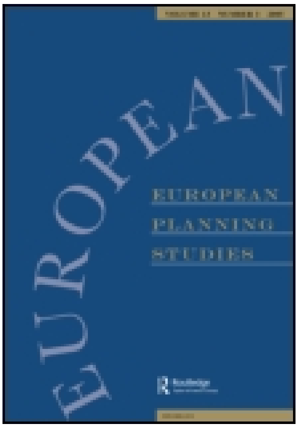

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RESEARCH BRIEFING

Transportation–Communication Capital and Economic Growth: A VECM Analysis for Turkey

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ABSTRACT *This paper analyses the short- and long-term relationships between the transportation–communication capital and the output for Turkey. The study applies a Cobb–Douglas production function under the assumption of constant returns to scale and employs co-integration analysis by estimating a vector error correction model (VECM). As a result of the VECM estimation, one co-integrating relationship is detected. The results based on the impulse response function analysis imply that per labour 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 the per labour non-residential total capital formation. Moreover, the results support the argument that the transportation–communication capital has a lagged impact on economic growth. The long-term accumulated elasticity of output to transportation–communication capital has been found to be 0.59. The long-term accumulated marginal product was also calculated. It implies that a 1 Turkish Lira increase in per labour transportation–communication capital results in a long-term rise of 1.45 Turkish Liras in per labour output. All these findings suggest that transportation–communication capital may be a powerful tool for policy-makers to promote long-term per labour real output growth in Turkey.*

1. Introduction

This paper explores whether transportation and communication capital acts as a productive input in the Turkish production process for the period 1963–2006. The main motivation of this study is to answer the following questions: Does the total transportation–communication capital have a positive impact on the real output of the Turkish economy? What is the magnitude and behaviour of this effect in the short- and long-term for the Turkish

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economy? Does transportation and communication capital crowd in, or crowd out of, total capital formation in Turkey?

The literature rather than analysing the economic effects of transportation and communication capital has separately grouped it under the heading public infrastructure capital and analysed the growth impact of public infrastructure capital as a whole (Ratner, 1983; Aschauer, 1989; Ram & Ramsey, 1989; Holtz-Eakin, 1992; Easterly & Rebelo, 1993; Pereira & de Frutos, 1999; Sturm *et al*., 1999; Everaert & Heylen, 2000; Pereira & Roca-Sagales, 2001; Haque & Kim, 2003; Pereira & Andraz, 2005; Herranz-Loncán, 2007). In the case of Turkey, such studies are far more limited. There are only two studies that analyse the relationship between public infrastructure capital and private sector productivity (Karadag *et al*., 2004; Ismihan *et al*., 2005).

However, improving transportation and communication facilities by itself enhances productivity by facilitating the accessibility and mobility of production factors and goods. As emphasized in World Bank (1996, p. 1); improved transport is on the core of the development process by (i) providing accession to 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 labour market efficiency, (v) allowing the scale economies conditions and agglomeration changes, (vi) increasing the frequency of people and freight, and hence mobility. Furthermore, the transportation and communication sector by itself has an undeniable contribution to the productive process in Turkey. As of 2006, the transportation and communication sector following the manufacturing and trade sectors constitutes 14.7% of Turkey's gross national product (TurkStat, 2006). In addition, the transportation–communication capital investments accounts for 19.41% of all total fixed capital investments made in 2006 in Turkey, thereby ranking second after the manufacturing sector which has a 35.2% share[1] (SPO, 2008). Therefore, in this study, we investigate the economic effects of transportation and communication capital separately from the other public infrastructure capital. To our knowledge, there is no study in the Turkish literature that examines the possible effects of the total transportation–communication capital on gross domestic product of Turkey. Hence, this paper can be seen as the first attempt to analyse the impact of the total transportation–communication capital on gross domestic product for the Turkish economy.[2]

The main aim of this paper is to assess both the short- and long-term relationships between transportation–communication capital and output for Turkey. For this purpose, the study has applied a Cobb–Douglas production function for the Turkish economy under the assumption of constant returns to scale and employed unit root tests and co-integration analysis by estimating a *co-integrated* vector autoregressive (VAR) model, or namely, a vector error correction model (VECM). Apart from accounting for the non-stationarity of time-series data, this methodology also allows the researcher to take into account the indirect relationships among different variables within the multivariate system. 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.

As a result of the VECM estimation, we have found one co-integrating relationship between the transportation–communication capital, other total capital and output. The weak exogeneity test results imply that the causality runs from transportation–communication capital and other total capital to output, thereby rationalizing our production function assumption. The impulse response function analysis reveals that transportation–communication capital not only increases output, but also has a positive crowding in effect on per labour non-residential total capital formation in Turkey. We also show that a 1 Turkish Lira increase in the per labour transportation–communication capital results in a long-term rise of 1.45 Turkish Liras in per labour output. Assuming that the average tax rate is around 0.25 for Turkey, this 1 TRY increase in per labour transportation–communication capital (k_2) would generate around 0.36 TRY in tax revenues over the long run, and hence it seems that it would pay approximately one-third (0.36 TRY) of his cost by itself in the long run in the form of additional tax revenues. Thus, the transportation–communication sector should not be overlooked in terms of its productive capacity in Turkey. Policy-makers can design policies that target this sector alone and thereby promote long-term per labour real output growth in Turkey.

The paper is organized as follows: in Section 2, a brief literature review is introduced, Section 3 is about the data issues, in Section 4, the VAR/VECM methodology of the study is presented and the estimation results of the model are reported. Section 4.1 presents the results of the impulse response analysis. Finally, Section 5 is reserved for the concluding remarks.

2. A Short Survey of the Literature

Transportation capital is usually regarded as a part of the total public infrastructure capital and therefore the impacts of transportation capital stock on the level of output and productivity generally are examined together with the other public capital. In the literature, only a small number of applied studies have included transportation capital as a *separate* category, and only very few studies have *directly* examined the impacts of transportation capital stock on economic growth (Banister & Berechman, 2003, p. 145).

The *production function approach* is one of the two main approaches that have been employed in the empirical literature to analyse the economic effects of public capital and/or transportation capital. The second approach is the *vector autoregressive (VAR/VECM) approach*.[3] The production approach assumes an *a priori* causal linkage running from *inputs* to the *output*, however, the VAR/VECM approach can be classified as a data-oriented methodology.

Some main studies of the production function approach can be enumerated as Ratner (1983), Aschauer (1989), Ram and Ramsey (1989) and Holtz-Eakin (1994). Ratner's (1983) seminal article estimates the effect of public infrastructure investment on private output, using the US annual data for the period 1949–1973 and finds that the *elasticity* of private output with respect to public capital is 0.06. Another seminal study is Aschauer (1989) which analyses the relationship between public infrastructure capital and aggregate output of private sector, using the US data for the period 1949–1985. His estimation result shows that private output *elasticity* with respect to public capital is 0.39. He then concludes that a 1% point increase in the public capital stock would promote aggregate output by around 0.4% points. The article of Ram and Ramsey (1989), using annual data for the period 1948–1985, documents that public capital has an important positive effect on the US private business output. On the other hand, Holtz-Eakin (1994) examining the relationship between public sector capital accumulation and private sector productivity for the US economy for the period 1969–1986 claims that there is no role of public capital on private sector productivity.

The *VAR/VECM approach* is the other methodology that has been employed in the empirical literature to study the economic impacts of public capital and/or transportation capital. As Kamps (2005, pp. 33–34) has rightly pointed out that there are three advantages of the VAR/VECM approach: (1) it allows analysing the possible *feedback effects* from the output to the inputs, since it does not assume an *a priori* causal linkage *only* running from the inputs to the output, (2) allows analysing the possible *indirect effects* of the public capital; i.e. the effects that have an impact on output indirectly through the impacts on the private inputs, and (3) does not necessarily admit that there should be at most one co-integration relationship. Many studies have been conducted using this approach, which include Looney (1997), Pereira and de Frutos (1999), Everaert and Heylen (2000) and Herranz-Loncán (2007). The article of Looney (1997) analyses the role of infrastructure variables (energy, transport, etc.) in Pakistan's economic expansion for the period 1973–1995, applying the Granger causality tests and finds that public facilities expand largely in response to the needs of the private sector. Pereira and de Frutos (1999) examine impacts of public capital on private sector variables for the US economy for the period 1956–1989. Their empirical result suggests that a one-dollar increase in public capital increases private output in the long term by 65 cents. The study of Everaert and Heylen (2000) investigate the effects of public capital on multifactor productivity in Belgium, using annual data for the period 1953–1996. Their results based on a single-equation co-integration analysis point to a strong positive relationship with causality running from public capital to productivity. Also, Herranz-Loncán (2007) examines the effect of infrastructure investment on Spanish economic growth for the period 1850–1935. The study emphasizes that while the growth impact of the local-scope infrastructure investment is positive; returns to investment in large nationwide networks are not significantly different from zero. The other studies which find that public capital increases output can be enumerated as follows: Ramirez (2000), Ligthart (2002), Albala-Bertrand and Mamatzakis (2001), Ramirez (2004); Mittnik and Neumann (2001), Pereira (2001), Kawakami and Doi (2004) and Kamps (2005). On the other hand; Ghali (1998) investigates the impact of public investments on Tunisian economic growth over the period 1963–1993, using a VECM, and concludes that the public investments have contributed negatively to Tunisia's economic growth. To our knowledge, among the studies that have used the VAR/VECM approach, this is the only study in which public investments have a negative impact on growth.

There are also some studies which examine transportation–communication investment separately. For example, Easterly and Rebelo (1993), using pooled regressions, point out that among the other sectoral components of public investment, only transportation–communication investment is positively correlated with growth with a very high coefficient between 0.59 and 0.66. The article of Flores de Frutos *et al*. (1998) carries out a VAR analysis, investigating the relationship between public transportation–communication investment and private sector output for Spain for the period of 1964–1992. The study estimates the *elasticity* of the private sector output with respect to the public transportation–communication investment as 0.21. Besides, the article of Pereira and Roca-Sagales (2001) explores possible effects of public transportation–communication investments on private sector output for Spain for the period 1970–1993, applying VAR models. They find that *elasticity* of private sector output with respect to public transportation–communication investment is 0.52 in the long term. Findings of this paper suggest that there is a two-way causality between public capital formation and private sector variables such as private output and employment, and *vice-versa*. Also Sturm *et al*. (1999), employing Granger-causality tests in a VAR framework, find a positive Granger causal relationship running from transportation investment to gross domestic product for the Netherlands for the period 1853–1913. Again using a VAR approach, Pereira and Andraz (2005) analyse the impacts of public investment in transportation infrastructure on private investment, employment, and output for Portugal for the period 1976–1998. They report that public investment in transportation infrastructure has a strong positive effect on output. Haque and Kim (2003) examine the relationship between public transportation–communication investment and economic growth this time using a dynamic panel model for 15 developing countries (Bahamas, Congo, Ethiopia, etc.) for the period 1970–1987. This paper shows that the public investment in transportation–communication Granger-causes economic growth; however, it does not support the existence of reverse causality.

Although there is voluminous literature studying the dynamic effects of public capital, using VAR methodology in other countries, for Turkey such studies are very limited (Karada *et al*., 2004; Ismihan *et al*., 2005). Karadag *et al.* (2004) examine the impact of public capital formation on private manufacturing sector performance at both the regional and the 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 macro-economic 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 investment has a positive effect on the output of Turkey, it crowds in private investment in the short run to medium run, but crowds out in the long run. In the paper, this last finding is attributed to the increasing and chronic macro-economic instability of the Turkish economy. Macro-economic instability damages, or even destroys, the complementarity between public and private investment in the long run.

To sum up, although there is evidence for reverse causality in the literature, it seems that public capital and/or transportation capital promotes output, hence the *expected impact* of the transportation–communication capital as an infrastructure capital on the real output is positive. In addition, many studies propose that the impact of public capital on growth varies across countries, regions and sectors; hence, *country and sector-specific* studies are of particular importance. This paper can be seen as a first attempt to analyse the dynamic interactions between the total transportation–communication capital and output for the Turkish economy since to our knowledge; there is no study that separately examines the possible effects of total transportation–communication capital on output for the Turkish economy. The study follows a hybrid path between the production approach and the VAR/VECM approach since we assume a Cobb–Douglass production function as a starting point. However, it should be noted that using a Cobb–Douglas production function is only the *theoretical standpoint* of the study because, by employing the VECM methodology, the article not only analyses the impacts of the transportation–communication capital on output, but also examines the indirect relationships among the related variables.

3. Data

The study uses *annual* data that covers the period *1963–2006*. Since there is no officially calculated and issued capital stock (K) data for the Turkish economy, to analyse the effects of transportation and communication capital on output, we generated a new capital stock data for Turkey. For this purpose, we followed an approach similar to Guariglia and Poncet (2008), Islam *et al*. (2006), Young (2003), Khan and Sasaki (2001), Fainzylber and Lederman (1999), Nadiri and Prucha (1996), Young (1995) and Harberger (1978).

The relevant capital stock series for the Turkish economy were generated using the following equation:

$$K_t^i = (1 - d^i)K_{t-1}^i + I_t^i, \tag{1}$$

where I_t^i is fixed investment at time t in sector i, K_t^i represents capital stock at the end of time t in sector i, and d^i denotes the average depreciation rate of capital stock in sector i. A problem related to the usage of Equation (1) is as to how to calculate the initial capital stock in sector i (denoted by K_0^i). There are alternative approaches in the literature, such as setting to *zero* (Corrado *et al*., 2009; Arslanalp *et al*., 2010) or taking the first three or five years of investment. We calculated the initial period capital stock estimates[4] in sector i using the equation $K_0^i = I_0^i/(g^i + d^i)$, where I_0^i denotes the fixed investment at the initial period in sector i, g^i is growth rate of fixed investment in sector i. The growth rate of fixed investment[5] in sector i has been calculated, using the following relation: $g^i = (\ln I_{2006} - \ln I_{1963})/43$. Hence, in the study g^i is calculated as the annual *average growth rate* of fixed investment in sector i over the entire sample period (1963–2006).

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).

In the literature, to our knowledge, there is no study that attempts to estimate depreciation rates for Turkey.[6] Since one of the most reliable data for fixed capital consumption is provided by the International Sectoral Data Base of the OECD (1998), in this study, we have used sector-specific depreciation rate averages that are calculated from this database.[7] The depreciation rate averages used in our study range from 1.6% to 4.4% for different sectors with an overall average of 3.55%.

Arslanalp *et al.* (2010) estimate the impact of public capital on economic growth for 22 OECD and 26 non-OECD countries for the period of 1960–2001. The investment data for 22 OECD countries are taken from the OECD database while for the 26 non-OECD countries the same data are obtained from the Penn World Tables. Arslanalp *et al.* state that the depreciation rates are perhaps the most important drawback in the construction of the capital stock estimates since country-specific annual estimates are not generally provided. The authors have carried out a kind of *sensitivity analysis* using alternative depreciation rates for the non-OECD countries. In the first scenario, time-varying depreciation rates of Kamps (2005), which range from 2.5% to 4.0% between 1960 and 2001, are adopted. In the second scenario, the depreciation rates are assumed *constant* for all years and equal to the average rate of 3.25% over the same period. In the third scenario, depreciation rates are assumed *constant* for all years and equal to the maximum rate of 4.0%. Their sensitivity analysis shows that under alternative depreciation rates, the results of the study do not change significantly, particularly among the constant depreciation rate scenarios. In other words, the magnitude of the constant depreciation rates (3.25% or 4.0%) does not affect the estimation results (estimates of output elasticities) significantly: the estimates of output elasticities are *robust* to changes in alternative depreciation rates (Arslanalp *et al.*, 2010, p. 8).

In addition, the main source of the variations in the derived capital stock data is probably due to the actual investment data, which is provided by the Statistical Institute of Turkey (TurkStat). The depreciation rates determine only the consumed portion of the actual investment. Unless the actual depreciation rates are *too high* and *too volatile*, which is a very unexpected situation in economics, the depreciation rates are not expected to have a significant impact on the variations of the capital stock data and hence on the identification of the co-integrating relationship and estimation results.

We are aware that the usage of OECD averages may not correctly represent the Turkish case, but for all the reasons discussed above, the reported estimates probably are not too sensitive to the usage of OECD depreciation rates. To sum, variations in the capital stock data can mostly be attributed to changes in investment rather than changes in replacement investment unless actual depreciation rates are *too high* and *too volatile*. Arslanalp *et al.* (2010), which shows that the estimation results are robust to the usage of other (constant or time varying) depreciation rates corroborates our line of reasoning.

4. Specification and Results

To investigate the growth impact of transportation–communication capital, a standard Cobb–Douglas production function in three inputs (augmented with transport-communication capital) under the assumption of constant returns to scale is used. Hence, the production function in the 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 to include the transportation–communication capital.

Expressed as a logarithmic expression after standardizing by *per unit of labour*, our Cobb–Douglas function reduces to

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

where ϕ_0 denotes the logarithm of a technology index, y_t is the output per labour, k_{1t} is the per labour total capital stock (excluding residential and transportation–communication capital), k_{2t} represents the transportation–communication capital per labour, t is time ($t = 1963, \ldots, 2006$) *and* ϕ_1 and ϕ_2 denote the output elasticity of the per labour total capital and the output elasticity of per labour transportation–communication capital, respectively.

In the empirical analysis, Equation (2) is fitted into a multivariate VECM, treating all variables as endogenous (Johansen, 1988, 1991). First, all variables were pre-tested 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 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 were used. The lag length for which at least two of them have agreed upon was chosen. If there was 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. Since too few lags may not be appropriate to remove serial correlation, we started with a relatively long lag length of 9. 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 appeared to have an increasing positive trend, while the first differences of the series seemed to fluctuate around a non-zero constant. Thus, we have included both a constant and a trend term in the test regression for the level of the series and only a constant term in the test regression of the first differenced series.

Table 1 presents the results of the ADF tests conducted on each of the variables included in our study. In all specifications, the lag length was selected to be zero (zero lag length 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, using the conventional ADF test y_t, k_{1t} and k_{2t} series were all found to be integrated into order one, $I(1)$.

The presence of structural breaks biases the standard ADF test towards non-rejection of the null of a unit root (Perron, 1989). Throughout the estimation period, there have been severe financial crises in Turkey that might have led to structural breaks in the series included. Thus, in addition to the ADF test, we have also carried out Lee and Strazicich (2003) minimum LM unit root tests with two structural breaks. The results of these tests are reported in Table 2. For the Crash model, where breaks in the trend function are restricted to the intercept, the results indicate that the null hypothesis of a unit root is not rejected for all series at the 1% significance level. The same result is obtained for the Trend break model that allows for breaks in both the intercept and the slope of the

Table 1. ADF unit root tests for stationarity

		Critical values[a]			
Variables	Levels	10%	5%	1%	LM test[b]
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[b]
y	−7.153[c,d,e]	−2.605	−2.933	−3.597	0.825
k_1	−5.102[c,d,e]	−2.605	−2.933	−3.597	0.174
k_2	−5.115[c,d,e]	−2.605	−2.933	−3.597	0.549

[a]MacKinnon critical values for rejection of null hypothesis of a unit root.
[b]LM test for residual serial correlation of order 12, p-values are presented.
[c]Denotes rejection of the null hypothesis of a unit root at the 10% level.
[d]Denotes rejection of the null hypothesis of a unit root at the 5% level.
[e]Denotes rejection of the null hypothesis of a unit root at the 1% level.

Table 2. Two-break minimum LM unit root tests

Crash model				Trend break model			
Series	k	Test statistic	(λ)	Series	k	Test statistic	(λ_1, λ_2)
y	0	−2.550*	(0.1, 0.9)	y	0	−4.397*	(0.2, 0.8)
k_1	0	−1.984*	(0.7, 0.9)	k_1	0	−3.672*	(0.4, 0.8)
k_2	0	−1.978*	(0.1, 0.7)	k_2	0	−4.758*	(0.2, 0.8)
Critical values				Critical values			
	1%	5%	10%	(λ_1, λ_2)	1%	5%	10%
λ	−4.545	−3.842	−3.504	(0.2, 0.4)	−6.16	−5.59	−5.27
				(0.2, 0.6)	−6.41	−5.74	−5.32
				(0.2, 0.8)	−6.33	−5.71	−5.33
				(0.4, 0.6)	−6.45	−5.67	−5.31
				(0.4, 0.8)	−6.42	−5.65	−5.32
				(0.6, 0.8)	−6.32	−5.73	−5.32

Notes: Critical values from Lee and Strazicich (2003). Note that for Crash model (Model A in Lee & Strazicich, 2003), the critical values are invariant to the location of the break points, $\lambda = T_B/T$. However, the critical values in the Trend break model (Model C in Lee & Strazicich, 2003) depend on the location of the break points. Critical values at additional break points can be interpolated. k is the optimal number of lagged first-difference terms included in the unit root test to correct for serial correlation.
*Significance at the 1%.

trend function. Thus, all the series continue to be non-stationary when structural breaks in the series are taken into account.

Since all the variables were found to be $I(1)$, the Johansen methodology could be used to test whether these $I(1)$ variables are co-integrated. In doing so, first, a VAR model is estimated using the 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 each equation should appear to be white noise and thus we have also conducted diagnostic tests on the residuals of the VAR model estimated. 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. Throughout the rest of the study, the dummy variable for the year 1994 will be denoted by D94 and takes on the value 1 at 1994 and zero otherwise. To take into account the effects of other financial crises that took place in Turkey during the estimation period, dummy variables for the years 1980 and 2001 were also included in the VAR model, but their coefficients were found insignificant in all three of the equations.[8] Therefore, in the rest of the analysis, only a single dummy variable will be included in the estimated VECM.

Akaike and Schwarz criteria selected order 2 for the VAR model. However, the lag exclusion tests showed that the lags 1–3 were statistically significant at the 10% significance level. To solve between the conflicting results regarding the lag length, we performed specifications tests to check whether at the chosen lag length the residuals are free from autocorrelation, heteroscedasticity and they are normally distributed. The

Table 3. Specification test 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

[a]Multivariate autocorrelation LM test. Under the null hypothesis of the no serial correlation of order h (here: $h = 1$) the test statistic is asymptotically distributed χ^2 with nine 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 six degrees of freedom.
*Denotes rejection at the 1% level of significance.

results indicate that at lag 3, there is no sign of residual serial correlation or heteroscedasticity and moreover the residuals seem to be normally distributed (Table 3). As Enders (2004) has rightly pointed out that if the lag length is too large, the degrees of freedom are wasted; if the lag length is too small, then the model is mis-specified. We believe that committing a mis-specification error is more serious than lost degrees of freedom and, thus, choose the order of the VAR model to be 3.

The second step is to determine the number of co-integrating vectors, which is carried out in this study, using the Johansen co-integration trace test (Johansen, 1988, 1991). Before implementing the test, there is a practical problem that the researcher has to decide. The series involved in the study may have non-zero means and deterministic trends as well as stochastic trends. Similarly, the co-integrating equations may have intercepts and deterministic trends. The asymptotic distribution of the test statistic for co-integration does not have the usual chi-square distribution and depends on the assumptions made with respect to deterministic trends (Johnston & Dinardo, 1997, p. 302). Therefore, in order to carry out the co-integration tests, one needs to make an assumption regarding the trend underlying the data. As mentioned before, since there appears to be a linear trend in the levels of the series, the co-integration tests were conducted by including an intercept term both in the co-integrating equations and in the VEC equation outside the co-integrating relations.

The estimated form of the model then is

$$\Delta x_t = A_0 + \pi x_{t-1} + \pi_1 \Delta x_{t-1} + \pi_2 \Delta x_{t-2} + b_1 D94 + \varepsilon_t, \quad (3)$$

where $x_t = (y_t, k_{1t}, k_{2t})'$ and π includes a constant term.

The estimated eigenvalues of the π matrix are 0.37, 0.21 and 0.11. Table 4 shows the calculated values of the trace statistics for the various possible values of r and the 5% critical values. In conducting these tests, one should stop at the first point the null hypothesis is not rejected and conclude that the number of co-integrating vectors is equal to the one specified by the not rejected null. From Table 4, it can be seen that the outcome of this test indicates 1 co-integrating vector at the 5% significance level.

After determining the number of co-integrating vectors (rank of π), the third step is to estimate the normalized co-integrating vector, analyse the speed of adjustment coefficients

Table 4. Co-integration test results

Trace tests			
Null hypothesis	Alternative hypothesis	Trace statistic	5% Critical value[a]
$r = 0$	$r > 0$	33.697*	29.797
$r \leq 1$	$r > 1$	14.628	15.495
$r \leq 2$	$r > 2$	4.788*	3.841

[a]The critical values are obtained from MacKinnon *et al*. (1999).
*Denotes rejection of the null hypothesis at the 5% level of significance.

and check the residual diagnostics of the estimated model. Table 5 gives the VEC model estimates for $r = 1$. The third, fourth and fifth part of this table reports the properties of the residuals of the estimated model. Any evidence that the errors are not white noise would usually indicate that lag lengths are too short. Table 5 shows that the residuals from the long-run equilibrium appear to be stationary and the residuals from each equation approximate a white noise process.

The upper part of Table 5 gives the co-integrating vector (normalized on y) estimates. Using this table, the *co-integrating vector* (normalized on y) can be expressed as follows:

$$y_t = 1.36 + 0.32\, k_{1t} + 0.30\, k_{2t}. \tag{4}$$

Equation (4) reports the co-integrating relationship between the variables of the production function. A chi-squared test is used to determine whether the 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 the 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 the output in Turkey 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 the Mexican economy. Albala-Bertrand and Mamatzakis (2001), again estimating co-integrating relationships within a VEC model, find that a 10% *ceteris paribus* increase in public infrastructure expenditure would have been expected to increase the output by around 2% for the Chilean economy. From Equation (4), it seems that the effects of total capital and transportation capital on the output are nearly the same in the long term. 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.[9] However, this result is valid in the long-run. To analyse the dynamic effects of transportation capital and total capital on the output and their relative importance in determining the output in shorter terms, say in 5 or 10 years, we next conduct impulse response analysis and variance decompositions.

Another point that we want to touch is the *speed of adjustment coefficients* that can be obtained from the estimates given in Table 5. First we have conducted weak exogeneity tests on the variables involved. More specifically, we have tested whether the speed of

Table 5. VECM estimates[a]

Co-integrating 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 (−2.75)	0.039 (1.13)	0.038 (0.85)
Δy_{t-1}	0.049 (0.29)	−0.000 (−0.01)	−0.028 (−0.41)
Δy_{t-2}	0.166 (1.06)	−0.005 (−0.11)	−0.007 (−0.11)
Δk_{1t-1}	1.556 (1.30)	0.036 (0.10)	−1.002 (−2.10)
Δk_{1t-2}	−2.178 (−1.69)	0.332 (0.82)	0.272 (0.53)
Δk_{2t-1}	−1.376 (−1.43)	0.282 (0.94)	1.219 (3.18)
Δk_{2t-2}	1.381 (1.39)	−0.167 (−0.54)	−0.205 (−0.52)
c	0.050 (1.81)	0.016 (1.86)	0.026 (2.30)
D94	−0.131 (−1.60)	−0.126 (−4.90)	−0.170 (−5.18)
Unit root test for the long-run error		−4.789[c,d,e](0)	
LM test[f]		0.765	
Unit root test for residuals[g]	−6.735[c,d,e] (0)	−6.283[c,d,e] (0)	−6.478[c,d,e] (0)
LM test[f]	0.919	0.377	0.431
Autocorrelation[h]		0.946	
Heteroscedasticity[i]		0.195	
Normality[j]		0.166	
R^2	0.370	0.485	0.511
Adj. R^2	0.213	0.356	0.389
Sum sq. resids	0.159	0.016	0.025
S.E. equation	0.071	0.022	0.028
F-statistic	2.353	3.766	4.180
Log likelihood	55.618	103.293	93.236
Akaike AIC	−2.274	−4.600	−4.109
Schwarz SC	−1.898	−4.224	−3.733
Mean dependent	0.040	0.030	0.058
S.D. dependent	0.080	0.027	0.036
Determinant resid covariance (dof adj.)		0.000	
Determinant resid covariance		0.000	
Log likelihood		292.846	
AIC		−12.822	
Schwarz criterion		−11.568	

[a] t-statistics are given in parenthesis, c denotes the intercept term.
[b] t-statistics are not provided for the co-integrating vector since these coefficients multiply non-stationary variables and inference on them could not be done, using the standard t-tests.
[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] LM test for residual serial correlation in the ADF regression of order 12, p-values are presented.
[f] Denotes rejection of the null hypothesis of a unit root at the 10% level.
[g] Gives the ADF tests conducted on the residuals of the estimated VECM model. The figure in parenthesis denotes the number of lags included in the ADF test.
[h] 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 nine degrees of freedom.
[i] Multivariate extension of White's (1980) heteroscedasticity test. Under the null hypothesis of homoscedastic residuals, the test statistic is asymptotically distributed $\chi 2$ with 216 degrees of freedom.
[j] 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 six degrees of freedom.

adjustment coefficients (i.e. α_i's in Table 5) in each equation are statistically significant. The calculated Chi-square statistics for the null hypotheses $\alpha_1 = 0$, $\alpha_2 = 0$ and $\alpha_3 = 0$ equal 6.62, 1.26, 0.64 with p-values 0.01, 0.26 and 0.42, respectively. Thus, total capital (k_{1t}) and transportation–communication capital (k_{2t}) are both found weakly exogenous, which shows us that the long run causality runs from total capital and transportation–communication capital to the output. Also the speed of the adjustment coefficient of the Δy_t equation is statistically significant and quite high in absolute value compared with the very low values of this parameter in the total capital and transportation capital equations, about 0.04 in both equations. Thus, we can conclude that Turkish output experiences significantly sharp increases with increases in the total capital and transportation capital.

4.1. *Impulse Response Analysis*

This section analyses the dynamic properties of the estimated VECM for Turkey with the help of impulse response functions. Figure 1 shows the generalized impulse responses[10] of per labour output (y) from a shock to per labour transportation–communication capital (k_2) and to per labour total capital (k_1).[11] The generalized impulse responses of per labour total capital (k_1) from a shock to the per labour transportation–communication capital (k_2) is provided in the last panel of Figure 1. The impulses are traced for a period of 15 years.

It is argued that the confidence interval representation of the standard impulse response analysis based on vector autoregressive models has a number of deficiencies. First of all, as pointed out by Benkwitz *et al.* (2001), impulse responses are obtained from estimated coefficients and hence are also estimates. In some seminal studies, only the point estimates are plotted and confidence intervals are not given (Sims, 1992; Hendry & Mizon, 1998; Pesaran & Shin, 1998). In most of the software packages, confidence intervals of impulse responses are not provided. If confidence intervals are provided, they are usually given only for simple unrestricted VAR's (e.g. Eviews) and they are usually based on bootstrap approaches with dubious theoretical properties (Benkwitz *et al.*, 2001, p. 81). Secondly, it has been claimed that the usual bootstrap procedure used for confidence intervals can fail completely by estimating confidence intervals with actual coverage probability of zero. Benkwitz *et al.* (2000, p. 96) do not recommend to use any of confidence intervals based neither on the first-order asymptotic theory nor on standard bootstrap methods in a full VAR context. Furthermore, Sims and Zha (1995) also criticize the bootstrap approach to construct confidence intervals for impulse responses. They point out that bootstrap intervals are based directly on the simulated small-sample distribution of an estimator, and hence without bias correction, they perform very badly. Thirdly, in many studies, it was also found that the confidence intervals are rather wide and, therefore, the impulse responses are not very informative (Benkwitz *et al.*, 2001, p. 82). As a result, due to the aforementioned problems about the confidence interval representation of the standard impulse response analysis based on vector autoregressive models, we do not provide the error bands for the impulse response analysis. Hence, we refrain from drawing conclusions over the confidence intervals of the estimated impulse responses.

There are mainly four issues that can be revealed from these impulse-response figures. First of all, the impulse-response analysis results point out that the effect of transportation–communication capital on gross domestic product is positive in the

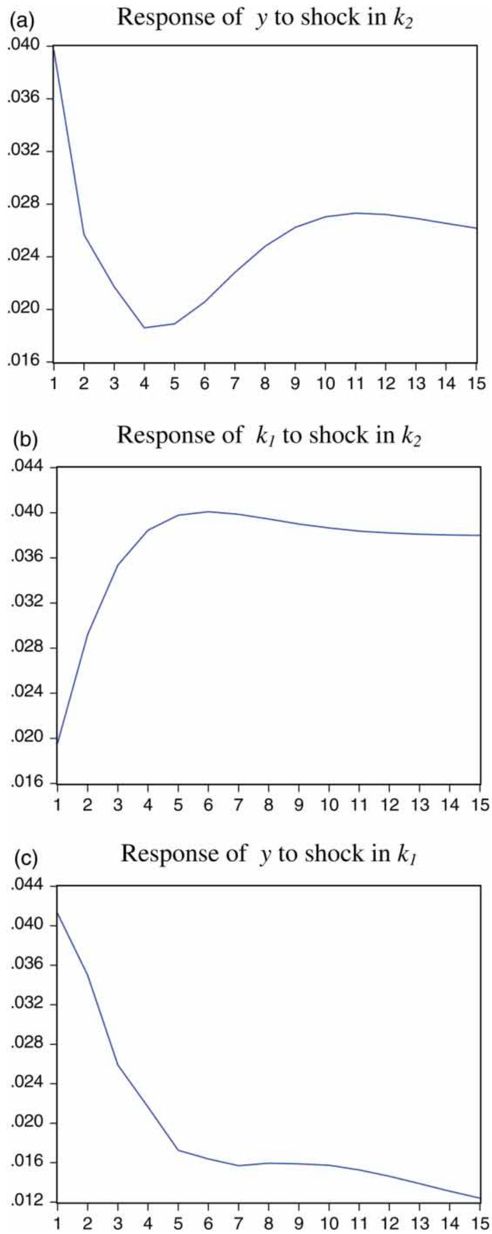

Figure 1. Impulse response to generalized one S.D. innovations.

short term. From the initial year to the fourth year, its impact on output gradually declines, but stays remarkably positive. It can be seen from the panel (a) of Figure 1 that, from the beginning of the fourth year of the shock, the positive impact of transportation–communication capital on output recovers and starts to increase and eventually it stabilizes around the second year's impact level. This finding is quite interesting since it supports the suggestion that, as Banister and Berechman (2003, p. 147) argued, the transportation–communication capital has a lagged impact on economic growth.

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

Thirdly, as the impulse-response graphic portrayed in Panel (c) of Figure 1 shows that the effect of per labour transportation–communication capital on total per labour non-residential capital stock is also positive in the short term. This means that as per labour transportation–communication capital increases, it has a positive *net* influence on the other sectors' capital stock within the economy. An increase in the transportation–communication capital may affect some sectors positively while it may have a negative impact on other sectors; however, it has a positive *net* effect on the total capital stock. This situation may be attributed to a possible complementarity property of transportation–communication capital. In other words, it seems that the transportation–communication capital operates as a complement for the other capital stock of the economy. This issue will be further investigated afterwards with the help of variance decomposition analysis below.

As a last point about the impulse response analysis, it is important to emphasize that the effect of transportation–communication capital on non-residential capital stock increases up to the fifth year, while the effect of transportation–communication capital on gross domestic product decreases up to the third year. What can be said about the implications of this situation? In accordance with the impulse-response analysis results, this situation may be attributed to a sequential process in which the transportation–communication capital affects, initially, the non-residential capital stock, then, the gross domestic product. Clearly, how does the transportation–communication capital affect the economic growth and its internal mechanisms are of special importance. Therefore, this study under the light of the comments provided above about these mechanisms provides a basis for more detailed studies for the Turkish economy on the effects of the transportation–communication capital.

Tables 6–8 tabulate the variance decomposition of each variable over a fifteen-year period.[12] The second column, labelled "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. From Tables 6 and 7, it can be seen that, after 15 years, a shock in per labour transportation–communication capital (k_2) explains 45.3% of the forecast error variance of per labour output (y) and 89.1% of that of per labour total capital (k_1). Per labour transportation–communication capital explains the variance in per labour output twice more than the total per labour 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%, respectively (Table 8). Hence, it appears that the figures support the complementarity hypothesis that transportation–communication investment such as roads, bridges, ports, railways, communication technology facilities,

Table 6. Variance decomposition of per labour 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 7. Variance decomposition of per labour 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

etc. complements the other total non-residential capital spending and hence has a crowd-in impact on total capital (k_1).[13] 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 the Turkish economy.

Table 9 displays long-run elasticities of the per labour total capital (excluding residential and transportation–communication capital) and the per labour real GDP with respect to the per labour transportation–communication capital stock, respectively. These elasticity figures should be taken as special for the fact that they capture the dynamic feedback between the three variables in the multivariate system. One should keep in mind that the

Table 8. Variance decomposition of per labour 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

Table 9. Long-term accumulated elasticities with respect to k_2

k_1	y
0.89 [0.11, 0.89]	0.59 [0.34, 0.59]

Notes: The first figure is obtained from generalized impulses as described by Pesaran and Shin (1998) which constructs an orthogonal set of innovations that does not depend on the VAR ordering. The upper and lower ranges which are shown in brackets are obtained from the Cholesky decomposition-based impulses, in other words, different ordering of variables (all combinations) was considered to calculate them. In the computation of long-term accumulated elasticities, the response horizon is set to $n = 500$ and hence the impulse responses have converged to their long-run levels.

long run elasticities presented here are conceptually different from the elasticities of a production function. In the production function case, the elasticity of y with respect to k_2, for example, gives the percentage change in y as a result of a 1% change in variable k_2 by keeping constant the variable k_1 (in other words, *ceteris paribus* assumption) and excluding the feedback effects from y to k_2. However, the so-called the long-term accumulated elasticities that are given here account for the dynamic interaction between the variables within the whole multivariate system (Kamps, 2004, p. 549). The long-term accumulated elasticities are calculated directly from the accumulated impulse–response functions. The elasticity figures are obtained by dividing the accumulated response of the per labour real GDP and total capital (excluding housing and transportation–communication capital) by the accumulated response of the per labour transportation–communication capital. These elasticities, therefore, should be understood as the total accumulated percentage point changes in the per labour real GDP and total capital (excluding housing and transportation–communication capital) variables per each long-term accumulated percentage point change in per labour transportation–communication investment when all the dynamic feedback among the different variables has been taken into account. It can be named as a total elasticity since it measures both the direct and the indirect effects of the per labour transportation–communication investment on the per labour real output (Pereira, 2001, p. 272).

Table 9 shows that the long-term accumulated elasticity of per labour output (y) with respect to per labour transportation–communication capital (k_2) is remarkably positive. This finding fortifies the hypothesis that the transportation–communication capital is productive.[14] On the other hand, the long-term accumulated elasticity of per labour total capital (k_1) with respect to per labour transportation–communication capital (k_2) is also positive, even higher than the output per labour elasticity. All these support the idea that per labour transportation–communication capital (k_2) is a complement for the other total per labour capital (k_1) in the long run. As a kind of sensitivity analysis or to check for the robustness of the results for the magnitudes and the sign of the calculated long-term elasticities; instead of generalized impulses of Pesaran and Shin (1998), all possible ordering of the variables for the Cholesky decomposition-based impulses have also been considered. The obtained upper and lower values are provided in Table 9. From the figures, it appears that similar conclusions can be drawn, which strengthen the validity of our remarks.

Using these accumulated elasticities, following Pereira and Roca-Sagales (2001, p. 378), one can also calculate long-term accumulated marginal products, which measure long-term accumulated Turkish Lira (TRY) changes in per labour output (y) or per labour total capital (k_1) per one TRY accumulated change in per labour transportation–communication capital (k_2). For example, for output (y); the marginal product with respect to per labour transportation-capital (k_2) is obtained by multiplying its elasticity by the ratio of the per labour output to the per labour transportation–communication capital (y/k_2). The calculated figures for long-term marginal products are presented in Table 10.

The output (y) marginal product with respect to k_2 is calculated as 1.45 Turkish Liras (TRY). This means that a 1 TRY increase in per labour transportation–communication capital (k_2) results in a long-term rise of 1.45 TRY in per labour output (y). The lower bound for this figure is calculated as 0.84 TRY. Another implication of these marginal product figures can be as follows: assuming that the average tax rate is around 0.25 for Turkey, a 1 TRY increase in per labour transportation–communication capital (k_2) would generate around 0.36 TRY in tax revenues over the long run. Consequently, as Pereira and Roca-Sagales (2001, p. 380) rightly pointed out, 1 TRY invested in per labour transportation–communication capital (k_2), apart from the generation of positive effects on per labour output (y), would pay approximately one-third (0.36 TRY) of this money by itself in the long run in the form of additional tax revenues. Table 10 reports the total capital (k_2) marginal product with respect to k_2 as 2.69 TRY, which is a remarkable figure, in fact. A similar reasoning can be done for k_2 as well. Notice that its lower bound is calculated as 0.33 TRY.

Table 10. Long-term accumulated marginal products with respect to k_2

k_1	y
2.69 [0.33, 2.69]	1.45 [0.84, 1.45]

Notes: The first figure is obtained from generalized impulses as described by Pesaran and Shin (1998). The upper and lower ranges which are shown in brackets are obtained from the Cholesky decomposition-based impulses.

5. 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 Cobb–Douglas production function for the Turkish economy under the assumption of constant returns to scale across the three inputs of total non-residential capital formation[15] (K_1), transportation–communication capital stock (K_2), and labour (L). For simplicity and due to degrees of freedom concerns, the variables were expressed in terms of the per effective labour throughout the analysis. The study applied unit root tests and co-integration analysis by estimating a VECM. As a result of the VECM estimation, one co-integrating relationship is detected for the Turkish economy for the period 1963–2006. According to the co-integrating vector estimates, it appears that a *ceteris paribus* 10% increase in expenditure in transportation–communication infrastructure would have been expected to increase the output in Turkey by around 3% which is a remarkable effect. On the other hand, from the VECM estimates, the speed of the adjustment coefficient of the Δy_t equation has found to be -0.3. This implies that the Turkish real output experiences sharp increases with increases in the total capital and transportation capital.

The VECM methodology, apart from accounting for the non-stationarity 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 the transportation–communication capital were also estimated and investigated.

The VECM analysis introduced in this paper indicates that the per labour transportation–communication capital has both a positive and economically significant effect on the per labour real output growth and on the total per labour non-residential capital formation for the Turkish economy. The results based on the impulse–response function analysis implies that the per labour 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 the per labour 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 the Turkish economy.

The impulse–response analysis results point out that the effect of per labour transportation–communication capital on per labour gross domestic product is positive in the short term. From the initial year to the fourth year, its impact on output gradually declines but stays remarkably positive. From the beginning of fourth year of the shock, the positive impact of transportation–communication capital on output recovers and starts to increase and eventually it stabilizes around the second year's impact level. This finding supports the argument of Banister and Berechman (2003) that the transportation–communication capital has a lagged impact on economic growth.

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

From the results based on the impulse–response function analysis, the long-term accumulated elasticities of the per labour output and total non-residential capital to transportation–communication capital per labour were also calculated. The long-term accumulated elasticities of the per labour output and the total non-residential capital to transportation–communication capital per labour have been found to be 0.59 and 0.89, respectively, for the Turkish economy. Using these accumulated elasticities, following Pereira and Roca-Sagales (2001, p. 378), the long-term accumulated marginal products were calculated. The output (y) marginal product with respect to per labour transportation–communication capital (k_2) was calculated as 1.45 Turkish Liras (TRY). This implies that a 1 TRY increase in per labour transportation–communication capital (k_2) results in a long-term rise of 1.45 TRY in per labour output (y). Assuming that the average tax rate is around 0.25 for Turkey, a 1 TRY increase in per labour transportation–communication capital (k_2) would generate around 0.36 TRY in tax revenues over the long run, and hence it seems that it would pay approximately one-third (0.36 TRY) of his cost by itself in the long run in the form of additional tax revenues. All these findings suggest that transportation–communication capital may be a powerful tool for policy-makers to promote the long-term per labour real output growth in Turkey.

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Notes

1. According to authors' own calculations based on SPO (1970–2008), this figure is 20.2% in average for the period of 1968–2006.
2. 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.
3. For a critical survey and the other classification of the studies on this subject, see, Romp and De Haan (2007).
4. The initial stock of capital has been obtained using the standard perpetual inventory procedure following the seminal paper of Harberger (1978). This approach uses the neoclassical growth model prediction of a constant capital-output ratio over time and hence is based on the assumption that the country was at its steady-state capital-output. The procedure is built on the accumulation equation $K_t = I_t + (1 - d)K_{t-1}$ which implies that $(K_t - K_{t-1})/K_{t-1} = I_t/K_{t-1} - d$. The left side of the expression is the growth rate of capital stock, g. Hence, one can write $K_{t-1} = I_t/(g + d)$. Neoclassical growth theory proposes that investment and capital grow at the same rate in the steady state. Thus, the growth rate of capital can be approximated by the growth rate of investment (Kamps, 2004, p. 14). In our study, following the approach of Kamps (2004), the growth rate of capital is approximated by the average growth rate of investment over the period 1963–2006. While the steady-state assumption of Harberger procedure is strong, it is probably better than assuming that an initial capital stock of zero (Beck *et al*., 1999). Setting the value of initial capital to zero might generate significant measurement error in application with short time series.
5. Recall that $I_t = (1 + g)^t I_0$, where $t = 0,1,2, \ldots, T$. Taking the natural logarithm of both sides yields $\ln I_t = t \cdot \ln(1 + g) + \ln I_0$. Rearranging we get $\ln(1 + g) = (\ln I_T - \ln I_0)/t$. For the growth rate between the initial and last year, it is $\ln(1 + g) = (\ln I_T - \ln I_0)/T$. A useful approximation is that for

any small number g, $\ln(1+g) \approx g$. Hence one can write $g \approx (\ln I_T - \ln I_0)/T$, which is nothing but the expression used in our study for the annual average growth rate of total fixed investment. Note that a log growth rate is a continuous rate of growth with continuous compounding. However, a percentage change is specific to a particular time horizon. When time spans are short, a percentage change and a log difference often produces very similar answers. However, when the process evolves over many years or decades (as in our case) the accuracy loss from using percentage changes can be large.

6. We think that without access to all the detailed official national and sectoral accounts and without collecting depreciation rate specific data with necessary surveys, the depreciation rates cannot be estimated accurately. In fact, the national statistical institutes should provide the depreciation rate estimates.
7. This database involves sectoral and national figures about the consumption of fixed capital from the beginning of 1960s for 12 OECD countries. The data for consumption of fixed capital are given for the following countries and periods (OECD, 1998): Australia (1966–1995), Belgium (1970–1996), Canada (1961–1997), Denmark (1966–1992), Finland (1960–1996), France (1970–1997), Germany (1990–1997), Germany (West, 1960–1994), Italy (1980–1994), Norway (1978–1997), Sweden (1980–1994), UK (1984–1994) and US (1960–1997). Most of the studies use depreciation rates of US only, but in our study we used the arithmetic mean of all countries. Hence, the averages are taken for several countries over a very long period of time.
8. We also included dummy variables to account for the break points suggested by the Lee and Strazicich (2003) Minimum Lagrange multiplier unit root test. However, neither of these dummy variables was found significant.
9. Note that the equality of the coefficient of k_1 to the coefficient of k_2 does not imply that k_1 and k_2 are perfect substitutes (i.e. identical inputs). Consider the constant elasticity of substitution (CES) functional form as $y = A \cdot [\alpha k_1^{\rho} + \beta k_2^{\rho}]^{r/\rho}$ where $\rho \leq 1$, $\rho \neq 0$, $r > 0$, α and β are share parameters between 0 and 1, r is homogeneity coefficient, and $\sigma = 1/(1-\rho)$ is elasticity of substitution. As known, if $\rho = 0$ ($\sigma =$ 1, unit elasticity of substitution), the CES function reduces to Cobb Douglass function since $\lim_{\rho \to 0} y = [A k_1^{\alpha} k_2^{\beta}]^r$. Hence the equality of the coefficient of k_1 to the coefficient of k_2 implies equal share parameters for inputs ($\alpha = \beta$). Consequently, according to the above reported estimation results, the share of transportation–communication capital (in production) alone seems to be around the share of all other capital.
10. Generalized impulses, as described by Pesaran and Shin (1998) constructs an orthogonal set of innovations that *does not depend* on the VAR ordering.
11. Excluding residential and transportation–communication capital.
12. In the variance decomposition analysis reported in Tables 5–7, the following Cholesky ordering is followed: $k_2 k_1 y$. The reason of this choice is that, in terms of impulse responses this ordering gives the closest figures to that of generalized impulses method which constructs an orthogonal set of innovations that does not depend on the VAR ordering.
13. 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).
14. For similar findings about the total public capital instead of transportation–communication capital, using the same methodology with us, see Kamps (2005, pp. 549–551).
15. Excluding transportation–communication capital.

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