# Engines of Development?

## Cross-Country Evidence on the Inter-connection between Private and State Railroad Construction and G.D.P., 1870-1912

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Abstract

Economic development and railroad construction were inter-connected during the period from 1870 to 1912. This paper analyzes the short-term and long-term relationship between G.D.P., private railroad construction, and state railroad construction using panel cointegration and vector error correction models. The results show that the numbers of miles constructed by private companies and states are both cointegrated with G.D.P. and G.D.P. per capita. The results also show that G.D.P. per capita had a positive short-run effect on private railroad miles, but not vice versa. By contrast state railroad miles had a positive short-run effect on G.D.P., but not vice versa. These findings suggest that state railroad construction was an engine of development while private railroad construction was more of a vehicle for profits and satisfying growing demand.

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## I. Introduction

Railroads were the largest infrastructure investment in world history before World War I. In Germany and New Zealand the construction cost of railroads was estimated to be 7.5% of total wealth; in the U.S. it reached 10% of the total wealth (Webb 1911, p. 630). The massive task of constructing railroad networks was largely undertaken by private companies and central governments (hereafter the state.) Private companies financed, constructed, and operated most of the early railroads, and in the process they enriched financiers, contractors, and in some cases shareholders. The state played the role of a facilitator: granting rights of way and providing assistance with interest guarantees, dividend guarantees, and land grants. After 1870, state authorities played a more direct role in financing, constructing, and operating their own railroads. The involvement of the state was by no means constant across countries. In some the state financed, constructed, and operated a substantial portion of the railroad network and in others it played a minimal role.

The era of railroad construction was also one of relatively rapid economic growth. G.D.P. and G.D.P. per capita increased steadily at rates that would have been unthinkable in previous eras given the level of population growth. Countries like U.S., Argentina, and Australia grew so rapidly that incomes soon exceeded those in Western European countries like the U.K., France, and Germany.

The inter-connection between railroads and economic development has been the subject of much research in economic history.[2] However, there is still relatively little cross-country evidence on the relationship between railroads and G.D.P. Moreover there is almost no evidence distinguishing between the role of railroads constructed by the private sector versus the state.

[2] See for example, Fogel (1964), Fishlow (1965), O'Brien (1983), and Summerhill (2005).

This paper fills this gap and analyzes the inter-connection between private railroad construction, state railroad construction, and economic development between 1870 and 1913.

Standard theories of the firm predict that private railroad companies will invest in infrastructure if it results in greater profits. This suggests that higher G.D.P. will encourage private companies to build railroads because it raises the demand for railroad services. In other words, if the number of railroad miles is 'small' relative to G.D.P. in a country then the demand for new railroad miles would be high and companies should respond by gradually increasing their investments. In addition to this long-term effect, higher G.D.P. may also have a short-term effect on private railroad construction. Models of investment under uncertainty predict that firms will not make irreversible investments, like building railroads, whenever the option value to waiting is high (see Pindyck 1991). Once pertinent information is revealed, such as the likely level of future demand, then the option value to waiting diminishes and firms are more likely to invest. This theory suggests that higher G.D.P. could increase private railroad construction by signaling a greater demand for railroad services in the future. Higher G.D.P. per capita could do the same by signaling that customers will have a greater willingness to pay for railroad services in the future.

It is less obvious whether higher G.D.P. should have a long-term or a short-term positive effect on state railroad construction. If the state placed the same weight on profits as firms then it should respond similarly to higher G.D.P. However if the state maximized some other objective, like economic development or political unification, then higher G.D.P. may have little short-term effect on state railroad construction. Moreover, the state might have been more likely to build railroads when economic growth decreased and the uncertainty about future demand was high. Building at times when companies were unwilling to invest would have smoothed the construction cycle resulting in less unemployment and a more steady expansion of the network. This argument suggests that higher G.D.P. may have a negative short-run effect on state railroad construction.

The feedback effect of private or state railroad construction on G.D.P. or G.D.P. per capita is also unclear. Railroads can contribute to G.D.P. through backward linkages, such as the increased demand for labor, iron, steel, and financial services. Railroads can also have forward linkages to the economy, such as the effects of lower transport costs on agriculture and industry. These arguments would suggest that the construction of private or state railroad miles might have a positive short-term or long-term effect on output or labor productivity. The magnitude depends in large part on where railroads were built. If the state chose projects to encourage development, then state railroad miles might have a positive effect on G.D.P. or G.D.P. per capita, whereas the same may not be true of private miles if they were built in areas where development already existed.

The connection between population and state railroad construction is also of interest. States might have built more railroads in response to higher population, especially from immigration, because there were prospective voters or supporters to be won over. State railroad construction might have also contributed to higher population by enabling the settlement of frontier areas.

This paper tests whether there were short-term and long-term relationships between private or state railroad construction and economic development within and across countries between 1870 and 1913. Widely used estimates of G.D.P., G.D.P. per capita, and population are combined with new data on the number of miles constructed by private companies and the state in several countries. The data are then analyzed using panel cointegration and panel vector error correction models which help to establish the existence of long-term and short-term relationships. The data are also split into European and non-European countries to see how the estimates differ.

The results show that the number of miles constructed by private companies and the number of miles constructed by the state are both cointegrated with G.D.P. and G.D.P. per capita. These findings suggest there was a long-term equilibrium relationship between output and both private and state railroad miles and there was a long-term equilibrium relationship between labor productivity and both private and state railroad miles. The results also show that G.D.P. per capita had a positive short-run effect on private railroad construction, but not vice versa. Instead the results suggest that private railroad miles had a negative short-run effect on G.D.P. per capita shortly after railroad miles opened. A similar set of results holds for G.D.P. and the effects are especially large in European countries. Overall these findings suggest that private railroads were not an engine of development and instead they should be viewed as a vehicle for earning profits and satisfying growing demand.

The results are quite different with respect to state railroads. The estimates suggest that state railroad miles had positive short-run effect on G.D.P., but not vice versa. State railroads also had a positive short-run effect on G.D.P. per capita, especially in European countries. These findings suggest that state railroads could be viewed as an engine of development. The one caveat concerns the relationship between state railroads and population in non-European countries. Here there is some evidence that population had a positive short-run effect on state railroad miles, but not vice versa. This finding suggests that state authorities in frontier countries, like Australia and New Zealand, reacted to population increases, especially from immigration.

The findings address several issues in the literature. First, there is a large body of scholarship on the relationship between infrastructure and economic development. Authors generally find mixed evidence on whether infrastructure causes development or vice versa (see Bannister and Berechman 2000 for an overview). The findings here suggest that it may be crucial to consider who is building the infrastructure. In the period before 1913 states tended to undertake projects with developmental effects whereas private companies tend to undertake projects in established areas where development already existed. There is a caveat in that institutions undoubtedly played a key role in determining the outcome of state investment. [3]

The results also relate to the literature on state behavior and development before World War I. Alexander Gerschenkron (1962) famously conjectured that European states responded to 'economic backwardness' by intervening more in the economy. The results show there is little evidence that states built more railroads at times when slow G.D.P. growth made companies unwilling to invest. However, there is evidence that state railroad construction had developmental benefits. Again, however, institutions appear to be crucial as some states borrowed heavily on international capital markets but did not invest in useful projects (see Fishlow 1985).

## II. Overview

### II.1 State and Private Ownership of Railroads: 1860-1912

Most of the literature on railroad ownership has relied on qualitative information regarding the degree of private vs. state ownership. This study is one of the first to assemble and use data on the number of miles owned by companies and the state across countries between

[3] For the literature on political institutions and infrastructure see Bortolotti et al., 2003; La Porta et al., 2002; Keefer and Knack, 2007; Blanc-Brude and Jensen, 2006; Gosh Banerjee et al. 2006

1840 and 1912.[4] Much of the cross-country data on ownership comes from *The Statistical Abstract for the Principal and Other Foreign Countries* and *The Statistical Abstract for the Several Colonial and other Possessions of the United Kingdom*, both of which were published by the British Board of Trade. For some countries, *the Statistical Abstracts* do not distinguish between miles owned by companies and the state. I use several additional sources to identify the ownership of railroads in such cases. For example, the *Estadistca de los Ferrocarriles en Explotacion* reports ownership data for all railroads in Argentina before 1913. In many cases, it was straightforward to fill the gaps by identifying state-owned and operated lines and privately-owned and operated lines. When track miles were state-owned, but privately-operated, I chose to assign miles to the state because it retained control over extensions to the network and it was the ultimate residual claimant.

It is not possible to directly infer miles constructed by companies or the state from the total number of miles owned by companies or the state because some miles were nationalized or privatized in previous years. One way around this problem is to simply add miles nationalized and subtract miles privatized from the total miles owned by companies in any year. Similarly miles privatized can be added and miles nationalized can be subtracted from the total owned by the state in any year. Unfortunately, the Statistical Abstracts do not provide information on miles nationalized or privatized and so it is necessary to use estimates. Another paper provides details on the estimates of railroad nationalizations and privatizations in each country between 1870 and 1912 (Bogart 2008). The estimates are consistent with contemporary sources which document nationalizations in various countries (see for example, Great Britain Board of Trade, *State Railways* 1913).

[4] See Millward (2004) for a cross-sectional analysis of ownership.

Table 1 provides information on total railroads miles, railroad miles constructed by companies, and railroad miles constructed by states in 1910 across countries in the sample. The countries are ordered from greatest to least according to the total number of railroad miles. Countries with high income and significant land area like the U.S., Germany, France, and the U.K. tended to have the largest railroad networks. Countries with smaller land area and lower income like Uruguay, Egypt, and Portugal tended to have the smallest networks. In the sample of countries, private companies constructed nearly 80% of the railroads, but this is partly due to the U.S. which had the largest railroad network by far. If the U.S. is removed then private companies constructed just over 63% of the miles.

Table 2 shows the fraction of miles constructed by private companies across countries from 1860 to 1910. Companies owned the vast majority of new railroad miles between 1860 and 1910 in the countries under the label "private throughout." They include the U.K., Spain, France, the U.S., Uruguay, Switzerland, Mexico, and Canada. In the U.K., private companies obtained authority to build railroads through private acts of Parliament. The acts gave companies rights of way, set maximum freight rates, and determined capitalization. A similar procedure was used in the U.S. during the mid-nineteenth century, except that state governments gave private companies authorization to build railroads. Later the U.S. federal government gave land grants to transcontinental railroads, like the Union Pacific. Government subsidies were common in many other countries where private ownership was predominant, although in most cases the state guaranteed dividends or interest payments on bonds. The aim of most guarantee policies was to attract foreign investment, particularly from Great Britain (Eichengreen, 1994).

Countries under the "state or mixed" label had high levels of state ownership from the beginning of their railroad construction up to 1912. The most extreme case was Egypt, which never had a privately owned railroad. Australia and New Zealand were also cases where state ownership predominated from the beginning. Their policies were different from Canada, which shared a similar colonial status and economic environment. Chile was unique in that around half of all railroads were constructed by the state between 1875 and 1912. Private ownership predominated in the north near the mining industry, while state ownership was common in the south where agriculture was the dominant sector (Splawn, 1928).

Many countries moved to state ownership after an initial period of private ownership. This group is labeled "private then state." Italy provides one example. In 1860 all railroads in Italy were privately-owned, but starting in the 1870s the state began constructing new railroads. This trend continued up to 1900 when only 55 percent of the miles were constructed by companies.

Japan is one of the few countries that began with state ownership and then switched to greater private ownership. The state owned the first railroad lines before private ownership increased dramatically in the 1880s and 1890s. Afterwards there was a shift back to greater state ownership. Sweden had a similar experience but the pattern was less pronounced. In Argentina greater private ownership was replaced by greater state ownership in the 1870s. This was followed by a move to greater private ownership during the 1880s and 1890s (Lewis, 1983). Denmark had a similar experience.

II.2 G.D.P. and G.D.P. per Capita: 1870-1912

The basic facts about G.D.P. and G.D.P. per capita from 1870 to 1912 are now well established thanks to the research of numerous scholars. Angus Maddison (2004) provides annual real G.D.P. and real G.D.P. per capita estimates for many countries beginning in the 1870s. Real G.D.P. per capita estimates from other scholars can also be incorporated for Russia, Hungary, Argentina, and Egypt, where Maddison does not provide annual data. The additional sources are described in the appendix.

Table 3 shows G.D.P. and G.D.P. per capita in 1910 for the countries in the sample. The countries are ordered from greatest to least according to the size of G.D.P. Notice there is a close similarity in the ordering between countries in tables 1 and 3. Countries with large railroad networks, like the U.S. and Germany, also tended to have high G.D.P.

### II.3 Summary of the Data

Table 4 provides summary statistics for the main variables: the natural log of miles constructed by companies (henceforth private miles), the log of miles constructed by the state (henceforth state miles), the log of real G.D.P., the log of real G.D.P. per capita, and the log of population for 28 countries between 1870 and 1912. All countries except Egypt had some private miles. Spain, the UK, Uruguay, and the U.S. did not have any state miles. G.D.P. is available for all 28 countries but not in every year. The average number of observations per country spans from 35 to 40 years. This implies that the data are sufficiently long to use time-series methods. The following section investigates the time-series properties of the data.

## III. Unit Root and Cointegration tests

The first step in analyzing the time-series data is to perform unit root tests. Levin-Lin-Chu panel unit root tests were performed on all the key variables (see Levin, Lin, Chu 2002). The test requires that the panel be balanced. There is no single way to 'balance' the panel. Including all countries shortens the panel considerably, but dropping countries throws out useful information. As a first step, five countries were omitted for private miles and nine countries were omitted for state miles. These countries are added again for the cointegration and vector error correction models.

The results of the panel unit root tests for the variables in log-levels are reported in the top of table 5. The test statistics imply that the hypothesis of a unit root cannot be rejected for the log of private miles, the log of G.D.P., the log of G.D.P. per capita, and the log of population at the 1% level. The bottom panel shows the panel unit root tests for the log-differenced variables. Here the test statistics imply that unit roots should be rejected for all the log-differenced variables. This suggests that the log of private miles, the log of G.D.P., the log of G.D.P. per capita, and the log of population are integrated of order one

The Levin-Lin-Chu test statistics yielded a different result for the log of state railroad miles. The test statistic suggests that a unit root hypothesis should be rejected for the log-level. Further analysis showed that the tests were highly sensitive depending on which countries were included in the balanced panel. To investigate the issue further, Augmented Dickey Fuller tests were performed for private miles, state miles, and G.D.P. in the individual countries (see table 6). In eight of the 24 countries the hypothesis of a unit root for state railroad miles could not be rejected. In 11 of the 27 countries the hypothesis of a unit root for private miles could not be rejected. Given that the series are non-stationary in several countries, it is assumed hereafter that state and private miles are both integrated of order one.

The second step in analyzing time series data is to perform cointegration tests. Table 7 reports Westerlund's panel cointegration tests between the log of private or state miles and the log of G.D.P., the log of G.D.P. per capita, and the log of population in contemporaneous years.[5] The results show mixed evidence on whether private miles are cointegrated with G.D.P. or G.D.P. per capita in contemporaneous years. The Group t and the Panel t test statistics are not

[5] See Westerlund (2007) for more details on the panel cointegration tests.

significant in both cases implying that the hypothesis of no cointegration cannot be rejected. All four test statistics confirm that private miles are cointegrated with population. In the case of state miles, all the tests statistics imply that it is cointegrated with G.D.P. or G.D.P. per capita, but the Group a test statistic implies that the hypothesis of no cointegration with population cannot be rejected.

The cointegration results suggest some preliminary findings. First, they are consistent with the argument that there was a long-term equilibrium relationship between state miles and G.D.P. and state miles and G.D.P. per capita. Unfortunately it is difficult to precisely identify this long-term relationship, but there is evidence that it exists. Second, the results suggest there is mixed evidence of a long-term equilibrium relationship between private miles and G.D.P. and private miles and G.D.P. per capita. These particular tests might be misleading, however, because they test for cointegration between the variables in contemporaneous years. Instead it might be more revealing to analyze cointegration between private (or state) miles in year t and G.D.P. with some lag to allow for construction times. Railroad miles that opened in year t were initiated as projects in some earlier year because it took time to build the railroad once the approval or charter was obtained. Therefore if the goal is to understand how G.D.P shaped private and state railroad construction and vice versa, cointegration tests should be performed with explanatory variables dated at the time when projects were initiated, not when they were completed.

Anecdotal evidence suggests that planning and construction took several years. For example, the promoters of the Baltimore & Ohio railroad secured a charter from the State of Maryland and the state of Virginia in 1827. Construction on the first section began in 1828 and was completed in 1830.[6] In another case, the promoters of the Great Western Railway in the UK obtained an act of Parliament in 1835 while the first section of the line between London Paddington to Maidenhead Bridge station opened in 1838.[7] In both cases, it took three years between the date the charter or act was obtained and the opening of the line. Clearly not all railroad projects were completed in three years, but it is seems like an appropriate starting point to assume a three year construction lag and reanalyze cointegration.

The top of table 8 reports the cointegration tests for the log of private miles in t and the log of G.D.P in t-3, the log of G.D.P. per capita in t-3, or the log of population in t-3. The results of all four test statistics indicate that the hypothesis of no cointegration between private miles in t and G.D.P. or G.D.P. per capita in t-3 can be rejected, but not in the case of population. The bottom panel of table 8 shows the same cointegration tests for state miles. All four test statistics reveal that state miles are cointegrated with G.D.P., G.D.P. per capita, and population in t-3.

Incorporating a construction lag significantly changes the conclusions regarding cointegration of private miles and G.D.P.. They indicate there was a long-term equilibrium relationship between the number of private miles and G.D.P. and G.D.P. per capita three years earlier, but not necessarily between the number of private miles and G.D.P. and G.D.P per capita in the same year. The difference might be explained if G.D.P. and G.D.P. per capita influenced private miles more than the other way around. In that case one might expect G.D.P. at the initiation of construction to be more strongly related to the number of private miles open three years later rather than the number of private miles open in the same year.

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[6] Wikipedia contributors, "Baltimore and Ohio Railroad," *Wikipedia, The Free Encyclopedia,* http://en.wikipedia.org/w/index.php?title=Baltimore_and_Ohio_Railroad&oldid=233990891 (accessed August 25, 2008).

[7] Wikipedia contributors, "Great Western Railway," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/w/index.php?title=Great_Western_Railway&oldid=232856958 (accessed August 26, 2008).

## IV. Vector Error Correction Models

More insights can be gleaned by studying the short-term as well as the long-term relationship between private or state railroad miles and G.D.P. As mentioned in the introduction, if there is a large number of private railroad miles compared to G.D.P., then demand for new railroad miles would be lower and companies should respond by gradually reducing their investments. At the same time, models of investment under uncertainty suggest that companies might have an additional response to higher G.D.P. because it signals there will be greater demand for railroad services in the future. This suggests that G.D.P. may have a positive short-run effect on private railroad construction even after controlling for the long-term adjustment process. G.D.P. per capita or population could also have a positive short-term effect on private railroad construction, although the former is likely to be more important because demand will remain low if customers don't have the income to pay railroad fares and freight charges.

The short-run relationship between G.D.P. and state railroad construction is less clear because the state might have placed less weight on earning profits. Instead, the state might have been more likely to build railroads when economic growth decreased and the expected future profits were low. Building at times when companies were unwilling to invest would have smoothed the construction cycle, resulting in less unemployment and a more steady expansion of the network. This argument suggests that higher economic growth may have a negative short-run effect on state railroad construction.

Another theory is that the state was more responsive to population than to G.D.P. per capita. Higher population growth, especially through immigration, could signal a greater demand for railroads in sparsely populated regions. The state might be especially responsive to these demands because immigrants are prospective voters and building railroads in frontier areas helped to solidify political control. This suggests that population might have a positive short-run effect on state railroad construction.

Theory also suggests there may be a feedback effect from railroads to G.D.P. and G.D.P. per capita. The backward linkages on iron, steel, and financial services sectors would suggest that railroads can increase G.D.P. during the construction phase. The forward linkages from lower transport costs would imply that railroads can increase G.D.P. or G.D.P. per capita once they are opened. However in practice the effects of railroads on G.D.P. or G.D.P. per capita may not be so simple. First, private railroads might be built after iron, steel, and financial services are well established and they might be built in areas already well served by water transport. As a result, there may be minimal backward and forward linkages resulting from private railroads. Second state railroads may have been built for political or military reasons and might yield few developmental benefits. Third, railroads could conceivably lower output or labor productivity in the short-run if they expose domestic producers to international competition.

These hypotheses can be tested using vector error correction models. The Granger Representation Theorem states that variables which are cointegrated must follow an error correction model (Engle and Granger 1987). Therefore vector error correction models are a natural extension of cointegration analysis. For private miles we examine the following dynamic fixed effects vector error correction model:

$$\Delta x_{it} = \alpha_i + \gamma_1 (x_{it-1} - \beta_1 y_{it-4}) + \rho_1 \Delta x_{it-1} + \phi_{1k} \sum_{k=1}^{K} \Delta y_{it-3-k} + \delta_{1t} + u_{1it} \qquad (1)$$

$$\Delta y_{it-3} = \alpha_i + \gamma_2 (y_{it-4} - \beta_2 x_{it-1}) + \rho_2 \Delta y_{it-4} + \phi_{2j} \sum_{j=1}^{J} \Delta x_{it-j} + \delta_{2t} + u_{2it} \qquad (2)$$

where $x_{it}$ is the log of private miles in country *i* and year *t*, $y_{it}$ is the log of G.D.P. in country *i* and year *t*, $\Delta x_{it}$ is the log difference between private miles in *t* and *t-1*, $\Delta y_{it}$ is the log difference between G.D.P. in *t* and *t-1*, $\alpha_i$ is a country fixed effect, $\delta_t$ is a dummy variable for each year t, and $u_{it}$ the error term. For state miles the same dynamic fixed effects vector error correction model is estimated after replacing the log of private miles with the log of state miles in all $x_{it}$.

There are several features of this model that need to be discussed. First, notice that equations (1) and (2) contain a lagged dependent variable (i.e. $\Delta x_{it-1}$ and $\Delta y_{it-4}$). These variables are included to control for unobservable factors which influence railroads miles and G.D.P. in the preceding year. However, their estimates can be biased because there is a correlation between the lagged dependent variable and the error term. One solution is to use further lags of the dependent variable as instruments, but this method does not always work well in practice because the instruments are often weak. Fortunately the bias from including a lagged dependent variable diminishes with T the length of the panel (see Nickell 1981). In this case, the panels average more than 30 years suggesting that the bias is fairly minimal. In the models analyzed below the lagged dependent variable is included without instruments.

Second, the timing of the model incorporates a three-year construction lag in allowing for two-way causality between private or state miles and G.D.P. In equations (1) and (2) the error correction terms $(x_{it-1} - \beta_1 y_{it-4})$ and $(y_{it-4} - \beta_2 x_{it-1})$ reflect the gap between the equilibrium number of railroad miles in year *t-1* and G.D.P. in *t-4*. Notice that the time difference in these variables is three years, which is the assumed construction lag. In equation (1) G.D.P. in $t-4,...,t-3-K$ is allowed to have a short run effect on railroad miles in *t*. In the main specification $K$ will be one so G.D.P. in *t-4* can have a short-run effect on railroad mileage in *t*. In equation (2) railroad miles in $t-1,...,t-J$ are allowed to have a short-run effect on G.D.P. in t-3. In the main specification $J$ will be four so that railroad miles in *t-1, t-2*, *t-3*, and *t-4* can affect G.D.P. in t-3. The timing incorporates the possibility that railroad miles which opened *t-1,* *t-2*, and *t-3* had 'backward linkage effects' on G.D.P. in *t-3* during the construction phase. It also allows railroad miles which opened in *t-4* to have 'forward linkage effects' on G.D.P. in *t-3*.

Two of the main coefficients in the model are $\gamma_1$ and $\gamma_2$. $\gamma_1$ is the coefficient for the error correction in the equation for railroad mileage and $\gamma_2$ is the coefficient for the error correction in the equation for G.D.P. Each measures the speed of adjustment towards the long-run equilibrium.[8] At least one of these coefficients must be negative and significant if private or state railroad miles and G.D.P. are cointegrated. If $\gamma_1$ is negative and significant then this suggests that private or state railroad miles gradually adjusted when there was a shock to G.D.P. If $\gamma_2$ is negative and significant then this suggests that G.D.P. gradually adjusted when there was a shock to private or state railroad miles.

The other main coefficients are $\phi_{11}$ and $\phi_{21}, \phi_{22}, \phi_{23}$, and $\phi_{24}$. A positive and statistically significant estimate for $\phi_{11}$ can be taken as evidence that higher G.D.P. caused higher private or state railroad miles in the short-run. Likewise a positive and significant coefficient on $\phi_{21}, \phi_{22}, \phi_{23}$, or $\phi_{24}$ can be taken as evidence that higher private or state railroad miles caused higher G.D.P. in the short-run. To identify the short-run causal effects it is necessary that the right-hand side variables be independent of all the error terms $u_{i1},...u_{iT}$. In equation (1) this assumption is likely to hold for $u_{i1},...u_{it}$ because G.D.P. in t-4 should not be correlated with shocks to railroad mileage from year one to *t* after the error correction term and the lagged dependent variable for railroad miles is included. It is less clear however whether G.D.P. in t-4 is correlated with $u_{it+1},...u_{iT}$ because of the feedback effect of railroad construction on G.D.P.

[8] In the dynamic fixed effects model estimated below, the coefficient $\gamma$ can be estimated by the coefficient on the lagged dependent variable in levels (i.e. $x_{it-1}$ in equation (1) and $y_{it-4}$ in equation (2)).

The possibility that the key right-hand side variables are sequentially exogenous, but not strictly exogenous, is less of a problem in this setting because the time-series is long and the degree of persistence (measured by $\rho_1$ and $\rho_2$) is low. As Hsiao (1986) shows, when the panel length T is large and the persistence is low the bias resulting from regressions with sequentially exogeneous variables tends to low. In the models analyzed below no instruments are used for lagged G.D.P. in equation (1) or lagged railroad miles in equation (2) with the caveat that some bias may still exist.

The top panel of table 9 reports the estimates of equation (1) for private and state miles across the entire sample and separately for European and non-European countries. The bottom panel reports estimates of equation (2) for private or state miles. The coefficient on the error correction term is negative and significant for private and state miles in all specifications of equations (1) and (2). This is consistent with the earlier results that private and state miles are cointegrated with G.D.P. It suggests that private or state miles adjusted when a shock to G.D.P. widened the gap between them and that G.D.P. also adjusted when a shock to private or state miles widened the gap between them. The results also show that higher G.D.P. has a positive short-run effect on private railroad miles in the full sample although the coefficient is just below statistical significance. G.D.P. is estimated to have a negative short-run effect on state railroad construction, but the coefficient is small and far from being statistically significant. The findings are qualitatively similar in the European and non-European samples.

Turning to the equation (2) the results show that private railroad miles had a positive and significant short-run effect on G.D.P. in the second year of construction (*t-2*), but this was offset by a negative and significant short-run effect on G.D.P. just after private railroad miles opened (*t-4*). State railroad miles, on the other hand, had a positive and significant short-run effect on

G.D.P. just after the state railroad was opened. In European countries the negative short-run effect from private railroad miles and the positive short-run effect from state railroad miles are even larger. In non-European countries the negative short-run effect from private miles is negligible but the positive short-run effect from state miles around the time of the railroad opening still holds.

These findings have a number of important implications. First, it does not appear that G.D.P. growth encouraged private companies to build significantly more railroads. Perhaps the reason is that it did not signal a large change in expectations about future demand. Another possibility is that land grants and government guarantees on dividends and bonds muted the short-run effects of G.D.P. These policies were designed to encourage private companies to invest at times and in places where they would not otherwise invest. If these guarantees were effective then companies' investment profiles might vary less with G.D.P.

Second, higher G.D.P. had practically no influence on state railroad construction in the short-run. States seem to have reacted less to changes in expectations about future demand than private companies. The estimates also suggest that few if any states smoothed the construction cycle by building railroads at times when companies were unwilling to invest because of low G.D.P growth.

Third, the results suggest that private railroad miles added to G.D.P. during their construction years, but once the lines were opened they had a negative impact. The larger negative effect in European countries suggests that this finding may reflect greater exposure to foreign competition. Jeffrey Williamson and Kevin O'Rourke (1999) provide evidence that the 'grain invasion' in Western Europe was propelled by railroads. O'Rourke (1997) also shows that grain imports tended to reduce real wages in some European countries like France and Germany.

Therefore it is possible that private railroads were linked with the grain invasion and contributed to a short-term loss in European output.

Fourth, the results suggest that state railroads added little to G.D.P. during their construction years, but once these lines were open they had a positive impact. These findings suggest that the causal relationship went from state miles to G.D.P. rather than the other way around. These findings also suggest that states may have built railroads in order to promote economic development. For example, states might have built railroads in places where companies were unwilling to build. As a result they would have brought modernized transport to areas that may not have been served otherwise.

The inter-connection between railroad miles and G.D.P. per capita can differ from G.D.P. because the latter provides a measure of output while the former provides a measure of labor productivity. Table 10 shows estimates of equation (1) and (2) after replacing G.D.P. with G.D.P. per capita. In this case the results show that higher G.D.P. per capita had a positive and significant short-run effect on private miles. The coefficient on G.D.P. per capita in equation (1) is also similar for European and non-European countries, suggesting this effect is relatively stable across the samples. In addition the results imply that state railroad miles had no short-run effect on G.D.P. per capita just after they were opened in the full sample or the non-European sample. There is some evidence, however, that state railroad miles had a positive short-run effect on G.D.P. per capita in European countries. In the case of private railroads, the results imply they had a negative short-run effect on G.D.P. per capita just after they were opened. The exception is the non-European sample where it appears that private railroads had no short-run impact.

Overall these estimates suggest that private investment behavior was driven by the consideration of profits, even though government guarantees were common. The estimates suggest private companies built more railroads in response to G.D.P. per capita growth because it signaled that customers would have a higher willingness to pay for railroad services in the future. Private railroads did not cause G.D.P. or G.D.P. per capita to increase in the short-run and they might have even lowered it temporarily. Therefore private railroads appear to be less of an engine of development and more of a vehicle for earning profits and satisfying growing demand.

The findings are also consistent with the theory of investment under uncertainty, which predicts that companies should invest more when the opportunity cost of waiting diminishes. Earlier this conclusion was in doubt given that G.D.P. had a positive but insignificant effect on private railroad miles. This finding provides a better indication of this mechanism because higher G.D.P. per capita should have a stronger influence on expected future demand than higher G.D.P. The estimates also suggest that states were unresponsive to changes in the opportunity cost of waiting. This may be an indication that states did not place a great weight on earning profits.

The results in table 10 also reveal that state railroad miles had a smaller impact on labor productivity compared to output. With the exception of European countries there was no significant short-term impact on G.D.P. per capita, whereas earlier there was a significant short-term impact on G.D.P. This may suggest that state railroads in non-European countries increased output, but they did not encourage greater competition or the adoption of new technologies which would increase labor productivity.

Table 11 explores the inter-connection between private and state miles and population. In the European sample, the error correction term was negative and significant in equation (1), but insignificant in equation (2). This suggests that long-run causation runs from population to private and state miles in Europe, but not the other way around. In non-European countries this was not the case as the estimates for the error correction term imply that population influenced state or private miles and vice versa. Another interesting finding is that population had a positive short-term effect on state railroad miles in non-European countries. This suggests that states in frontier areas built more railroads in response to immigration. Immigrants were an emerging constituency in societies, such as Australia and New Zealand, and politicians wanted to court their support by providing such public transport.

## V. Conclusion

This paper tests whether there were short-term and long-term relationships between private or state railroad construction and economic development within and across countries between 1870 and 1913. Panel cointegration tests suggest there was a long-term equilibrium relationship between aggregate output and both private and state railroad miles and there was a long-term equilibrium relationship between aggregate labor productivity and both private and state railroad miles. The results from a vector error correction model show that G.D.P. per capita had a positive short-run effect on private railroad miles, but not vice versa. By contrast state railroad miles had a positive short-run effect on G.D.P., but not vice versa. Overall the findings suggest that private and state railroads were influenced by different factors and played separate roles in economic development before World War I. State railroads were more of an engine of development while private railroads were more of a vehicle for profits and satisfying growing demand.

## VI. Appendix: Data sources

Data on railroad miles owned by companies and the government comes from several sources. I use several reports published by the British Board of Trade. They include *The Statistical Abstract for the Principal and Other Foreign Countries* (various years), *The Statistical Abstract for the Several Colonial and other Possessions of the United Kingdom* (various years), *The Statistical Abstract for British India* (various years), *Report on State Railways, British Possessions and Foreign Countries*, and *Railways, Foreign Countries and British Possessions*. I also use other sources. For Italy, I consulted *Sviluppo delle ferrovie italiane dal 1839 al 31 dicembre 1926* published by the Direzione generale delle ferrovie dello Stato. For Chile, I used additional information from the *Annuario Estadistico de la Republica de Chile* published by Oficina Central de Estadistica. For Brazil, I used additional information from *the Ministério da Indústria, Viação e Obras Públicas* (1893-1909) and *Viacao E Obras Publicas* (1909-1914). For Argentina, I used additional information from *Estadistica de los Ferrocarriles en Explotacion* published by the Ministerio de Obras Publicas.

Angus Maddison (2004) provides real G.D.P. and G.D.P. per capita in constant 1995 dollars for several countries and British colonies in 1820, 1850, 1860, and every year after 1870. In some cases, however, Maddison provides real G.D.P. for 1870, 1890, and 1913 only. To fill the gaps, I use other sources for annual G.D.P. and convert them into 1995 dollars using Maddison's estimate from 1913. For example, I use Gregory (1982), Schulz (2000) for Hungary, Yousef (2002) for Egypt, Braun et. al. (2006) for Chile, della Paolera and Taylor (2003) for Argentina, and Koc, Filiztekin, and Pamuk (2006) for Turkey.

For population data I used Maddison (2004) whenever possible. However, Maddison's figures did not always apply to boundaries in the $19^{th}$ century and so I supplemented Maddison's figures with Lahmeyer and *the Statistical Abstracts*.

## References

Argentina, Ministerio de Obras Publicas. *Estadistica de los Ferrocarriles en Explotacio.* Buenos Aires, 1916.

Banister, David and Joesph Berechman. *Transport Investment and Economic Development.* London: UCL, 2000.

Bogart, Dan. "Nationalizations and the Development of Transport Systems: Cross Country Evidence from Railroad Networks: 1860-1912." Forthcoming Journal of Economic History.

Braun, Juan, Ignacio Briones, José Díaz, Rolf Luders, and Gert Wagner. "Economía Chilena 1810-1995: Estadísticas Históricas," *P. Universidad Católica de Chile, Departamento de Economía, Documento de Trabajo # 187*, Chile, 2000.

Brazil. *Ministério da Indústria, Viação e Obras Públicas*, annual series, 1893-1909, Sao Paulo: Brazil.

Brazil. *Viacao E Obras Publicas*. annual series, 1909-1914, Sao Paulo: Brazil.

Chile, Oficina Central de Estadistica. *Annuario Estadistico de la Republica de Chile,* Santiago: Soc. Imprenta Y Litografia Universo, 1912.

Della Paolera, Gerardo and Alan M. Taylor. *A New Economic History of Argentina.* Cambridge: Cambridge University Press, 2003.

Duncan, Julian Smith. *Public and Private Operation of Railways in Brazil*. New York: AMS Press, 1932.

Eichengreen, Barry. "Financing Infrastructure in Developing Countries: Lessons from the Railway Age." *The World Bank Research Observer* 10 (1995): 75-91.

Engle, R. F. and Granger, C. W. J. “Co-integration and error-correction: Representation, estimation and testing,” *Econometrica* 55 (1987), 251—276.

Ericson, Steven J. *The Sound of the Whistle: Railroads and the State in Meiji Japan*. Cambridge: Harvard University Press, 1996.

Fishlow, Albert. *American Railroads and the Transformation of the Antebellum Economy*. Cambridge: Harvard University Press, 1965.

Fishlow, Albert, "Lessons from the Past: Capital Markets and Foreign Lending During and 19th Century and the Interwar Period," in Miles Kahler (ed.), *The Politics of International Debt*, Ithaca: Cornell University Press, 1984 pp.37−94.

Fogel, Robert. *Railroads and American Economic Growth: Essays in Econometric History.* Baltimore: John Hopkins, 1964.

Gerschenkron, Alexander. *Economic Backwardness in Historical Perspective*. Cambridge: Belknap Press, 1962.

Gosh Banerjee, Sudeshna, Jennifer Oetzel, and Rupa Ranganathan. “Private Provision of Infrastructure in Emerging Markets: Do Institutions Matter?” *Development Policy Review* 24 (2006): 175-202.

Great Britain, Board of Trade. *Statistical Abstract for the Principal and other Foreign Countries in each Year*, annual series, London: HM Stationary.

Great Britain, Board of Trade. *the Statistical Abstract for the Several Colonial and other Possessions of the United Kingdom*, annual series, London: HM Stationary.

Great Britain, Board of Trade. *the Statistical Abstract for British India*, annual series, London: HM Stationary.

Great Britain, Board of Trade. *Report on State Railways (British Possessions and*

*Foreign Countries)*, London: HM Stationary, 1913.

Great Britain, Board of Trade. *Railways (Foreign Countries and British Possessions)*, London: HM Stationary, 1907.

Gregory, Paul. *Russian National Income, 1885-1913*. Cambridge: Cambridge University Press, 1982.

Huenemann, Ralph W. *The Dragon and the Iron Horse: The Economics of Railroads in China, 1876-1937*. Cambridge MA: Harvard University Press.

Hsiao. C. *Analysis of Panel Data*. Cambridge: Cambridge University Press, 1986.

Jensen, Olivia and Frederic Blanc-Brude. "The Handshake: Why do Governments and Firms Sign Private Sector Participation Deals? Evidence from the Water and Sanitation Sector in Developing Countries." *World Bank Working Paper 3937*, 2006.

Italy. Direzione generale delle ferrovie dello Stato. *Sviluppo delle ferrovie italiane dal 1839 al 31 dicembre 1926*, Roma, Tipografia ditta L. Cecchini, 1927.

Keefer, Philip and Stephen Knack. "Boondoggles, Rent-Seeking, and Political Checks and Balances: Public Investment under Unaccountable Governments." *The Review of Economics and Statistics* 89 (August 2007): 566-572.

Koc, Sumru Altug, Alpay Filiztekin, and Sevket Pamuk. "Sources of Long-term Economic Growth for Turkey, 1880-2005." Working Paper, 2006.

Lahmeyer, Jan. "Populstat Website," http://www.library.uu.nl/wesp/populstat/populhome

Levin, Andrew, Lin, Chien-Fu and Chia-Shang James Chu. "Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties." *Journal of Econometrics*, 108, 1-24, 2002.

Lewis, Colin. *British Railways in Argentina 1857-1914: A case Study in Foreign Investment*. London: Athlone, 1983.

Maddison, Angus. *The world economy: historical statistics*. Paris: Development Centre, OECD, 2003.

Mitchell, B.R. *International Historical Statistics: Africa, Asia, & Oceania, 1750-1988.* New York: MacMillan, 1995.

Mitchell, B.R. *International Historical Statistics: The Americas, 1750-2000*. New York: Palgrave MacMillan, 2003.

Mitchell, B.R. *International Historical Statistics: Europe, 1750-1988*. New York, MacMillan, 1992.

Millward, Robert*. Private and Public Enterprise in Europe: Energy, Telecommunications, and Transport, 1830-1990.* Cambridge: Cambridge University Press, 2005.

Nickell, Stephen. "Biases in Dynamic Models with Fixed Effects," *Econometrica*, 49 (1981).

O'Brien, Patrick (eds.), *Railways and the Economic Development of Western Europe, 1830-1914.* MacMillan, St. Anthony's College Oxford, 1983.

O'Rourke, Kevin. "The European Grain Invasion." *Journal of Economic History* 57 (Dec., 1997): 775-801

O'Rourke, Kevin, and Jeffrey Williamson. *Globalization and History: The Evolution of a Nineteenth Century Atlantic Economy*. Cambridge: M.I.T. Press, 1999.

Pindyck, Robert. "Irreversibility, Uncertainty, and Investment." *Journal of Economic Literature* 29 (1991): 1110-1148.

Schulz, Max-Stephan. "Patterns of Growth and Stagnation in the Late 19th Century Hapsburg Economy," *European Review of Economic History* 4 (2000).

Splawn, Walter. *Government Ownership and Operation of Railroads*. New York: The MacMillan Company, 1928.

Summerhill, Bill. “Big Social savings in a Small Laggard Economy: Railroad-LedGrowth in Brazil.” *Journal of Economic History* 65 (March 2005): 72-102.

Webb, Augustus Duncan. *The New Dictionary of Statistics: A Complement to the Fourth Edition of Mulhall's "Dictionary of Statistics."* London: Routledge, 1911.

Westerlund, J. “Testing for error correction in panel data.” *Oxford Bulletin of Economics and Statistics* 69 (2007): 709-748.

Wikipedia contributors, "Baltimore and Ohio Railroad," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/w/index.php?title=Baltimore_and_Ohio_Railroad&oldid=233990891 (accessed August 25, 2008).

Wikipedia contributors, "Great Western Railway," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/w/index.php?title=Great_Western_Railway&oldid=232856958 (accessed August 26, 2008).

Wooldridge, Jeffrey. *Econometric Analysis of Cross Section and Panel Data*. Cambridge: M.I.T. Press, 2002.

Yousef, Tarik. “Egypt’s Growth Performance Under Economic Liberalism: A Reassessment with New GDP estimates, 1886-1945.” *Review of Income and Wealth* 48 (December 2002): 561-579.

Tables

Table 1: Total Railroad Miles and Miles Constructed by Private Companies or the State in 1910

| Country | Railroad Miles | Private Miles | State Miles |
|---|---|---|---|
| US | 249902 | 249902 | 0 |
| Germany | 36658 | 11912 | 24746 |
| Russia | 34990 | 19605 | 15385 |
| India | 32159 | 10662 | 21497 |
| France | 30673 | 27518 | 3155 |
| Canada | 24731 | 22975 | 1756 |
| UK | 23387 | 23387 | 0 |
| Australia | 17429 | 2358 | 15071 |
| Argentina | 17395 | 13271 | 4124 |
| Mexico | 15404 | 14357 | 1047 |
| Austria | 14012 | 9685 | 4327 |
| Brazil | 13331 | 8888 | 4442 |
| Hungary | 12822 | 9978 | 2844 |
| Italy | 10573 | 5792 | 4781 |
| Spain | 9113 | 9113 | 0 |
| Sweden | 8594 | 6013 | 2581 |
| Japan | 5556 | 3311 | 1819 |
| Chile | 3693 | 1945 | 1749 |
| Belgium | 2906 | 1447 | 1459 |
| Switzerland | 2893 | 2718 | 175 |
| New Zealand | 2790 | 250 | 2540 |
| Finland | 2267 | 192 | 2075 |
| Netherlands | 2250 | 1073 | 1177 |
| Denmark | 2120 | 1172 | 948 |
| Norway | 1848 | 291 | 1557 |
| Uruguay | 1545 | 1545 | 0 |
| Portugal | 1524 | 485 | 1039 |
| Egypt | 1453 | 0 | 1453 |
| Total | 582018 | 459864 | 121763 |
| total without US | 332116 | 209962 | 121763 |

Sources: see text.

Table 2: Fraction of Railroad Miles Constructed by Companies, 1860-1910

| Country | 1860 | 1870 | 1880 | 1890 | 1900 | 1910 |
|---|---|---|---|---|---|---|
| "Private throughout" | | | | | | |
| UK | 1 | 1 | 1 | 1 | 1 | 1 |
| Spain | 1 | 1 | 1 | 1 | 1 | 1 |
| France | 1 | 1 | 0.93 | 0.89 | 0.9 | 0.9 |
| U.S. | 1 | 1 | 1 | 1 | 1 | 1 |
| Uruguay | 1 | 1 | 1 | 1 | 1 | 1 |
| Switzerland | 1 | 1 | 1 | 1 | 1 | 0.94 |
| Mexico | | 1 | 1 | 1 | 1 | 0.93 |
| Canada | | | 0.84 | 0.9 | 0.91 | 0.93 |
| "State or Mixed throughout" | | | | | | |
| Egypt | 0 | 0 | 0 | 0 | 0 | 0 |
| Belgium | 0.57 | 0.7 | 0.56 | 0.52 | 0.51 | 0.5 |
| Australia | | 0.03 | 0.08 | 0.06 | 0.08 | 0.14 |
| Chile | | 0.49 | 0.47 | 0.61 | 0.52 | 0.53 |
| Germany | | 0.56 | 0.49 | 0.41 | 0.36 | 0.32 |
| New Zealand | | | 0 | 0.08 | 0.1 | 0.09 |
| Finland | | | | | | 0.08 |
| "Private Then State" | | | | | | |
| Norway | 1 | 0.19 | 0.06 | 0.04 | 0.09 | 0.16 |
| Italy | 1 | 0.87 | 0.78 | 0.63 | 0.55 | 0.55 |
| Brazil | 1 | 0.82 | 0.74 | 0.73 | 0.76 | 0.67 |
| Austria | 1 | 1 | 0.93 | 0.8 | 0.75 | 0.69 |
| India | 1 | 0.99 | 0.66 | 0.44 | 0.35 | 0.33 |
| Hungary | 1 | 1 | 0.8 | 0.72 | 0.76 | 0.78 |
| Netherlands | 1 | 0.43 | 0.43 | 0.48 | 0.47 | 0.48 |
| Portugal | 1 | 1 | 0.48 | 0.39 | 0.32 | 0.32 |
| Russia | | 0.9 | 0.96 | 0.79 | 0.62 | 0.56 |
| "State then Private" | | | | | | |
| Sweden | 0.5 | 0.36 | 0.67 | 0.68 | 0.68 | 0.7 |
| Japan | | | 0 | 0.52 | 0.76 | 0.65 |
| "Private then State then back to Private" | | | | | | |
| Argentina | 1 | 0.79 | 0.52 | 0.66 | 0.7 | 0.76 |
| Denmark | 1 | 0.35 | 0.36 | 0.4 | 0.53 | 0.55 |

Sources: see text.

Table 3: G.D.P. and G.D.P. per Capita in 1910

| Country | GDP per capita In 1990 dollars | GDP In 1990 dollars |
|---|---|---|
| US | 4970 | 461051990 |
| India | 697 | 210563700 |
| Germany | 3348 | 210535632 |
| Russia | 1488 | 196445760 |
| UK | 4611 | 193376118 |
| France | 2965 | 122229160 |
| Austria | 3290 | 92778000 |
| Italy | 2332 | 85285904 |
| Japan | 1304 | 64571472 |
| Hungary | 2054 | 42981093 |
| Spain | 1895 | 37630910 |
| Belgium | 4064 | 30471872 |
| Canada | 4066 | 29226408 |
| Mexico | 1694 | 25410000 |
| Chile | 3822 | 25171692 |
| Argentina | 3699 | 23418369 |
| Australia | 5210 | 22793750 |
| Netherlands | 3789 | 22438458 |
| Brazil | 769 | 17084104 |
| Switzerland | 4378 | 16351830 |
| Sweden | 2980 | 16238020 |
| Denmark | 3705 | 10677810 |
| Egypt | 880 | 10299935 |
| Chile | 2656 | 8934784 |
| Portugal | 1228 | 7274672 |
| Finland | 1906 | 5582674 |
| New Zealand | 5316 | 5555220 |
| Norway | 2256 | 5378304 |
| Uruguay | 3136 | 3549952 |

Sources: see text.

Table 4: Summary Statistics

| Variable | mean | st. dev. | min | max | Obs. | # of countries | average obs. per country |
|---|---|---|---|---|---|---|---|
| log Private RR miles | 7.969 | 1.736 | 3.713 | 12.44 | 1022 | 27 | 37.85185 |
| log State RR miles | 7.426 | 1.122 | 3.295 | 10.15 | 836 | 24 | 34.83333 |
| log Real GDP | 16.75 | 1.381 | 13.55 | 19.98 | 1080 | 28 | 38.57143 |
| log Real GDP per capita | 7.625 | 0.542 | 6.179 | 8.611 | 1080 | 28 | 38.57143 |
| log population | 9.182 | 1.47 | 5.723 | 12.622 | 1138 | 28 | 40.64286 |

Sources: see text.

Table 5 Levin-Lin-Chu Panel Unit Root Tests

| variable | t-value | P-value |
|---|---|---|
| log Private RR miles | -8.176 | 0.0378 |
| log State RR miles | -10.938 | 0 |
| log Real GDP | -10.609 | 0.0778 |
| log Real GDP per capita | -10.341 | 0.1676 |
| log population | -7.136 | 0.0162 |
| | | |
| Δlog Private RR miles | -22.822 | 0 |
| Δlog State RR miles | -22.68 | 0 |
| Δlog Real GDP | -28.533 | 0 |
| Δlog Real GDP per Δapita | -28.588 | 0 |
| Δlog propulation | -21.699 | 0 |

Sources: see text.

Notes: Δ means difference between t and t-1. See Levin-Lin-Chu (2002) for details on the test.

Table 6: Augmented Dickey Fuller Tests for Unit Roots

| Country | log private | log state | log gdp |
|---|---|---|---|
| Russia | -0.346 | -4.119* | -0.457 |
| Finland | 1.308 | -1.451 | -0.188 |
| Norway | 1.662 | -3.933* | 1.162 |
| Sweden | -3.094* | -2.954* | 0.047 |
| Denmark | -1.387 | -4.129* | 1.595 |
| Nether. | -4.472* | -1.278 | 0.023 |
| Belgium | -3.009* | -9.617* | -0.645 |
| France | -2.663 | -5.912* | 0.083 |
| Switz | -4.317* | -4.263* | -0.602 |
| Portugal | -0.243 | -2.303 | -0.25 |
| Spain | (-2.98)* | | -0.769 |
| Italy | -2.902* | -4.638* | 1.155 |
| Austria | -0.87 | -4.229* | 0.345 |
| Hungary | -0.433 | -4.35* | -0.244 |
| Japan | -7.527* | -2.088 | -0.084 |
| Egypt | | -1.273 | -1.317 |
| US | -4.858* | | -0.398 |
| Mexico | -3.136* | -1.633 | -0.87 |
| Chile | -4.902* | -1.333 | -0.331 |
| Brazil | -3.849* | -6.985* | -0.193 |
| Uruguay | -1.442 | | -0.093 |
| Argentina | -3.812* | -5.845* | -0.729 |
| UK | -5.772* | | -0.292 |
| Germany | -9.422* | -5.412* | 1.055 |
| India | -11.073* | -3.615* | -1.274 |
| Australia | -2.56 | -5.852* | -0.937 |
| New Zealand | -2.532 | -9.149* | -1.944 |
| Canada | -3.951* | -2.141 | 1.518 |

Sources: see text.
Notes: * indicates significance at the 5% level or below.

Table 7: Westerlund Panel Cointegration tests: Contemporaneously Dated Variables

| test statistic | log private-log gdp | log private-log gdp per capita | log private-log population |
|---|---|---|---|
| Group t | -2.499 | -2.526 | -3.465 |
| | (0.177) | (0.135) | (0)* |
| Group a | -14.027 | -16.466 | -15.04 |
| | (0.048)* | (0)* | (0.006)* |
| Panel t | -11.832 | -11.302 | -20.388 |
| | (0.16) | (0.353) | (0)* |
| Panel a | -12.037 | -12.548 | -14.507 |
| | (0.004)* | (0.001)* | (0)* |
| | log state-log gdp | log state-log gdp per capita | log state-log population |
| Group t | -3.316 | -3.664 | -3.963 |
| | (0)* | (0)* | (0)* |
| Group a | -17.246 | -20.552 | -9.649 |
| | (0)* | (0)* | (0.963) |
| Panel t | -14.892 | -14.217 | -19.3 |
| | (0)* | (0)* | (0)* |
| Panel a | -17.397 | -17.084 | -13.301 |
| | (0)* | (0)* | (0)* |

Sources: see text.
Notes: P-values are in parentheses. * indicates significance at the 5% level or below. Variables are dated in t and t respectively. For details on the panel cointegration test statistics see Westerlund (2007).

Table 8: Westerlund Panel Cointegration Tests: non-contemporaneously dated variables

| test statistic | log private-log gdp t-3 | log private-log gdp per capita t-3 | log private-log population t-3 |
|---|---|---|---|
| Group t | -3.444 | -3.4 | -4.612 |
| | (0)* | (0)* | (0)* |
| Group a | -14.612 | -17.227 | -15.509 |
| | (0.017)* | (0)* | (0.002)* |
| Panel t | -12.596 | -13.311 | -12.343 |
| | (0.03)* | (0.003)* | (0.088) |
| Panel a | -11.501 | -14.551 | -9.32 |
| | (0.013)* | (0)* | (0.373) |
| | log state-log gdp t-3 | log state-log gdp per capita t-3 | log state-log population t-3 |
| Group t | -3.928 | -3.516 | -2.973 |
| | (0)* | (0)* | (0)* |
| Group a | -17.436 | -19.049 | -15.227 |
| | (0)* | (0)* | (0.004)* |
| Panel t | -15.224 | -15.957 | -16.327 |
| | (0)* | (0)* | (0)* |
| Panel a | -17.162 | -17.088 | -12.493 |
| | (0)* | (0)* | (0.001)* |

Sources: see text.
Notes: P-values are in parentheses. Variables are dated in t and t-3 respectively. For details on the panel cointegration test statistics see Westerlund (2007).

Table 9: Dynamic Fixed Effects Error Correction Model: Real GDP and Private and State RR Miles

| | all Countries | | | | European countries | | | | Non-European countries | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Private | | State | | Private | | State | | Private | | State | |
| | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat |
| equation (1) | | | | | | | | | | | | |
| error correction term | -0.075 | -9.44 | -0.17 | -11.8 | -0.053 | -5.35 | -0.11 | -6.17* | -0.111 | -6.86* | -0.23 | -8.8* |
| Short-run effect of Real GDP in t-4 | 0.078 | 1.62 | -0.02 | -0.18 | 0.099 | 1.43 | 0.005 | 0.04 | 0.055 | 0.77 | 0.019 | 0.14 |
| equation (2) | | | | | | | | | | | | |
| error correction term | -0.07 | -5.06 | -0.08 | -5.38 | -0.118 | -5.12 | -0.12 | -4.58 | -0.076 | -3.08 | -0.08 | -3.6 |
| Short-run effect of RR Miles in t-1 | 0.024 | 1.04 | 0.014 | 0.65 | -0.022 | -0.8 | 0.019 | 0.94 | 0.068 | 1.54 | 0.024 | 0.46 |
| Short-run effect of RR Miles in t-2 | 0.039 | 1.7 | 0.017 | 0.83 | 0.037 | 1.29 | 0.025 | 1.3 | 0.037 | 0.89 | -0.01 | -0.14 |
| Short-run effect of RR Miles in t-3 | -0.014 | -0.64 | 0.009 | 0.63 | 0.041 | 1.46 | 0.042 | 2.21 | -0.03 | -0.74 | 0.005 | 0.18 |
| Short-run effect of RR Miles in t-4 | -0.048 | -2.66 | 0.026 | 1.95 | -0.083 | -2.95 | 0.011 | 0.81 | -0.021 | -0.64 | 0.048 | 1.8 |
| cumulative short-term effect of rr miles | 0.001 | | 0.066 | | -0.027 | | 0.097 | | 0.054 | | 0.07 | |

Sources: see text.

Notes: Coefficients in shaded boxes are statistically significant at the 10% level or below.

Table 10: Dynamic Fixed Effects Error Correction Model: Real GDP Capita and Private and State RR Miles

| | all Countries | | | | European countries | | | | Non-European countries | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Private | | State | | Private | | State | | Private | | State | |
| | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat |
| equation (1) | | | | | | | | | | | | |
| error correction term | -0.069 | -9.55 | -0.17 | -11.9 | -0.053 | -5.36 | -0.11 | -6.15 | -0.106 | -6.61 | -0.23 | -8.67 |
| Short-run effect of Real GDP per cap. in t-4 | 0.088 | 1.82 | -0.05 | -0.58 | 0.082 | 1.18 | -0.02 | -0.14 | 0.07 | 0.97 | -0.05 | -0.38 |
| equation (2) | | | | | | | | | | | | |
| error correction term | -0.115 | -6.68 | -0.11 | -6.17 | -0.17 | -6.17 | -0.16 | -4.94 | -0.098 | -3.7 | -0.10 | -3.96 |
| Short-run effect of RR Miles in t-1 | 0.023 | 0.99 | 0.015 | 0.69 | -0.028 | -1.03 | 0.018 | 0.84 | 0.07 | 1.6 | 0.025 | 0.47 |
| Short-run effect of RR Miles in t-2 | 0.03 | 1.33 | 0.012 | 0.61 | 0.032 | 1.12 | 0.019 | 0.95 | 0.021 | 0.51 | -0.02 | -0.32 |
| Short-run effect of RR Miles in t-3 | -0.006 | -0.29 | 0.001 | 0.13 | 0.038 | 1.33 | 0.036 | 1.83 | -0.021 | -0.53 | -0.01 | -0.34 |
| Short-run effect of RR Miles in t-4 | -0.037 | -2.1 | 0.02 | 1.53 | -0.087 | -3.11 | 0.006 | 0.43 | -0.008 | -0.25 | 0.039 | 1.46 |
| cumulative short-term effect of rr miles | 0.01 | | 0.048 | | -0.045 | | 0.079 | | 0.062 | | 0.039 | |

Sources: see text.

Notes: Coefficients in shaded boxes are statistically significant at the 10% level or below.

Table 11: Dynamic Fixed Effects Error Correction Model: Population and Private and State RR Miles

| | all Countries | | | | European countries | | | | Non-European countries | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Private | | State | | Private | | State | | Private | | State | |
| | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat | Coeff | z-stat |
| equation (1) | | | | | | | | | | | | |
| error correction term | -0.082 | -9.93 | -0.16 | -14.9 | -0.055 | -5.61 | -0.12 | -8.21 | -0.115 | -8.07 | -0.191 | -10.1 |
| Short-run effect of Population in t-4 | 0.035 | 0.1 | 0.793 | 1.61 | 0.461 | 0.83 | 0.165 | 0.32 | -0.163 | -0.34 | 1.61 | 1.81 |
| equation (2) | | | | | | | | | | | | |
| error correction term | -0.012 | -3.3 | -0.02 | -4.13 | 0.002 | 0.47 | -0.01 | -0.83 | -0.019 | -2.83 | -0.01 | -2.02 |
| Short-run effect of RR Miles in t-1 | 0.002 | 0.68 | 0.001 | 0.62 | 0.007 | 2.26 | 0 | -0.02 | -0.003 | -0.58 | 0.001 | 0.51 |
| Short-run effect of RR Miles in t-2 | 0.006 | 2.28 | 0.003 | 1.3 | 0.003 | 1.04 | 0.003 | 0.81 | 0.009 | 0.005 | 0.003 | 1.01 |
| Short-run effect of RR Miles in t-3 | -0.013 | -4.9 | 0.004 | 2.46 | 0.001 | 0.46 | 0.006 | 1.56 | -0.017 | -3.92 | 0.003 | 1.62 |
| Short-run effect of RR Miles in t-4 | 0.007 | 3.12 | 0.002 | 1.54 | 0.003 | 1.12 | 0.006 | 2.22 | 0.01 | 2.59 | -0.001 | -0.27 |
| cumulative short-term effect of rr miles | 0.002 | | 0.01 | | 0.014 | | 0.015 | | -0.001 | | 0.0064 | |

Sources: see text.

Notes: Coefficients in shaded boxes are statistically significant at the 10% level or below.