IMPACTS OF TRANSPORTATION- COMMUNICATION INVESTMENT ON ECONOMIC GROWTH: A STUDY FOR TURKEY

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I. INTRODUCTION

In this paper, we analyze the effect of transportation-communication capital on gross domestic product in Turkey for the period of 1968-2006 based on a vector error correction model. Since transportation-communication capital is a kind of infrastructure capital, in the related literature, its impact on the level of output and productivity has generally investigated together with the other public infrastructure capital. In this paper, the transportation-communication capital is analyzed separately. Hence, the main question that is addressed in our paper is as follows: Does total transportation-communication capital have a positive impact on the real output and what is the magnitude and behavior of this effect in the short and long term for the Turkish economy?

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This question above in terms of public infrastructure capital is answered by various studies for several countries using different approaches (Ratner, 1983; Aschauer, 1989; Ram and Ramsey, 1989; Holtz-Eakin, 1992; Easterly and Rebelo, 1993; Pererira and de Frutos, 1999; Sturm, Jacobs and Groote, 1999; Everaert and Heylen, 2000; Pereira and Roca-Sagales, 2001; Haque and Kim, 2003; Pereira and Andraz, 2005; and Herranz-Loncan, 2007). However, there are only a few studies analyzing the relationships between public infrastructure capital and private sector productivity for the Turkish economy (Karadag, Deliktas and Onder, 2004; Ismihan, Metin-Ozcan and Tansel, 2005). Furthermore, to our knowledge, no study examines the possible effect of the total transportation-communication capital on gross domestic product for the Turkish economy. Hence, this paper can be seen as the first attempt to analyze the impact of the total transportation-communication capital on gross domestic product for the Turkish economy.[4]

The reason why we choose transportation-communication sector for this kind of analysis can be found in its significant place in the Turkish economy. The share of the transportation-communication capital investments in the total fixed capital investments is 19.41 % for the year 2006 in Turkey.[5] This ratio is the second after the manufacturing sector which is 35.2 % SPO (2008). Another characteristic of the transportation-communication sector is its share within the gross national product, which reaches to 14.7 % in the year 2006, coming just after the manufacturing and trade sectors TurkStat (2006). Apart from these stylized facts, there are also several *theoretical points* regarding the possible impacts of transportation-communication capital on the economy. As emphasized in the World Bank (1996, p.1); improved transport is on the core of the development process, i) providing the accession to the jobs, education, health, resources, markets, ii) promoting the social return to private investment in the absence of a crowding out effect to the other productive capital, iii) reducing rural transport costs and thus agricultural production costs directly, iv) advancing urban transport and therefore increasing labor market efficiency, v) allowing the scale economies conditions and agglomeration changes, vi) increasing the frequency of people and freight, and hence mobility. Briefly, improving transport affects productivity by facilitating the accessibility and mobility of the production factors and goods. Therefore, it may cause to several dynamics to increase the output of a country. Thus, all these reasons make the analysis

[4] Due to the non-separated official data of TurkStat, we had to process transportation sector with communication sector under the name of transportation-communication sector.

[5] According to authors' own calculations based on SPO (1970-2008), this figure is 20.2 % in average for the period of 1968-2006.

of the transportation-communication capital for its possible impacts on the economic growth an important issue.

As stated above, the main point of this paper is the assessment of the short and long term relationships between transportation-communication capital and output for Turkey. The study applies a Cobb-Douglas production function for Turkish economy under the assumption of constant returns to scale and employs unit root tests and cointegration analysis by estimating a *cointegrated* vector autoregressive (VAR) model, or namely, a *vector error correction model* (VECM). Apart from accounting for the *nonstationarity* of time-series data, this methodology also allows taking into account the *indirect relationships* among different variables within the multivariate system.

The paper is organized as follows: in Section II a brief literature review is introduced, Section III is about the data issues, in Section IV the VAR/VECM methodology of the study is presented, Section V gives the specification details and the estimation results of the model together with a discussion of the findings. Finally, Section VI is reserved for concluding remarks.

II. A SHORT SURVEY OF THE LITERATURE

Kamps (2005) gives a brief survey of the studies that apply VAR/VECM methodology to analyze the dynamic effects of public capital. The majority of these studies have found that the long term effect of public capital on output is positive. Most of the studies that are not surveyed by Kamps (2005) and use VAR/VECM methodology also find that public capital increases output (Ramirez, 2000; Ligthart, 2002; Everaert and Heylen, 2000; Looney, 1997; Albala-Bertrand and Mamatzakis, 2001; Ramirez 2004; Mittnik and Neumann, 2001; Pereira 2001; Kawakami and Doi, 2004; Kamps, 2005). Among others, the only exception is the study by Ghali (1998) that investigates for the impact of the public investments on Tunisian economic growth over the period 1963-1993. Ghali (1998), using a vector error correction model, claims that the public investments have contributed negatively to Tunisia’s economic growth.

The studies that emphasize the role of infrastructure variables separately are very limited in the literature. Among others, Looney (1997) analyses the role of infrastructure variables such as energy and transport in Pakistan's economic expansion for the period 1973-1995 based on a vector error correction model and finds that public facilities expand largely in response to the needs by private sector.

Although there is a voluminous literature studying the dynamic effects of public capital using VAR methodology in other countries, for Turkey such studies are very limited (Ismihan, Metin-Ozcan and Tansel, 2005; Karadag, Deliktas and Onder, 2004). Karadag et al. (2004) examine the impact of public capital formation on private manufacturing sector performance at both regional and aggregate level for the period 1980-2000 using a VAR model. They show that public capital affects private output positively in aggregate and in all regions apart from the Black Sea and Mediterranean regions. However, public capital is found to crowd out private employment and capital in the aggregate. At the regional level, only in the Marmara region public capital is found to crowd in both private capital and employment. Ismihan et al. (2005) corroborates the above findings at the aggregate level. Their study differs by studying the effects of macroeconomic instability on public and private capital accumulation and growth in Turkey over the period 1963-1999 using a VECM. The results show that while total public invetment has a positive effect on output of Turkey, it crowds in private investment in the short run to medium run, but crowds out it in the long run. In the paper, this last finding is attributed to the increasing and chronic macroeconomic instability of the Turkish economy. Macroeconomic instability damages, or even destroys, the complementarity between public and private investment in the long run.

As stated before, to our knowledge, there is no study that separately examines the possible effects of total transportation-communication capital on gross domestic product for the Turkish economy. Thus, this paper can be seen as a first attempt to analyze the dynamic interactions between the total transportation-communication capital and gross domestic product for the Turkish economy.

III. DATA

There is no officially calculated and issued capital stock (*K*) data for the Turkish economy. Due to the lack of capital stock data, the number of studies about Turkish economy concerning the capital stock is rather limited. One of the aims of this paper was to generate a new capital stock data for Turkey. Hence, it can be stated that this study is of special importance in this regard.

The relevant capital stock series for Turkey were generated by the help of the following equation:

$$K_{it} = (1 - d_i)K_{it-1} + I_{it} \tag{1}$$

where I_{it} is fixed investment during time *t* in sector *i*, K_{it} represent capital stock at the end of time *t* in sector *i*, d_i denotes the average depreciation rate of capital stock in sector *i*. A problem with the method in equation (1) is how to calculate the capital stock of the initial period in the sample. Following Khan and Sasaki (2001, p.161), the initial period capital stock estimates are obtained by the equation $K_0^T = IK_0^T / (g_K + d_K^T)$ where IK_0^T denotes total fixed investment at initial period, g_K is growth rates of fixed investments, d_K^T represents weighted depreciation rate of capital stock. The weighted depreciation rate of capital stock is given by $d_K^T = \sum w_i^K d_i$ and the weights are defined as average share of each sector's fixed investment in total investment. Since sectoral depreciation rates in Turkey were not available, we used the rates of OECD (1998). The growth rate of fixed investment *g* has been used differently in the literature; following Khan and Sasaki (2001) we used the average growth rate over the entire sample period employing the following relation: $g_K = (\ln IK_{2006} - \ln IK_{1963}) / 43$. Initial capital stocks for each sector are calculated using following ratios: $K_0^i = (\sum_t IK_t^i / \sum_t IK_t^T).K_0^T$.

Gross fixed investments by sectors and *public sector fixed capital investment deflators* are obtained from SPO (1970-2008) and SPO (2008). Gross Domestic Product, GDP deflator and employment data are obtained from TurkStat (2006). The overall data set covers the period 1963-2006 for Turkey.

IV. METHODOLOGY

A vector autoregression (VAR) model of order p with n variables can be represented by the following equation:

$$x_t = A_1 x_{t-1} + A_2 x_{t-2} + ... + A_p x_{t-p} + By_t + \varepsilon_t \quad (2)$$

where x_t is an $(n \times 1)$ vector of endogenous variables $x_{1t}, x_{2t}, ..., x_{nt}$, y_t is an $(m \times 1)$ vector of deterministic terms, B is an $(n \times m)$ matrix of coefficients on the deterministic term, A_i's for $i=1,2,..,p$ are $(n \times n)$ matrix of autoregressive coefficients, and ε_t an $(n \times 1)$ vector of non-autocorrelated disturbances (innovations) with zero mean and contemporaneous covariance matrix $E\left[\varepsilon_t \varepsilon_t'\right] = \Omega$.

The Var(p) model defined in equation (2) can be appropriately reparametrized as:

$$\Delta x_t = \pi x_{t-1} + \sum_{i=1}^{p-1} \pi_i \Delta x_{t-i} + By_t + \varepsilon_t \quad (3)$$

where now $\pi = -(I - \sum_{i=1}^{p} A_i)$ and $\pi_i = -\sum_{k=i+1}^{p} A_k$ are $(n \times n)$ matrix of coefficients and I is an $(n \times n)$ identity matrix.

The rank of matrix π equals to the number of independent cointegrating vectors. The rank of this matrix (denoted by r) could be between 0 and n. If rank of matrix π is equal to 0, all of the n variables are unit root processes and are not cointegrated. In this case, the VAR should be solely specified in first differences. It is clear from this discussion that, a VAR model in *first differences* should not be estimated unless there are no cointegrating relationships between the I(1) variables involved. At the other extreme, if rank of π equals to n, then the VAR model consists of all stationary variables. In the interim cases, where the rank of π is between 1 and (n-1), there are multiple cointegrating vectors. In this last case, it is appropriate to work with the *vector error correction* (VEC) formulation of the VAR model given in equation (3). Granger's representation theorem asserts that there exist $(n \times r)$ matrices (or vectors if *r* equals to 1) α and β each with rank *r* such that $\pi = \alpha\beta'$ and $\beta' x_{t-1}$ is I(0). Each row of β' is the cointegrating vector and the elements of α are known as the adjustment coefficients in the VEC model. Johansen's methodology is to estimate the π matrix from an unrestricted VAR and to determine its rank. The asymptotic distribution of the test statistics for cointegration do not have the usual chi-square distribution and depends on the assumptions made with respect to deterministic terms y_t in equation (3) (Johnston and Dinardo, 1997, p.302). The series involved may have nonzero means and deterministic trends as well as stochastic trends. Similarly, the cointegrating equations may have intercepts and deterministic trends. Therefore, in order to carry out the cointegration tests, one needs to make an assumption regarding the trend underlying the data. Johansen (1995, pp. 156-157) distinguishes among five cases depending on the way the deterministic terms are restricted.

A shock given to one of the variables in a VAR model at time *t* not only affects itself (at time *t*) but causes a chain reaction in *t+1*, *t+2*, and so on in all variables in the VAR through the dynamic lag structure inherent in the model. *Impulse response* functions calculate these chain reactions. In the VAR model a shock given to one variable affects another variable not only directly but also indirectly through its affect on another variable. To analyze all these dynamic interactions between variables one needs to analyze the impulse response functions. However, when the VAR involves nonstationary variables the impulse response functions obtained from that VAR cannot be interpreted with safety[6]. Then, in such a case one must resort to the impulse responses obtained from the VEC formulation of the VAR model with cointegrated nonstationary variables.

While impulse response functions show how a shock given to one variable is transmitted on to the other variables in the VAR model, *variance decomposition* separates this variation in a variable into its components. That is to say, variance decompositions show whether the movement in one variable is affected most by a shock to itself or to a shock to other variables. Thus, variance decomposition provides information about the relative importance of each random innovation in affecting the variables in the VAR. Again, if variables are cointegrated you can work with the VEC formulation. Since with a cointegrated system, the error correction term and all lagged first differenced terms are stationary, impulse responses and variance decompositions yield consistent estimates of the variables.

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[6]As argued in Johnston and Dinardo (1997, p.298), there is little point in studying impulse response functions for nonstationary systems.

To sum, VEC models are a way to model nonstationary variables that appear to converge to a long-run cointegrating relationship. In the VEC model the adjustment parameters show how each variable deviates in the short-run from the long-run equilibrium relationships given by the cointegrationg vectors. Therefore, to study both the short-run and the long-run dynamics between nonstationary but cointegrated variables and the dynamic interactions between them one should estimate a VEC model and make inferences using this system.

In light of the above discussions, to study the impact of transportation capital on output, we will follow the Johansen methodology. First we will set up an unrestricted undifferenced VAR model to select the lag length *p* of equation (2). Before this step, the variables will be pretested for the presence of unit roots and their orders of integration will be determined. After all there is little point in testing the rank of π if all the variables are already stationary. In case that the variables are found to be integrated of different orders than one has to carry out multicointegration tests. After determining the order of the VAR the model given in equation (3) will be estimated and the rank of π will be determined. Finally, impulse response and variance decomposition analysis on the VEC model will allow us to study the dynamic relations between the variables involved.

V. SPECIFICATION AND RESULTS

To investigate the growth impact of transportation-communication investment, a standard Cobb-Douglas production function on three inputs (augmented with transport-cummunication capital) under the assumption of constant returns to scale is used. Hence, the production function in study is similar to the specifications used in Herranz-Loncán (2007), Albala-Bertrand and Mamatzakis (2001), Ramirez (2000) and Ramirez (2004); but here it is revised for to include transportation-communication capital.

Expressed as a logarithmic expression after standardizing by *per unit of labor*, our Cobb-Douglas function reduces to:

$$y_t = \phi_0 + \phi_1 k_{1t} + \phi_2 k_{2t} \tag{4}$$

where ϕ_0 denotes the logarithm of a technology index, y_t is output per labor, k_{1t} is the per labor total capital stock (excluding residential and transportation-communication capital), k_{2t} represents the transportation-communication capital per labor, *t* is time (*t=1963, ..., 2006*) and ϕ_1 and ϕ_2 are elasticities.

In the empirical analysis this equation is fitted into a multivariate *vector error correction model* (VECM), hence all variables are treated as endogenous (Johansen, 1988 and 1991). In the VECM specified in this study, x_t is a (3×1) vector:

$$x_t = (y_t, k_{1t}, k_{2t})' \tag{5}$$

As outlined above, first all variables were pretested to assess their orders of integration. For this purpose, the formal augmented *Dickey-Fuller* (ADF) unit root tests were applied to each series.

The ADF tests were conducted sequentially on first the first difference and then the level of the series. In choosing the lag length for the ADF test the *Akaike Information Criterion* (AIC), the *Schwarz Information Criterion* (SIC) and the *Hannan-Quinn Information Criterion* (HQ) were used. The lag length for which at least two of them have agreed upon was chosen. We started with a maximum lag of 9 in each case. If there were no agreement among the information criteria, the outcome of the criterion that provided us with the longest lag length was used, since the aim in adding the lagged difference terms in the ADF test is to remove any serial correlation present in the residuals. After choosing the lag length, the residuals were tested for serial correlation using the *Breusch-Godfrey Lagrange Multiplier* (LM) test and more lags were added if still some autocorrelation was present in the residuals. When deciding on the deterministic regressors to be included in the ADF regression we recoursed to the visual inspection of the series. The level of the series do not fluctuate around a constant or zero mean but appear to be have an increasing positive trend. The first differences of the series seem to fluctuate around a nonzero constant. Thus, we have decided to include both a constant and a trend term in the test regression for the level of the series and only a constant term for that of the first differenced series.

Table 1 presents the results of the ADF test. In all specifications the lag length was selected to be zero (zero lag lenght yields the standard DF test). This choice was sufficient to remove serial correlation in the residuals, which can be seen from the last column of Table 1. The first differences of all the series were found to be stationary: the ADF test rejected the null hypothesis of a unit root at 1%, 5% and 10% significance levels. However, the null hypothesis of a unit root could not be rejected at the conventional significance levels for the level of the series. Therefore, y_t, k_{1t}, and k_{2t} series are all found to be integrated of order one, I(1).

Table 1 Unit root tests

Variables	**Levels**	**Critical values** [a]			**LM test**[e]
		10%	**5%**	**1%**	
y	-2.703	-3.190	-3.518	-4.187	0.400
k_1	-1.179	-3.190	-3.518	-4.187	0.188
k_2	-0.468	-3.190	-3.518	-4.187	0.661
	First Differences	**10%**	**5%**	**1%**	**LM test**[e]
y	-7.153 [b, c, d]	-2.605	-2.933	-3.597	0.825
k_1	-5.102 [b, c, d]	-2.605	-2.933	-3.597	0.174
k_2	-5.115 [b, c, d]	-2.605	-2.933	-3.597	0.549

Notes:
[a] *MacKinnon critical values for rejection of null hypothesis of a unit root.*
[b] *Denotes rejection of the null hypothesis of a unit root at the 10% level.*
[c] *Denotes rejection of the null hypothesis of a unit root at the 5% level.*
[d] *Denotes rejection of the null hypothesis of a unit root at the 1% level.*
[e] *p-values are presented.*

Since all the variables were found to be I(1), the Johansen methodology outlined before could be used to test whether these I(1) variables are cointegrated. In doing so, first, a VAR model is estimated using undifferenced data and its order is determined using the same lag length tests as in a traditional VAR. Since T = 44 for our data set we begun with a maximum lag length of 4 (i.e. $44^{1/3}$). The appropriate lag length for the model is determined using the AIC, SIC, and by conducting lag exclusion (Wald) tests on the VAR.

At the chosen lag length the residuals from equation (3) should appear to be white noise, therefore, we performed specifications tests that check whether for the lag length selected the residuals are free from autocorrelation, heteroscedastic, and are normally distributed. For all estimations a constant term and a dummy variable to take into account the 1994 economic crises in Turkey were included in the model. The dummy variable for 1994 will be denoted by D94 and takes on the value 1 at 1994 and zero otherwise. A dummy variable for the year 1980 was also included in the VAR model but its coefficient was found to be insignificant in all three of the equations. Therefore, throughout the rest of the analysis only a single dummy variable will be included in the models.

Akaike and Schwarz criteria selected order 2 for the VAR model. The lag exclusion tests, however, pointed out that lags 1-3 were statistically significant at the 10% significance level, therefore choosing *p*=3. The residuals from the VAR(3) model appeared to be non-autocorrelated, non-heteroscedastic and normally distributed (Table 2). As Enders (2004) has rightly pointed out that if the lag length is too large, degrees of freedem is wasted; if the lag length is too small, the model is misspecified. We believe that committing a misspecification error is more serious than lost degrees of freedem and thus choose the order of the VAR model to be 3.

Table 2 Specification Tests for VAR order

VAR Order	**Specification tests**		
	Autocorrelation[a]	**Heteroscedasticity**[b]	**Normality**[c]
2	11.338	183.777	51.791*
3	8.280	244.925	12.737

Notes:

[a] Multivariate autocorrelation LM test. Under the null hypothesis of no serial correlation of order h (here: h=1) the test statistic is asymptotically distributed χ^2 with 9 degrees of freedom.

[b] Multivariate extension of White's (1980) heteroscedasticity test. Under the null hypothesis of homoscedastic residuals the test statistic is asymptotically distributed χ^2 with 234 degrees of freedom.

[c] Multivariate extension of the Jarque-Bera residual normality test. Under the null hypothesis of normally distributed residuals the test statistic is asymptotically distributed χ^2 with 6 degrees of freedom.

*Denotes rejection at the 1% level of significance.

The second step is to determine the rank of π. The number of cointegrating vectors (rank of π) is tested using the Johansen cointegration trace test (Johansen, 1988 and 1991). In the trace statistic, the null hypothesis that the number of cointegrating vectors is less than or equal to *r* against a general alternative is tested. Before implementing the test, as discussed above, the researcher has to decide on the specification of the deterministic terms. As mentioned before, since all our series exhibit a sustained tendency to increase, the cointegration tests were conducted by including an intercept term both in the cointegrating equations and in the VEC equation outside the cointegrating relations.

The estimated form of the model then is:

$$\Delta x_t = \gamma + \pi x_{t-1} + \pi_1 \Delta x_{t-1} + \pi_2 \Delta x_{t-2} + b_1 D94 + \varepsilon_t \quad (6)$$

where p-1 = 2, $x_t = (y_t, k_{1t}, k_{2t})'$, γ is an $(n \times 1)$ vector of intercept terms and $\pi = \alpha\left(\beta' x_{t-1} + \mu\right)$.

The estimated eigenvalues of the π matrix are 0.37, 0.21, and 0.11. Table 3 shows the calculated values of the trace statistics for the various possible values of *r* and the 5% critical values. In conducting this test one should stop at the first point the null hypothesis is not rejected and conclude that the number of cointegrating vectors is equal to the one specified by the not rejected null. From Table 3, it can be seen that the outcome of this test indicates 1 cointegrating vector at the 5% significance level.

Table 3 Cointegration Test Results

Trace tests			
Null Hypothesis	**Alternative Hypothesis**	**Trace statistic**	**5% Critical Value[a]**
r = 0	r > 0	33.697*	29.797
r ≤ 1	r > 1	14.628	15.495
r ≤ 2	r > 2	4.788*	3.841

Notes:
[a] The critical values are obtained from MacKinnon, Haugh and Michelis (1999).
*Denotes rejection of the null hypothesis at the 5% level of significance.

After determining the rank of π, the third step is to estimate and analyze the normalized cointegrating vector and the speed of adjustment coefficients. Table 4 gives the VEC model estimates for *r* = 1. The upper part of Table 4 gives the cointegrating vector (normalized on *y*) estimates.

From these estimates, the *cointegrating vector* (normalized on *y*) can be expressed as follows:

$$y_t = 1.36 + 0.32\,k_{1t} + 0.30\,k_{2t} \quad (7)$$

Equation (7) reports the cointegrating relationship between the variables of the production function. A chi-squared test is used to determine whether these coefficients of total capital (k_{1t}) and transportation-communication capital (k_{2t}) are jointly significant. The calculated Chi-square statistic equals to 4.96 with a *p*-value of 0.08. Thus, both coefficients are found to be statistically significant. The transportation-communication capital appears to exhibit a positive and significant effect on output for Turkish economy. For the period of the study, it appears that a *ceteris paribus* 10% increase in expenditure in transportation-communication infrastructure would have been expected to increase output in Turkey in the long run by *3%,* which is a remarkable effect. This finding is reasonable within the framework of recent related literature. For example Ramirez (2004), using a VEC model, reports a *3.7%* increase in output as a result of a 10% *ceteris paribus* increase in expenditure on public capital for Mexican economy. Albala-Bertrand and Mamatzakis (2001), again estimating cointegrating relationships within a VEC model, find that a 10% *ceteris paribus* increase in public infrastructure expenditure would have been expected to rise output by around *2%* for Chilean economy.

Another point that we want to touch is the *speed of adjustment coefficients* that can be obtained from the estimates given in Table 4. The speed of adjustment coefficient of the Δy_t equation is -0.3, which is quite high compared to the very low absolute values of this parameter in the total capital and transportation capital equations, about 0.04 in both equations. Turkish output experiences sharp increases with increases in total capital and transportation capital.

It seems that the effects of total capital and transportation capital on output are nearly the same in the long term (Equation 7). We could not reject the null hypothesis that the coefficient of k_{1t} is equal to k_{2t} with a p-value equal to 0.75. However, this result is valid in the long-run. To analyze the dynamic effects of transportation capital and total capital on output and their relative importance in determining output in shorter terms, say in 5 or 10 years, we next conduct impulse response analysis and variance decompositions.

Table 4 VECM Estimates [a]

Cointegrating Equation:	β_i [b]		
y(-1)	1.000		
k_1(-1)	-0.320		
k_2(-1)	-0.304		
c	-1.356		
	Δy_t	Δk_{1t}	Δk_{2t}
α_i	-0.306	0.039	0.038
	(-2.75)	(1.13)	(0.85)
Δy_{t-1}	0.049	-0.000	-0.028
	(0.29)	(-0.01)	(-0.41)
Δy_{t-2}	0.166	-0.005	-0.007
	(1.06)	(-0.11)	(-0.11)
Δk_{1t-1}	1.556	0.036	-1.002
	(1.30)	(0.10)	(-2.10)
Δk_{1t-2}	-2.178	0.332	0.272
	(-1.69)	(0.82)	(0.53)
Δk_{2t-1}	-1.376	0.282	1.219
	(-1.43)	(0.94)	(3.18)
Δk_{2t-2}	1.381	-0.167	-0.205
	(1.39)	(-0.54)	(-0.52)
c	0.050	0.016	0.026
	(1.81)	(1.86)	(2.30)
D94	-0.131	-0.126	-0.170
	(-1.60)	(-4.90)	(-5.18)

[a] *t-statistics are given in parenthesis, c denotes the intercept term.*
[b] *t-statistics are not provided for the cointegrating vector since these coefficients multiply non stationary variables and inference on them could not be done using the standard t-tests.*

Impulse Response Analysis

This section analyzes the dynamic properties of the estimated vector error correction model by analyzing the impulse response functions. Figure 1 plots the generalized impulse responses[7] of per labor output (y) and per labor total capital (k_1) [8] from a shock given to per

[7] Generalized impulses, as described by Pesaran and Shin (1998) constructs an orthogonal set of innovations that *does not depend* on the VAR ordering.

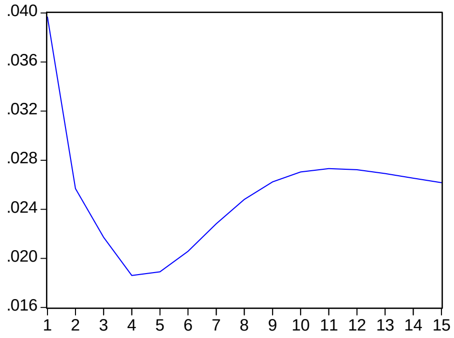
labor transportation-communication capital (k_2). The impulses are traced for a period of 15 years.

There are mainly three issues that can be revealed from these impulse-response figures. First, as Panel (a) of Figure 1 shows, the effect of transportation-communication capital (k_2) on gross domestic product (y) is positive in the *short to medium term*. This finding fortifies the hypothesis that transportation-communication capital is *productive*. From the initial year to the fourth year, its impact on output gradually declines, but stays remarkably positive. However, from the beginning of fourth year of the shock, the positive impact of transportation-communication capital on output recovers and eventually stabilizes around the second year's impact level. From these findings we can conclude that the productive effect of transportation-communication capital on output reveals itself immediately after the shock in the short term, but for the full effect to be realized one should wait for about 10 years, in a way the medium term. This finding is quite interesting since it supports the suggestion that, as argued by Banister and Berechman (2003, p.147), transportation-communication capital has a lagged impact on economic growth.

Second, while transportation-communication capital stock has various affects on economic growth process such as productivity improvement, accessibility changes, mobility changes, multiplier effect, external economies, value-added changes and linkage effects (Banister and Berechman, 2003); the net influence of all of these effects appear to be positive and economically significant for Turkish economy. In other words, taking all the possible effects of transportation-communication capital on economic growth into account, the meaning of the positive impact in the short and medium term emphasizes that the *net* effect of transportation-communication capital is positive and economically significant.

[8] Excluding housing and transportation-communication capital.

(a) Response of y to shock in k_2



(b) Response of k_1 to shock in k_2

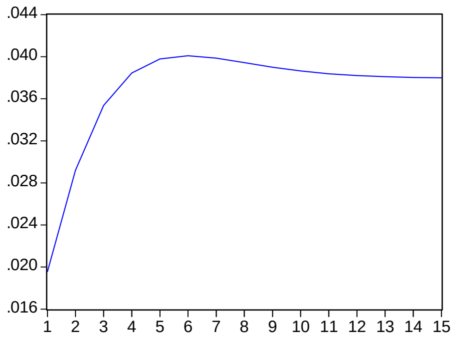


Figure 1 Impulse Response to Generalized One S.D. Innovations

Third, as the impulse-response graphic portrayed in Panel (b) of Figure 1 shows, the effect of per labor transportation-communication capital (k_2) on total per labor non-residential capital stock (k_1) is also positive in the short to medium term. This means that as per labor transportation-communication capital increases, it has a positive *net* influence on the other sectors' capital stock within the economy. In other words, although an increase in transportation-communication may affect the capital stock of some sectors positively and others negatively, it has a net positive effect on the total capital stock. This situation may be attributed to a possible *complementarity* property of transportation-communication capital. Therefore, it seems that the transportation-communication capital operates as a *complement* for the other capital stock of the economy. Thus, transportation-communication investment could be used as a policy tool to increase the capital input of the other sectors in the economy. This issue will be further investigated afterwards with the help of *variance decomposition* analysis below.

Tables 5, 6 and 7 tabulate the *variance decomposition* of each variable over a fifteen year period.[9] The second column, labeled "S.E.", contains the forecast error of output at the given forecast horizon. The source of this forecast error is the variation in the current and future values of the innovations to each endogenous variable in the VEC model. The remaining columns give the percentage of the forecast variance due to each innovation, with each row adding up to 100.

Table 5 Variance Decomposition of per labor Output (y)

Period	S.E.	y	k_1	k_2
1	0.1	64.9	3.4	31.6
2	0.1	61.7	10.8	27.5
3	0.1	63.9	10.3	25.8
4	0.1	63.2	10.4	26.4
5	0.1	62.1	9.9	28.0
6	0.1	60.1	9.7	30.2
7	0.1	57.3	9.9	32.7
8	0.1	54.1	10.6	35.3
9	0.1	50.7	11.7	37.6
10	0.1	47.4	12.9	39.7
11	0.1	44.3	14.3	41.4
12	0.1	41.5	15.7	42.8
13	0.1	38.9	17.2	43.9
14	0.1	36.7	18.6	44.7
15	0.1	34.6	20.1	*45.3*

Table 6 Variance Decomposition of per labor total capital (k_1)

Period	S.E.	y	k_1	k_2
1	0.0	0.0	21.2	78.8
2	0.0	0.3	15.1	84.5
3	0.1	0.7	13.0	86.3
4	0.1	1.3	11.5	87.2
5	0.1	1.9	10.6	87.6
6	0.1	2.5	9.8	87.7
7	0.1	3.0	9.3	87.7
8	0.1	3.5	8.8	87.7
9	0.1	3.8	8.3	87.8
10	0.1	4.1	7.9	88.0
11	0.1	4.3	7.6	88.2
12	0.1	4.4	7.2	88.4
13	0.1	4.5	6.9	88.6
14	0.1	4.5	6.6	88.8
15	0.2	4.6	6.4	*89.1*

[9] In the variance decomposition analysis reported in Table 5, 6 and 7, the following Cholesky ordering is followed: k_2 k_1 y. We have chosen this ordering following Kamps (2005, p 545) who does a similar study for public capital.

From Table 5 and 6, it can be seen that, after 15 years, a shock in per labor transportation-communication capital (k_2) explains 45.3 percent of the forecast error variance of per labor output (y) and 89.1 percent of that of per labor total capital (k_1). Per labor transportation-communication capital explains the variance in per labor output twice more than total per labor capital. On the other side, after 15 periods, the percentage error variation of k_2 due to y and k_1 are 0.2 and 62.1 percents, respectively (Table 7). Hence, it appears that the figures support the *complementarity hypothesis* that transportation-communication investment such as roads, bridges, ports, railways, communication technology facilities, etc. complements the other total non-residential capital spending and hence has a crowd-in impact on total capital (k_1).[10] Recall that this issue has been also addressed in the discussion of impulse response results, above. Thus, the variance decomposition analysis fortifies the complementarity argument about the transportation-communication capital, at least for Turkish economy.

Table 7 Variance Decomposition of per labor transportation-communication capital (k_2)

Period	**S.E.**	***y***	**k_1**	**k_2**
1	0.0	0.0	0.0	100.0
2	0.1	0.0	3.8	96.2
3	0.1	0.0	8.8	91.2
4	0.1	0.0	14.9	85.1
5	0.1	0.0	21.2	78.8
6	0.1	0.0	27.4	72.5
7	0.2	0.0	33.3	66.7
8	0.2	0.0	38.7	61.2
9	0.2	0.0	43.6	56.4
10	0.2	0.0	47.9	52.1
11	0.2	0.1	51.6	48.3
12	0.2	0.1	54.8	45.1
13	0.3	0.1	57.6	42.2
14	0.3	0.2	60.0	39.8
15	0.3	*0.2*	*62.1*	37.7

VI. CONCLUSIONS

In this study, the short and long term relationships between the transportation-communication capital formation and real output for Turkish economy were investigated. The analysis uses a

[10] In fact, this analysis can be much more interesting in this respect if our study would distinguish the private and public capital. However, for the sake of simplicity and the degrees of freedom concerns due to the limited observations, this type of analysis could not be detailed here. For a good example of the discussion of *complementarity hypothesis* in terms of private and public capital using impulse-response and variance decomposition analyses, see Ramirez (2004, pp.169-172).

Cobb-Douglas production function for Turkish economy under the assumption of constant returns to scale across the three inputs of total non-residential capital formation[11] (K_1), transportation-communication capital stock (K_2), and labor (L). For simplicity and due to degrees of freedom concerns, the variables were expressed in terms of *per effective labor* throughout the analysis.

The study applied unit root tests and cointegration analysis by estimating a *vector error correction model* (VECM). As a result of the VECM estimation, one cointegrating relationship is detected for Turkish economy for the period of 1963-2006. According to the cointegrating vector estimates, it appears that a *ceteris paribus* 10% increase in expenditure in transportation-communication infrastructure would have been expected to increase output in Turkey by around *3%* which is a remarkable effect. On the other hand, from the VECM estimates, the speed of adjustment coefficient of the Δy_t equation has found to be -0.3. This implies that Turkish real output experiences sharp increases with increases in total capital and transportation capital.

The VECM methodology, apart from accounting for the nonstationarity of time-series data, allows also taking into account the feedback effects from output to the two input variables within the multivariate system treating all variables as endogenous. Hence, by means of the VECM methodology the dynamic effects of transportation-communication capital were also estimated and investigated.

The VECM analysis introduced in this paper indicates that per labor transportation-communication capital has both a positive and economically significant effect on per labor real output growth and on total per labor non-residential capital formation for Turkish economy. The results based on impulse response function analysis implies that per labor transportation-communication capital appears both to have been a crucial input in the Turkish productive process and to have had a positive *crowding in* effect on per labor non-residential total capital formation over the studied period of 1963-2006. These findings fortify the *complementary* face of the transportation-communication capital for the total non-residential capital stock in Turkish economy.

[11] Excluding transportation-communication capital.

The variance decomposition analysis based on the impulse functions indicates that, after 15 years, a shock in per labor transportation-communication capital (k_2) explains 45.3 percent of the forecast error variance of per labor output (y) and 89.1 percent of that of per labor total capital (k_1). Hence, the transportation-communication capital per labor explains the variance in output per labor twice more than total per labor non-residential capital. Thus, the variance decomposition analysis fortifies the complementarity argument about the transportation-communication capital, at least for Turkish economy.

All these findings suggest that transportation-communication capital may be a powerful tool for policy-makers to promote long-term per labor real output growth in Turkey.

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