. On the Short-Term versus Long-Term Effects of Railroad Investment

We now consider the decomposition of the effect of railroad investment into contemporaneous effects and effects that result from the dynamics of the process 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 impact over time as the effects of railroad investment reverberate through the economy.

Our results, also presented in Table 5, 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 long-run network effects that contribute towards the reduction in transportation costs.

4.6. On the Evolution of the Marginal Product of Railroad Investment

To assess the effects of scarcity we calculate the marginal products using alternative time periods for the computation of the ratio of GDP to railroad investment. We consider 10-year moving averages for the ratios beginning in 1828. Results are presented in Figure 4.

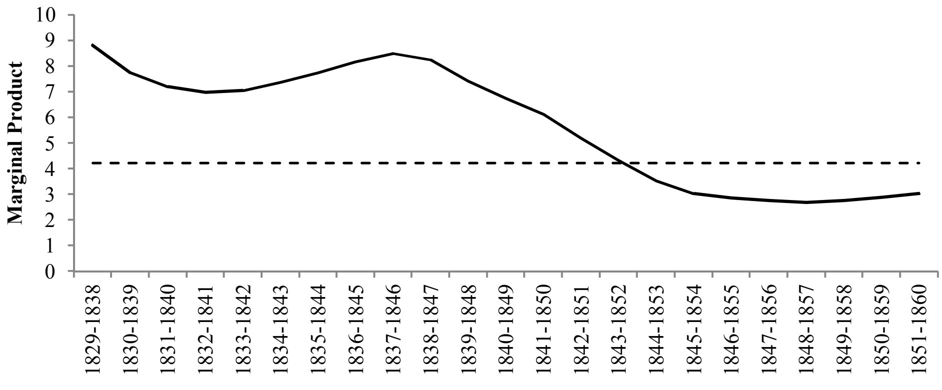

Figure 4. Evolution of the Marginal Product of Railroad Investment

We identify a clear pattern of diminishing marginal productivity of railroad investments. Indeed, we observe that the marginal product was initially consistently very high, around 8 to 9 dollars for the period until the middle 1940s. After that, it shows a clear decline over time reaching a low of between 2 and 3 dollars when more recent time periods are considered in the computations of the marginal product. This diminishing marginal return is consistent with economic theory and suggests that with a more developed stock of railroad infrastructure incremental additions through investment will have progressively smaller economic effects.

4.7. On the Potential Budgetary Effects of Railroad Investment

Finally, and in terms of their budgetary implications, our estimates for the marginal product of railroad investments suggest that, as far as the public sector is concerned, an equilibrium effective tax rate of 23.8% would be required for these investments to be self-financing. Accordingly, as this condition clearly was not met in the antebellum United States, it appears clear that railroad infrastructure investment did not pay for itself during this period. Indeed, the stimulus to economic performance induced by railroad investment was markedly insufficient, given the prevailing effective tax rates in the economy – estimated to be between 4% and 5% of GDP during the period (see, for example Howe and Reeb, 1997; Wallis, 2000) – to cover the capital investments undertaken.

Even the relatively higher marginal products we identified earlier in the period would require effective tax rates of around 12.5%. Accordingly, given the low effective tax rates practiced in the 1830s it is clear that even then these investments were not self-financing and may have contributed, along with state investments in canals and banks, to high levels to high levels of public indebtedness (see, for example, Wallis, 2000), which, when aggravated by depressed economic conditions in the late 1830s, ultimately led many states to default on their debt.

5. CONCLUDING REMARKS

This paper addresses three fundamental questions regarding railroad investment in the antebellum United States. First, did railroad investment follow or precede economic development in the antebellum period? Second, what were the effects of railroad investment on GDP during this time and how can these effects be decomposed into short-run and long-run effects? And, third, were railroad investments self-financing for the public sector?

We test for Granger causality between economic growth and railroad investment to answer the first question. We find clear evidence for bidirectional causality between railroad infrastructure investment and GDP during the antebellum period. Accordingly, while railroad investments favorably affected economic conditions they also responded to favorable economic conditions.

With respect to the second question, our estimates suggest that railroad investment had a substantial impact on economic performance in the antebellum period- we estimate 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. Furthermore, our results show that about one-third of the overall effect occurs on impact, i.e., the short-term demand effects are substantial. The bulk of the estimated effect, however, nearly two-thirds of the total, stems from the long-term, supply side effects.

Finally, regarding the third question, we conclude that, given the low effective tax rates practiced during the period under discussion and given the magnitude of the effects we estimate, these investments were not self-financing. Indeed, they may have contributed, in part, to high levels of public indebtedness which, when aggravated by depressed economic conditions in the late 1830s, ultimately led many states to default on their debt.

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