The Productivity Impact of Infrastructure in Turkey, 1987 - 2006

J.W. Fedderke and T.E. Kaya

ERSA working paper 333

March 2013

Economic Research Southern Africa (ERSA) is a research programme funded by the National Treasury of South Africa.

The Productivity Impact of Infrastructure in Turkey, 1987-2006*

J.W.Fedderke† and T.E.Kaya‡

March 12, 2013

Abstract

This paper explores the impact of some key infrastructure measures in transportation, telecommunication and electricity production sectors on labor productivity, using data on two-digit sectors for the Turkish economy for the years 1987 to 2006. We find both statistical and economic significance of infrastructure on productivity growth, for road, port and air transport, telecommunications and electricity production. In the railway sector, only measures of actual freight carried are consistently statistically significanctly associated with productivity growth, while other measures of infrastructure are insignificantly or perversely associated with productivity growth. Given that the railway transport sector is the only infrastructure sector that remains closed to competition and private participation, this raises the issue of the significance of private sector involvement in infrastructure provision.

Introduction

Investment in infrastructure can increase the productive capacity of an economy either directly by augmenting the factor endowments of the economy, or indirectly by increasing the productivity of the existing factors of production.

In the present paper we explore the productivity impact of infrastructure in the Turkish economy. The latter is of particular interest in connection with infrastructure investment. Since the 1980s the Turkish economy has pursued a process of economic liberalization, that has included a privatization programme, periods of macroeconomic and political instability, a major financial crisis and subsequent stabilization programmes.

For Turkey, specifically, sources of productivity growth are also of considerable policy importance. The rate of productivity growth is an important factor determining the Turkish economy's convergence to per capita income levels of the developed countries. Given the income disparity between Turkey and the European Union and since Turkey is a candidate country to the EU, it is particularly important to identify possible policy options to eliminate the income disparity.

Accordingly, in this paper, the productivity impacts of a range of distinct infrastructure measures are analyzed employing a panel data of disaggregated sectors from Turkey between 1987 and 2006. In particular the question of whether different forms of infrastructure have different impacts on productivity in different sectors is examined. We use disaggregated sectors as the productivity impacts may only be found at a more disaggregated level rather than the aggregate economy. However, we can only use 2-digit sectors because of data availability, which precludes greater disaggregation. For the same reason we chose 1987 as the starting year.

The paper proceeds as follows: in section we provide a very brief overview of some theoretical background; section provides some general growth- and policy-relevant background on the Turkish economy; given that the paper employs some new infrastructure measures, section provides an overview of Turkish infrastructure developments, both in terms of the magnitude of infrastructure stocks and the institutional context within which it is provided; section presents the outcome of a growth accounting exercise for Turkey; in section we

*J.W.Fedderke acknowledges the research support of Economic Research Southern Africa. The views expressed in this papers are the personal views of the authors alone, and do not necessarily represent to views of the Ministry of Customs and Trade, the Republic Turkey.

†Pennsylvania State University, Economic Research Southern Africa and University of the Witwatersrand.

‡Ministry of Customs and Trade, the Republic Turkey.

present additional data sources; sections and present the empirical specification and empirical estimation results respectively, and section concludes.

Theoretical Background

The core rationale for infrastructural investment that emerges from the theoretical literature is that it has both a direct impact on output, but also raises the marginal product of other factors of production (typically capital) used in production.

Under an endogenous growth model in which government capital is included explicitly in the aggregate production function, under a balanced budget constraint, the steady state growth rate is nonlinear in the proportion of final output allocated to the provision of public capital - see Barro (1990). The growth rate declines in the resultant tax burden of public capital provision, but rises in the positive impact of public capital on the marginal product of private capital. The capital productivity effect dominates at low levels of government capital provision, while the tax effect dominates at high levels of such provision. The Barro framework provides a clear theoretical link between output and government infrastructure investment. Infrastructure investment can prevent diminishing returns to scale in private-sector capital, raise the marginal product of private-sector capital, and raise the rate of growth of output. However, an equally important message is that government intervention of this nature can raise economic growth *only within limits*, and can have both positive and negative impacts on growth. Since the marginal product of public capital diminishes, there exists a threshold level of public capital beyond which further increases in public capital are *harmful* to economic growth, since the tax effect comes to dominate the capital productivity effect.

The impact of infrastructure capital on output may therefore be direct, or indirect - by raising the marginal product of the private sector capital stock. Under the latter channel of influence, infrastructure would impact not output per worker, but total factor productivity (TFP).

A number of empirical studies confirmed a positive and significant results for infrastructure investment. For example, Aschauer (1989a) found an output elasticity of non-military public capital stock as high as 0.39 - see also Munnell (1990). Storng economic growth impacts have been reported even when concerns regarding the estimation techniques of the early studies - see Holtz-Eakin (1994) and Baltagi and Pinnoi (1995) - have been addressed. This is true of studies employing cross-national data - see Canning (1999), Esfahani and Ramirez (2003); country-specific regional data - see Aschauer (1998), Kemmerling and Stephan (2002); country-specific specific infrastructure types - see Everaert and Heylen (2001), Fernald (1999); aggregate country data - see Fedderke, Perkins and Luiz (2006), Ramirez (2002); and sectoral data - see Fernandez and Montuenga-Gomez (2003), Paul, Sahni and Biswal (2004).

Nevertheless countervailing evidence of ambiguous, insignificant or negative impacts of public capital on development prospects continues to emerge also - see Canning and Pedroni (2004) by way of example.

What may account for the contradictory findings? We identify five possible reasons from the literature (other than data quality).

First, the relationship between public capital and output may be non-linear, with the corollary that both under- and over-investment in infrastructure are feasible. Non-linearity is implicit in the model proposed by Barro (1990), and Canning and Pedroni (2004) provide an explicit treatment of this possibility, and find that both under- and over-provision of infrastructure applies across countries. A second possible reason for any finding of negative impacts of public capital on output and/or growth, may be the presence of crowd-out effects from public investment - see Aschauer (1989b), Yakita (2004) and Lachler and Aschauer (1998). Third, where infrastructure provision itself positively responds to productivity, endogeneity of infrastructure measures follows, raising the prospect of bias and inconsistency of standard estimators. Possible reasons for such a feedback would arise under increased reliance on the private sector for the provision of infrastructure services, or under successful lobbying by industry interest groups that experience either positive productivity gains or constraints on performance due to infrastructure provision - see the discussion in Estache, Foster and Wodon (2002). Various studies have tried to address this issue. Röller and Waverman (2001) explicitly model and estimate the impact of telecommunications under simultaneity. See also Calderón and Servén (2003), Fedderke, Perkins and Luiz (2006), and Fedderke and Bogetić (2009). Fourth, public capital may not exercise its impact on output directly, but rather indirectly by raising the marginal product of private sector capital. Under these circumstances, it becomes critical whether the productivity impact is being investigated with respect to output per worker, or with respect to total factor productivity growth - see for instance Reinikka and Svensson (2002). Finally aggregate measures of infrastructure may come to hide the productivity impact of infrastructure at a more disaggregated level. Thus for example Shioji (2001) finds that the positive impact of infrastructure emerges in panels of US and Japanese industry once public capital is suitably disaggregated.

The approach adopted in this paper examines whether infrastructure has an impact on labor productivity directly. The specification for this exploration is derived from Fedderke and Bogetić (2009). The general specification estimated is:

$$\left(\frac{Y}{L}\right)_{i,t} = f\left(\frac{K}{L}, S, U, F\right)_{i,t} \tag{1}$$

where Y denotes real value added of industry i in period t, L the size of the labor force, K the size of the physical capital stock, S a vector of additional control variables, and F denotes the infrastructure measures used for this study.

In principle, a second approach should identify the impact of infrastructure on TFP. However, as we detail in section of the paper, productivity growth in Turkey has been predominantly based on factor accumulation, rather than TFP growth. As such, the direct impact of infrastructure is the more likely channel for Turkey. we nevertheless undertook estimation for TFP growth, under relevant instrumentation strategies. Results confirmed the general insignificance of infrastructure measures for TFP productivity growth, suggesting the direct channel of influence for infrastructure is the more important for Turkey. For the sake of parsimony we do not report the TFP results. They are available from the authors on request.

We proceed with the application to Turkish data.

Overview of the Turkish Economy

Until the 1980s Turkey followed an inward oriented, import substituting industrialization and state-led economic growth strategy, with trade restrictions and financial repression. Heavy public investment, especially in the manufacturing sector was used to promote industrialization and economic development (Ismihan and Metin-Ozcan, 2006). As noted by Altug and Filiztekin (2006), during the import substitution industrialization period, State Economic Enterprises (SEEs) invested in large scale intermediate goods production leaving consumer goods production to the private sector. During the late-1970s, Turkey faced many macroeconomic problems including trade deficits, high inflation and unemployment rates, as well as political instability, which culminated in a military coup in September 1980. Those events also determined the end of the import substitution industrialization period.

After a severe foreign exchange crisis at the end of the 1970s, Turkey adopted a new and liberal economic policy package in January 1980. Accordingly, both the growth strategy and the state's role in it changed dramatically (Ismihan and Metin-Ozcan, 2006). Turkey undertook a major devaluation of the currency and switched to an export led economic growth model. The main characteristics of the 1980s were export promotion and gradual import liberalization as well as deregulation of capital movements (in 1989). The state's investment strategy changed from manufacturing to infrastructure. The state-owned companies in cement, mining-copper, sugar and tyre production and in banking, insurance and airport services were taken into the privatization program and privatized gradually - see Okten (2006) for a detailed list. Following the military regime between 1980 and 1983, there has been a period of relative political and macroeconomic stability compared with late 1970s. In the early 1980s, the Turgut Ozal government embarked on an ambitious program of infrastructure investment financed by borrowing - see Altug and Filiztekin (2006). The share of government expenditures in GDP rose from 18% in 1983 to 24% in 1990 (Kruger, 1995). With the late 1980s the Motherland Party of Turgut Ozal began losing popularity while government deficits began rising from transfer payments, instability increased and persisted during the entire 1990s (Altug and Filiztekin, 2006). International capital flows did not fund long-term investment projects but entered as short-term volatile portfolio flows. The main characteristics of the 1990s were coalition governments, populist policies with associated public sector imbalances relying on domestic borrowing, high interest and inflation rates. Despite the IMF program of 1999 aimed at correcting public sector imbalances, the major economic crisis of 2001 reduced GDP by 7.5%.

INSERT TABLE 1 ABOUT HERE.

Following the 2002 parliamentary elections, the Party of Justice and Development implemented a new program backed by the IMF and the World Bank, successfully reducing macroeconomic instability. Political instability fell and Turkey enjoyed an unprecedented economic growth rate at an average of 7.2% between 2002 and 2006, while the Central Bank was successful in reducing the inflation from almost 54.4% in 2001 to 9.6% in 2006.

In the sample period of the current study, between 1987 and 2006, Turkey grew 4.1% annually, a relatively low growth rate for a developing country. More importantly, as mentioned above, the growth rate followed a very unstable path following the economic and political instabilities. The Turkish economy experienced negative growth in 1994 and 2001 as a result of economic crises and in 1999 after a devastating earthquake. A summary of economic indicators for Turkey is provided in Table 1.

In the Turkish context, productivity growth is an important determinant for the sustainability of economic policies and convergence of per capita income levels and standard of living to those in the EU and other developed countries. Labor productivity serves as the basis for this convergence. According to the OECD (2004), Turkey's labor productivity is about 30 percent of the level of the United States. Figure 1 provides the historical evaluation of labor productivity in the total economy as well as the labor productivity annual growth rates for four decades according to OECD data.

INSERT FIGURE 1 ABOUT HERE.

As Altug and Filiztekin (2006) mention, unlike part of the 1960s, labor productivity growth became unstable during the 1970s, as the import substitution industrialization policy was nearing its end in Turkey. During the early-1980s, the early trade and financial liberalization period, productivity increases. Several authors have questioned the basis of the growth and productivity performance of 1980s and argued that they were achieved at the expense of unsustainable cost savings on labor wages, where real wages became insensitive to productivity increases - see Voyvoda and Yeladan (2001), Onaran (2002). The combination of economic and political instability is reflected as low and unstable productivity growth rates during the 1990s, which is often labeled as a lost decade for Turkey (OECD, 2004). The political and economic stability achieved during the 2000s on the other hand can be followed in the increases in labor productivity.

Developments of Infrastructure in Turkey

In this section we provide an overview of physical infrastructure in Turkey. Sectors analyzed are energy, transportation and telecommunications, which were owned and controlled by the state until the 1980s. State Economic Enterprises (SEEs) in Turkey were established in the 1930s to jump-start the economy, and due to their strong growth by 1960 the share of the public sector in manufacturing was almost 60% (Okten, 2006).

The liberalization efforts of the 1980s resulted in major reforms aimed at better functioning markets. Reforms included privatization, liberalizing restrictions on entry, and normal business practices to ensure competition (Okten, 2006). Although there are still state monopolies, especially in railways and electricity transmission, the physical infrastructure related sectors now include private companies and state owned companies with more market-oriented approaches. However, the privatization efforts began slowly - while from 1985 to 2009 the total proceeds of privatization amounted to $36.7 billion, 85% of that amount was realized between 2000 and 2009 (Tektas, 2011).

Almost all infrastructures related sectors have observed significant improvements in the last decade, although for the last 3 decades railways suffered from insufficient infrastructure investment under the state monopoly. Especially improvements in the telecommunication and airline sectors as well as private electricity production supports the argument that accelerated privatization of state economic enterprises and forming more competitive markets have improved infrastructure in Turkey.

Energy and Electricity

Turkey's total primary energy supply was 106 million tons of oil equivalent (Mtoe) in 2009 (Agis, 2011). It increased by 87% while the economy doubled in size between 1990 and 2008. Turkey depends on imports for 72% of its energy supply: almost 98% of oil and natural gas and most of the coal. Those three fossil fuels account for 90% of the energy supply with approximately equal shares, while renewable energy sources provide the remaining 10%. Industry and residential sectors are the largest users, accounting for a third of demand each, followed by the transportation sector with 20% (Tektas, 2011).

INSERT FIGURE 2 ABOUT HERE.

Total electricity production increased from 27 TWh to 194 TWh between 1983 and 2009, a six fold increase (data is from the Turkish Electricity Transmission Company). Figure 2 provides the historical pattern of electricity production in Turkey by producer type. As is evident, the share contributed by the public and private sectors have changed dramatically: in 1983 the public sector supplied 87% of the production, while by 2002 the private sector supplied more than 50% of electricity output, split between production companies (under built-operate-transfer contracts in which the private sector finances, constructs and operates the facility and after a specified period the ownership is transferred to the government) and auto producers (companies which generate electricity wholly or partially for their own use).

Transportation

While until the mid-1950s railroads assumed a primary role in public transportation infrastructure, since then the primacy of rail has been gradually replaced by road transport.

The Turkish railway system continues to consists of a state owned monopoly railway company, Turkish State Railways (TCDD), operating with 749 locomotives, 1010 passenger and 16925 freight rail cars as of 2009. Its infrastructure remains deficient. Railway infrastructure connects 37 of 81 cities, leaving almost 30% of the population without access to railways, including some major and commercial centers like Bursa. In addition, the quality of the railway tracks is questionable; of the almost 11000 km of railways, only 5% are double lines and 34% are older than 25 years. In contrast to rail infrastructure, total roads increased 0.70 % annually between 1983 and 2009, while highways increased 16% annually reaching 2025 km in 2006 from 38 km in 1983 (Tektas, 2011).

INSERT FIGURE 3 ABOUT HERE.

The contribution of railways to the transport of passengers and freight has declined relative to road transport over time. As Figure 3 illustrates, with the exception of freight all indicators of rail capacity and services have been in either stasis or decline since the 1980s. Even the positive trend in freight is misleading since the proportion of freight carried by rail declined from 78% in 1950, to under 5% in 2009, with road transport carrying 91% of total freight by 2010. In passenger transport, the switch to road transport is even more dramatic - less than 1.7% of the total passenger transportation was by rail in 2009, while road transportation's share was 96% in 2010.

There has also been a significant increase in airways passenger traffic in recent years in Turkey. Following the liberalization of air transport and privatization efforts, the competition in airways increased, prices decreased and new entrant airlines operated to new routes. As a result, the passenger traffic increased by 240% from 2003 to 2009 (Tektas, 2011).

Telecommunication

Turkey's telecommunication sector has shown significant growth in the last two decades. Until the late 1980s the percentage of the population connected to the phone line network was exceptionally low, as a consequence of a capital-starved state monopoly. Since the late 1990s, there has been a rapid growth in mobile phone subscriptions while the number of landline subscribers stagnated. As of 2009, the number of mobile line subscribers and landline subscribers were about 64 million and 16.8 million respectively (Tektas, 2011). The state owned monopoly land line provider, Turk Telekom, could only be privatized in 2005 after two unsuccessful attempts, while three operators compete in the mobile line market.

INSERT FIGURE 4 ABOUT HERE.

Sources of Growth in Turkey

To assess the impact of infrastructure on productivity, we identify the relative contribution of factor accumulation and total factor productivity (TFP) to economic growth. Thus, we provide a growth accounting exercise for the disaggregated 2-digit Turkish economy over the 1987-2006 period.

There are a few studies that provide the determinants of growth and the contribution of productivity in Turkey. Filiztekin (2000) finds a negative TFP contribution in Turkish manufacturing sectors for the entire 1970-1996 period. However, he suggests that the trade liberalization in the 1980s created significant improvements in productivity growth, while factor accumulation decreased until later years of liberalization as macroeconomic stability fell. Saygili et al (2001, 2005) find that the determinant of growth in Turkey is factor accumulation, and TFP in Turkey relative to the TFP in US stays around 7% without any significant improvement during 1972-1993 period. Ismihan et. al. (2006) on the other hand, suggest that TFP was a crucial source of growth during the 1960-2004 period and was positively affected by imports and public infrastructure investment and negatively affected by macroeconomic instability. Finally, Altug et al. (2008) find that output growth in Turkey is primarily due to capital accumulation rather than TFP growth, though they also note that the rate of capital growth declined during the 1980s and especially during 1990s, while political and macroeconomic instability was prevalent.

We compute TFP by means of the primal decomposition. Previous studies of Turkish productivity growth have provided growth accounting exercises under the assumption of constant factor shares in production. Specifically, the share of labor in output has been set between 0.35 and 0.65 - for a detailed account of these studies see Ismihan et al. (2008). For this study we calculate the share of labor from compensation to workers data of the Turkish Statistical Institute (TurkStat). Results of the growth accounting exercise are reported in Table 2.

INSERT TABLE 2 ABOUT HERE.

Our results indicate that output growth in Turkey is generally due to capital accumulation, but TFP growth is an important secondary source, especially for some sectors. As shown in Table 2, for certain sectors and certain periods TFP has a positive contribution to growth. During the last period (2002-2006) the high growth rates, in especially construction and transportation are translated into TFP increases. However those results should be interpreted with caution as the unprecedented growth rates reflects the base year effects because the economy shrank in 1999 with a devastating earthquake and in 2001 after the most serious economic crisis of Turkey. Compatible with the findings of Filiztekin (2000), following the trade liberalization of 1980s, TFP has a positive contribution in manufacturing, as well as the mining and electricity sectors. Although the contribution of TFP is limited for the entire period and sectors, the positive contribution of TFP should be interpreted under suitable caveats as we fail to take into account the quality differentials in factors of production, especially human capital, which renders our TFP estimations upward biased. Finally, apart from other services, the contribution of labor is modest, and in the case of agriculture it is negative.

The importance of capital accumulation in economic growth in general confirms the findings of the existing studies on the subject for Turkey. Given that growth in Turkey is primarily based on factor accumulation, our interest will be on the impact of the infrastructure measures on labor productivity, rather than total factor productivity.

The Data

For the current study, we employ panel data for the sub-sectors mentioned in Table 3, with observations from 1987 to 2006. The output, labor force, exports and import, research and development (R&D) expenditure as a share of GDP and compensation to employees data of this paper is drawn from the Turkish Statistical Institute (TurkStat), the Central Bank of the Republic of Turkey and the Ministry of Development. For the capital stock data, we rely on Saygili et al. (2005), because of the lack of official data.

INSERT TABLE 3 ABOUT HERE.

In order to control for other determinants of productivity and market conditions, we also employ the openness ratio (the ratio of the sum of import and export to the output in each sector), R&D expenditure as a share of GDP, average years of total schooling from the Barro-Lee database (www.barrolee.com), and political rights and civil liberties rating obtained from Freedom House (www.freedomhouse.com). Freedom House provides an annual numerical rating from 1 (most free) to 7 (least free) for both political rights and civil liberties, a negative regression relation between rights and productivity. From Tektas (2011), we obtain the infrastructure measures specified in Table 4.

INSERT TABLE 4 ABOUT HERE.

Empirical Specification

Infrastructural investment has both a direct impact on output and an indirect impact by raising the marginal product of other factors. A growth model following the Barro (1990) framework provides a theoretical link between output and mostly government financed infrastructure investment. Infrastructure investment can prevent diminishing returns and raise the marginal product of private capital and consequently raise the growth rate of output. However as the rate of growth will decline in the resultant tax burden of public investment, economic growth can rise only within limits and as a consequence, the net impact depends on positive productivity and negative tax burden effects.

Following that framework, we examine whether infrastructure has an impact on labor productivity under the general specification given by:

$$\ln\left(\frac{Y}{L}\right)_{i,t} = \beta_0 + \beta_k \ln\left(\frac{K}{L}\right)_{i,t} + \beta_s S_{i,t} + \beta_f F_{i,t} + b_i + c_t + \varepsilon_{i,t} \tag{2}$$

where Y denotes real value added, L the size of the labor force and K the size of capital stock for sector i in period t, S denotes a vector of additional control variables and F is a vector of variables measuring infrastructure capital stock summarized in Table 2. Finally, b_i and c_t denote group and time effects respectively.

We incorporate a range of control variables that may be relevant to productivity growth, including the openness of sectors (OPEN) measured by the ratio of sum of exports and imports in each sector, political rights and civil liberties rating (RIGHTS) obtained from Freedom House, average schooling years (EDU) obtained from the Barro-Lee index and finally research and development as a share of GDP in Turkey (R&D).

It is argued in the literature that international trade may increase competitive pressure on domestic firms, and thereby increase their output and productivity growth - see Aghion et al (2001), and see also the evidence in Sachs and Warner (1995). In addition, initially backward countries may catch up with developed countries more rapidly when the economy is open due to either learning-by-doing or technological spillover effects. Filiztekin (2000) found that significant improvements in productivity growth in Turkish manufacturing industries can be observed after the economy is opened to free trade. The political rights and civil liberties in a country, on the other hand, may have positive externalities by improving economic freedoms; for example secure property rights may increase the tendency to invest. Since Freedom House provides an annual numerical rating from 1 (most free) to 7 (least free) for both political rights and civil liberties, our linear combination of the two measures denoted RIGHTS, would return a negative regression coefficient in the event of a benevolent association between rights and productivity.

However, while infrastructure investment may have an impact on productivity, that increased productivity may trigger increased investment demand for infrastructure. If there is a feedback mechanism from productivity to infrastructure (e.g. through interest group lobbies); then an appropriate instrumentation strategy for the infrastructure measures would be needed. In the present paper we pursue the instrumentation strategy of Fedderke and Bogetić (2009), by estimation the first step regression given by:

$$F_t = \alpha_0 + \alpha_y \left(\frac{Y}{P}\right)_t + \alpha_a A_t + \alpha_I I_t + \eta_t \tag{3}$$

where F are our infrastructure measures, Y denotes output, P is population, and A and I denote the share of agricultural and industrial sectors in the aggregate Turkish economy respectively. Both the infrastructure variables and the reduced form variables used for the instrumentation are aggregate and apply to all sectors. Empirically we proceed with instrumentation under the standard VECM cointegration time series methodology (see Johansen and Juselius (1990), Johansen (1991), and Fedderke and Bogetić (2009)), taking into account the non-stationarity characteristics of the data used, rendering a multivariate cointegration approach in the estimation necessary.

On the other hand, since we employ two-digit sectors of the Turkish economy in our estimations, there is no guarantee of homogeneity across sectors in terms of the productivity impact of infrastructure investment. To allow for this possibility, we estimate equation (2) under the pooled mean group estimator, again allowing for the endogeneity of the infrastructure measure by means of the instrumentation strategy detailed by equation (3). Details of the estimator are provided in the Appendix of the paper.

Estimation Results

Our interest lies in the labor productivity impact of the infrastructure measures. Following the empirical model provided in Section , we estimate under the within estimator, controlling for time effects. We report estimation results for both uninstrumented and instrumented infrastructure variables, in order to clarify the extent to which the potential endogeneity of infrastructure impacts results. Then we estimate the impact of infrastructure measures on labor productivity under the PMG estimator in order to control for group heterogeneity.

Labor Productivity Impacts of Infrastructure Measures

Results of estimating equation (2) under the within estimator for uninstrumented and instrumented infrastructure measures are reported in Table 5a and Table 5b, and Table 6a and Table 6b respectively. We report results that exclude time effects, due to the greater statistical coherence of these results. However, we also estimated in the presence of time effects. Results are not affected, with a few exceptions that we note in the discussion that follows. Specifically, in the presence of time effects the statistical and economic significance of the infrastructure variables tends to be stronger than those we report below (results are available from the authors on request).

INSERT TABLES 5a AND 5b ABOUT HERE.

INSERT TABLES 6a AND 6b ABOUT HERE.

The capital labor ratio $\ln(K/L)$ proves to have a positive and significant impact on labor productivity as expected from standard growth theory as well as our growth decomposition results where capital is the single most important contributor of growth in Turkey for most of the sample period and sectors. The elasticity of labor productivity with respect to the capital labor ratio is as high as 0.70.

The openness of sectors (OPEN), calculated as the ratio of export and import total to the total value added in each sector consistently has a positive and statistically significant impact on productivity. The civil and political rights rating (RIGHTS) indicates that better rights are associated with higher productivity growth and generally proves statistically significant (recall that higher is worse on the Freedom House metric). Both the R&D and the education measures are generally statistically insignificant, but report a theoretically counterintuitive negative sign. Where we include time effects in estimation, average schooling years and total R&D expenditure as a share of GDP provide inconsistent results. Education enters with a correct (positive) sign, but generally is statistically insignificant. However, the R&D measure is statistically significant and continues to report a negative sign. One possible explanation of the human capital findings is that average schooling years and R&D as a share of GDP are inadequate indicators of education and innovation expenditure in Turkey.

As the focus of this paper is on the impact of infrastructure measures on productivity, we turn our attention to their discussion. The introduction of time effects in estimation does not change the inferences of any of the infrastructure results, except where we explicitly note these in the ensuing discussion.

Road transportation constitutes the predominant mode of transportation in Turkey. All road measures including the measures for the number of vehicles (row 14-24) report significant and positive results except in the case of paved roads (PRDS) and gas prices (GPRC). Under instrumentation, the sign of the gas prices becomes negative as expected, but both gas prices and paved roads have insignificant elasticities. Apart from those measures, total roads (TRDS), highways (HRDS), total cars (TCARS) as well as passenger and commercial cars (PCARS and CCARS) provide positive and significant elasticities. In the case of total roads, under instrumentation the estimated elasticity is particularly strong (1.227). Paved roads is the one variable to return countervailing results: it reports a negative and significant coefficient in the absence of instrumentation, and an insignificant coefficient under instrumentation. One possible reason for this finding may be that the process of road improvement may lead to road straightening and widening, thus generating the apparently perverse association we report. See the discussion in Fedderke and Bogetič (2009) on this point.

Other transportation measures, namely port cargo handled (CARGO) and air passengers (APASS) report significant and positive elasticities. The instrumentation improves the significance level of the air passenger measure. The elasticities are 0.273 and 0.539 respectively (row 26 and 27 in Table 6a).

Under telecommunication measures (rows 28-29), fixed and total telephone lines (TTEL and FTEL) report positive and significant elasticities with or without instrumentation, and the magnitude of the estimated impact increases particularly for total lines under instrumentation.

For electricity production (rows 30-35), the state (ESTATE) and total electricity (ETOTAL) generation is positively and statistically significantly related with labor productivity in Turkey. By contrast, private production (EPRO) and the production of auto-producers (EAUTO) is either negatively, or at best insignificantly associated with productivity growth. Improvements in the total network loss (NLOSS) have particularly strong impacts in the absence of instrumentation, with a 1% decrease in network loss leading to a 1.7% increase in labor productivity, though the impact is statistically insignificant under instrumentation. This is one instance in which the introduction if time effects does impact results. In particular, with time effects total network loss is statistically significant with or without instrumentation, and proves to have a powerful economic impact. Specifically, a 1% decrease in network loss would lead to a 3.45% and 2.24% increase in labor productivity respectively.

Finally, the railway infrastructure measures (rows 6-13, in Table 5a and in Table 6a) report either positive but insignificant or significant but negative results with respect to labor productivity. The only exceptions are passengers (RPASS), freight (FRGHT) and goods capacity (GCAP) - though the introduction of time effects eliminates the statistical significance of the passenger measure. Instrumentation (Table 6a) does not change the results, except for the passengers (RPASS) and goods capacity (GCAP), which have lower magnitudes and significance levels under appropriate instrumentation. The magnitude of the impact of freight (FRGHT) increases with instrumentation, where freight has an elasticity of 0.421 (row 8 in Table 6a).

In summary, the findings on the impact of infrastructure on Turkish 2-digit sector labor productivity suggest that both statistical and economic significance can be attached to infrastructure measures. The only exception is the railroad sector. Significantly, this is the only infrastructure sector which is still closed to competition and private participation. In the case of the other infrastructure measures, positive and relatively high elasticities with respect to labor productivity are found. This finding is invariant to controlling for the potential endogeneity of the infrastructure measures.

Labor Productivity Impacts of Infrastructure under the PMG Estimator

We proceed with the PMG estimator proposed by Pesaran et. al. (1999) in order to deal with the possibility of heterogeneity across sectors. We report estimation results only under instrumented infrastructure measures. We estimated in the absence of instrumentation also, but report only the instrumented results for the sake of parsimony. In general results are symmetrical - though the impact of infrastructure measures is stronger under instrumentation.

We report the homogeneous long-run parameters in Tables 7a and 7b. Estimation results confirm the presence of adjustment to equilibrium -see the error correction coefficient (ECM) of Table 7a and 7b. The joint Hausman tests, denoted as h-test, fail to reject the homogeneity restriction on the long run coefficients for Turkish sub-sectors, which also confirms the legitimacy of the PMG estimator. Moreover, the capital labor ratio proves to have positive and significant impact on labor productivity as under the within estimator, with a higher elasticity of 0.9.

INSERT TABLES 7a AND 7b ABOUT HERE.

The results from the PMG estimation generally confirm the robustness of the estimation results of section .

The measures of total (TRDS), paved (PRDS) and toll or highway roads (HRDS) return strong positive elasticities with respect to labor productivity, but only the latter two are statistically significant (rows 10-12) . As the total roads measure may be inadequate in capturing improvements in the road infrastructure, (the distance between cities and accordingly total recorded roads may decrease as a consequence of road widening and/or straightening), we focus on the latter two. The elasticities are 0.3 and 0.1 for paved and highway roads respectively. Total (TCARS), passenger (PCARS) and commercial cars (CCARS) return with strong, positive and statistically significant elasticities of 0.312, 0.274 and 0.415 respectively compatible with the labor productivity impact of road transportation as a whole (rows 13-15). The gas price (GPRC) as expected has a negative sign but it is statistically insignificant, like previous estimations under the within estimator.

Of the remaining transportation measures, air passenger traffic (APASS) and port cargo handled (CARGO) report statistically significant and positive elasticities of 0.274 and 0.362 (rows 18-19).

The fixed (FTEL) and total telephone (TTEL) lines, which include mobile as well as fixed lines, return positive and significant elasticities. The elasticity of total lines is 0.312 (row 20).

For electricity production (rows 22-25), unlike under within estimation, state (ESTATE) electricity production has a negative but statistically insignificant elasticity with respect to labor productivity. Other electricity production measures, on the other hand, have positive and statistically significant elasticities. Total electricity (ETOTAL) generation has an elasticity of 0.299, while production company production (EPRO) has an elasticity of 0.055. The improvements in the total network loss (NLOSS) are very strong as under within estimations (row 26). Finally, natural gas consumption (NGCONS) reports a positive and significant elasticity of 0.274.

Out of the railway measures (row 2-9), only railway lines (RAIL) and freight (FRGHT) (row 2 and 4) return with positive and statistically significant elasticities. The elasticity of railway lines is 0.007. Since the annual rate of railway line increase during the sample period is only 0.15%, the inference is that even small developments in the railway infrastructure return significant improvements in the labor productivity. The elasticity of labor productivity with respect to freight is as high as 0.41. Other railway measures consistently report statistically insignificant or significant but negative signs with respect to labor productivity.

Conclusions and Evaluation

This paper explores the impact of some key infrastructure measures in transportation, telecommunication and electricity production sectors on labor productivity, using data on two-digit sectors for the Turkish economy for the years 1987 to 2006. We control for the potential impact of endogeneity of infrastructure investment to productivity growth, as well as heterogeneity across sectors in terms of the impact of infrastructure on productivity growth.

INSERT FIGURE 5 ABOUT HERE.

We summarize the findings of the paper in Figure 5, which reports the magnitude of the estimated elasticity impact of the alternative infrastructure measures on labor productivity, under the alternative estimators we employ.

Transport infrastructure is clearly important for Turkish productivity growth. Road, port and air traffic infrastructure are all positively and significantly associated with productivity growth. The road infrastructure measures carry the strongest elasticity impacts on productivity growth, with elasticity values ranging from 0.3 through 1.227, but with consistent elasticities around 0.5. In the case of port and air transport, the elasticity with respect to productivity growth ranges from 0.3 to 0.5. The one exception are the rail infrastructure measures. In this instance we report both (strong) negative and positive elasticities - and unlike for the case of the other transport measures, the rail infrastructure measures are not stable across estimation methodologies. It is perhaps noteworthy that the railways sector is the one area of public capital goods provision that has seen very little liberalization and involvement by the private sector.

Energy provision is also positively associated with productivity growth in Turkey. Elasticity measures for total energy output range from 0.3 through 0.55. What is more, it is not only energy output, but crucially also efficiency of energy provision that is important for productivity growth. Reductions in inefficiency return a particularly growth impact, with a 2.06% increase in productivity growth for each percent of efficiency improvement.

Finally, telecommunications also carry positive productivity growth impacts. our estimates for both total and fixed line telecommunications capacity are consistently positive and significant, and range from an elasticity with respect to productivity growth from 0.2 through 0.56.

For policy purposes, the greatest returns emerge for the road transportation, telecommunications, and the *efficiency* of electricity transmission rather than the absolute magnitude of electricity production measures.

Our findings thus suggest both statistical and economic significance of infrastructure on productivity growth, for road, port and air transport, telecommunications and electricity production. The only exception is provided by the railway sector, in which only measures of actual freight carried are consistently statistically significantly associated with productivity growth. Given that the railway transport sector is the only infrastructure sector that remains closed to competition and private participation, this raises the issue of the significance of private sector involvement in infrastructure provision as an important future area of research.

Appendix 1: The Pooled Mean Group Estimator

To test for the potential impact of sectoral heterogeneity in the impact of infrastructure on labor productivity, we employ the Pooled Mean Group (PMG) estimator of Pesaran, Shin and Smith (1999).

Consider the unrestricted error correction ARDL(p, q) representation:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \boldsymbol{\beta}_i' \mathbf{x}_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \boldsymbol{\delta}_{ij}' \Delta \mathbf{x}_{i,t-j} + \mu_i + \varepsilon_{it}, \tag{4}$$

where $i = 1, 2, ..., N$, $t = 1, 2, ..., T$, denote the cross section units and time periods respectively. Here y_{it} is a scalar dependent variable, $\mathbf{x}_{it}$ $(k \times 1)$ a vector of (weakly exogenous) regressors for group i, and μ_i represents fixed effects. Allow the disturbances ε_{it}'s to be independently distributed across i and t, with zero means and variances $\sigma_i^2 > 0$, and assume that $\phi_i < 0$ for all i. Then there exists a long-run relationship between y_{it} and $\mathbf{x}_{it}$:

$$y_{it} = \boldsymbol{\theta}_i' \mathbf{x}_{it} + \eta_{it}, \; i = 1, 2, ..., N, \; t = 1, 2, ..., T, \tag{5}$$

where $\boldsymbol{\theta}_i = -\boldsymbol{\beta}_i'/\phi_i$ is the $k \times 1$ vector of the long-run coefficients, and η_{it}'s are stationary with possibly non-zero means (including fixed effects). This allows (4) to be written as:

$$\Delta y_{it} = \phi_i \eta_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \boldsymbol{\delta}_{ij}' \Delta \mathbf{x}_{i,t-j} + \mu_i + \varepsilon_{it}, \tag{6}$$

where $\eta_{i,t-1}$ is the error correction term given by (5), and thus ϕ_i is the error correction coefficient measuring the speed of adjustment towards the long-run equilibrium.

This general framework allows the formulation of the PMG estimator, which allows the intercepts, short-run coefficients and error variances to differ freely across groups, but the long-run coefficients to be homogenous; i.e. $\boldsymbol{\theta}_i = \boldsymbol{\theta} \; \forall \; i$. Group-specific short-run coefficients and the common long-run coefficients are computed by the pooled maximum likelihood estimation. Denoting these estimators by $\tilde{\phi}_i$, $\tilde{\boldsymbol{\beta}}_i$, $\tilde{\lambda}_{ij}$, $\tilde{\boldsymbol{\delta}}_{ij}$ and $\tilde{\boldsymbol{\theta}}$, we obtain the PMG estimators by $\hat{\phi}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\phi}_i}{N}$, $\hat{\boldsymbol{\beta}}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\boldsymbol{\beta}}_i}{N}$, $\hat{\lambda}_{jPMG} = \frac{\sum_{i=1}^{N} \tilde{\lambda}_{ij}}{N}$, $j = 1, ..., p-1$, and $\hat{\boldsymbol{\delta}}_{jPMG} = \frac{\sum_{i=1}^{N} \tilde{\boldsymbol{\delta}}_{ij}}{N}$, $j = 0, ..., q-1$, $\hat{\boldsymbol{\theta}}_{PMG} = \tilde{\boldsymbol{\theta}}$.

PMG estimation provides an intermediate case between the dynamic fixed effects (DFE) estimator which imposes the homogeneity assumption for all parameters except for the fixed effects, and the mean group (MG) estimator proposed by Pesaran and Smith (1995), which allows for heterogeneity of all parameters. It exploits the statistical power offered by the panel through long-run homogeneity, while still admitting short-run heterogeneity. As long as sector-homogeneity is assured, the PMG estimator offers efficiency gains over the MG estimator, while granting the possibility of dynamic heterogeneity across sectors unlike the DFE estimator. In the presence of long-run homogeneity, therefore, our preference is for the use of the PMG estimator.

The crucial question is whether the assumption of long-run homogeneity is justified, given the threat of inefficiency and inconsistency noted by Pesaran and Smith (1995). We employ a Hausman (1978) test (hereafter h test) on the difference between MG and PMG estimates of long-run coefficients to test for long-run heterogeneity. Note that as long as the homogeneity Hausman test is passed in our estimations, we report only PMG estimation results.

It is worth pointing out that a crucial advantage of the estimation approach of the present paper, is that the dynamics generally argued to be inherent in growth processes are explicitly modelled, while recognizing the presence of a long-run equilibrium relationship underlying the dynamics. This is particularly important given the recurrent debate in the context of growth studies concerning the appropriate length of the time window used in averaging data for cross country studies. Justification for averaging rests on the need to remove short-run fluctuations in growth studies. The choice of any window is in the final instance arbitrary. Indeed, some panel studies do not average at all. Unfortunately the estimators used in turn are generally not dynamic, so that the results obtained may also be driven by short-term fluctuations. Thus the justification for the use of the PMG estimator is that it is consistent both with the underlying theory of an homogenous long-run relationship, while allowing for the explicit modelling of short-run dynamics around the long-run relationship, and the possibly heterogeneous dynamic time series nature of the data in the dynamics of adjustment.

References

[1] Aghion, P., Fedderke, J.W., Howitt, P., and Viegi, N., (2011). Testing Creative Destruction in an Opening Economy: the Case of the South African Manufacturing Industries, ERSA Working Paper No. 93.

[2] Agis, O., (2011). The Development of Cogeneration Systems in Turkey and Its Future Trend, 4th SE European Code Workshop, Thessaloniki, Greece, 10 – 11th of March 2011.

[3] Altug, S. and Filiztekin, A., (2006). Productivity and growth, 1923–2003. In S. Altug and A. Filiztekin (eds.), The Turkish Economy: The Real Economy, Corporate Governance, and Reform. London: *Routledge Studies in Middle Eastern Economics*, pp. 15-62.

[4] Altug, S., Filiztekin A. and Pamuk S., (2008). Sources of Long Term economic growth for Turkey, 1880-2005. *Eurpean Review of Economic History*, 12, pp. 393-430.

[5] Aschauer, D.A., (1989a). Is public expenditure productive? *Journal of Monetary Economics*, 23(2), 177–200.

[6] Aschauer, D.A., (1989b). Does Public capital Crowd Out Private Capital? *Journal of Monetary Economics*, 24(2): 171–88.

[7] Aschauer, D.A., (1998). The Role of Public Infrastructure Capital in Mexican Economic Growth, *Economia Mexicana Nueva Epoca*, 7(1), 47-78.

[8] Baltagi, H., and Pinnoi, N., (1995). Public Capital Stock and State Productivity Growth: Further Evidence from an Error Correction Model, *Empirical Economics*, 20, 351-59.

[9] Barro, R.J., (1990). Government Spending in a Simple Model of Endogenous Growth, *Journal of Political Economy*, 98(5), S103-S125.

[10] Calderón, C., and Servén, L., (2003). The Output Cost of Latin America's Infrastructure Gap, in W.Easterly and L.Servén, (eds.) *The Limits of Stabilization: Infrastructure, Public Deficits, and Growth in Latin America*, Stanford University Press and the World Bank, 119-38.

[11] Canning, D., (1999). The Contribution of Infrastructure to Aggregate Output, *World Bank Policy Research Working Paper No. 2246.*

[12] Canning, D., and Pedroni, (2004). The Effect of Infrastructure on Long Run Economic Growth, mimeo: Harvard University, November 2004.

[13] Everaert, G., and Heylen F., (2001). Public Capital and Productivity Growth: Evidence for Belgium, 1953-1996, *Economic Modelling*, 18(1), 97-116.

[14] Esfahani, H. S., and Ramirez, M. T. (2003). Institutions, infrastructure and economic growth. *Journal of Development Economics*, 70, pp. 443–477.

[15] Estache, A. Foster, V., and Wodon, Q., (2002). Accounting for Poverty in Infrastructure Reform: Learning from Latin America's Experience, WBI Development Studies, Washington DC: The World Bank.

[16] Fedderke, J.W., and Bogetić, Ž., (2009), Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures, *World Development*, 37(9), 1522-39.

[17] Fedderke, J.W., Perkins. P., and Luiz, J.M., 2006, Infrastructural Investment in Long-run Economic Growth: South Africa 1875-2001, *World Development*, 34(6), 1037-59.

[18] Fernald, J.G., (1999). Roads to Prosperity? Assessing the Link between Public Capital and Productivity, *American Economic Review*, 89(3), 619-38.

[19] Fernandez, M., and Montuenga-Gomez, V.M., (2003). The Effects of Public Capital on the Growth of Spanish Productivity, *Contemporary Economic Policy*, 21(3), 383-93.

[20] Filiztekin, A. (2000). Openness and productivity growth in Turkish manufacturing. Sabanci University Discussion Paper Series no. 0104.

[21] Hausman, J.A., (1978), Specification tests in economics, *Econometrica*, 46, 1251-70.

[22] Holtz-Eakin, D. (1994). Public sector capital and the productivity puzzle. *Review of Economics and Statistics*, 76, pp. 12–21.

[23] Ismihan, M. and Metin-Ozcan, K. (2006). The growth performance of the Turkish economy, 1960-2004. Paper presented at the ICE-TEA International Economics Conference, September 10–13, 2006, Ankara.

[24] Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica*, 59(6), pp. 1551–1580.

[25] Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration –With applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52(2), pp. 169–210.

[26] Kemmerling, A., and Stephan, A., (2002). The Contribution of Local Public Infrastructure to Private Productivity and its Political Economy: Evidence from a Panel of Large German Cities, *Public Choice*, 113(3-4), 403-24.

[27] Krueger, A.O. (1995) Partial Adjustment and Growth in the 1980s in Turkey. In Reform, recovery and Growth: Latin Ameriaca and the Middle East , National Bureau of Economics Research Project Report Series, Chicago, IL and London: University of Chicago Press, pp. 343-367.

[28] Lachler, U., and Aschauer, D.A., (1998). Public Investment and Economic Growth in Mexico, *World Bank Policy Research Working Paper Series No. 1964*.

[29] Munnell, AH., (1990). How does public infrastructure affect regional economic performance? *New England Economic Review*, September/October 1990: 11–32.

[30] OECD (2004), Economic Surveys: Turkey. October, Paris.

[31] Okten, C. (2006). Privatization in Turkey: What has been achieved? In S. Altug and A. Filiztekin (eds.), *The Turkish Economy: The Real Economy, Corporate Governance, and Reform*. London: Routledge Studies in Middle Eastern Economics, pp. 227-251.

[32] Onaran, O. (2002). Measuring Wage Flexibility? The Case of Turkey Before and After Structural Adjustment. *Applied Economics* 34, pp.767-781.

[33] Paul, S., Sahni, B.S., and Biswal, B.P., (2004). Public Infrastructure and the Productive Performance of Canadian Manufacturing Industries, *Southern Economic Journal*, 70(4), 998-1011.

[34] Pesaran, M. H., Shin, Y., and Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogenous panels. *Journal of the American Statistical Association*, 94, pp. 621–634.

[35] Pesaran, M.H., and Smith, R.P., (1995), Estimating Long-Run Relationships from Dynamic Heterogeneous Panels, *Journal of Econometrics*, 68,79-113.

[36] Ramirez, M.D., (2002). Public Capital Formation and Labor Productivity Growth in Mexico, *Atlantic Economic Journal*, 30(4), 366-79.

[37] Reinikka, R., and Svensson, J., (2002). Coping with poor public capital, *Journal of Development Economics*, 69(1), 51-69.

[38] Röller, L-H., and Waverman, L., (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach, *American Economic Review*, 91(4), 909-23.

[39] Sachs, J.D., and Warner, A., (1995). Economic Reform and the Process of Global Integration, *Brookings Papers on Economic Activity*, The Brookings Institution.

[40] Saygili, S., Cihan, C., and Yurtoglu, H. (2001), Productivity and growth in OECD countries: an assessment of the determinants of productivity. *Yapi Kredi Economic Review* 12, pp. 49–64.

[41] Saygili, S., Cihan, C., and Yurtoglu, H. (2005). Turkiye Ekonomisinde Sermaye Birikimi, Buyume ve Verimlilik, 1972–2003. State Planning Organization Publication Number 2686, Ankara.

[42] Shioji, E., (2001). Public Capital and Economic Growth: A Convergence Approach, *Journal of Economic Growth*, 6(3), 205-27.

[43] Tektas, M. (2011). Development of Infrastructure in Turkey: 1983-2009. Unpublished Master's Paper in International Affairs, The Pennsylvania State University, School of International Affairs.

[44] Vovyada, E. and Yeldan I. (2001). Patterns of Productivity Growth and Wage Cycle in Turkish Manufacturing. *International Review of Applied Economics* 15, pp. 375-396.

[45] Yakita, A., (2004). Elasticity of Substitution in Public Capital Formation and Economic Growth, *Journal of Macroeconomics*, 26(3), 391-408.

Tables and Figures

Table 1 Selected Economic Indicators for Turkey

	1980-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010
Growth (%)	3.65	5.63	3.34	4.21	4.7	3.28
Population (000)	47,290	53,286	57,909	62,466	66,866	71,070
GDP per capita ($, PPPs)	3,565	5,121	6,630	8,380	9,525	14,384
Foreign Trade Volume (%GDP)	18.67	19.55	20.53	30.27	40.04	43.02
Current Account Balance (%GDP)	-1.78	-1.31	-0.44	-1.08	-1.81	-5.17
Labor Force Participation rate (%)	58.1	55.42	52.68	50.34	46.94	47.22
Unemployment (%)	7.95	8.66	8.86	7.4	10.41	11.48
Consolidated Budget Balance (%GDP)	-1.89	-2.34	-3.63	-6.93	-7.97	-2.65

Source: OECD and Ministry of Development (term averages)

Table 2 Decomposition of Growth into the Contribution of Factors of Production and Total Factor Productivity (%)

Agriculture	% Y	of K	of L	of TFP	Transportation, Communication and Storage	% Y	of K	of L	of TFP
1987-1991	1.33	1.46	0.22	-0.35	1987-1991	5.24	3.98	0.37	0.89
1992-1996	1.73	1.63	-0.07	0.17	1992-1996	6.03	4.58	0.64	0.81
1997-2001	-0.09	2.35	-0.25	-2.19	1997-2001	4.73	5.17	1.37	-1.82
2002-2006	3.63	0.80	-0.95	3.77	2002-2006	10.04	2.24	1.33	6.47
1987-2006	1.65	1.56	-0.26	0.35	1987-2006	6.51	3.99	0.93	1.59
Mining	**% Y**	**of K**	**of L**	**of TFP**	**Construction**	**% Y**	**of K**	**of L**	**of TFP**
1987-1991	2.57	-0.23	-1.03	3.84	1987-1991	3.13	5.77	-0.35	-2.30
1992-1996	-0.53	-1.09	-1.97	2.53	1992-1996	2.65	5.92	1.85	-5.11
1997-2001	0.00	-0.01	-0.03	0.04	1997-2001	-1.99	3.23	-0.23	-4.98
2002-2006	2.60	0.80	1.64	0.17	2002-2006	12.73	0.74	0.38	11.61
1987-2006	1.16	-0.50	-1.06	2.72	1987-2006	4.13	3.91	0.41	-0.19
Manufacturing	**% Y**	**of K**	**of L**	**of TFP**	**Other**	**% Y**	**of K**	**of L**	**of TFP**
1987-1991	5.34	0.00	0.65	4.70	1987-1991	5.21	4.82	1.32	-0.92
1992-1996	5.69	2.05	0.81	2.83	1992-1996	5.31	3.44	1.46	0.41
1997-2001	1.36	1.65	0.53	-0.83	1997-2001	2.82	4.18	2.45	-3.81
2002-2006	7.96	5.55	0.60	1.81	2002-2006	5.87	4.50	2.24	-0.87
1987-2006	5.09	2.31	0.65	2.13	1987-2006	4.80	4.24	1.87	-1.30
Electricity	**% Y**	**of K**	**of L**	**of TFP**					
1987-1991	8.63	3.91	0.15	4.57					
1992-1996	8.67	0.22	9.77	-1.31					
1997-2001	2.28	4.58	0.29	-2.59					
2002-2006	7.61	1.66	-0.21	6.17					
1987-2006	6.80	2.59	2.50	1.71					

Source: Own calculations

Table 3 Sectors of Turkey included in the panel

Agriculture
Mining & Quarrying
Manufacturing
Electricity, Gas and Water Supply
Transportation and Communication
Construction
Other

Table 4 Measures of Infrastructure Capital Stock and Denotations

Railways	**Denotation**	**Ports**	**Denotation**
Line (km)	RAIL	Cargo Handled (tons)	CARGO
Passenger (thousand)	RPASS	**Airways**	
Freight (thousand tons)	FRGHT	Passenger	APASS
Locomotives	LOCO	**Telecommunication**	
Coaches	COACH	Fixed	FTEL
Coach Capacity	CCAP	Total (Fixed+Mobile)	TTEL
Goods Stock	GOODS	**Electricity Production by Producer (GWh)**	
Goods Capacity	GCAP	State Electricity Production Co. (EUAS)	ESTATE
Roads		Production Companies	EPRO
Total (km)	TRDS	Auto producers	EAUTO
Paved (km)	PRDS	Total	ETOTAL
Highway (km)	HRDS	Total Network Loss	ELOSS
Motor Vehicles		Natural Gas Consumption	NGCONS
Total	TCARS	**Control Variables**	
Passenger	PCARS	Openness ((I+M)/Y)	OPEN
Commercial	CCARS	Political Rights and Civil Liberties rating	RIGHTS
Gas Price	GPRC	Average Schooling Years	EDU
		Total R&D expenditure as a share of GDP	R&D

Table 5a Estimation of labor productivity effect of infrastructure

Dependent Variable		ln(Y/L)	1	2	3	4	5	6	7	8	9	10	11	12	13
	1	ln(K/L)	0.617*** (0.062)	0.616*** (0.061)	0.622*** (0.058)	0.618*** (0.063)	0.618*** (0.062)	0.622*** (0.062)	0.616*** (0.061)	0.615*** (0.061)	0.617*** (0.063)	0.619*** (0.061)	0.617*** (0.062)	0.622*** (0.060)	0.620*** (0.061)
Control Variables	2	OPEN	0.142*** (0.042)	0.153*** (0.041)	0.146*** (0.041)	0.146*** (0.040)	0.143*** (0.041)	0.143*** (0.042)	0.141*** (0.041)	0.146*** (0.040)	0.154*** (0.041)	0.142*** (0.040)	0.151*** (0.040)	0.155*** (0.041)	0.155*** (0.041)
	3	RIGHTS	-0.023 (0.02)	-0.023 (0.015)	-0.023 (0.015)	-0.026* (0.014)	-0.033*** (0.011)	-0.024 (0.015)	-0.023 (0.013)	-0.025 (0.014)	-0.040*** (0.012)	-0.017 (0.012)	-0.049*** (0.011)	-0.047*** (0.013)	-0.054*** (0.011)
	4	EDU	0.125* (0.11)	0.212*** (0.051)	-0.015 (0.061)	0.002 (0.068)	0.102** (0.051)	0.072 (0.056)	0.130 (0.082)	0.139** (0.065)	0.098* (0.054)	0.253** (0.117)	0.030 (0.077)	-0.320*** (0.111)	-0.258 (0.118)
	5	R&D	-6.621 (15.27)	-9.214 (14.70)	-11.482 (14.63)	-11.921 (13.87)	-11.406 (12.37)	-3.236 (15.73)	-7.955 (15.42)	-17.852 (14.89)	-16.879 (12.13)	-2.079 (13.97)	-14.495 (13.10)	-17.234 (13.37)	-17.763 (12.79)
Infrastructure Measures	6	ln(RAIL)	-2.884** (1.158)												
	7	ln(RPASS)		0.364*** (0.099)											
	8	ln(FRGHT)			0.399*** (0.40)										
	9	ln(LOCO)				-0.493*** (0.135)									
	10	ln(COACH)					-0.285 (0.205)								
	11	ln(CCAP)						-0.211*** (0.081)							
	12	ln(GOODS)							0.413* (0.227)						
	13	ln(GCAP)								0.872*** (0.20)					
	14	ln(TRDS)									0.680*** (0.237)				
	15	ln(PRDS)										-0.376*** (0.148)			
	16	ln(HRDS)											0.085*** (0.024)		
	17	ln(TCARS)												0.577*** 0.101	
	18	ln(PCARS)													0.427*** (0.09)
	i	R^2	0.781	0.792	0.794	0.785	0.780	0.780	0.779	0.787	0.791	0.783	0.791	0.801	0.798
	ii	N	140	140	140	140	140	140	140	140	140	140	140	140	140
	iii	Within	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Coefficients and standard errors respectively. *, ** ,*** denotes significance at the 10%, 5% and 1% probability levels respectively.*

Table 5b Estimation of labor productivity effect of infrastructure (continued)

Dependent Variable		ln(Y/L)	14	15	16	17	18	19	20	21	22	23	24	25
	19	ln(K/L)	0.624*** (0.060)	0.619*** (0.061)	0.623*** (0.060)	0.623*** (0.059)	0.614*** (0.061)	0.616*** (0.062)	0.619*** (0.061)	0.618*** (0.063)	0.623*** (0.061)	0.622*** (0.061)	0.618*** (0.061)	0.616*** (0.061)
Control Variables	20	OPEN	0.152*** (0.041)	0.138*** (0.041)	0.150*** (0.041)	0.143*** (0.041)	0.148*** (0.040)	0.150*** (0.041)	0.155*** (0.041)	0.144*** (0.040)	0.149*** (0.040)	0.153*** (0.041)	0.141*** (0.042)	0.147*** (0.040)
	21	RIGHTS	-0.032** (0.014)	-0.022** (0.008)	-0.006 (0.015)	-0.028* (0.015)	-0.034** (0.014)	-0.047*** (0.010)	-0.054*** (0.012)	-0.039*** (0.013)	-0.023 (0.014)	-0.043*** (0.012)	-0.006 (0.007)	-0.032** (0.013)
	22	EDU	-0.304** (0.085)	0.130 (0.180)	-0.159** (0.071)	-0.118* (0.061)	-0.511*** (0.196)	-0.367 (0.097)	0.074 (0.058)	0.241*** (0.069)	0.286*** (0.075)	-0.357** (0.156)	0.074 (0.061)	-0.036 (0.091)
	23	R&D	-14.677 (14.27)	-3.220 (11.39)	-5.245 (16.00)	-4.543 (15.49)	-26.20** (10.99)	-18.545* (10.24)	-28.34** (10.93)	-12.032 (13.19)	-9.498 (15.04)	-7.487 (14.77)	1.755 (13.57)	-14.984 (11.81)
Infrastructure Measures	24	ln(CCARS)	0.633*** (0.073)											
	24	ln(GPRC)		0.014 (0.031)										
	26	ln(CARGO)			0.360*** (0.038)									
	27	ln(APASS)				0.157*** (0.021)								
	28	ln(TTEL)					0.413*** (0.120)							
	29	ln(FTEL)						0.174* (0.089)						
	30	ln(ESTATE)							0.328*** (0.073)					
	31	ln(EPRO)								-0.067** (0.026)				
	32	ln(EAUTO)									-0.160*** (0.023)			
	33	ln(ETOTAL)										0.601*** (0.163)		
	34	ELOSS											-1.697** (0.757)	
	35	ln(NGCONS)												0.075** (0.035)
	i	R^2	0.800	0.778	0.799	0.793	0.787	0.786	0.799	0.782	0.795	0.797	0.783	0.785
	ii	N	140	140	140	140	140	140	140	140	140	140	140	140
	iii	Within	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

*Coefficients and standard errors respectively. *, ** ,*** denotes significance at the 10%, 5% and 1% probability levels respectively.*

Table 6a Estimation of labor productivity effect of infrastructure (Instrumented infrastructure variables)

Dependent Variable		**ln(Y/L)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	1	**ln(K/L)**	0.673*** (0.051)	0.697*** (0.049)	0.699*** (0.047)	0.701*** (0.049)	0.697*** (0.051)	0.701*** (0.048)	0.696*** (0.051)	0.695*** (0.047)	0.705*** (0.048)	0.699*** (0.048)	0.701*** (0.048)	0.708*** (0.048)	0.708*** (0.049)
Control Variables	**2**	**OPEN**	0.118*** (0.038)	0.109*** (0.038)	0.111*** (0.038)	0.107*** (0.038)	0.108*** (0.038)	0.115*** (0.038)	0.107*** (0.038)	0.109*** (0.037)	0.120*** (0.039)	0.108*** (0.037)	0.115*** (0.038)	0.114*** (0.038)	0.114*** (0.039)
	3	**RIGHTS**	-0.027** (0.012)	-0.029*** (0.013)	-0.037*** (0.012)	-0.026** (0.011)	-0.031*** (0.009)	-0.025* (0.013)	-0.028*** (0.009)	-0.025** (0.011)	-0.041*** (0.011)	-0.021*** (0.008)	-0.053*** (0.011)	-0.049*** (0.013)	-0.047*** (0.012)
	4	**EDU**	0.076 (0.084)	0.147* (0.082)	0.046 (0.058)	-0.014 (0.055)	0.069 (0.052)	0.097* (0.056)	0.086 (0.108)	0.122 (0.076)	0.130** (0.054)	0.225 (0.141)	-0.072 (0.072)	-0. 299*** (0.077)	-0.34*** (0.098)
	5	**R&D**	-12.730 (10.82)	-20.049 (12.22)	-28.24*** (9.693)	-15.91 (11.06)	-16.238 (13.19)	-21.558** (10.57)	-16.39 (10.21)	-19.645 (12.23)	-22.30** (10.34)	-6.511 (7.854)	-13.322 (11.93)	-20.366* (10.86)	-15.33 (11.41)
Infrastructure Measures	**6**	**ln(RAIL)**	-0.646 (1.675)												
	7	**ln(RPASS)**		0.160** (0.078)											
	8	**ln(FRGHT)**			0.421*** (0.076)										
	9	**ln(LOCO)**				-0.646** (0.325)									
	10	**ln(COACH)**					0.076 (0.239)								
	11	**ln(CCAP)**						-0.507*** (0.090)							
	12	**ln(GOODS)**							0.160 (0.426)						
	13	**ln(GCAP)**								0.766** (0.351)					
	14	**ln(TRDS)**									1.227*** (0.226)				
	15	**ln(PRDS)**										-0.322 (0.206)			
	16	**ln(HRDS)**											0.111*** (0.020)		
	17	**ln(TCARS)**												0.556*** (0.074)	
	18	**ln(PCARS)**													0.539*** (0.087)
	i	**R^2**	0.811	0.820	0.825	0.821	0.818	0.830	0.818	0.824	0.834	0.822	0.828	0.834	0.832
	ii	**N**	126	119	119	119	119	119	119	119	119	119	119	119	119
	iii	**Within**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

*Coefficients and standard errors respectively. *, ** ,*** denotes significance at the 10%, 5% and 1% probability levels respectively.*

Table 6b Estimation of labor productivity effect of infrastructure (Instrumented infrastructure variables; continued)

Dependent Variable		ln(Y/L)	14	15	16	17	18	19	20	21	22	23	24	25
	19	ln(K/L)	0.708*** (0.048)	0.697*** (0.050)	0.706*** (0.047)	0.708*** (0.049)	0.708*** (0.048)	0.699*** (0.051)	0.706*** (0.049)	0.719*** (0.051)	0.707*** (0.048)	0.705*** (0.048)	0.699*** (0.048)	0.699*** (0.050)
Control Variables	20	OPEN	0.114*** (0.038)	0.107*** (0.038)	0.113*** (0.038)	0.114*** (0.038)	0.114*** (0.038)	0.112*** (0.039)	0.114*** (0.0380	0.092** (0.037)	0.111*** (0.038)	0.115*** (0.039)	0.107*** (0.037)	0.110*** (0.038)
	21	RIGHTS	-0.037*** (0.013)	-0.030** (0.013)	-0.017 (0.011)	-0.057*** (0.012)	-0.049*** (0.013)	-0.049*** (0.007)	-0.057*** (0.013)	-0.032*** (0.010)	-0.027** (0.012)	-0.041*** (0.011)	0.014*** (0.004)	-0.035*** (0.011)
	22	EDU	-0.234*** (0.064)	0.065 (0.059)	-0.088 (0.054)	-0.343*** (0.098)	-0.29*** (0.077)	-0.062 (0.128)	0.097* (0.057)	-0.043 (0.054)	0.206*** (0.077)	-0.314*** (0.118)	0.081 (0.066)	0.191 (0.141)
	23	R&D	-21.565* (11.05)	-15.904 (12.05)	-13.549 (11.21)	-15.333 (11.41)	-20.366* (10.86)	-21.703** (8.62)	-39.90*** (8.906)	-24.75** (11.42)	-20.40* (11.59)	-13.304 (11.91)	-12.759 (9.460)	-40.08*** (7.303)
Infrastructure Measures	24	ln(CCARS)	0.514*** (0.072)											
	24	ln(GPRC)		-0.0021 (0.0037)										
	26	ln(CARGO)			0.273*** (0.043)									
	27	ln(APASS)				0.539*** (0.087)								
	28	ln(TTEL)					0.556*** (0.074)							
	29	ln(FTEL)						0.214*** (0.155)						
	30	ln(ESTATE)							0.328*** (0.049)					
	31	ln(EPRO)								0.013 (0.021)				
	32	ln(EAUTO)									-0.093*** (0.020)			
	33	ln(ETOTAL)										0.546*** (0.113)		
	34	ELOSS											-1.296 (0.928)	
	35	ln(NGCONS)												0.234*** (0.089)
	i	R^2	0.833	0.818	0.834	0.832	0.834	0.821	0.831	0.821	0.827	0.843	0.822	0.822
	ii	N	126	119	119	119	119	119	119	105	119	119	119	119
	iii	Within	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Coefficients and standard errors respectively. *, ** ,*** denotes significance at the 10%, 5% and 1% probability levels respectively.*

Table 7a Estimation of labor productivity effect of infrastructure (PMG estimator for instrumented infrastructure variables)

Dependent Variable		ARDL ln(Y/L)	1 1,0,0	2 2,1,0	3 1,0,0	4 2,0,0	5 1,0,0	6 1,0,0	7 1,0,0	8 1,1,0	9 2,1,0	10 1,0,0	11 1,0,0	12 1,0,0	13 1,0,0
	1	ln(K/L)	0.920* (0.036)	1.121* (0.196)	0.959* (0.050)	0.893* (0.040)	0.847* (0.041)	1.015* (0.047)	0.955* (0.039)	0.969* (0.142)	1.292* (0.245)	0.897* (0.040)	0.977* (0.046)	0.919* (0.032)	0.931* (0.033)
Infrastructure Measures	2	ln(RAIL)	0.007* (0.001)												
	3	ln(RPASS)		0.000 (0.000)											
	4	ln(FRGHT)			0.410* (0.159)										
	5	ln(LOCO)				-1.240* (0.170)									
	6	ln(COACH)					-0.898* (0.144)								
	7	ln(CCAP)						-0.177 (0.153)							
	8	ln(GOODS)							-1.120* (0.112)						
	9	ln(GCAP)								-0.810* (0.271)					
	10	ln(TRDS)									0.332 (0.584)				
	11	ln(PRDS)										0.336* (0.032)			
	12	ln(HRDS)											0.100* (0.017)		
	13	ln(TCARS)												0.312* (0.026)	
	14	ln(PCARS)													0.274* (0.024)
	i	ECM	-0.544* (0.151)	-0.257* (0.055)	-0.675* (0.154)	-0.634* (0.137)	-0.653* (0.131)	-0.633* (0.132)	-0.584* (0.147)	-0.281* (0.105)	-0.224* (0.055)	-0.571* (0.147)	-0.669* (0.159)	-0.597* (0.153)	-0.596* (0.152)
	ii	h-test	4.55 (0.10)	0.38 (0.83)	2.75 (0.25)	2.37 (0.31)	4.90 (0.09)	2.79 (0.25)	5.09 (0.08)	0.07 (0.97)	5.54 (0.06)	3.35 (0.19)	1.76 (0.41)	1.60 (0.45)	1.88 (0.39)
	iii	RLL	143.07	151.64	124.64	132.53	131.23	123.97	137.01	159.71	151.83	136.15	132.26	140.03	138.91
	iv	ULL	167.92	168.67	143.63	148.55	145.82	135.54	159.18	171.55	159.97	161.09	150.90	160.01	159.08

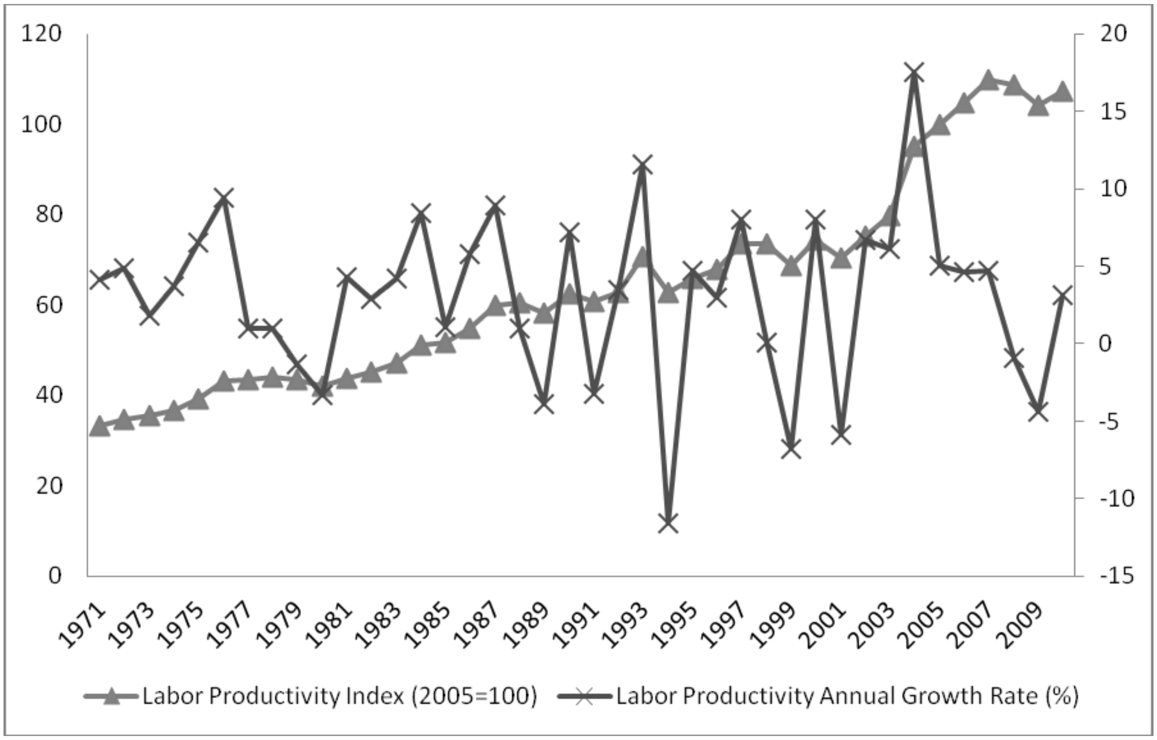
*Figures denote coefficients and standard errors respectively. * denotes significance at the 5% level.*

Table 7b Estimation of labor productivity effect of infrastructure (PMG estimator for instrumented infrastructure variables; continued)

Dependent Variable		ARDL ln(Y/L)	14 1,3,0	15 2,1,0	16 1,2,0	17 1,0,0	18 1,0,0	19 1,0.0	20 2,0,0	21 1,0,0	22 1,0,0	23 1,0,0	24 1,2,0	25 1,0,0
	15	ln(K/L)	0.829* (0.098)	1.465* (0.332)	0.903* (0.068)	0.931* (0.033)	0.919* (0.032)	0.975* (0.041)	1.064* (0.067)	0.893* (0.047)	0.920* (0.048)	0.910* (0.033)	0.936* (0.024)	0.883* (0.038)
Infrastructure Measures	16	ln(CCARS)	0.415* (0.061)											
	17	ln(GPRC)		-0.023 (0.016)										
	18	ln(CARGO)			0.362* (0.058)									
	19	ln(APASS)				0.274* (0.024)								
	20	ln(TTEL)					0.312* (0.026)							
	21	ln(FTEL)						0.268* (0.033)						
	22	ln(ESTATE)							-0.120 (0.087)					
	23	ln(EPRO)								0.055* (0.011)				
	24	ln(EAUTO)									0.092* (0.014)			
	25	ln(ETOTAL)										0.299* (0.027)		
	26	ELOSS											-2.063* (0.205)	
	27	ln(NGCONS)												0.151* (0.015)
	i	ECM	-0.343* (0.111)	-0.187* (0.050)	-0.325* (0.061)	-0.596* (0.152)	-0.597* (0.153)	-0.609* (0.153)	-0.611* (0.122)	-0.683* (0.128)	-0.602* (0.139)	-0.604* (0.146)	-0.424* (0.196)	-0.602* (0.144)
	ii	h-test	2.69 (0.26)	3.01 (0.22)	4.93 (0.09)	1.88 (0.39)	1.60 (0.45)	2.94 (0.23)	1.89 (0.39)	1.32 (0.52)	4.13 (0.13)	0.53 (0.77)	2.48 (0.29)	1.93 (0.38)
	iii	RLL	147.83	153.11	158.95	138.91	140.032	134.28	122.12	114.98	131.24	141.00	163.63	137.78
	iv	ULL	162.08	160.43	164.86	159.08	160.01	158.13	137.80	127.92	152.21	162.43	189.90	161.22

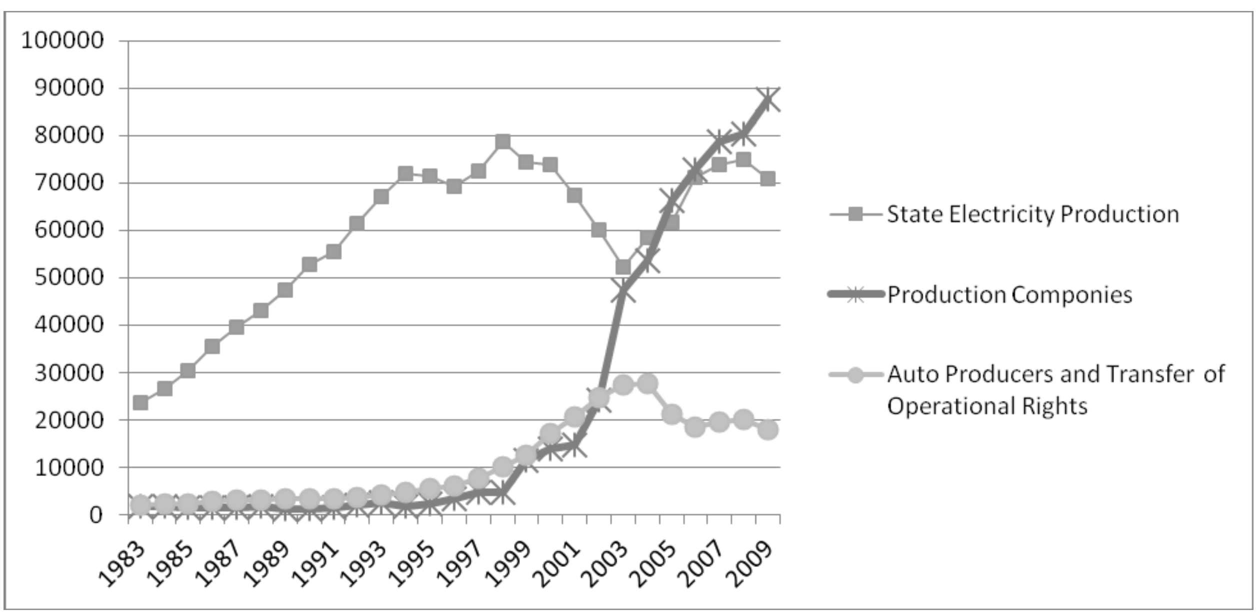
*Figures denote coefficients and standard errors respectively. * denotes significance at the 5% level.*

Figure 1 Labor Productivity in the total economy for Turkey (Index, 2005=100)



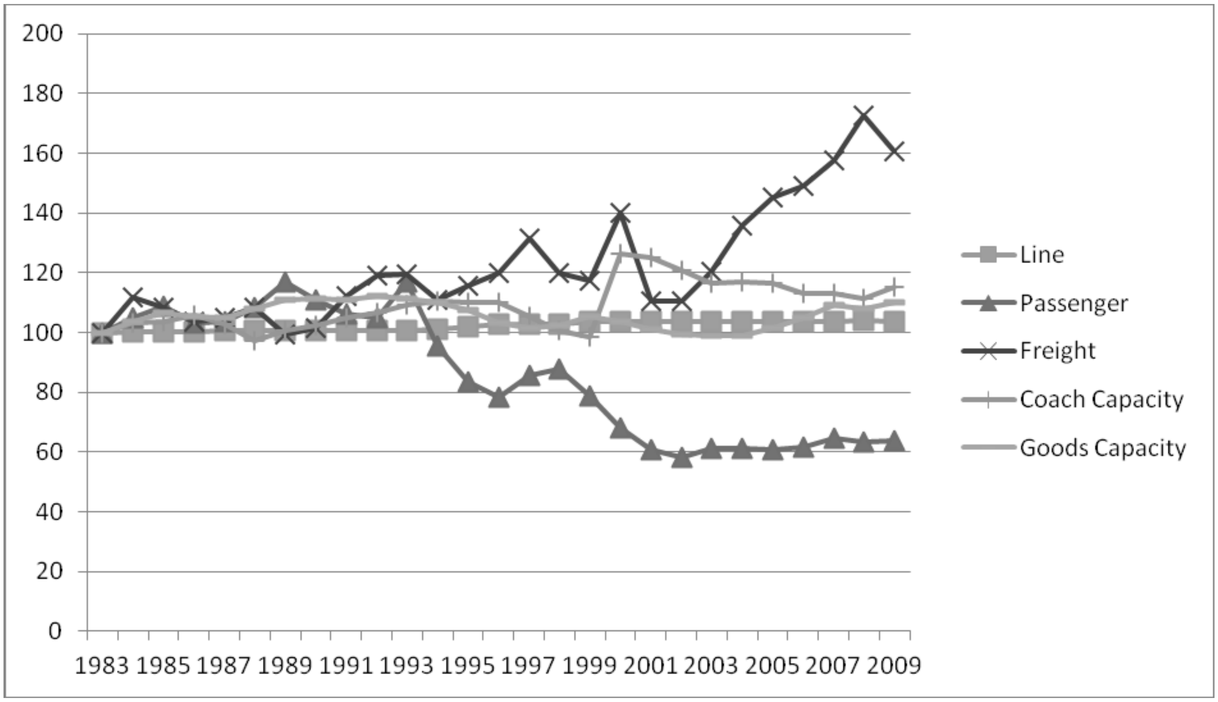
Source: OECD

Figure 2 Electricity production by producer type (GWh)



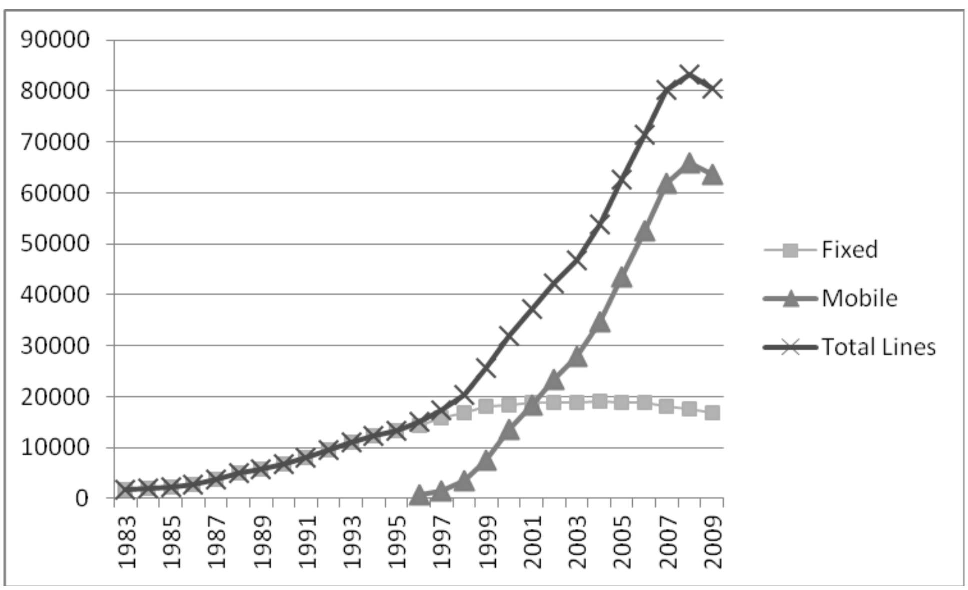
Source: TEIAS (Turkish Electricity Transmission Company; www.teias.gov.tr)

Figure 3 Some Railway Infrastructure Measures (Index 1983=100)



Source: Tektas, (2011)

Figure 4 Fixed, Mobile and Total Phone Subscribers (Thousand)



Source: Tektas (2011)

Figure 5: Relative Magnitudes of Productivity Elasticities under Alternative Infrastructure Measures and Estimators