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Infrastructure, Economic Growth and Population Density in Turkey

Mehmet Aldonat Beyzatlar[1], Yeşim Kuştepeli[2]

Abstract

Transportation infrastructure is an exciting topic for public policy, private sector and the connection between them. This study deals with the impact of railways as hard type of transportation infrastructure on economic growth and population density. The purpose of this study is to search for historical relationships between railway infrastructure and economic growth; and between railway infrastructure and population density in Turkey. By using annual data for 1950-2004, both tangible and intangible effects of railway infrastructure are aimed to be estimated. The results form cointegration and causality tests imply that there is a positive long run relationship between railway length and population density and between railway length and real GDP per capita. Railway length causes real GDP per capita to increase only in the long run but it causes population density to increase both in the long and the short run. These results confirm the theoretical framework that improvements in transportation infrastructure lead to higher income and higher population in the investigated area.

Keywords: Hard types of infrastructure, Public Policy, Transportation systems, Railways, Causality

JEL classification: H54, O40, L92

1. Introduction

Public and private sector complementarities have many important linkages for stabilized continuity in terms of infrastructure in wide range (such as transportation, communication). Firm clusters, national and international companies establish their production facilities near transportation sources to benefit from the services they provide. Firms are in need of more opportunities and maintenance from public authorities for various transportation systems. In addition, when new plants are built, public service expenditures such as water, sewer, electricity, telephone lines and internet lines are provided by public sector. Public authorities' support is crucial for private sector settlements for different

[1] Dokuz Eylül University Kaynaklar Campus Facuty of Business Department of Economics, 35160 Buca – Izmir, e-mail. mehmet.beyzatlar@deu.edu.tr

[2] Dokuz Eylül University Kaynaklar Campus Facu

kinds of reasons; for example, more plants offer new job opportunities, thus, they reduce unemployment around those areas.

This perspective argues that public policies create important incentives for private sector as they affect private sector output, labour market, manufacturing industry and many other economic measures. Therefore, public policy should contain feasible and beneficial elements of infrastructure investment to sustain development. Thus, transportation infrastructure is an exciting topic for public policy, private sector and the connection between them. Transportation systems improve rapidly and these improvements go parallel to economical issues such as manufacturing industry production and exports. This is a strong basis for public sector to make innovations, purchase new equipments and provide better maintenance for transport infrastructure.

There are two types of infrastructures; hard type of infrastructure and soft type of infrastructure. Transportation systems or in other words transportation infrastructure is considered to be a part of both types. Hard type of infrastructure deals with roads, highways, railways, harbours, airports, water and sewer and other. Soft type of infrastructure concerns telephone lines, internet, other communication infrastructures and institutional infrastructure types which act as complements to hard types of infrastructure. In this study, hard types of transportation infrastructure, and especially railways, are taken into consideration due to their positive role in the historical economic development of Turkey.

The purpose of this study is to search for historical causality relationships between railway infrastructure and economic growth and between railway infrastructure and population density. By these, it is aimed to measure not only the tangible but also the intangible effects of railways.

The next section of the study provides the literature review about the proposed hypothesis. The third part includes the data as well as the methodology. The results, which are obtained by relevant econometric tests, are presented in the empirical analysis part. The conclusion and the policy implications are given in the fifth section.

2. Literature Review[1]

2.1 Transportation Infrastructure and Economic Measures

The effects of infrastructure on economic measures have been investigated for more than three decades. These effects became more visible with the increase of trade in the world which resulted in the requirement of faster and multi dimensional trade routes. Firms began to form clusters near airports and harbours. More firms meant more plants which increased the demand for infrastructure. Therefore, infrastructure investment became one of the most susceptible connections between the private sector and public authorities.

The pioneer study which considers the relationship between economic and infrastructure measures from public and private sector complementarity perspective,

[1] This section provides only a brief discussion of the literature. The authors have conducted a comprehensive literature survey which is dismissed due to space limitations.

is Aschauer (1989) where he investigates the impact of public capital on private sector productivity. His results indicate that the elasticity of private sector productivity with respect to public capital is positive, meaning that infrastructure has positive impact on private sector productivity.

In a later study, Aschauer (1990) defines an exact transportation infrastructure rather than a basket of infrastructure measures and selects highways to analyse the impact on per capita income. His findings denote there is a positive relationship.

Government expenditures on transportation are analysed by Jones (1990) and Mofidi and Stone (1990) with the help of a production function; where Jones (1990) takes employment, income and investment as economic measures and finds that transportation expenditures have positive effects on these economic measures. Mofidi and Stone (1990) also find positive interaction between highway spending and manufacturing investments and employment. Munnell and Cook (1990) follow previous studies and they show that highways increase Gross State Product (GSP). Similarly, Duffy-Deno and Eberts (1991), Eisner (1991), Garcia-Mila and McGuire (1992) and Moonmaw, et al. (1995) find a positive relationship between transport infrastructure and per capita income. Singletary, et al. (1995), Crihfield and Panggabean (1995), Garcia-Mila, et al. (1996) and Fernald (1999) attain similar results, such that highway constructions have positive impact on manufacturing industry employment growth, manufacturing output, private sector output and productivity.

The researchers that use cost function approach also come up with positive impact of transportation infrastructure. Berndt and Hansson (1992), Lynde and Richmond (1993), Seitz (1993), Nadiri and Mamuneas (1994), Conrad and Seitz (1994) and Boarnet (1996; 1998) analyse Sweden, United Kingdom, West Germany and USA, respectively, and their common outcome is that transportation infrastructure is a cost reducing element in different geographies and industries.

The marginal contribution of public infrastructure relies on the structure of economy and previous conditions of the country (Crihfield and Panggabean, 1995). There is not a consensus on its effect on growth rate of output when transportation is viewed as public capital. The payoff of the investment is related to the size and configuration of the network, being usually smaller in the case of larger networks. If public capital is viewed as a public good, increases in the public capital shift the production function upward, raising the steady state level of output and the growth rate of the economy in the transition to the steady state. On the contrary, many services provided by the public capital stock may be subject to congestion, and therefore the marginal increments of the public capital stock may not have an impact on output. Sanchez-Robles (1998) show that infrastructure expenditures as a share of GDP yield inconclusive results but the indexes of infrastructure physical units are significantly and positively related to per capita growth.

2.1 Transportation Infrastructure and Demographic Measures

In addition to the effects of transportation infrastructure on tangible measures such as output, there are also intangible effects on demographic variables such as living standards, population and migration. People may desire to live in a city, where their children can receive better education and they can find jobs with higher wages. This kind of behaviour tends to be seen more in developing countries rather than developed countries. That is why investing in transportation infrastructure has often been appraised as an effective strategy for policy-makers in underdeveloped areas rather than developed ones.

Although scholars define the role of transportation infrastructure differently on the basis of regional economic theories, all recognise the fact that it plays an important role in regional economic growth and development (Mikelbank, 1996). Demographers view transportation infrastructure as a necessary but not sufficient requirement for local economic growth and development (Halstead and Deller, 1997), as if transportation infrastructure is one of many factors affecting population change (Boarnet and Haughwout, 2000; Bohm and Patterson, 1971, 1972; Briggs, 1981; Hobbs and Campbell, 1967; Taylor, Broder, and McNamara, 1987; William, 1958).

Chi, Voss and Deller (2006) provide an extensive summary of the existing literature for transportation and population change. They argue that there are two ways to understand the relationship between transportation and population: the possible paths by which investments in transportation influence population change in addition to the stages (preconstruction, construction, and post construction) and spatial areas (urban, suburban, and rural) that population change is related to transportation. At the county and municipal levels, they address transportation as indirect causes of population change via economic growth, employment change, socio-demographic structures, and environmental change.

Growth theories (neoclassical growth theory, growth pole theory, and location theories) are the principal regional economic theories that relate transportation infrastructure investment to economic growth and population change. Neoclassical growth theory is insightful in explaining and predicting metropolitan development after the transportation network has been built. Neoclassical growth theory considers transportation infrastructure as an input into the production process (Boarnet, 1997; Eberts, 1990), an enhancer to increase the productivity of other inputs such as labour (Eberts, 1994) or a household amenity factor to attract workers (Eberts, 1994).

Growth pole theory is useful for forecasting population change from the standpoint of decision makers because it specifically outlines how resources should be invested in a region given limited resources to devote to economic growth and development (Thiel, 1962). Growth pole theory interprets transportation investment as a catalyst of change to influence population growth in its surrounding areas where population decline is also a possible outcome. Location theory is strong in interpreting geographic distributions of human settlements. This theory perceives transportation infrastructure as a facilitator for the flows of raw materials, capital, finished goods, consumers, and ideas among central places and their neighbourhoods and a limitation on these flows, as a means of importing inputs into and exporting outputs out of a location (Vickerman, 1991); or as necessary but not sufficient for local economic growth and development (Halstead and Deller, 1997).

Allen and MaClennan (1970) use growth pole theory to identify centers of economic activity that are believed to attract investment because of their agglomerative powers. They observe regional problems which are caused directly and/or indirectly by public policies in Italy and France. The study identifies growth poles as urban areas having population interval between 30,000 and 200,000 residents. The research concludes that rural areas close to these cities may benefit from spread effects and public policies are effective among those benefit relations. Hansen (1971) uses regional development theory to determine the best use of infrastructure investment at a minimum population threshold of 250,000 for areas deemed worthy of infrastructure investment. He argues that investment in public infrastructure should be concentrated in urban areas that have some level of prior dynamism or development.

Gaegler, March and Weiner (1979) and Lichter and Fuguitt (1980) investigate the relationship between interstate highways and demographic measures such as employment population characteristics for various service industries in non-metropolitan counties during the period 1950-75. They find that counties with interstate highways consistently maintained an advantage over other counties in net migration and employment growth. Population growth was also found to be the greatest in interstate highway counties, with positive effects of highways on net migration, and the strongest in less remote areas.

Hilewick, Deak and Heinze (1980) is another empirical study which looks at rural growth effects of investing in transportation networks compared with the effects of investing in communications systems, thus, providing a comparison among soft type and hard type of infrastructure systems. They conclude that investing in communication results in stronger short-term and long-term effects rather than transportation investments on demographic and economic measures such as population, jobs, income, gross regional product and overall economic structure.

Carlino and Mills (1987) and McHugh and Wilkinson (1988) investigate the factors affecting US county population and employment growth during the 1970s. Total employment, manufacturing employment and population density are positively affected by the presence of limited-access highways.

Just as population change can have many causal factors, transportation can influence population change by several paths: economic growth or decline, employment and socio-demographic structure. Forkenbrock and Foster (1996) examine the degree to which highways as transportation measures are likely to influence business location decisions. They argue that access to highways generally has become a less important factor in location decisions than it was earlier. State-level highway investment policies that emphasise proper maintenance and relatively minor improvements are likely to be more cost-effective strategies for economic development than expensive highway construction projects.

3. Data and Methodology

3.1 Data

The variables used in this study are railway length for railway infrastructure, population density and real GDP per capita for economic growth. These variables are represented by RW, PD and GDP respectively throughout the analysis. Data for railway length is acquired from Turkish State Railways (TCDD) (http://www.tcdd.gov.tr) in kilometers. Population and real GDP per capita data are acquired from Penn World Tables (http://pwt.econ.upenn.edu) and the areas in square kilometers are obtained from Turkish Statistical Institute (TUIK) (http://www.turkstat.gov.tr).

Population density data is not directly acquired from any database and therefore, population density[2] is calculated by dividing the population of the observed place by the area of the same place in square kilometers[3]. All data are obtained annually for the period from 1950 to 2004.

3.2 Methodology

The aim of this study is to investigate the historical relationships between railway infrastructure and economic growth as well as between railway infrastructure and population density for Turkey by using time series analysis (cointegration and causality analysis). The literature reveals that production-function and cost-function approaches in addition to causality analysis are widely used to test the relationship between transportation infrastructure and economic growth. Causality analysis is also used to investigate the effect of transportation infrastructure on demographic measures.

Time-series analysis requires that the variables should be tested in order to find their stationarity by applying unit-root tests. The stationarity of the variables are determined by the use of three different tests to check the robustness of the results: ADF (Augmented Dickey-Fuller), PP (Phillips-Perron) and KPSS (Kwiatkowski-Phillips-Schmidt-Shin) unit-root tests.

After unit-root tests, cointegration tests are performed as the second step. A cointegration analysis is used to determine whether a group of non-stationary variables are cointegrated or not. The Engle-Granger cointegration test, which is also called Engle-Granger two-step cointegration test, is conducted first and is composed of two steps. The first step gives the long-run relationship with respect to the coefficients and t-statistics of variables, integrated in the same order. The error term, which is taken from first step, is saved and ADF unit-root test is applied to error term (u_t) to find that if it is stationary or not. Error Correction Mechanism (ECM) is the aim of the second step and is the first lagged value of the error term (u_{t-1}) obtained from the first step. If that value is between 0 and -1, ECM is said to work.

Johansen cointegration test is also performed to compare the results of Engle-Granger cointegration test as the second test. Johansen cointegration test implements Vector auto-regression (VAR) based cointegration analysis developed by Johansen in the early 1990s.

Causality relationship analysis is the third step after unit root testing and cointegration analysis. Causality tests can be performed in both bivariate and multivariate models. A

2 Population Density = Population / Area (number of inhabitants per square kilometer)

3 Lakes are excluded in the calculation of the population density of the observed area.

stationary variable X_{1t} is said to Granger-cause another stationary variable X_{2t} if the past values of X_{1t} are significant in the explanation of X_{2t}. If the variables are found to be cointegrated, the error correction terms of the cointegrating vectors are included in causality testing. Granger-Causality test is modeled as follows:

(1)
$$X_1(t) = \sum_{j=1}^{p} A_{11j} X_1(t-j) + \sum_{j=1}^{p} A_{12j} X_2(t-j) + E_1(t)$$

$$X_2(t) = \sum_{j=1}^{p} A_{21j} X_2(t-j) + \sum_{j=1}^{p} A_{22j} X_1(t-j) + E_2(t)$$

This model tests the causality relationship between two variables in both directions such as from railways to population and from population to railways. The direction of the effect is important as well as the magnitude of the relation. The test uses F-test on lagged values of both variables during the estimation process of the regression model. The general model (1) above is transformed to model (2) in order to test the relationship between real GDP per capita and RW and in order to test the relationship between PD and RW it is transformed to model (3). If the variables are found to contain unit roots, they should be differenced until they are stationary.

(2)
$$GDP(t) = \sum_{j=1}^{p} A_{11j} GDP(t-j) + \sum_{j=1}^{p} A_{12j} RW(t-j) + E_1(t)$$

$$RW(t) = \sum_{j=1}^{p} A_{21j} RW(t-j) + \sum_{j=1}^{p} A_{22j} GDP(t-j) + E_2(t)$$

(3)
$$PD(t) = \sum_{j=1}^{p} A_{11j} PD(t-j) + \sum_{j=1}^{p} A_{12j} RW(t-j) + E_1(t)$$

$$RW(t) = \sum_{j=1}^{p} A_{21j} RW(t-j) + \sum_{j=1}^{p} A_{22j} PD(t-j) + E_2(t)$$

4. Empirical Analysis

Before starting to employ the econometric tests, it is deemed valuable to graph the variables in question and provide descriptive statistics about them. Figure 1 through 3 plots the variables against the time period. Each variable is shown in individual graphs as their scales are different. Table 1 presents the descriptive statistics of the three series.

Figure 1: Population Density (number of inhabitants per square kilometer)

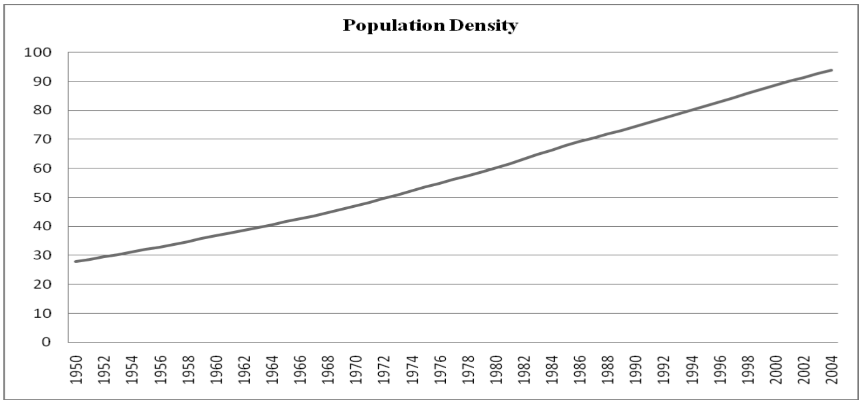

Figure 2: Real GDP per capita

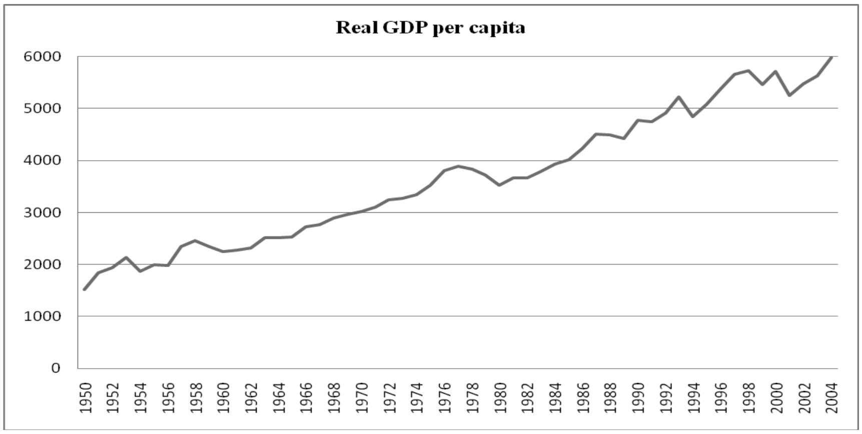

Figure 3: Railway Length (in km)

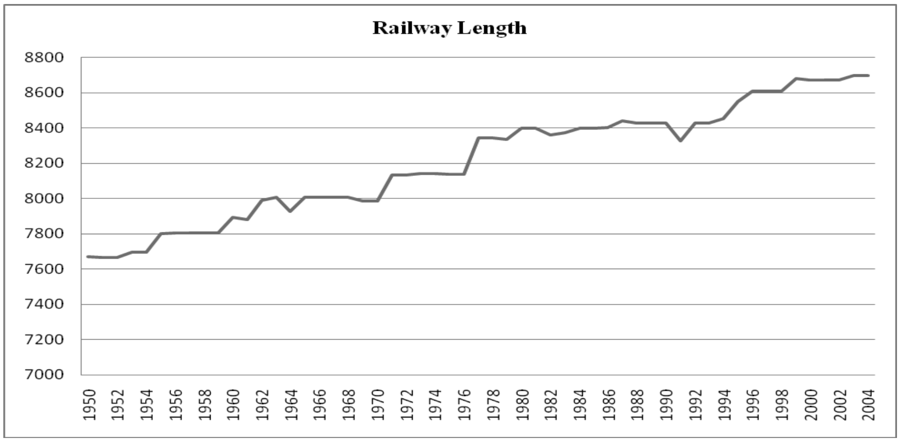

Table 1: Descriptive Statistics of Series

	PD	GDP	RW
Mean	3,9962	8,1407	9,0123
Standart Deviation	0,3678	0,3661	0,0389
Skewness	-0,2095	-0,2655	-0,1999
Kurtosis	-1,2139	-1,0046	-1,1651

Cointegration analysis is feasible only if the variables under consideration are integrated of the same order, i.e. if they have the same number of unit roots. Table 2 shows the results of the Augmented Dickey Fuller (ADF), Phillips-Perron and KPSS unit root tests for RW, PD and GDP. The results indicate that all variables have one unit root or in other words, they are integrated of order (1). This implies that cointegration analysis can be pursued.

Table 2: Unit-Root Tests

			GDP	RW	PD
ADF	No Trend	Level	-1,849** (1)	0,972** (1)	-1,367** (1)
		1st Dif.	-9,113 (0)	-9,135 (0)	-3,012 (2)
	Trend	Level	-1,804** (3)	-3,36** (1)	-3,047** (3)
		1st Dif.	-5,72 (0)	-9,082 (0)	-4,172 (2)
PP	No Trend	Level	-2,762** (0)	-0,866** (2)	-4,672 (1)
		1st Dif.	-14,857 (3)	-9,463 (3)	-2,560* (2)
	Trend	Level	-4,913 (0)	-3,37** (3)	-3,90* (5)
		1st Dif.	-28,285 (3)	-9,440 (2)	-0,935 (1)
KPSS	No Trend	Level	1,912* (2)	0,883** (6)	1,079** (5)
		1st Dif.	0.394 (2)	0,058 (2)	0,340 (6)
	Trend	Level	0.219** (3)	0,189** (2)	0,183* (4)
		1st Dif.	0.056 (3)	0,036 (2)	0,189 (9)

Note: *, ** and *** denotes the unit root existence at 1%, 5% and 10% significance levels respectively. The numbers in parenthesis are optimum number of lags determined according to AIC for ADF test; critical values are based on MacKinnon (1991). For PP and KPSS tests, numbers in parenthesis are the truncation lag determined according to Bartlett Kernel.

In the next step Engle-Granger two-step cointegration test is performed and Table 3 and Table 4 show the results of this test on the two hypotheses of the paper. In both cases, there is evidence of positive long run cointegration relationship. Railway length affects gross domestic product and population density positively with very close coefficients (11.29 and 11.84 respectively). ECM is obtained from the second step of Engle-Granger test as -0,17 and -0,02 for both hypotheses, which can be monitored in tables 3 and 4 respectively. ECM is working in both hypotheses because the values of the ECM terms are between 0 and -1 and are statistically significantly less than 0. It should be mentioned that the ECM term in the second regression in Table 4 is only just significant at the 10 % level and the coefficient of the term is much smaller than the one in Table 3, implying a much weaker error feedback effect.

Table 3: Engle-Granger Cointegration Test for railway length and real GDP per capita

$lgdp_t = \beta_0 + \beta_1 lrw_t + u_t$				
1st STEP	Regressor	Coefficient	Standard Dev.	T-stat (Prob.)
	C	-96.2828	3.5321	-27.2594 [.000]
	RW	*11.2855*	0.3816	*29.5701 [.000]*
ADF on residuals: -3.5245** (1)				
$\Delta lgdp_t = \alpha_0 + \alpha_1 \Delta lrw_t + \alpha_2 u_t(-1) + e_t$				
2nd STEP	Regressor	Coefficient	Standard Dev.	T-stat (Prob.)
	u_{t-1} (ECM)	-0.1709	0.0847	-2.017 [.049]

Note: * denote the rejection of the null hypothesis and ** denote the non-rejection of the null hypothesis at 5% level respectively. Critical value are based on MacKinnon (1991) and at 5% significance level are -2.9179; models include constant and no trend; *k* is the lag length used in the test for each series and number of lags are determined according to the AIC and given in parenthesis.

Table 4: Engle-Granger Cointegration Test for railway length and population density

$lpd_t = \beta_0 + \beta_1 lrw_t + u_t$				
1st STEP	Regressor	Coefficient	Standard Dev.	T-stat (Prob.)
	C	-45.8564	1.1087	-41.3595 [.000]
	RW	*11.8422*	0.2758	*42.9251 [.000]*
ADF on residuals : -3.6124** (1)				
$\Delta lpd_t = \alpha_0 + \alpha_1 \Delta lrw_t + \alpha_2 u_t(-1) + e_t$				
2nd STEP	Regressor	Coefficient	Standard Dev.	T-stat (Prob.)
	u_{t-1} (ECM)	-0,0176	0,0105	-1.6777 [.100]

Note: * denote the rejection of the null hypothesis and ** denote the non-rejection of the null hypothesis at 5% level respectively. Critical value are based on MacKinnon (1991) and at 5% significance level are -2.9179; models include constant and no trend; *k* is the lag length used in the test for each series and number of lags are determined according to the AIC and given in parenthesis.

Although Engle-Granger test is suitable for an analysis with two variables, Johansen cointegration test is also applied in order to test the robustness of the results. The results of this test provided in Tables 5 and 6, confirm the results of the Engle-Granger test of a cointegration relationship for both of the relationships. The coefficients are 13.09 and 10.64 respectively and statistically significant.

Table 5: Johansen Cointegration Tests for railway length and real GDP per capita

TRACE TEST					
Null	Alternative	Statistics	1 %	5 %	10 %
r = 0	r >= 1	35.6366	25.0781*	20.2618*	17.9803*
r <= 1	r >= 2	8.6456	12.7607	9.1645	7.5567*
MAXIMUM EIGENVALUE TEST					
Null	Alternative	Statistics	1%	5%	10%
r = 0	r >= 1	26.9910	25.0781*	15.8921*	13.9059*
r <= 1	r >= 2	8.6456	12.7607	9.1645	7.5567*
$lgdp_t = -49.17^* + 13.095^* lrw_t$					

*, *** denote statistical significance at 1 and 10 % respectively.

Table 6: Johansen Cointegration Tests for railway length and population density

TRACE TEST					
Null	Alternative	Statistics	1 %	5 %	10 %
r = 0	r >= 1	66.9313*	31.1538	25.8721	23.3423
r <= 1	r >= 2	7.4890	16.5538	12.5179	10.6663
MAXIMUM EIGENVALUE TEST					
Null	Alternative	Statistics	1%	5%	10%
r = 0	r >= 1	59.4423	23.9753	19.3870	17.2341
r <= 1	r >= 2	7.4890***	16.5538	12.5179	10.6663
$lpd_t = -40.97^{*} + \mathit{10.641}^{*} lrw_t$					

*, *** denote statistical significance at 1 and 10 % respectively.

Granger causality test takes into account the cointegration relationships between the variables and tests the causality of this long run in addition to the short run causality by determined lag lengths. The causality test is carried through a vector auto regression where the short run causality is tested with F-test and the long run cointegration relationship is tested with t-test. All variables are in their first differences as they are found to contain one unit root. In addition, the ECM terms are included and tested as long term causality.

According to the results posted in Table 7, the long run relationship for railway length and real GDP per capita is significant for both directions; meaning that they cause each other in the long run. However, in the short run, real GDP per capita causes railway length to decrease (-0.036, -0.008).

Railway length causes population density to increase both in the short and the long run. The size of the F-statistics is interestingly very large (12943.36). Population density affects railway length only in the long run as the coefficient of the cointegration relationship is found to be significant.

Table 7: Granger Causality Test

null hypotheses	dependent variable	# of lags	f-test for short run	coefficients	t-test for long run
Railway length doesn't cause GDP	Δ *(GDP)*	(2)	2.226	-0.388 -3.067	-2.100**
GDP doesn't cause railway length	Δ *(railway length)*	(2)	3.744***	-0.036 -0.008	3.183*
Railway length doesn't cause population density	Δ *(population density)*	(3)	12943.36*	0.011 0.006 0.001	2.822*
Population density doesn't cause railway length	Δ *(railway length)*	(3)	2.004	-3.454 5.577 -2.535	2.739*

*, ** and *** indicate the rejection of the null hypothesis at 1, 5 and 10% significance levels respectively. Δ denotes change.

5. Conclusion

From the perspective of public sector and private sector complementarities, transportation infrastructure constitutes an important and interesting topic. National and international companies establish their production facilities near transportation sources to benefit from the services they provide. Firms are in need of more opportunities and maintenance from public authorities for various transportation systems. In addition, when new plants are built, public service expenditures such as water, sewer, electricity, telephone lines and internet lines are provided by public sector.

This study investigates the historical causality relationships between railway transport infrastructure and economic growth as well as that between railway infrastructure and population density in Turkey for 1950-2004. The long run estimation results indicate that both of the relationships are positive in the long run. Railway length causes real GDP per capita to increase only in the long run but it causes population density to increase both in the long and the short run. These results confirm the theoretical framework that transportation infrastructure leads to higher income and higher population in the investigated area.

There is also evidence that although increase in real GDP per capita leads to an increase in railway length in the long run, in the short run it leads to a decrease. This implies that when income of the country increases, resources are devoted out of railway infrastructure to other areas, but in the long run investment in railways continues. In addition, as railways cause population density to increase in the long run, population density makes the same effect on railway length.

Finally, it should be emphasised that this study has focused only on bilateral relationships between railways and population and also between railways and income per capita. Future research on the topic will therefore be directed towards enhancing the analysis by utilising multi-variable econometric tools such as Vector Auto Regression Analysis (VAR) in which other relevant variables (e.g. agricultural production) can be included.

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