The Role of Knowledge on Economic Growth: The Case of Turkey, 1963-2010

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Abstract
The importance of knowledge for long-run economic growth has long been an important research area for economists and policy makers. For instance, the developments in the communications technologies have immensely increased the creation and dissemination of knowledge. This, in turn, has increased the impact of knowledge on total factor productivity and hence on economic growth. Apart from these developments factors such as human capital (education), research and development (R&D) are among other important pillars of knowledge which have high potential to contribute to economic growth.

This paper attempts to analyze the impact of knowledge on economic growth in Turkey over the 1963-2010 period by using a production function approach. In contrast to early studies, which have analyzed the impact of a single dimension of knowledge on economic growth, a knowledge index is constructed to see the impact of various dimensions of knowledge with a single and comprehensive measure of the “level” of knowledge in the economy. Moreover, time series methods, such as cointegration and impulse response analysis are used to analyze the role of knowledge on economic growth in Turkey. The empirical results indicate that the higher level of knowledge had a positive impact on the growth rate of Turkish economy over the sample period. Therefore, it is necessary to create an economic environment that is conducive to enhance the level of knowledge and hence economic growth in Turkey.

1 This paper is based on my Ph.D. Thesis in process titled “The Role of Knowledge on Economic Growth: The Case of Turkey, 1963-2010, Department of Science and Technology Policies, METU.
1. Introduction

Prior 1960s economists were mainly analyzing the impact of two factors of production, namely capital and labor, on long-run economic growth. The other factors, such as technology and knowledge were considered to be “manna from heaven”. Later on, after the publication of the seminal works of Arrow (1962), Sheshinski (1967), Nelson and Phelps (1966) and Uzawa (1965) who introduced the ideas of education and learning by doing into the literature. During the late 1980s with the publications of Romer (1986) and Lucas (1988) this strand of literature has exploded, because these studies have equipped, both researchers and economists, with more advanced models to analyze the long-run growth trends of countries.

When we analyze the studies on the role of knowledge in economic growth of Turkish economy we see that the majority of them are descriptive and/or review articles. Furthermore, most of the other (empirical) studies are, unfortunately, not sufficient either in terms of empirical analysis or data or scope. Moreover, most of the empirical studies on the relationship between knowledge and the economic growth of Turkey focus on the role of a single or specific dimension of knowledge (e.g. education) on economic growth. Without any doubt, these studies attempted to provide useful insights on the role of specific dimensions of knowledge on economic growth. However, a more efficient analysis would be to use a production function framework to see the effects of various pillars of knowledge - education, R&D, ICTs and institutional environment-, taken together within a single model, on economic growth of Turkey.

In this paper, I have analyzed the impact of knowledge on economic growth in Turkey over the 1963-2010 period by using a production function approach. In contrast to early studies, which have analyzed the impact of a single dimension of knowledge on economic growth I constructed a knowledge index that helps us to see the impact of various dimensions of knowledge with a single and comprehensive measure of the “level” of knowledge in the economy. Moreover, I used popular time series methods, such as cointegration and impulse response analyses, to analyze the role of knowledge on economic growth in Turkey.

3 See, for example, Kar and Ağır (2004), Özsoy (2009) and Şimşek and Kadılar (2010).
2. The Growth Theory

The neoclassical growth theory (Solow-Swan Model) is based on production functions with strict neoclassical assumptions, such as, constant returns to scale, diminishing returns to inputs and the perfect competition assumption. Only two factors, capital and labor, are considered in the production function. According to this model economic growth performance of a country is influenced by exogenous factors, namely, technology\(^4\) and population growth.\(^5\) According to Solow (1956) time was the only variable that affected the level of productivity.

The most important prediction of the neoclassical theory was that the poor countries would eventually converge to the growth levels of the rich countries. But in reality instead of converging the economic growth gap between the rich and some poor countries in the world has increased.\(^6\)

Later on with the new growth theories endogenous factors within the economies were recognized to be the main source that caused economic growth and accounted for the observed differences of the economic growth of countries (Romer, 1994). Lucas (1988) and Romer (1986) have stressed the importance of human capital and technological progress in growth theory. Human capital has been recognized as the most important factor that has influenced performance of the richer countries since it is the key input in R&D which accelerates technological progress (Romer, 1990). Thus the endogeneous growth theory internalized technological progress and tried to explain the growth rates of countries by internalizing the factors of production into the models.

3. The Model

During the last decade economists have tried to measure the impact knowledge on economic growth in various ways. For example, Chen and Dahlman (2004) postulated that there are four pillars (or preconditions) of knowledge economy which transforms knowledge into an effective engine of growth. These pillars are economic and institutional

\(^4\) Which is available to every single country in the world because it is “manna from heaven”.
\(^5\) Technology, or total factor productivity, enters the growth accounting (production function) as a residual, and is called as the Solow residual.
\(^6\) It is acknowledged that the performance of the East Asian countries is contradictory to this statement.
regime, educated and skilled population, dynamic information infrastructure and efficient innovation system. They argue that when these four pillars are strengthened this would increase the accumulation of quality knowledge used in production, and thus increase economic growth via affecting total factor productivity (TFP).

In line with Chen and Dahlman (2004) and considering the previous studies I will attempt to use the following Cobb-Douglas production function -as the initial specification- in my empirical investigation of the role of knowledge on economic growth.

\[ Y_t = \beta_0 S_t^\beta E_t^\beta R_t^\beta I_t^\beta K_t^\beta L_t^\beta \]  

where \( S \) represents the economic structure (regime) of the economy, \( E \) denotes education, \( R \) represents country’s level of domestic innovation and \( I \) denotes country’s communication infrastructure, \( Y \) is output, \( K \) is capital and \( L \) is labor.\(^7\)

Equation (1) can be restated as the following log-linear model.

\[ \ln Y_t = \beta_0^* + \beta_1 \ln S_t + \beta_2 \ln E_t + \beta_3 \ln R_t + \beta_4 \ln I_t + \beta_5 \ln K_t + \beta_6 \ln L_t \]  

where \( \beta_0^* = \ln \beta_0 \) and \( \beta_i \)'s represent the respective elasticities (e.g. \( \beta_3 \) is the elasticity of output (Y) with respect to capital (K)).

Equation (2) allows us to investigate the role of the four dimensions (indicators) of knowledge on growth (that is, the role of openness, education, country’s level of domestic innovation and country’s communication infrastructure). However, these four indicators are highly correlated; therefore, I attempted to construct a proper knowledge index (KNIW). Construction of such an index provides us a single but comprehensive measure on the “level” of knowledge in the economy, which has a multi-dimensional facets (see, for instance, World Bank, 2006b). Thus, considering all these issues, equation (2) can be re-written as follows,

\[ \ln Y_t = \beta_0^* + \theta \ln KNIW_t + \beta_1 \ln K_t + \beta_6 \ln L_t \]  

where KNIW is the knowledge index and all the other variables are as defined earlier.

\(^7\) It should be noted that TFP \( (A_t) \) is explicitly modelled in Equation (1), and equals to \( \beta_0 S_t^\beta E_t^\beta R_t^\beta I_t^\beta \). Thus, it is not “manna from heaven” but requires deliberate policy actions and is available at a cost.
In line with the literature constant returns to scale is imposed on equation (3) and we obtain the following per labor specification.

$$\ln\left(\frac{Y}{L}\right) = \beta_0 + \theta KNIW_t + \beta_3 \ln\left(\frac{K}{L}\right)$$  \hspace{1cm} (4)

where \( Y/L \) is the output per labor, \( K/L \) is the physical capital per labor and \( KNIW \) is the knowledge index.

I will use the following empirical (stochastic) log-linear model in my empirical applications.

$$\ln\left(\frac{Y}{L}\right) = \alpha_0 + \alpha_1 KNIW_t + \alpha_2 \ln\left(\frac{K}{L}\right) + u_t$$  \hspace{1cm} (5)

Note that \( \alpha_0 = \beta_0^* \), \( \alpha_1 = \theta \), \( \alpha_2 = \beta_3 \) and \( u \) is the disturbance term

4. The Data

Output (Y) is measured by Gross Domestic Product (GDP) at 1998 constant prices. The Turkish Statistical Institute (TurkStat) has provided a new GDP series (at 1998 prices, billion TL) from 1998 onwards. The Turkish State Planning Organization (SPO)\(^8\) extended the series back to 1950s.

Capital Stock (\( K_t \)) is constructed based on the perpetual inventory method\(^9\), that is,

$$K_t = (1-\delta) K_{t-1} + I_t ,$$  \hspace{1cm} (6)

where \( I_t \) is gross fixed capital investment and \( \delta \) is the depreciation rate (0 < \( \delta < 1 \)).

Turkstat has recently changed the definitions of investment series (\( I_t \)) for 1998-2010 period and Saygılı and Cihan (2008) extended it back to 1948. In accordance with various studies (see for example, Bosworth and Collins (2003)) I have set the depreciation rate at 5% (\( \delta = 0.05 \)). Initial capital stock is calculated in line with Altuğ et al. (2008).\(^{10}\) It should be noted that the estimated capital stock series is at 1998 constant prices.

\(^8\) Ministry of Development.
\(^9\) See, for example, among many others, Bosworth and Collins (2003) and Altuğ et al. (2008).
\(^{10}\) The initial capital stock is \( K_{49} = I_{50}/(g + \delta) \), where \( g \) is average growth rate of GDP over 1950-2010.

Foreign trade to GDP ratio (TRADR)\textsuperscript{11} is used as an indicator of the openness that has been followed by Turkey. Data is obtained from Turkstat.

Education (ET) is measured by the average years of schooling of the labor force (age 15-64). I have used the series in Altuğ et al. (2008) and I have extended this series to 2010.

A Country’s Level of Domestic Innovation (RT)\textsuperscript{12} is measured by the total patent applications. I have used the series of World Bank (WDI).

Total number of telephone subscribers (TOTTEL)\textsuperscript{13}, including mobile phone subscribers, is used to represent communications infrastructure. The data on telephone subscribers are obtained from the Turkstat and Telecommunications Authority.

Figure 1 shows the time plots of the seven variables; namely, Y, K, L, TRADR, ET, RT and TOTTEL.

**Figure 1. Time Plot of Y, K, L, TRADR, ET, RT and TOTTEL.**

\textsuperscript{11} TRADR is used to represent the variable S in Equations (1) and (2).

\textsuperscript{12} RT represents the variable R in Equations (1) and (2).

\textsuperscript{13} TOTTEL represents the variable I in Equations (1) and (2).
5. The Knowledge Index

As noted before, construction of a knowledge index would provide us with a single and comprehensive measure on the “level” of knowledge in the economy. Moreover, such an index could also prevent the potential problem of multi-collinearity in the empirical analyses since the indicators of knowledge economy are highly correlated (Table 1).

<table>
<thead>
<tr>
<th>Table 1. Correlation Matrix of the Knowledge Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>LNTOTTEL</td>
</tr>
<tr>
<td>LNRT</td>
</tr>
<tr>
<td>LNET</td>
</tr>
<tr>
<td>LNTRADR</td>
</tr>
</tbody>
</table>

Since the four physical indicators of knowledge are in different units and have different ranges (minimums and maximums), I use the Human Development Index (HDI) methodology to obtain a common range for them. That is, I set a minimum and a maximum bound to each one of the four indicators and obtain a number (index value) for each observation of these indicators between 0 and 1. Formally speaking, with this conversion the four indicators become indices which are labeled as ILNTOTTEL, ILNRT, ILNE and ILNTRADR. More precisely, the four indices are calculated as follows:

\[
ILNTOTTEL_i = \frac{LNTOTTEL_i - \text{Min}(LNTOTTEL)}{\text{Max}(LNTOTTEL) - \text{Min}(LNTOTTEL)}
\]  

(7)

\[
ILNRT_i = \frac{LNRT_i - \text{Min}(LNRT)}{\text{Max}(LNRT) - \text{Min}(LNRT)}
\]  

(8)

\[
ILNET_i = \frac{LNET_i - \text{Min}(LNET)}{\text{Max}(LNET) - \text{Min}(LNET)}
\]  

(9)

\[
ILNTRADR_i = \frac{LNTRADR_i - \text{Min}(LNTRADR)}{\text{Max}(LNTRADR) - \text{Min}(LNTRADR)}
\]  

(10)

Figure 2 provides the time plots of the four sub-indices; namely, ILNTOTTEL, ILNRT, ILNET and LNTRADR.
The Knowledge Index (KNIW) is calculated as a weighted average of the four sub-indices:

\[
\text{KNIW} = w_1 \text{ILNTOTTEL} + w_2 \text{ILNET} + w_3 \text{ILNRT} + w_4 \text{ILNTRADR}
\]  \hspace{1cm} (11)

where \(w_i\)’s denote weights of the respective variables.

\textbf{Figure 2. The Plot of the Sub-indices}

In order to determine the weights of the four sub-indices I have used the method of principal component analysis. The results are presented in Table 2.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
\textbf{Variable} & \textbf{Eigen Vectors (Weights)} & \textbf{Relative Weights (\(w_i\))} \\
\hline
ILNTOTTEL & 0.525308 & 0.2633 \\
ILNET & 0.519244 & 0.2602 \\
ILNRT & 0.441353 & 0.2212 \\
ILNTRADR & 0.509553 & 0.2554 \\
\hline
\end{tabular}
\caption{Principal Component Analysis}
\end{table}
By using the results obtained in Table 2 I have constructed KNIW as follows:

\[
KNIW = 0.2633 \text{ILNTOTTEL} + 0.2602 \text{ILNET} + 0.2212 \text{ILNRT} + 0.2554 \text{ILNTRADR} \quad (12)
\]

Figure 3 shows the time plot of the knowledge index.

**Figure 3. KNIW, 1963-2010.**

In sum, the knowledge index (KNIW) is a composite of the four sub-indices which roughly captures the four main dimensions of knowledge. Therefore, the KNIW shows the level of knowledge in a given time period. As a consequence, KNIW gives us the possibility to analyze performance of Turkey, in terms of the attainment of knowledge, over time. For example, if Turkey has a higher KNIW value in the current year compared to the previous year, then we may say that there has been improvement in the knowledge level.
6. Empirical Results

6.1. Unit Root Tests

Before estimating the production function with the yearly time series data from 1963 to 2010, it is essential to check for the presence of a unit root in each series. Figure 4 provides the time plots of $\ln (Y/L)$, $\ln (K/L)$ and KNIW. There is a visual evidence of nonstationarity in each series (Figure 4).

![Figure 4. The Time plot of the data, 1963-2010.](image)

Table 3 provides the unit root (DF-GLS)

The Elliott-Rothenberg-Stock (ERS) DF-GLS tests (Elliott et al., 1996) are considered to be better (i.e. more powerful) than ordinary ADF tests (see for example, Zivot and Wang (2006) and Enders (2010)).
deterministic (linear) trend in these two variables. Fortunately, Johansen cointegration method is capable for handling this empirical issue.

### Table 3. Unit Root (DF-GLS) Tests

<table>
<thead>
<tr>
<th>Variables</th>
<th>DF-GLS Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
</tr>
<tr>
<td></td>
<td>Without Trend</td>
</tr>
<tr>
<td>Ln (Y/L)</td>
<td>1.1518 (0)*</td>
</tr>
<tr>
<td>Ln (K/L)</td>
<td>-0.2111 (2)</td>
</tr>
<tr>
<td>KNIW</td>
<td>1.6291 (0)</td>
</tr>
</tbody>
</table>

*The optimal lag chosen by SBC (Schwarz Bayesian Criterion) are given in parentheses. The maximum lag length is 2. SBC is recommended by ERS (1996) for selecting lag length (Also see Enders (2010:241)). bThe asterisk indicates the rejection of null hypothesis (i.e. the existence of unit root) at the 5% significance level.

### 6.2. Empirical Results

#### 6.2.1. Cointegration Analysis

I use Johansen cointegration analysis (Johansen, 1995) for investigating the long-run relationship between knowledge and output (growth). Considering the possibility of linear trends in data and following Hendry and Juselius (2001), the deterministic components of the VAR model is specified as constant term entering unrestrictively and with no trend term in the cointegration relation.

Johansen cointegration tests; namely the Trace and Max tests suggest one cointegration relation among the three variables in Equation (5) (see Table 4).

### Table 4. Eviews Output for Trace and Max Tests

#### Unrestricted Cointegration Rank Test (Trace)

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>0.05</th>
<th>0.05 Critical Value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None *</td>
<td>0.416716</td>
<td>32.22694</td>
<td>29.79707</td>
<td>0.0258</td>
<td></td>
</tr>
<tr>
<td>At most 1</td>
<td>0.117626</td>
<td>6.890156</td>
<td>15.49471</td>
<td>0.5905</td>
<td></td>
</tr>
<tr>
<td>At most 2</td>
<td>0.021231</td>
<td>1.008623</td>
<td>3.841466</td>
<td>0.3152</td>
<td></td>
</tr>
</tbody>
</table>

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

#### Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

<table>
<thead>
<tr>
<th>Hypothesized</th>
<th>Max-Eigen</th>
<th>0.05</th>
</tr>
</thead>
</table>

15 Johansen approach is more efficient than the Engle-Granger approach in the case of more than two variables.
<table>
<thead>
<tr>
<th>No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Statistic</th>
<th>Critical Value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None *</td>
<td>0.416716</td>
<td>25.33679</td>
<td>21.13162</td>
<td>0.0120</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.117626</td>
<td>5.881533</td>
<td>14.26460</td>
<td>0.6285</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.021231</td>
<td>1.008623</td>
<td>3.841466</td>
<td>0.3152</td>
</tr>
</tbody>
</table>

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Johansen method estimated the production function in Equation (5) as follows:

\[
\ln\left(\frac{Y}{L}\right) = 4.1910 + 0.5914 \times KNIW_t + 0.3974 \times \ln\left(\frac{K}{L}\right), \tag{13}
\]

Equation (13) implies that the output per labor is positively affected by both physical capital per labor and knowledge index. These findings are statistically significant and consistent with theoretical expectations.16

Fully Modified Least Squares (FM-OLS) method (Philips and Hansen, 1990) provided a similar results:

\[
\ln\left(\frac{Y}{L}\right) = 4.0134 + 0.4731 \times KNIW_t + 0.4244 \times \ln\left(\frac{K}{L}\right), \tag{14}
\]

As before, these findings are statistically significant and consistent with theoretical expectations (See Appendix 2 for Eviews Output).

Both Johansen and FM-OLS methods yield similar estimates for equation (5) and they are consistent with the theory. Thus, we can confidently conclude that knowledge has a positive impact on the Turkish economy during the 1963-2010 period.

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16 Considering the sample size, lag length of the VAR is chosen as 1. Residuals of the equations of vector error correction (VEC) model are not serially correlated and homoscedastic at 5% and satisfy normality at 1% level of significance. After examining the residuals plot of the equations (see Appendix 1), I also re-performed the analysis by including an impulse dummy for 1994, to account for the significant economic crisis. In this case (including 1994 impulse dummy), residuals are not serially correlated, homoscedastic and normal at 5% level of significance. Estimated equation is quite similar to that of equation (16) (see Appendix 1).

17 The FM-OLS approach also takes into consideration the endogeneity problem and non-stationarity of the data (Philips and Hansen, 1990). Finally, note that the OLS method has provided quite similar results (see Appendix 2) but unsurprisingly the estimates are not as close as the estimates of Johansen and FM-OLS techniques.
6.2.2. Impulse Response Analysis

In order to investigate the short-term dynamics of the production function model, this section provides the impulse response analysis. Figure 5 provides the generalized impulse response functions of $\ln (Y/L)$ [LNYOL] and $\ln (K/L)$ [LNKOL] to a positive unit shock in KNIW.\(^{18}\)

As is seen from the upper panel of Figure 5, $\ln (Y/L)$ is initially negatively affected from an increase in KNIW. However, $\ln (Y/L)$ is eventually positively affected from KNIW. That is, in the end a rise in the level of knowledge has favorable effects on output per worker. This is consistent with the theoretical arguments that I have mentioned before: improvements in TFP (here, via knowledge indicators) is not “manna from heaven” but requires deliberate policy actions and is available at a cost.

**Figure 5. Impulse Responses to KNIW**

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\(^{18}\) I have preferred generalized impulse responses rather than the ones based Cholesky (orthogonalized) innovations because generalized impulse responses are not sensitive to the ranking of the variables within the model (Pesaran and Shin, 1998).
Lastly, as can be seen from the lower panel of Figure 5, the dynamic effects of a rise in KNIW on Ln (K/L) is not favorable. This result is also in line with the theory. The higher level of knowledge (or a rise in total factor productivity) requires less capital per labor to produce same output.

7. Conclusion

The impact of knowledge on economic growth in Turkey in general has been analyzed by considering a single dimension of knowledge on economic growth. In this study I construct a knowledge index to see the impact of various dimensions of knowledge with a single and comprehensive measure of the “level” of knowledge in the economy. Moreover I used time series methods to analyze the role of knowledge on economic growth in Turkey over the 1963-2010 period by using a production function approach. The empirical results indicate that the higher level of knowledge had a positive impact on the growth rate of Turkish economy over the sample period. Therefore, it is necessary to create an economic environment that is conducive to enhance the level of knowledge and hence economic growth in Turkey.
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