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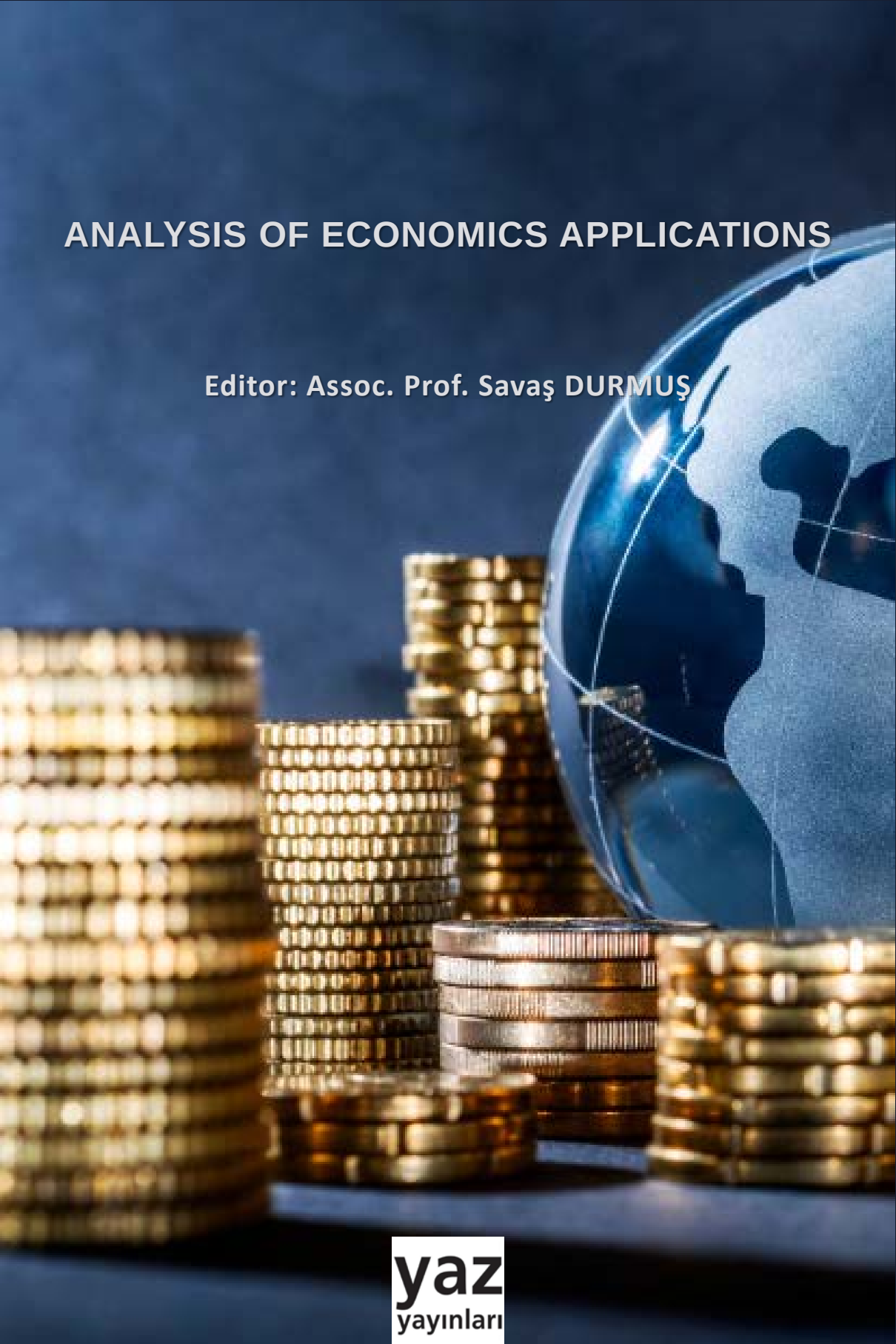

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CONTENT

URBANIZATION AND ENERGY CONSUMPTION IN TURKEY: EMPIRICAL EVIDENCE FROM ARDL APPROACH

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1. INTRODUCTION

Energy plays a vital role in all consumption and production processes. Therefore, it is an important indicator of economic development (Kraft and Kraft, 1978; Yu and Jin, 1992; Apergis and Payne, 2009; Zhang and Cheng, 2009; Ozturk, 2010; Moe, 2010; Stern, 2011; Magazzino, 2015; Cheng,1999; Ang,2008; Lise and Montfort,2007; Moroney,1992). Energy literature argues the link among energy consumption and socio-economic factors for a long time. In this respect, some scholars analyze the relationship among energy consumption, democracy and political regime (Van Beers and Strand, 2013; Adams et al., 2016). Energy is linked with financial development. It is recommended that the causality runs from energy consumption to financial development (Al-mulali and Sab, 2012; Islam et al., 2013; Zeren and Koc, 2014; Sadorsky,2010). Several studies such

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as Camagni et al. (2002), Ayres et al. (2007), Kaygusuz (2009), Shahbaz et al. (2013), Munir and Riaz (2019), Ali et al. (2017) deal with the link among energy consumption and environmental quality. They deduce that energy consumption has both positive and negative effects on environmental deterioration.

Several studies such as Jones (1989; 1991), Imai (1997) and York (2007) suggest that energy consumption is substantially linked with urbanization. The studies reveal how urbanization may theoretically affect energy use. Firstly, urbanization leads to economic activities to concentrate on metropolitan areas. Therefore, the scale economies emerge. Thus, urbanization can increase energy demand and consumption by its effect on production. Secondly, increasing of population in cities requires construction and maintenance of transportation. Construction materials such as cement and structural steel are produced in energy-intensive industries. Therefore, construction activities can increase energy expenditures. In addition, public infrastructure investments in cities entail intensive energy use. Thirdly, urbanization generates industrialization and per capita income growth. Industrialization modifies product mixes and expedites the transition to the energy intensive technologies. Thus, both direct and indirect energy demands increase. Duan et al. (2008) assert that urbanization rises energy consumption. In this respect, they examine the Chinese economy over the period of 1978-2005. The study suggests an elasticity coefficient that enables us to evaluate changes in energy use at different urbanization phases.

The urbanization-energy consumption link is of considerable research interest in the empirical literature. However, there exists no consensus on the connection among urbanization and energy consumption. Table 1 shows selected time series studies. Applying an OLS analysis, Imai (1997), Lariviere and Lafrance (1999), Holtedahl and Joutz (2004), Lenzen et al. (2006) and Ewing and Rong (2008) test the

urbanization-energy consumption link. Imai (1997) for Thailand, Holtedahl and Joutz (2004) for Thailand, Lenzen et al. (2006) for India and Ewing and Rong (2008) for USA provide a positive link between the variables whereas a negative relationship is confirmed by Lariviere and Lafrance (1999) for Canada and Lenzen et al. (2006) for Australia, Brazil, Denmark and Japan. According to the study of Raza et al. (2023), CO2 emissions, gross domestic product, urbanization and fossil fuel consumption were found to be significant in the long run. Empirical results show that there is short- and long-term causality among the variables. According to Belloumi and Alshehry (2016), which examines the relationship between urbanization and energy intensity in Saudi Arabia, it is stated that urbanization is determined by energy intensity in the long run. The finding is confirmed by Komal and Abbas (2015), who employ the GMM estimation method to analyze the effect of urbanization on energy consumption for Pakistan. The same results are obtained by Keho (2016) for Benin, Congo, Ghana, South Africa and Togo, Azam et al. (2015) for Thailand and Indonesia.

Sbia et al. (2017) state that the relationship among urbanization and energy consumption in the UAE is in an inverted U shape. It is also stated that there is a long-run and bi-directional causality among the variables. Applying a STIRPAT method, Shahbaz et al. (2015) for Malaysia indicate that urbanization increases and causes energy consumption in the long run. Similar effects are found by Shahbaz et al. (2017) for Pakistan and Halicioglu (2007) for Turkey. Using the VECM Granger causality test, Azam et al. (2016) investigate the factors affecting energy consumption in the state of Greece. The empirical evidences show that there consists no causal contact among urbanization and energy consumption. The same result is determined by Belloumi and Alshehry (2016) for Saudi Arabia.

Mahalik et al. (2017), in their study for Saudi Arabia, showed that urbanization has a long-term positive effect on energy consumption by applying the Bayer-Hanck and ARDL cointegration approach. Solarin and Shahbaz (2013), who stated that there is a long-term bi-directional causality between the variables, also applied the same methodology. Shahbaz and Lean (2012), who stated that urbanization is positively related to energy consumption, used the ARDL method for Tunisia. The results show that there is bidirectional causality among the variables. Liu (2009), on the other hand, uses the ARDL test and the VECM Granger causality technique for China to state that causality is from urbanization to energy consumption. In the study of Lebe and Akbaş (2015) on the Turkish economy, The DOLS and FMOLS estimation results show that there is a positive relationship among urbanization and energy consumption. Similarly, Aslan (2021) analyze the relations between Turkey's economic growth, energy consumption and urbanization rate have been analyzed between 1965-2019. Short and long-termed relationships between the variations have been predicted by the model of autoregressive distributed lag (ARDL). The findings obtained, cointegration tests indicate that there is a long-term connection among the variations, and short-term error-correcting coefficient is meaningful.

There are many researchers dealing with long-run causality between urbanization and energy consumption using different panel data methods. According to Al-Mulali et al. (2013), who studied for Mena countries, there is a positive correlation and causality among the variables in the long run. The results are similar to the study of Wang et al. (2014). Abbasi et al. (2020) analyzes the impact of urbanization and energy consumption on carbon dioxide emissions (CO2) for 8 Asian countries between 1982 and 2017. According to Zhang and Lin (2012), who analyzed the impact of urbanization on energy

consumption and CO2 emissions in China between 1995 and 2010 using the STIRPAT model, urbanization increases energy consumption and CO2 emissions. Chen et al. (2019) obtained an inverted U-shaped result in their study. Ulucak et al (2021) concluded that urbanization and renewable energy reduce CO2 emissions in developing Mediterranean countries with the STIRPAT model. Yazdi and Dariani (2019) state that there is a bidirectional causality between economic growth, urbanization and CO2 emissions in their study with the Granger test between 1980 and 2014. In addition, some scholars explore only the long-run link between the variables. Using a dynamic extended STIRPAT model for 78 countries, Sheng et al. (2017) show that urbanization determines energy consumption. On the other hand, Li and Lin (2015) reveal a negative link among the variables by using a similar framework. This finding is in line with Sadorsky (2014) for emerging economies. Applying a panel Granger causality test for new emerging market countries, According to Bakırtaş and Akpolat (2018), urbanization leads to energy consumption. Wang et al. (2018) state that there is a bidirectional causality between urbanization and energy consumption in the long run. Wang et al. (2019) show a positive link and bi-directional causality among the variables applying the Johansen and Toda-Yamamoto methods for 186 countries. Employing the threshold STIRPAT model, Yang et al. (2019) for China find that urbanization increases energy consumption.

When the time series studies are examined, it can be seen from Table 1 that there are very few studies on the Turkish economy. Turkey's urban population (% of total population) has increased from 25% in 1990 to 76% in 2015. The average urban population growth rate has been 2.04% during 2015-2020 (WDI, 2023). The rapid urbanization of Turkey has changed the country demographically and economically (Karam, 2015). On the other hand, energy demand in Turkey is increasing due to rapid

urbanization, economic and population growth. Turkey's energy consumption will rise by 50% over the next decade. The main characteristics of Turkey's energy policy are reducing dependency on imports, rising energy security, efficiency, productivity and diversity (MFA, 2020). Therefore, it has been very vital to research the link among urbanization and energy use for Turkish economy.

These developments lead us to empirically research how urbanization affects energy consumption in Turkey. The present study examines the relationship between urbanization and energy consumption between 1974 and 2015, including economic growth, population, trade openness and foreign direct investment. This study uses the classical unit root methods like ADF, DF-GLS and KPSS tests recommended by Dickey and Fuller (1981), Elliott et al. (1996) and Kwiatkowski et al. (1992), respectively. This study also uses the Lee-Strazicich (1993) unit root test allowing for two endogenous structural breaks. For cointegration analysis, ARDL bounds test, which was discussed by Pesaran et al. (2001), was used the causality method developed by Toda and Yamamoto (1995). The findings allow us to provide important policy suggestions for Turkey.

Table 1. Selected Time-Series Studies

Author	Period/Country	Methodology	Cointegration	Long-run impact	Long-run causality
Yang et al. (2019)	1996-2014 China	Threshold STIRPAT model	Not investigated	Positive	Not investigated
Wang et al. (2019)	1980-2015 186 countries	Johansen, Toda-Yamamoto	Yes	Positive	URB ↔ EN
Shia et al. (2017)	1975-2011 UEA	ARDL, VECM	Yes	Inverted U-shaped	URB ↔ EN
Shahbaz et al. (2017)	1972Q1-2011Q4 Pakistan	ARDL, VECM	Yes	Positive	URB → EN
Mahalik et al. (2017)	1971-2011 Saudi Arabia	Bayer-Hanck cointegration, ARDL	Yes	Positive	Not investigated
Keho (2016)	1970-2011 SSA countries	ARDL	Yes	Positive (Benin, Congo, Ghana, South Africa, Togo) Negative (Gabon, Kenya)	Not investigated
Belloumi and Alshehry (2016)	1971-2012 Saudi Arabia	ARDL, Toda-Yamamoto	Yes	Positive	No
Azam et al. (2016)	1975-2013 Greece	Johansen, VECM	Yes	Not investigated	No
Shahbaz et al. (2015)	1970Q1-2011Q4 Malaysia	ARDL, VECM	Yes	Positive	URB → EN
Azam et al. (2015)	1980-2012 Indonesia, Malaysia, Thailand	OLS	Not investigated	Positive (Thailand, Indonesia)	Not investigated
Lebe and Akbas (2015)	1960-2012 Turkey	DOLS, FMOLS, SVAR	Yes	Positive	Not investigated
Komal and Abbas (2015)	1972-2012 Pakistan	GMM	Not investigated	Positive	Not investigated
Solarin and Shahbaz (2013)	1971-2009 Angola	Gregory-Hansen cointegration, ARDL, VECM	Yes	Not investigated	URB ↔ EN
Shahbaz and Lean (2012)	1971-2008 Tunisia	ARDL, VECM	Yes	Positive	URB → EN
Liu (2009)	1978-2008 China	ARDL, VECM	Yes	Not investigated	URB → EN
Ewing and Rong (2008)	1940-2000 USA	OLS	Not investigated	Positive	Not investigated
Halicioglu (2007)	1968-2005 Turkey	ARDL, VECM	Yes	Positive	URB → EN
Lenzen et al. (2006)	1993-1999 Australia, Brazil, Denmark, India, Japan	OLS	Not investigated	Positive (India) Negative (Australia, Brazil, Denmark, Japan)	Not investigated
Holtedahl and Joutz (2004)	1955-1995 Taiwan	Johansen, OLS	Yes	Positive	Not investigated
Lariviere and Lafrance (1999)	1991 Canada	OLS	Not investigated	Negative	Not investigated
Imai (1997)	1980-1993 Thailand	OLS	Not investigated	Positive	Not investigated

Note: URB and EN denote urbanization and energy consumption, respectively. → and ↔ indicate uni-directional causality and bi-directional causality, respectively. **Source:** Author's own compilation

2. MODEL SPECIFICATION and DATA

The study concentrates the effect of urbanization on energy consumption. Following Liu (2009), Le and Lin (2015) and Belloumi and Alshehry (2016), we employ the log-linear regression specifications to analyze the link among the variables. The energy consumption functions considered in the study are as follows:

$$LEN_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LURB_t + \beta_3 LPOP_t + \varepsilon_{t1} \quad (1)$$

$$LEN_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LURB_t + \beta_3 LPOP_t + \beta_4 LOP_t + \varepsilon_{t1} \quad (2)$$

$$LEN_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LURB_t + \beta_3 LPOP_t + \beta_4 LOP_t + \beta_5 LFDI_t + \varepsilon_{t1} \quad (3)$$

where EN indicates per capita energy consumption (kg of oil equivalent); GDP is per capita real GDP (constant 2010 US $); URB is an urban population (percentage of the total population); POP is total population; OP is trade openness (foreign trade, % of GDP) and FDI is a foreign direct investment (net inflows, % of GDP). β0 is the intercept and εt1, εt2 and εt3 are the error terms. β1, β2, β3, β4 and β5 are the parameters which show the long-run impact of independent variables on energy consumption.

This study employs annual data from 1974 to 2015. The reason why we consider this period is that the energy consumption data per capita was completed in 2015. Time series data is from the World Bank (2019). The logarithmic forms of the variables are included in the empirical analyses. Table 2 reports a description of the variables and their expected signs. The summary statistics of the variables are illustrated in Table 3. Fig. 1. indicates the trends of the series.

Table 2. Description of the Variables and Their Expected Signs

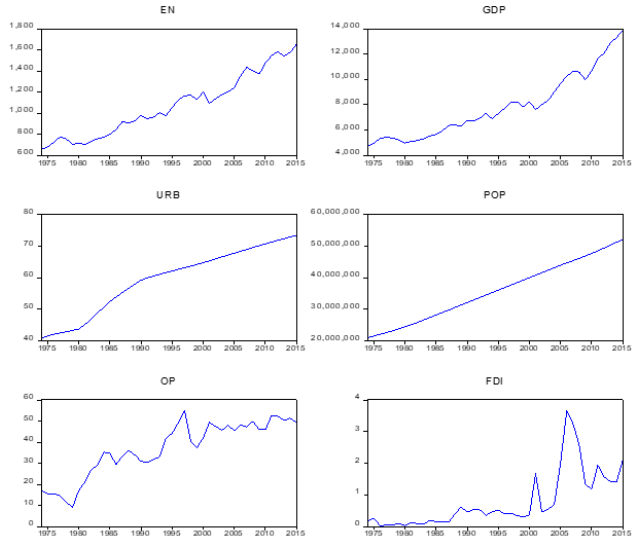
Variable	Definition	Data source	Expected sign
Energy consumption (EN)	Per capita energy consumption (kg of oil equivalent)	WDI	-
Economic growth (GDP)	Per capita real GDP (constant 2010 US$)	WDI	(+) Shahbaz and Lean (2012)
Urbanization (URB)	The percentage of the urban population in the total population	WDI	(+) (Jones, 1991)
Population (POP)	Total population	WDI	(+) (-) York (2017), Balezentis (2020)
Trade openness (OP)	Foreign trade (% of GDP)	WDI	(+) (-) Koengkan (2018)
Foreign direct investment (FDI)	Net inflows (% of GDP)	WDI	(+) (-) Mielnik and Goldemberg (2002)

WDI; World Development Indicator, 2019.

Table 3. Summary Statistics for the Period 1974-2015

Statistics	EN	GDP	URB	POP	OP	FDI
Mean	1069.043	7826.913	59.291	35813611	36.804	0.788
Median	1028.418	7329.135	61.856	35718581	38.837	0.438
Std. dev.	294.942	2520.468	10.358	9441363	13.035	0.897
Min.	656.847	4744.295	40.920	21043859	9.099	0.019
Max.	1656.803	13898.300	73.397	52140380	54.970	3.653
Skewness	0.383	0.793	-0.477	0.057	-0.594	1.597
Kurtosis	2.006	2.664	1.910	1.766	2.197	4.886
Observations	42	42	42	42	42	42

Fig. 1. The Trends of the Variables



3. EMPIRICAL STRATEGY

The empirical strategy of the study consists of three steps. The study begins with the classical unit root tests. We use the ADF, DF-GLS and KPSS tests to analyz the stationarity of the variables. However, these tests do not deal with structural breaks in the series. Therefore, their empirical results may be biased and inappropriate (Shahbaz et al., 2016). In the study, the Lee-Strazicich unit root procedure with two endogenous structural breaks is also employed. This procedure uses the LM statistic obtained from the following regression:

$$\Delta y_t = \delta' \Delta Z_t + \tilde{S}_{t-1} + \varepsilon_t \ (4)$$

where $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t\tilde{\delta}(t = 2, \ldots., T)$. $\tilde{\delta}$ specifies a vector of coefficients in the specification of Δy_t on ΔZ_t. $\tilde{\psi}_x = y_1 - Z_1\tilde{\delta}$, where Z_t denotes a vector of exogenous variables determined by the data producing process. We use Model C developed by Lee-Strazicich (2003). This model lets two shifts in the intercept and the slope, and this is expressed as follows:

$$Z_t = [1, t, D_{1t}, D_{2t}DT_{1t}DT_{2t}]' (5)$$

where $DT_{jt} = t - T_{Bj}$ for $t \geq T_{Bj} + 1$, j=1,2 and zero otherwise. D_{jt} and T_{Bj} denote the break date and a dummy indicator variable, respectively. Here, the hypotheses established in this approach are expressed as follows:

$$H_0: y_t = u_0 + d_1B_{1t} + d_2B_{2t} + d_3D_{1t} + d_4D_{2t} + y_{t-1} + \mu_{1t} (6)$$

$$H_A: y_t = u_1 + \delta_t + d_1D_{1t} + d_2D_{2t} + d_3DT_{1t} + d_4DT_{2t} + y_{t-1} + \mu_{2t} (7)$$

where μ_{1t} and μ_{2t} are stationary error terms, $T_{jt} = 1$ for $t = T_{Bj} + 1$, j=1,2 and zero otherwise. The minimum LM unit root test finds the break points as follows:

$$lnf\tilde{\tau}(\tilde{\lambda}) = lnf_{\lambda}\tilde{\tau}(\lambda);\ \lambda = \frac{T_B}{T} (8)$$

The breakpoints are selected to be where the *t*-test statistic is minimized. The critical values are scheduled by Lee and Strazicich (2003).

The ARDL bounds test is applied to analyze the cointegration among the series. This approach is superior to the classical methods presented by Engle and Granger (1987), Johansen and Juselius (1990), and Stock and Watson (1993). Firstly, in this procedure, the regressors can be *I*(0) or *I*(1). Secondly, the bounds testing approach stops from the pre-testing problems. Thirdly, the unrestricted error correction model (UECM) as an important part of the ARDL model investigates both the long-run and short-run dynamics. Finally, this test is convenient for small sample data sets (Pesaran and Shin, 1999; Pesaran et al., 2001). Considering three regression specifications in this study, the UECMs are defined as follows:

$$\Delta LEN_t = \gamma_0 + \sum_{i=1}^{m} \gamma_{1i}\, \Delta LEN_{t-i} \sum_{i=0}^{m} \gamma_{2i} \Delta LGDP_{t-i} + \sum_{i=0}^{m} \gamma_{3i} \Delta LURB_{t-i} + \sum_{i=0}^{m} \gamma_{4i} \Delta LPOP_{t-i} + \delta_1 DUM_{1997} + \delta_2 DUM_{2007} + \delta_3 LEN_{t-1} + \delta_4 LGDP_{t-1} + \delta_5 LURB_{t-1} + \delta_6 LPOP_{t-1} + \mu_{t1} \quad (9)$$

$$\Delta LEN_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\, \Delta LEN_{t-i} \sum_{i=0}^{m} \alpha_{2i} \Delta LGDP_{t-i} + \sum_{i=0}^{m} \alpha_{3i} \Delta LURB_{t-i} + \sum_{i=0}^{m} \alpha_{4i} \Delta LPOP_{t-i} + \sum_{i=0}^{m} \alpha_{5i} \Delta LOP_{t-i} + \delta_1 DUM_{1997} + \delta_2 DUM_{2007} + \delta_3 LEN_{t-1} + \delta_4 LGDP_{t-1} + \delta_5 LURB_{t-1} + \delta_6 LPOP_{t-1} + \delta_7 LOP_{t-1} + \mu_{t2} \quad (10)$$

$$\Delta LEN_t = \theta_0 + \sum_{i=1}^{m} \theta_{1i}\, \Delta LEN_{t-i} \sum_{i=0}^{m} \theta_{2i} \Delta LGDP_{t-i} + \sum_{i=0}^{m} \theta_{3i} \Delta LURB_{t-i} + \sum_{i=0}^{m} \theta_{4i} \Delta PLOP_{t-i} + \sum_{i=0}^{m} \theta_{5i} \Delta LOP_{t-i} + \sum_{i=0}^{m} \theta_{6i} \Delta LFDI_{t-i} + \delta_1 DUM_{1997} + \delta_2 DUM_{2007} + \delta_3 LEN_{t-1} + \delta_4 LGDP_{t-1} + \delta_5 LURB_{t-1} + \delta_6 LPOP_{t-1} + \delta_7 LOP_{t-1} + \delta_8 LFDI_{t-1} + \mu_{t3} \quad (11)$$

In this equation, DUM is a dummy variable; μt1, μt2 and μt3 are error terms, and Δ is the difference operator. In this procedure, we first build the appropriate lag length for the ARDL model by using the AIC or SBC. Second, Pesaran et al. (2001) and Narayan (2005) proposed F-test was applied for lagged level variables. Third, the critical bounds from the Pesaran et al. (2001) and Narayan (2005) are compared with the *F*-statistic. If the F-statistic exceeds the upper critical limit (UCB), we can say that there is cointegration between the series. If the *F*-statistic is smaller than the lower critical bound (LCB), we decide that there does not exist cointegration among the series. Additionally, if the *F*-statistic is among two critical bounds we do not supply information about cointegration.

Diagnostic tests are used to analyze the suitability of the ARDL model. Moreover, the CUSUM and CUSUMsq tests developed by Brown et al. (1975) were also used to test the stability of the parameters.

4. FINDINGS

At the first step, we research the order of integration of the variables by using the ADF, DF-GLS and KPSS tests. Table 4 gives the findings of these unit root tests. According to the results,

it is stationary at the level of real GDP per capita, and the other series are stationary after taking the first difference. The study also uses the Lee-Strazicich test. The findings reveal that energy consumption and industrialization are integrated at *1*(1), the order of integration of other series are *I*(0) (see Table 5). The results enable us to apply the ARDL bounds test for cointegration analysis.

Table 4. Conventional Unit Root Tests

Regressor	ADF	DF-GLS	KPSS
LEN	-0.321 (0)	1.115 (0)	0.801 (5)
LGDP	0.696 (0)	1.913 (0) *	0.801 (5)
LURB	-3.048 (9)**	-0.609 (4)	0.761 (5)
LPOP	-4.035 (2)***	-3.301 (1)**	0.806 (5)
LOP	-1.457 (0)	-0.788 (0)	0.663 (5)**
LFDI	-1.634 (0)	-1.564 (0)	0.711 (5)***
ΔLEN	-6.338 (0)***	-6.224(0)***	0.072(6)***
ΔLGDP	-6.003 (0)***	-	0.154 (1)***
ΔLURB	-	-1.982 (1)**	0.385 (5)**
ΔLPOP	-	-	0.666 (5)**
ΔLOP	-4.618 (1)	-4.141 (1)***	-
ΔLFDI	-8.994 (0)	-8.619 (0)***	-

Note: ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

Table 5. Lee-Strazicich LM test

Panel A: Level	LEN	LGDP	LURB	LPOP	LOP	LFDI
Test statistics	-5.378	-6.657**	-19.880***	-9.408	-5.901	
Lag	4	3	8	8	8	
TB1	1997	1985	1987	1984	1996	
TB2	2007	1999	1994	1993	1999	
Panel B: First difference	ΔLEN	ΔLGDP	ΔLURB	ΔLPOP	ΔLOP	ΔLFDI
Test statistics	-7.523***	-	-	-	-7.704***	
Lag	5	-	-	-	4	
TB1	1992	-	-	-	1985	
TB2	1998	-	-	-	2007	

Note: TB1 and TB2 indicate the break dates. Critical values are in Lee and Strazicich (2003). *** and ** denotes significance at 1% and 5% level, respectively.

The selection of optimal lag length is very important for cointegration and causality analyses. The results obtained from various criteria through the VAR model are presented in Table 6. In this study, the SBC is employed by following Tiwari et al. (2013). The results show that the appropriate lag for models (1), (2) and (3) is determined as two.

Table 6. Lag Length Selection

Panel A: Model 1	LR	FPE	AIC	SIC	HQ
1	513.641	8.79e-17	-25.624	-24.762	-25.318
2	102.207	6.20e-18*	-28.307*	-26.755*	-27.755*
3	10.219*	1.03e-17	-27.873	-25.632	-27.076
4	15.204	1.36e-17	-27.755	-24.825	-26.713
Panel B: Model 2	LR	FPE	AIC	SIC	HQ
1	551.249	7.86e-19	-27.511	-26.218	-27.051
2	105.714	6.28e-20*	-30.110	-27.740*	-29.267*
3	21.801*	1.05e-19	-29.785	-26.338	-28.559
4	33.697	8.21e-20	-30.452*	-25.927	-28.842
Panel C: Model 3	LR	FPE	AIC	SIC	HQ
1	565.504	1.24e-19	-26.534	-24.724	-25.890
2	107.131	1.31e-20	-28.925	-25.564*	-27.729
3	35.489*	2.05e-20	-28.898	-23.985	-27.150
4	56.215	4.82e-21*	-31.328*	-24.863	-29.028*

Note: * indicates optimal lag length.

After the selection of lag length, we conduct the cointegration analysis. The bounds F-test findings presented in Table 7 show that the F-statistics are larger than the UCB at 1% level. Therefore, the null hypothesis is refused in all the models. This means that there exists cointegration between the series. So, we reveal a long-run connection among the series employed in the study.

Table 7. Cointegration Analysis

Panel A: Bounds *F*-test	Model 1		Model 2		Model 3	
ARDL lag structure	[1,0,0,2]		[1,0,0,2,0]		[1,1,1,0,1]	
SIC optimal lag length	2		2		3	
Structural breaks	1997, 2007		1997, 2007		1997, 2007	
F-statistic	17.888***		17.827***		17.014***	
ECT_{t-1}	-1.006***		-0.918***		-0.898***	
Pesaran et al. (2001) critical value bounds						
Significance level	Lower *I*(0)	Upper *I*(1)	Lower *I*(0)	Upper *I*(1)	Lower *I*(0)	Upper *I*(1)
1%	4.29	5.61	3.74	5.06	3.29	4.37
5%	3.23	4.35	2.86	4.01	2.56	3.49
10%	2.72	3.77	2.45	3.52	2.20	3.09
Narayan (2005) critical value bounds (T = 42)						
Significance level	Lower *I*(0)	Upper *I*(1)	Lower *I*(0)	Upper *I*(1)	Lower *I*(0)	Upper *I*(1)
1%	5.01	6.61	4.42	6.25	4.42	6.25
5%	3.54	4.80	3.20	4.54	3.20	4.54
10%	2.93	4.02	2.66	3.83	2.66	3.83

Note: *** denotes significance at 1% level.

In Table 8, we can see the long-run estimates. The positive relationship between urbanization and energy consumption is

seen in all models. This means that urbanization enhances energy consumption in the long run. This finding is consistent with Azam et al. (2015), who research the factors which affect energy consumption for ASEAN countries. The study shows a positive link among the variables in Thailand and Indonesia. The similar results are determined by Shahbaz et al. (2017) for UEA, Mahalik et al. (2017) for Saudi Arabia, Belloumi and Alshehry (2016) for Saudi Arabia, Keho (2016) for Benin, Congo, Ghana, South Africa and Togo, Shahbaz et al. (2015) for Malaysia, Lebe and Akbas (2015) for Turkey, Komal and Abbas (2015) for Pakistan, Ewing and Rong (2008) for the USA, Halicioglu (2007) for Turkey, Shahbaz and Lean (2012) for Tunisia, Holtedahl and Joutz (2004) for Taiwan, Imai (1997) for Thailand, Li and Lin (2015) for 73 countries. Our result does not coincide with Sbia et al. (2017), who indicate an inverted U-shaped link among the variables by applying the ARDL model for UEA. Applying the panel OLS estimation technique for China, Liu et al. (2017) reveal a negative relationship among the variables. The same findings are found by Lariviere and Lafrance (1999) for Canada, Lenzen et al. (2006) for Brazil, Australia, Japan and Denmark, Sadorsky (2014) for emerging countries and Keho (2016) for Gabon and Kenya.

The results show that there is a positive relationship between real GDP per capita and energy consumption in all models. This finding coincides with Shahbaz et al. (2015), who analyze the urbanization-energy consumption relation for Malaysia through the STIRPAT model. Using the ARDL approach, they reveal that in the long run economic growth is positively related to energy consumption. The similar findings are obtained by Azam et al. (2015) for Thailand, Indonesia and Malaysia, Sheng et al. (2017) for 78 countries, Sadorsky (2014) for emerging countries, Liu et al. (2017) for China, Li and Lin (2015) for 73 countries, Keho (2016) for Cameroon, Congo,

Gabon, Ghana, South Africa and Togo. Our result is dissimilar to Belloumi and Alshehry (2016), who explores the link between the variables for Saudi Arabia. The study suggests no statistically significant between the variables. Sbia et al. (2017) for UEA reveal that the link between the series is an inverted-U shaped while Keho (2016) for Benin indicates a negative link between the series.

The long-run findings assert that the population is negatively correlated with energy consumption. In other words, the population negatively affects energy consumption in the long run. This result is not logical with Sheng at al. (2017), who employ the GMM estimation method for 78 countries. It is found that the population positively affects energy consumption. Applying the panel POLS and FGLS techniques for 73 countries, Li and Lin (2015) present similar results.

We recommend that trade openness is positively related to energy consumption in the long run. This states that in the long run trade openness increases energy consumption. The same result is indicated by Shahbaz et al. (2015) for Malaysia. The result contrasts with Salim et al. (2017), who apply the ARDL, DOLS, FMOLS and CCR methods for China. We also find that FDI is negatively relationed with energy consumption in the long run. This suggests that FDI decreases energy consumption in the long run. This conclusion is in line with Keho (2016), who shows a negative link among the variables for Benin.

The findings of diagnostic tests are presented in the lower section of Table 8. The findings say that the long-run models pass all diagnostic tests i.e. Jarque-Bera test, Breusch-Godfrey LM test, ARCH test, and Ramsey-Reset test successfully. Moreover, in Figures 1, 2 and 3 the statistics for CUSUM and CUSUMsq are shown for all three models. These findings specify that CUSUM

and CUSUMsq plots, located between two important lines, reveal the accuracy of long-run forecasts.

Table 8. Long-Run Estimates

Panel A: Variables	Model 1	Model 2	Model 3
C	6.764***	8.689***	7.895***
LGDP	0.626***	0.700***	0.698***
LURB	0.950***	0.852***	0.908***
LPOP	-0.524**	-0.659***	-0.625***
LOP	-	0.066*	0.067**
LFDI	-	-	-0.014*
D_1997	0.036	0.022	0.013
D_2007	0.026	0.016	0.019
Panel B: Diagnostic tests			
R^2	0.993	0.994	0.995
Adjusted-R^2	0.991	0.992	0.993
F-statistic	595.932***	602.965***	587.151***
Breusch-Godfrey LM test	1.772 (0.568)	0.082 (0.776)	0.087 (0.769)
ARCH LM test	0.015 (0.900)	2.610 (0.114)	0.051 (0.821)
J-B normality test	0.816 (0.664)	1.299 (0.522)	2.253 (0.439)
Ramsey RESET test	1.459 (0.248)	1.263 (0.216)	0.699 (0.324)

Note: Figures in parentheses are t-statistics. ***, ** and * denote the significant at 1%, 5% and 10% level, respectively.

Fig. 2. CUSUM and CUSUMsq Tests for Model (1)

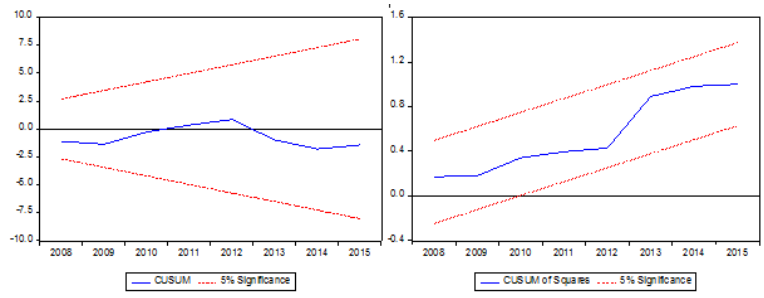


Fig. 3. CUSUM and CUSUMsq Tests for Model (2)

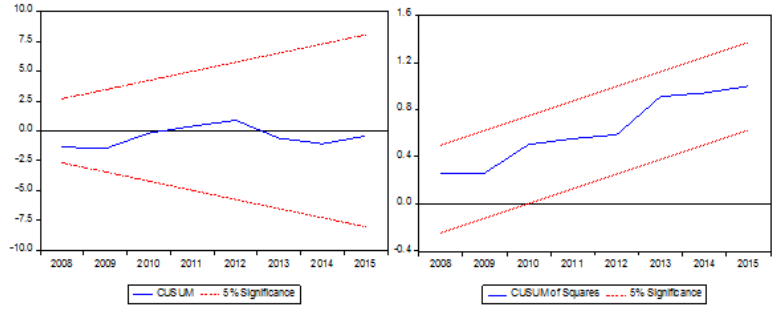
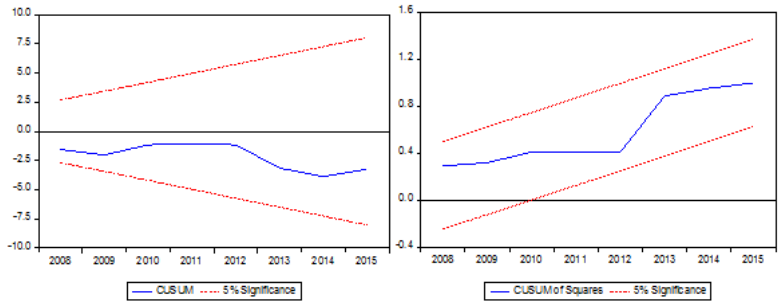


Fig. 4. CUSUM and CUSUMsq Tests for Model (3)



The causality results provided in Table 9 indicate no causality between urbanization and energy consumption. This finding is similar to Azam et. Al (2016), who examine the factors affecting energy consumption for Greece. Al-mulali et al. (2013) reveal a long-run bi-directional causality among the variables for MENA countries using panel VECM Granger causality method. The same results are found by Wang et al. (2018), who investigate the main determinants of environmental pollution for 170 countries applying the panel VECM Granger causality test. Our finding does not coincide with Shahbaz et al. (2017), who test the causality among urbanization and energy consumption for Pakistan. Using the VECM Granger causality approach, the study determines that energy consumption is the reason of urbanization in the long run.

The causality analysis shows that economic growth causes energy consumption. This finding contrasts with the bi-directional causality detected by Azam et al. (2016) among the variables for Greece. Ibrahiem (2018) for Egypt reveals that energy consumption causes economic growth in the long run. We detect that the population causes energy consumption. This result is not in line with Ibrahiem (2018), who reveals no causal relationship between the variables for Egypt. We also specify that there exists no causality among trade openness and energy consumption. This result contrasts to Shahbaz et al. (2015), who

determine a uni-directional causality from trade openness to energy consumption in the long run for Malaysia. The present study suggests that there exists no causal connection among FDI and energy consumption. This finding is dissimilar to Kivyiro and Arminen (2014), who find that FDI causes energy consumption for Congo.

Table 9. Causality Analysis

Dependent variable	LEN	LGDP	LURB	LPOP	LOP	LFDI
Panel A: Model 1						
LEN	-	4.740*	1.269	4.769*	-	-
LGDP	1.919	-	1.706	1.682	-	-
LURB	4.352	8.304**	-	11.084***	-	-
LPOP	3.653	0.767	0.161	-	-	-
Panel B: Model 2						
LEN	-	6.451**	0.019	1.956	1.840	-
LGDP	2.213	-	2.565	1.756	0.973	-
LURB	1.857	4.259	-	3.112	17.641***	-
LPOP	6.006**	1.680	2.327	-	1.177	-
LOP	0.433	3.232	2.327	6.838**	-	-
Panel C: Model 3						
LEN	-	3.624	0.851	0.934	2.492	1.941
LGDP	2.283	-	2.807	2.282	0.907	0.532
LURB	1.882	3.154	-	0.931	17.499***	0.992
LPOP	5.676*	0.942	2.758	-	1.578	1.266
LOP	0.592	4.256	2.580	7.861**	-	0.296
LFDI	4.242	7.837**	21.379***	15.795***	10.014**	-

Note: ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.

5. CONCLUSION

This study has researched the effect of urbanization on energy consumption applying three different energy demand specifications in the state of Turkey over the 1974-2015 period. The classical unit root tests such as ADF, DF-GLS and KPSS are used to survey the stationarity of the variables. The Lee-Strazicich test with two structural breaks is also used. The ARDL bounds test is applied to conduct the cointegration analysis. We employ the Toda-Yamamoto test to detect the causality among the series.

Our results suggest that there exists cointegration among the series under the structural breaks. Considering the structural breaks, this finding indicates a long-run connection among the variables over the period. The long-run estimates suggest that urbanization is positively related to energy consumption. The long-run estimates also show that economic growth positively affects energy consumption. The findings assert that urbanization and economic growth rise energy consumption in the long run. We state that population and FDI negatively affect energy consumption in the long run. Finally, the long-run effect of trade openness on energy consumption is positive.

All the results suggest that in the long run energy consumption is affected by urbanization, economic growth, population, trade openness and FDI, respectively. Empirical results may ensure several policies for Turkish economy. First of all, these factors should be included in future energy strategies. Decreasing energy use is not an accurate thinking for Turkey because this will be a negative effect on future development matters such as economic growth, exports and employment. Economic growth and urbanization are the important dynamic forces of energy consumption in Turkish economy. This confirms the hypothesis that urbanization increases economic activities owing to a higher concentration of consumption and production, thus it increases the demand for energy. This is not a surprising result for Turkey because urban population rate has reached 75% in 2015. Besides, energy use in industrial production is high in urban and metropolitan areas in Turkey. Therefore, Turkey's energy simulations that concentrate on future energy use should significantly consider urbanization. The finding that the population negatively affects energy consumption is not in line with the results of the empirical literature. However, the energy users should be informed and awakened about the energy savings, efficient use of energy and dependence on foreign energy sources.

The entrepreneurs' projects which improve energy efficiency and increase energy savings should be supported by government and financial sector. These projects may encapsulate the self-sufficient energy sources, especially renewable energy sources. Moreover, FDI is a determinant of energy consumption in Turkey. The inflows of FDI may support innovation-based technological developments, therefore improve the efficient use and productivity of energy.

The present study may guide future studies. It may be revised by integrating different energy sources into the empirical specifications. It may also be revised by employing time-series analyses for more emerging countries. Thus, it is possible to provide comparative evidences and policy suggestions. Future studies may apply panel data techniques to obtain empirical evidences on the country groups.

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DOES INADEQUATELY EDUCATED WORKFORCE HINDER INNOVATION ACTIVITIES?

Bilge ERİŞ DERELİ[1]

1. INTRODUCTION

It is a well-known fact that innovation stands as an important driver of firm productivity, competitive advantage, and overall performance. Analyzing its determinants is of great importance for public policymakers in terms of efficient allocation of resources. Among many determinants of innovation, human capital acquring the required skills to generate and apply new ideas and knowledge and adopting new technologies has long been recognized among the most important ones. Kim (2002) discusses that adopting and implementing innovation activities are easier for highly educated workers than for less-educated workers. Toner (2011) also demonstrated that observed differences across countries in the patterns of innovation are explained by the differences in the quality of employer skills.

There are various studies examining the determinants of innovation decisions for Turkish firms. These studies consider various factors such as operational environment, organizational culture, innovation strategy, technological capabilities, customer and supplier relationships, subsidy, foreign ownership share and competition incentive as the determinants of innovation. However, there is a lack of analysis examining the relationship between difficulties in accessing to an educated workforce and innovation decisions. Taking into account the fact that

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inadequately educated workforce is reported as an important constraint by Turkish firms, this paper contributes to the prior literature by examining the relationship between this obstacle and innovation activities of small and medium sized domestic enterprises[2] (SMEs) operating in manufacturing sector in Türkiye using the World Bank's 2019 Enterprise Survey.

The remainder of the paper is as structured as follows: Section 2 briefly presents the prior literature on the determinants of firm-level innovation, especially focusing on studies carried out for Türkiye. Section 3 explains the dataset used for the analysis and outlines the methodological issues. Section 4 presents the main findings and Section 5 concludes with some policy recommendations.

2. LITERATURE REVIEW

There is extensive literature on the determinants innovation activities at firm level, where less attention has been paid to workforce skills and educated labor force. Using a dataset of 333 Finnish manufacturing firms from 1987 to 1991, Leiponen (1996) finds that competences and skills acquired through education and work experience significantly influence the likelihood of making product and process innovations, as well as incremental product improvements. The research suggests that various types of innovation are affected by distinct competences, with education playing a crucial role in product innovation, technical skills in both innovation and incremental product improvement, and firm-specific work experience in incremental product improvements and process innovation.

[2] Enterprises with 5-19 and 20-99 employees are categorized as small and médium sized firms, respectively.

Amara et al. (2008) employs a two-stage approach, first examining the presence/absence of product and process innovations and then assessing the degree of novelty in innovations among the subset of firms with such innovations. The findings highlight the influence of various learning types, including learning by doing, training, and interacting, on both the presence of innovation and the degree of novelty. Overall, the study suggests that the learning-related variables significantly impact the innovation dynamics of established SMEs, offering practical implications for owners, managers, and policymakers.

Focusing on Sub-Saharan countries with lower human capital levels, Van Uden et al. (2017) explores whether the general schooling level within a firm and formal training positively influence innovative output. Research analyzes how various combinations of human capital elements impact innovation. The findings emphasize the crucial role of internal mechanisms in driving human capital for innovative output.

Khadan (2018) explores the relationship between human capital, innovation, and economic growth in the Caribbean region and investigates how the inability to find skilled and appropriately educated workers influences a firm's innovation decisions using firm-level data. The findings reveal that firms struggling to recruit skilled employees are less likely to generate innovative activities, both in the past and for future technological and non-technological decisions.

There are studies analyzing the determinants of innovation decisions in Turkey, however the number of studies covering the relationship between difficulties in accessing to educated and engaging in innovation activities remains insufficient. Duygulu et al. (2008) investigates the innovation capacities of small and medium-sized enterprises (SMEs) in Turkey, focusing on the impact of the operational environment, organizational culture,

and structure. The findings suggest that the innovation dimension of organizational culture has a discernible but relatively low explanatory power for innovation capabilities..

Kamasak (2015) explores the factors influencing innovation performance in firms, examining the relationships among innovation strategy, formal structure, innovation culture, technological capabilities, and innovation performance. The findings reveal that innovation strategy and technological capabilities play more significant roles in enhancing innovation performance.

Utilizing World Bank Enterprise Survey datasets, Limanlı (2015) explores the factors influencing the research and development (R&D) decisions of firms in Turkey for the years 2008 and 2013. The estimation findings highlight the significance of factors such as sales, subsidy, foreign ownership share, competition incentive, enterprise scale, and domestic and foreign trade shares in influencing the probability of R&D investment.

In a recent study Durmaz and Düzgün-Öncel (2022) investigate the link between firms' innovation processes and their strategies for improving product quality and introducing new products. Logit estimations reveal significant and positive relationships between product variety objectives, technology level indicators, and the likelihood of product innovation. Additionally, for small and medium-sized firms, patent applications exhibit a positive association with the probability of innovation. Notably, the probability of engaging in innovation activities is positively linked to variety objectives, while quality objective indicators remain insignificant.

Armatlı Koroglu and Ozelci Eceral (2015) is one of the rare studies related to this one. It explores the connection between innovation and human capital, considering them as crucial factors for industrial competitiveness and focusing on the defense and

aviation industry in Ankara. The findings reveal that the defense and aviation industry exhibit a unique structure in terms of innovation capacity compared to other sectors. Moreover, the study indicates positive clues regarding the association between human capital and innovation activities in this specialized industry.

3. DATA AND METHODOLOGY

This study uses a comprehensive firm-level survey conducted under the World Bank's Enterprise Survey[3] in 2019. The survey covers 1663 firms operating in different regions and sectors. The sample of the study consists of 723 small and medium sized domestic firms operating in manufacturing sector.

Innovation has directly and indirectly been measured in various ways. R&D investments and their share in firms' sales is considered as the indirect measure of innovation, whereas the existence of innovative activities is considered as direct measures. Following Ayalew and Xianzhi (2019) and Okumu et al. (2019), this study adopts two direct measures of innovation: Product and process innovation. Firms are considered as product-innovative if they answer yes to the question "*during the last three years, has this establishment introduced new or significantly improved products or services*?". Similarly, firms are considered as process-innovative if they answer yes to the question "*during the last three years, has this establishment introduced any new or significantly improved process (including methods of manufacturing products or offering services, logistics, delivery, or distribution methods for inputs, products, or services, or*

[3] Despite its rich coverage, Enterprise Surveys are rarely used in studies conducted for Türkiye. Şeker (2010), Karacaovalı (2017), Yorulmaz et al. (2019), Düzgün-Öncel and Eriş-Dereli (2021) are some examples of studies that have utilized this dataset.

supporting activities for processes)?" Finally, the aggregate measure of innovation is calculated which equals to 1 if the firm engaged in either process or product innovation activities or both and 0 otherwise.

A dichotomous variable is constructed to capture whether firms evaluate inadequately educated workforce as an obstacle or not. This is done by examining the question *"To what degree is inadequately educated workforce an obstacle to the current operations of this establishment?"*. Inadequately educated workforce (IEW) obstacle variable takes the value 1 if the firms answer as minor/moderate/major/very severe obstacle and 0 if firms answer no obstacle to the previous question.

A set of firm-level control variables are included in the model. Firm age indicates the number of years since the establishment began its operations to date of the survey. Log(sales) is the logarithm total annual sales (in TRY) of the establishment for all products and services in the last fiscal year. Exporter is a dichotomous variable which is equal to 1 if the share of either direct or indirect exports in national sales is greater than 0, and 0 if the share of both direct and indirect exports in national sales is equal to zero. Formal training is a binary variable which equals to 1 if the establishment has formal training program(s) for its permanent, full-time employees in last fiscal year and 0 otherwise. Certification is a dichotomous variable which takes the value 1 if the establishment has an internationally recognized quality certification and 0 otherwise. Multi-establishment is a dichotomous variable which takes the value 1 if establishment is a multi-establishment firm. Finally, sectors (with 9 categories) and regions (with 12 categories) are included.

To clarify the relationship between inadequately educated workforce and innovation activities, 3 different specifications of the following basic logit model are estimated:

$$Pr(Firm\ is\ innovative|X) = \phi(\alpha + \beta_1 \text{IEW} + \beta_2 \text{Age} + \beta_3 Age^2 + \beta_4 \text{Logsales} + \beta_5 \text{Exporter} + \beta_6 \text{Formal training} + \beta_7 \text{Certification} + \beta_8 \text{Multiestablishment} + \beta_9 \text{City population})$$

where Pr indicates the probability of a firm engaging in innovation activities and ϕ represents the logistic cumulative distribution function. Beta coefficients are the log odds ratios in the logistic regression. This base specification is first estimated without sector and region controls. Then region controls are included. Finally, both sector and region controls are included in the specification.

4. RESULTS

This section starts with the firms' distribution within the sample regarding their answers to the question that asks the biggest obstacle their establishments faced with. There are 15 potential answers to the biggest obstacle question: Access to finance, labor regulations, practices of competitors in the informal sector, access to land, business licensing and permits, corruption, political instability, courts, crime, electricity, customs and trade regulations, theft and disorder, inadequately educated workforce, tax administration, tax rates and transport. Table 1[4] presents the share of five biggest obstacles that affect the operations of the establishments[5]. It is observed that 6% of the firms report inadequately educated labor force as their biggest obstacle making it the top 5th obstacle among 15 possible

[4] Figure A1 in Appendix presents the worldwide percentages of manufacturing firms which choose inadequately educated workforce as their biggest obstacle.

[5] Sample weights are used for all calculations.

obstacles that an establishment faced with among Turkish manufacturing firms[6].

Table 1: Biggest obstacle affecting the operation of the establishments

	%
Access to finance	27.05
Tax rates	26.95
Political instability	19.23
Electricity	8.23
Inadequately educated workforce	6.05

Table 2 documents all variables' summary statistics. The statistics indicate that 9% of the firms included in the sample engage in innovation activities and 81% of the firms consider inadequately educated workforce[7] as an obstacle. The average firm age and log(sales) are 18 years and 16.2, respectively. The table also shows that approximately one-third of the firms are exporters (33%), offer formal training to their employers (26%), have internationally recognized quality certification (38%) and are multi-establishment (5%).

Table 2: Summary statistics

Variable	Mean	Minimum	Maximum
Innovation	.087	0	1
IEW obstacle	.815	0	1
Firm age	18.293	2	99
Age-squared	506.705	4	9801
Log(sales)	16.262	10.82	18.498
Exporter	.325	0	1
Formal training	.256	0	1
Certification	.375	0	1
Multiestablishment	.049	0	1

Table 3 documents the log odds ratios of the three specifications of the logistic regressions where the main variable

[6] Access to finance, tax rates, political instability and electricity are among the top 4 biggest obstacles that the establishments faced with.

[7] Detailed distribution of the inadequately educated workforce obstacle question is given in Table A1 in Appendix.

of interest in IEW (inadequately educated workforce) obstacle. The findings indicate strong negative coefficient of IEW for all specifications indicating that as firms consider inadequately educated labor force as an obstacle for their operations, they are less likely to engage in innovation activities. This finding is consistent with Leiponen (1996) and Khadan (2018) that demonstrate negative relationship between human capital constraints and innovation activities. It can be argued that firms with educated labor are expected to adopt and implement innovation activities more easily. The coefficients of the age variable indicate a U-shaped relationship between the likelihood of innovation activities and age. In other words, the probability of conducting innovation activities first declines after the firm starts its operations, then this probability increases after a threshold age level. It makes sense in terms of the fact that firms usually initiate innovation activities as they maintain a good performance level. All remaining control variables (sales, exporter, formal training, certification, and multi-establishment) are positively associated with the probability of introducing new products/process.

Table 3: Estimation results (log-odds ratio)

	(1)	(2)	(3)
IEW obstacle	-0.634***	-0.438***	-0.690***
	(0.046)	(0.054)	(0.061)
Firm age	-0.012***	-0.042***	-0.033***
	(0.004)	(0.004)	(0.006)
Firm age-squared	0.000**	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Log(sales)	0.071***	0.254***	0.328***
	(0.016)	(0.021)	(0.023)
Exporter	0.998***	1.304***	1.512***
	(0.036)	(0.041)	(0.050)
Formal training	0.502***	1.524***	1.095***

	(0.042)	(0.061)	(0.068)
Certification	0.759***	0.537***	0.163***
	(0.039)	(0.042)	(0.051)
Multiestablishment	1.388***	0.636***	1.219***
	(0.060)	(0.064)	(0.074)
Constant	-3.483***	-6.398***	-7.594***
	(0.262)	(0.344)	(0.408)
Sector Controls	No	No	Yes
Region Controls	No	Yes	Yes
Observations	723	723	723

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$

5. CONCLUSION

This paper attempts to fill the gap on the extent to which inadequately educated workforce hinders innovation decisions of small and medium sized enterprises operating in manufacturing sector in Türkiye. The statistics indicate that Turkish firms ranked inadequately educated workforce among important obstacles for their operations. Shedding light on the relationship between innovation and inadequately educated workforce is critical for policymakers when the importance of innovation activities on countries' economic growth is considered. In this regard, this paper employed several logistics regression to provide empirical evidence.

The findings indicate that constraints regarding human capital have statistically significantly negative effect on firm-level innovation decisions in Turkish manufacturing sector. Firms who consider inadequately educated workforce as an obstacle are less likely to engage in innovation activities. In addition to this finding, in-firm formal training is found to be positively associated with innovation decisions. Among the other controls, the relationship between the probability of innovation and age is

found to be U-shaped. Sales, being an exporter, having an internationally recognized certification and being a multi-establishment firm are also positively associated with the likelihood of introducing new products/process.

The factors underlying the negative association between innovation decisions and human capital constraints may be attributed to low quality of education, skills mismatches, and shortages within the Turkish framework. A careful future analysis with a more inclusive and up to date dataset is required to examine the underlying factors of this relationship. Information asymmetries between educational and training institutions and labor demand of the private sector signals like an important aspect to be considered. Other obstacles that firms face should also be evaluated for a comprehensive approach to identify innovation decisions and paths of firms.

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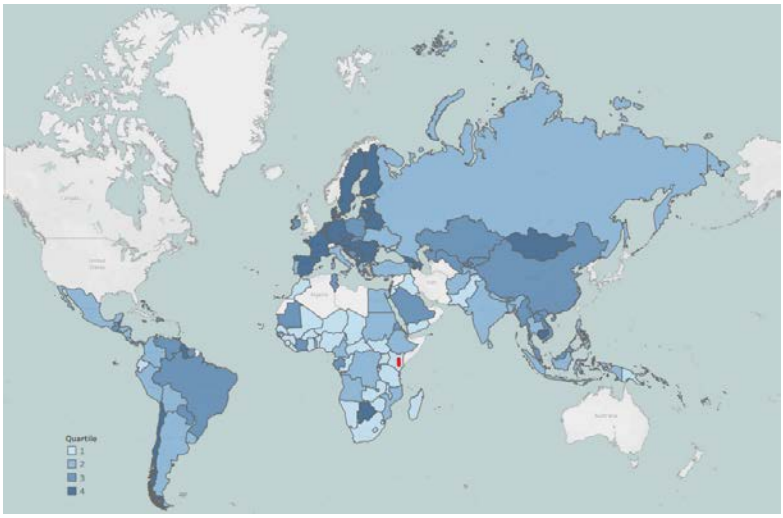
APPENDIX

Figure A1: Percent of firms choosing inadequately educated workforce as their biggest obstacle (Manufacturing sector)



Source: World Bank, Enterprise Surveys website.
https://www.enterprisesurveys.org/en/graphing-tool

Table A1: Distribution of firms considering inadequately educated workforce as an obstacle

	%
No obstacle	18.11
Minor obstacle	15.75
Moderate obstacle	40.09
Major obstacle	19.75
Very severe obstacle	6.30

TECHNOLOGICAL CATCH-UP AND ECONOMIC GROWTH: A PANEL DATA ANALYSIS

Fatma Muazzez UTKU-İSMİHAN[1]

1. INTRODUCTION

One of the focus areas of economic growth literature is the relationship between technological catch-up and economic growth performances of countries. Following the successful catch-up of efforts of East Asian countries, the importance integrating technological factors into industrial policies have been seen as a way for structural transformation by many developing countries.[2] The notion of catch-up was first introduced by Gerschenkron (1962). Gerschenkron (1962) and his followers argue that in terms of technology there is a leading country, and the follower countries are trying to catch-up the leader country in order to attain higher growth rates and eventually reduce the technological gap by imitating the frontier technologies of the leaders. However, there were only few countries were successful at catching up the leading countries while the majority were stuck at the "middle income trap" or worse could not get out of the "low income trap". Thus, as it turned out technological catch-up is a complex process that requires skilled human capital, ability to adapt and create new technologies, necessary institutional and physical infrastructure and more importantly financial means to establish these requirements. The lack of these capabilities

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[2] See for example Ames and Rosenberg (1963), Nelson (1993) and Dosi (1988).

prevents countries to use the available technology to take-off or catch-up with the leading economies.

More importantly, there is also the time constraint for adopting new technologies. Comin and Hobijn (2004) indicate that most new technologies originated in leading countries and the follower countries are in general very slow in adopting these new technologies. The process of adoption in the following countries are so slow that by the time they had the chance to adopt the current technology the leading countries started to use more advanced technologies. According to Comin and Hobijn (2004) main the factors that positively contributed to the speed of adoption were per capital GDP, human capital, openness to trade and the determination of the policy makers.

This paper investigates the main factors that contribute to the technological catch-up process of 167 countries using panel data from 1990 to 2019.[3] This multi-country analysis gives us the opportunity to see the diffusion of technology between countries and the potential of lagging countries to catch-up with the leading countries. The paper is organized as follows, section 2 provides a brief literature review. Section 3 gives information about the model and empirical results followed section 4 which provides the concluding remarks.

2. BRIEF LITERATURE REVIEW

The neoclassical growth model, based on Solows' (1956) model, predicts that in the long run, eventually, the growth rates of developing countries would converge to the growth levels of the developed countries since technology was freely available to all countries. However, as the years passed, with the exception of few East Asian countries, the opposite gap between the developed

[3] The Penn World Tables (PWT 9) have data available until 2019.

and developing countries widened. Led by Gerschenkron (1962) a group of economists argued that technological-gap was the prime cause for differences in the growth rates of developed and developing countries (Fagerberg, 1994). In other words, these economist saw technological-gap as the main factor for the economic growth rate difference between countries.

Nelson and Phelps (1966) emphasized the importance of human capital accumulation for the ability of the follower countries to use the technology transfered from the leading countries and to develop new Technologies. In their study they utilized the catch-up hypothesis of Gerschenkron (1962). In their model human capital determines the rate at which the technological gap between the leader and follower country would close. That is,

$$\frac{\dot{A}_t}{A_t} = c(h) \left[\frac{T_t - A_t}{A_t} \right] \qquad (1)$$

where A_t is the total factor productivity at time t, h is the human capital and T_t is the theoretical knowledge at time t.

Equation (1) postulates that the speed of convergence of technology between developing and developed countries is determined by the level of human capital stock. Thus the main contribution of Nelson and Phelps (1966) is that they included human capital (i.e. education as is referred by the authors) into the production function and moreover the most important contribution of Nelson and Phelps (1966) is they included education indirectly into the production function so that it does not cause "gross misspecification of the relation between education and the dynamics of production" (Nelson and Phelps, 1966:75). Later, Benhabib and Spiegel (1994) augmented the Nelson and Phelps' approach by utilizing the endogenous nature of technological progress. Benhabib and Spiegel (1994) used

cross-country estimates of physical and human capital stocks of 60 countries between 1965-1985 period.

In their model Benhabib and Spiegel (1994) introduced a "catch-up term" an interaction term of human capital and technology gap. Human capital is endogenous, that is, an increase in human capital causes a direct increase in the level of total factor productivity growth. In the model the following countries are trying to catch-up the technology level of the leading country and the follower countries growth rate of total factor productivity is;[4]

$$\frac{\dot{A}_{it}}{A_{it}} = g(h_i) + c(h_i) \left[\frac{\max_j A_{jt} - A_{it}}{A_{it}} \right] \qquad (2)$$

where A_{it} is the total factor productivity of the follower at time t, A_{jt} is the total factor productivity of the leader at time t, $g(h_i)$ is the "endogenous growth rate" and h_i is the followers' level of human capital.

As can be seen form Equation (2) in this model the change in a follower countries' productivity depends on the available stock of human capital and human capital both enhances the domestic capability of technological innovation and enables the adaptation and implementation of imported technology. The last term in the model is the technological catch-up , which is the technology gap, the difference between the leading countries' productivity and the productivity of the follower country divided by the productivity of follower country. That is, in their model the growth rate of total factor productivity is dependent on human capital stock level and in terms of diffusion of technology between countries they found that countries with higher education level cought the leading country much faster than the ones that had relatively low quality human capital.

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[4] The production function that they use in their study is: $Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta}$.

Comin and Hobijn (2004) sudied the evolution of 25 technologies in 23 countries during a period of 200 years. Their research showed that, in general, new technologies were produced in developed countries and the follower (developing) countries were slow to adopt these new Technologies and they found that factors that had positive impact on the speed of adoption were per capital GDP, human capital, and engaging in foreign trade, and the government type.

3. MODEL AND EMPIRICAL RESULTS

As indicated previously in this study we want to analyze the relationship between technological catch-up and economic growth performances of countries. In our model the factors that concontribute to the diffusion of technology are human capial, trade and the ability of the country to engage in research and development activities.

3.1. The Model

We have augmented Bengabib and Spiegel (2000) model by incorporating these factors. Initially we have the following Cobb-Douglas production function,

$$Y_{it} = A_{it} K_{it}^{\theta_1} L_{it}^{\theta_2} \tag{3}$$

where A is TFP,Y is output, K is capital and L is labor of country i at time t.

Then following Benhabib and Spiegel (2000) we impose constant returns to scale and obtain the per worker and growth form as follows,

$$\Delta y_{it} = \Delta a_{it} + \theta_1 \Delta k_{it} \tag{4}$$

where Δx is the growth rate of X (i.e. log difference of X) and all other variables are as defined earlier.

Equation (4) indicates that the growth rate of output is determined by the growth rates of total factor productivity (At) and physical capital (Kt). Since our aim is to investigate technological catch-up process the speed of catch-up and diffusion of technology for follower countries is modeled as follows:

$$\Delta a_{it} = \alpha_0 + \alpha_1 \Delta y_{it-1} + \alpha_2 h + \alpha_3 RD + \alpha_4 T + \beta_1 H \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] + \beta_2 RD \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] + \beta_3 T \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] \quad (5)$$

where Ypit is the per capita output of country i at time t, Δy_{it} is the per capita output of country i at time t-1, Yp_{maxt} is the per capita output of the leading country at time t, $[(Yp_{maxt}/\ Yp_{it})/\ Yp_{it}]$ represents the economic (technological) backwardness of country i and all the variables are as defined before.

In Equation (5) the three variables following the lag term represent the endogenous technical progress ability of country i at time t to innovate and the latter three terms present the catch-up effect of each endogenous technical progress. Following Benhabib and Spiegel (2000) and others in this model we assume the leader country to be USA.[5]

Inserting Equation (4) into (5) gives us,

$$\Delta y_{it} = \alpha_0 + \alpha_1 \Delta y_{it-1} + \alpha_2 h + \alpha_3 RD + \alpha_4 T + \beta_1 h \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] + \beta_2 RD \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] + \beta_3 T \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right]$$

[5] See for example, Inklaar and Timmer (2013).

$$+\gamma t + \phi i + \theta_1 \Delta k_{it} \qquad (6)$$

where all the variables are as defined earlier.

3.2.The Empirical Results

We have augmented Bengabib and Spiegel (2000) model by incorporating these factors. Initially we have the following Cobb-Douglas production function,

Equation (3.8) is re-stated for empirical purpose in stochastic form as follows

$$\Delta y_{it} = \alpha_0 + \alpha_1 \Delta y_{it-1} + \alpha_2 h + \alpha_3 RD + \alpha_4 T + \beta_1 h \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] + \beta_2 RD \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] + \beta_3 T \left[\frac{Yp_{max\,t} - Yp_{it}}{Yp_{it}}\right] + \gamma t + \phi i + \theta_1 \Delta k_{it} + \varepsilon_{it} \qquad (7)$$

where all the variables are as defined before and ε_{it} is the error term.

We will estimate our model by utilizing Panel Data Regression using balanced panel data from 167 countries[6] from 1990 to 2019.[7] The main reason as to why we have preferred to use panel data regression analysis are; firstly panel data suggests that countries are heterogeneous; panel data simplifies computation and statistical inference; in panel data when time series data are not stationary and observations among cross-sectional units are independent then the limiting distributions of many estimators remain asymptotically normal; with multiple observations for a given country this method of estimation helps

[6] The list of countries are provided in Appendix 1.

[7] The World Development Indicators (WDI) data set of World Bank and recent version of the Penn World Tables (PWT 9) are used in this study. The main variables that are used in the model are output (Y), capital stock (K), human capital (h) are from WDI and research and development (RD) and foreign trade (T) are obtained from PWT 9.

us to overcome under identification problem; it is better at uncovering dynamic relationships; it has greater capacity for capturing the complexity of variables (in our case countries) than a single cross-section; and finally it has less multicolinearity among the variables, more degrees of freedom and more efficiency compared to cross section.[8]

The descriptive statistics of the variables and the correlation between the variables are presented in Table 1 (Appendix 2 provides descriptive statistics of the variables for different income groups) and Table 2, respectively.

To cross check our model, as can be seen in Table 3, three models were estimated. Model 1 is a model that investigates the relationship between real GDP per worker (Δlny) and capital stock per worker (Δlnk). This model is provided for robustness check. In Model 2 Benhabib and Spiegel's' (2000) specification– a la Nelson and Phelps – was replicated using our data, this will be our benchmark model. The last model is our technological catch-up model.[9]

Table 1 Descriptive Statistics of the Variables

Variable	*Definition*	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Δy	*Log difference of real GDP per worker at current PPPs (in mil. 2005US$)*	3154	0.016132	0.108931	-2.05041	1.131728

[8] Of course we are also aware of (and in some instances have experienced) the limitations of panel data, i.e. design and data collection problems, distortions of measurement errors, short time series dimension and selectivity problems.

[9] The models in Table 3 are the final fixed effect robust estimated models selected after the process that are explained bellow.

Δk	*Log difference of Capital stock per worker at PPPs (in mil. 2005US$)*	3161	0.036307	0.071431	-0.51668	0.93589
h	*Human capital per worker (based on years of schooling and returns to education)*	2728	2.404274	0.5751	1.128569	3.618748
RD	*Research and development expenditure (% of GDP)*	1112	0.984021	0.979467	0.00614	4.83528
T	*Trade (% of GDP)*	3274	87.21296	52.09514	10.83072	562.0604
C_h	*Human Capital Catch up term*	2728	20.92425	31.87939	-1.40089	484.0117
C_RD	*R&D Catch up term*	1112	1.730347	3.460613	-0.79196	60.48601
C_T	*Trade Catch up term*	3274	811.0216	1413.421	-153.369	22269.11

Note: C_ is the catch up term, that is C_= $\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right]$ and C_x = $x\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right]$, for example C_h = $h\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right]$. Yp_{maaxt} is the GDP per worker of USA at time t.

Table 2. Correlation Table

	Δk	**h**	**RD**	**T**	**C_h**	**C_RD**	**C_T**
Δk	1						
h	0.0277	1					
RD	-0.071	0.5094	1				
T	0.0458	0.1455	-0.0455	1			
C_h	-0.0352	-0.4321	-0.2959	-0.1041	1		
C_RD	0.0186	-0.5277	-0.2169	-0.1827	0.6768	1	
C_T	-0.0436	-0.418	-0.2602	-0.0313	0.8975	0.6621	1

Table 3. Panel Data Analysis (Δlny)

VARIABLES	**Model 1**	**Model 2 Benhabib and Spiegel**	**Model 3 Our Model**
L.dlny	0.003128	0.043626	-0.448471**
dlnk	0.364597***	0.358585***	0.327856***
h		0.050287**	0.180227**
RD			-0.017042*
T			0.000724***
C_h		-0.001146***	-0.004218**
C_RD			0.002549
C_T			-0.000016***
Constant	0.002080	-0.092517*	-0.400983**
Observations	2596	2136	689
Countries	134	108	86

*** p<0.01, ** p<0.05, * p<0.1

Due to the possibility that there may be unobserved heterogeneity in the explanatory variables of our model and that this unobserved heterogeneity may be correlated with the explanatory variables, fixed effects estimator was used, to allow for a country fixed effect that is correlated with the determinants.[10]

To check for autocorrelation and heteroskedasticity Wooldridge autocorrelation test and Wald test for group wise heteroskedasticity were used. The Wooldridge autocorrelation

[10] The Hausman Test also supported our decision. The results of the Hausman Test, also supports our choice of estimators in Model 2.

test indicated that the null hypothesis of no serial correlation could not be rejected (Wooldridge test: Prob > F = 0.0758), in other words there was no evidence of autocorrelation at 5% significance level. In the Modified Wald test for group wise heteroskedasticity the null hypothesis is homoskedasticity (or constant variance). According to Modified Wald test for group wise heteroskedasticity in fixed effect regression of our model (Prob>chi2 = 0.0000) the null hypothesis was rejected, that is there was a presence of heteroskedasticity. To overcome this problem Huber/White or sandwich estimators, i.e. heteroskedasticity-robust standard errors were used.

As can be seen from Table 3 in the fixed effects estimations of Model 2 all control variables are significant. That is, all the variables representing the endogenous technical progress ability of countries (h, RD and T) seems to be statistically significant at conventional critical values and theoretically consistent. The estimated coefficients of human capital (h) and capital accumulation (k) are both statistically significant and have the expected signs, i.e. they have a positive impact on the productivity growth of countries.

There is a controversy in the literature with regards the impact of R&D (RD) on economic growth. In our model (Model 3) R&D is statistically significant and has a negative impact on productivity growth. This is an expected result. The countries in our sample are very heterogeneous in terms of income and technological capability. These factors have direct impact on R&D investment decisions. The counties with little tolerance or could not afford the cost of ambiguity in R&D would prefer not investing in R&D. Moreover, although R&D is vital for many innovation activities of countries and their competitiveness, for the countries that are lagging well behind, absorptive capacity of the existing technologies rather than innovative capacity may be more important.

Even though our estimated coefficient on foreign trade (T) seems to have positive impact on productivity growth, due to the heterogeneity between the income levels of the countries in our sample, the nature of the trade between countries can vary significantly.

Regarding the catch-up terms, the estimated coefficients for human capital catch-up term (C_h) and trade catch-up term (C_T) are highly statistically significant. The catch-up term of R&D (C_RD) is positive but insignificant at conventional critical values.

The catch-up terms of human capital (C_h) and trade (C_T) are negative and this can be an indicator of a "catch-up trap". Thus, contradictory to the traditional Nelson and Phelps approach and consistent with the predictions of the researchers such as Cozzi and Giordani (2011), the further the country is behind the leader (technological frontier), the lower is the rate of productivity growth, i.e. the possibility of catch-up is very difficult. Thus, unless a country does not have a sufficient absorption capability it cannot catch-up with the leading country.

Thus, our analysis indicates that the standard convergence approach (i.e. Bengabib and Spiegel, 2000) ignores the heterogeneity among countries. That is, countries were assumed to be homogeneous even though they have fundamentally different structures in terms of absorptive capacity, income, institutional systems, and so on. One of the most important results of our study is that Gerschenkrons' catch-up hypothesis[11] does not hold in reality. That is, the follower country can catch the leader country only if the initial gap between them is not too wide, otherwise countries end up in a catch-up trap. In sum,

[11] Gerschenkrons' catch-up hypothesis is that, the larger the initial (knowledge) gap that separates a follower country from the leading country is the higher is the catch-up potential of the follower country.

convergence is much easier among countries with similar social and absorptive capabilities.[12]

4. CONCLUSION

In this paper analyzed the impact of technological capability of follower countries in catching-up with the leading countries' GDP per capita. In order to do so we utilized various variables that indicate the technological capability of the following country and some catch-up terms as a key economic convergence indicators.

Our results indicate that technological capability indicators, as proxied by total factor productivity, are important for economic growth, but there is substantial variance across country groups in the relative importance of these indicators for economic growth. As we have seen, one of the fundamental drawbacks of the current cross country models are their homogenous structure even though there is a large heterogeneity across country groups. So it is important to analyse in more detail how the different income groups are doing on various technological capability indicators.

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[12] See, for example, Jovanovic (1998) and Hobijn (2001) for more detail. Similarly Basu and Weil (1998) with their appropriate technology model argue that new technologies can only be implemented successfully by countries with appropriate endowments.

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APPENDIX 1. LIST OF COUNTRIES

COUNTRY	*Code*	*Region*	*Income group*
Afghanistan	AFG	South Asia	Low income
Albania	ALB	Europe & Central Asia	**Upper middle income**
Algeria	DZA	Middle East & North Africa	Upper middle income
American Samoa	ASM	East Asia & Pacific	Upper middle income
Andorra	ADO	..	High income: nonOECD
Angola	AGO	Sub-Saharan Africa	Upper middle income
Antigua and Barbuda	ATG	**..**	**High income: nonOECD**
Argentina	ARG	Latin America & Caribbean	Upper middle income
Armenia	ARM	Europe & Central Asia	Lower middle income
Aruba	ABW	..	High income: nonOECD
Australia	AUS	..	High income: OECD
Austria	AUT	..	High income: OECD
Azerbaijan	AZE	Europe & Central Asia	Upper middle income
Bahamas, The	BHS	..	High income: nonOECD
Bahrain	BHR	..	High income: nonOECD
Bangladesh	BGD	South Asia	Low income
Barbados	BRB	..	High income: nonOECD
Belarus	BLR	Europe & Central Asia	Upper middle income
Belgium	BEL	..	High income: OECD
Belize	BLZ	Latin America & Caribbean	**Upper middle income**
Benin	BEN	Sub-Saharan Africa	Low income
Bermuda	BMU	..	High income: nonOECD
Bhutan	BTN	South Asia	Lower middle income
Bolivia	BOL	Latin America & Caribbean	Lower middle income
Bosnia and Herzegovina	BIH	Europe & Central Asia	Upper middle income
Botswana	BWA	Sub-Saharan Africa	Upper middle income
Brazil	BRA	Latin America & Caribbean	Upper middle income
Brunei Darussalam	BRN	..	High income: nonOECD
Bulgaria	BGR	Europe & Central Asia	Upper middle income
Burkina Faso	BFA	Sub-Saharan Africa	Low income
Burundi	BDI	Sub-Saharan Africa	Low income
Cambodia	KHM	East Asia & Pacific	Low income
Cameroon	CMR	Sub-Saharan Africa	Lower middle income
Canada	CAN	..	High income: OECD
Cape Verde	CPV	Sub-Saharan Africa	Lower middle income

Cayman Islands	CYM	..	High income: nonOECD
Central African Republic	CAF	Sub-Saharan Africa	Low income
Chad	TCD	Sub-Saharan Africa	Low income
Channel Islands	CHI	..	High income: nonOECD
Chile	CHL	**..**	**High income: OECD**
China	CHN	East Asia & Pacific	Upper middle income
Colombia	COL	Latin America & Caribbean	Upper middle income
Comoros	COM	Sub-Saharan Africa	Low income
Congo, Dem. Rep.	ZAR	Sub-Saharan Africa	Low income
Congo, Rep.	COG	Sub-Saharan Africa	Lower middle income
Costa Rica	CRI	Latin America & Caribbean	Upper middle income
Côte d'Ivoire	CIV	Sub-Saharan Africa	Lower middle income
Croatia	HRV	..	High income: nonOECD
Cuba	CUB	Latin America & Caribbean	Upper middle income
Curaçao	CUW	..	High income: nonOECD
Cyprus	CYP	..	High income: nonOECD
Czech Republic	CZE	..	High income: OECD
Denmark	DNK	..	High income: OECD
Djibouti	DJI	Middle East & North Africa	Lower middle income
Dominica	DMA	Latin America & Caribbean	Upper middle income
Dominican Republic	DOM	Latin America & Caribbean	Upper middle income
Ecuador	ECU	Latin America & Caribbean	Upper middle income
Egypt, Arab Rep.	EGY	Middle East & North Africa	Lower middle income
El Salvador	SLV	Latin America & Caribbean	Lower middle income
Equatorial Guinea	GNQ	..	High income: nonOECD
Eritrea	ERI	Sub-Saharan Africa	Low income
Estonia	EST	..	High income: OECD
Ethiopia	ETH	Sub-Saharan Africa	Low income
Faeroe Islands	FRO	..	High income: nonOECD
Fiji	FJI	East Asia & Pacific	**Upper middle income**
Finland	FIN	..	High income: OECD
France	FRA	..	High income: OECD
French Polynesia	PYF	..	High income: nonOECD
Gabon	GAB	Sub-Saharan Africa	Upper middle income
Gambia, The	GMB	Sub-Saharan Africa	Low income
Georgia	GEO	Europe & Central Asia	Lower middle income

Germany	DEU	..	High income: OECD
Ghana	GHA	Sub-Saharan Africa	Lower middle income
Greece	GRC	..	High income: OECD
Greenland	GRL	..	High income: nonOECD
Grenada	GRD	Latin America & Caribbean	Upper middle income
Guam	GUM	..	High income: nonOECD
Guatemala	GTM	Latin America & Caribbean	Lower middle income
Guinea	GIN	Sub-Saharan Africa	Low income
Guinea-Bissau	GNB	Sub-Saharan Africa	Low income
Guyana	GUY	Latin America & Caribbean	Lower middle income
Haiti	HTI	Latin America & Caribbean	Low income
Honduras	HND	Latin America & Caribbean	Lower middle income
Hong Kong SAR, China	HKG	..	High income: nonOECD
Hungary	HUN	**Europe & Central Asia**	**Upper middle income**
Iceland	ISL	..	High income: OECD
India	IND	South Asia	Lower middle income
Indonesia	IDN	East Asia & Pacific	Lower middle income
Iran, Islamic Rep.	IRN	Middle East & North Africa	Upper middle income
Iraq	IRQ	Middle East & North Africa	**Upper middle income**
Ireland	IRL	..	High income: OECD
Isle of Man	IMY	..	High income: nonOECD
Israel	ISR	..	High income: OECD
Italy	ITA	..	High income: OECD
Jamaica	JAM	Latin America & Caribbean	Upper middle income
Japan	JPN	..	High income: OECD
Jordan	JOR	Middle East & North Africa	Upper middle income
Kazakhstan	KAZ	Europe & Central Asia	Upper middle income
Kenya	KEN	Sub-Saharan Africa	Low income
Kiribati	KIR	East Asia & Pacific	Lower middle income
Korea, Dem. Rep.	PRK	East Asia & Pacific	Low income
Korea, Rep.	KOR	..	High income: OECD
Kosovo	KSV	Europe & Central Asia	Lower middle income
Kuwait	KWT	..	High income: nonOECD
Kyrgyz Republic	KGZ	Europe & Central Asia	Low income
Lao PDR	LAO	East Asia & Pacific	Lower middle income
Latvia	LVA	**..**	**High income: nonOECD**
Lebanon	LBN	Middle East & North Africa	Upper middle income
Lesotho	LSO	Sub-Saharan Africa	Lower middle income
Liberia	LBR	Sub-Saharan Africa	Low income

Libya	LBY	Middle East & North Africa	Upper middle income
Liechtenstein	LIE	..	High income: nonOECD
Lithuania	LTU	**..**	**High income: nonOECD**
Luxembourg	LUX	..	High income: OECD
Macao SAR, China	MAC	..	High income: nonOECD
Macedonia, FYR	MKD	Europe & Central Asia	Upper middle income
Madagascar	MDG	Sub-Saharan Africa	Low income
Malawi	MWI	Sub-Saharan Africa	Low income
Malaysia	MYS	East Asia & Pacific	Upper middle income
Maldives	MDV	South Asia	Upper middle income
Mali	MLI	Sub-Saharan Africa	Low income
Malta	MLT	..	High income: nonOECD
Marshall Islands	MHL	East Asia & Pacific	**Upper middle income**
Mauritania	MRT	Sub-Saharan Africa	**Lower middle income**
Mauritius	MUS	Sub-Saharan Africa	Upper middle income
Mexico	MEX	Latin America & Caribbean	Upper middle income
Micronesia, Fed. Sts.	FSM	East Asia & Pacific	Lower middle income
Moldova	MDA	Europe & Central Asia	Lower middle income
Monaco	MCO	..	High income: nonOECD
Mongolia	MNG	East Asia & Pacific	Lower middle income
Montenegro	MNE	Europe & Central Asia	Upper middle income
Morocco	MAR	Middle East & North Africa	Lower middle income
Mozambique	MOZ	Sub-Saharan Africa	Low income
Myanmar	MMR	East Asia & Pacific	Low income
Namibia	NAM	Sub-Saharan Africa	Upper middle income
Nepal	NPL	South Asia	Low income
Netherlands	NLD	..	High income: OECD
New Caledonia	NCL	..	High income: nonOECD
New Zealand	NZL	..	High income: OECD
Nicaragua	NIC	Latin America & Caribbean	Lower middle income
Niger	NER	Sub-Saharan Africa	Low income
Nigeria	NGA	Sub-Saharan Africa	Lower middle income
Northern Mariana Islands	MNP	..	High income: nonOECD
Norway	NOR	..	High income: OECD
Oman	OMN	..	High income: nonOECD
Pakistan	PAK	South Asia	Lower middle income

Palau	PLW	East Asia & Pacific	Upper middle income
Panama	PAN	Latin America & Caribbean	Upper middle income
Papua New Guinea	PNG	East Asia & Pacific	Lower middle income
Paraguay	PRY	Latin America & Caribbean	Lower middle income
Peru	PER	Latin America & Caribbean	Upper middle income
Philippines	PHL	East Asia & Pacific	Lower middle income
Poland	POL	..	High income: OECD
Portugal	PRT	..	High income: OECD
Puerto Rico	PRI	..	High income: nonOECD
Qatar	QAT	..	High income: nonOECD
Romania	ROM	Europe & Central Asia	Upper middle income
Russian Federation	RUS	..	**High income: nonOECD**
Rwanda	RWA	Sub-Saharan Africa	Low income
Samoa	WSM	East Asia & Pacific	Lower middle income
San Marino	SMR	..	High income: nonOECD
São Tomé and Principe	STP	Sub-Saharan Africa	Lower middle income
Saudi Arabia	SAU	..	High income: nonOECD
Senegal	SEN	Sub-Saharan Africa	Lower middle income
Serbia	SRB	Europe & Central Asia	Upper middle income
Seychelles	SYC	Sub-Saharan Africa	Upper middle income
Sierra Leone	SLE	Sub-Saharan Africa	Low income
Singapore	SGP	..	High income: nonOECD
Sint Maarten (Dutch part)	SXM	..	High income: nonOECD
Slovak Republic	SVK	..	High income: OECD
Slovenia	SVN	..	High income: OECD
Solomon Islands	SLB	East Asia & Pacific	Lower middle income
Somalia	SOM	Sub-Saharan Africa	Low income
South Africa	ZAF	Sub-Saharan Africa	Upper middle income
South Sudan	SSD	Sub-Saharan Africa	**Low income**
Spain	ESP	..	High income: OECD
Sri Lanka	LKA	South Asia	Lower middle income
St. Kitts and Nevis	KNA	Latin America & Caribbean	High income: nonOECD
St. Lucia	LCA	Latin America & Caribbean	Upper middle income
St. Martin (French part)	MAF	..	High income: nonOECD
St. Vincent and the Grenadines	VCT	Latin America & Caribbean	Upper middle income
Sudan	SDN	Sub-Saharan Africa	Lower middle income
Suriname	SUR	Latin America & Caribbean	Upper middle income

Swaziland	SWZ	Sub-Saharan Africa	Lower middle income
Sweden	SWE	..	High income: OECD
Switzerland	CHE	..	High income: OECD
Syrian Arab Republic	SYR	Middle East & North Africa	Lower middle income
Tajikistan	TJK	Europe & Central Asia	Low income
Tanzania	TZA	Sub-Saharan Africa	Low income
Thailand	THA	East Asia & Pacific	Upper middle income
Timor-Leste	TMP	East Asia & Pacific	Lower middle income
Togo	TGO	Sub-Saharan Africa	Low income
Tonga	TON	East Asia & Pacific	**Upper middle income**
Trinidad and Tobago	TTO	..	High income: nonOECD
Tunisia	TUN	Middle East & North Africa	Upper middle income
Turkey	TUR	Europe & Central Asia	Upper middle income
Turkmenistan	TKM	Europe & Central Asia	Upper middle income
Turks and Caicos Islands	TCA	..	High income: nonOECD
Tuvalu	TUV	East Asia & Pacific	Upper middle income
Uganda	UGA	Sub-Saharan Africa	Low income
Ukraine	UKR	Europe & Central Asia	Lower middle income
United Arab Emirates	ARE	..	High income: nonOECD
United Kingdom	GBR	..	High income: OECD
United States	USA	..	High income: OECD
Uruguay	URY	..	**High income: nonOECD**
Uzbekistan	UZB	Europe & Central Asia	Lower middle income
Vanuatu	VUT	East Asia & Pacific	Lower middle income
Venezuela, RB	VEN	Latin America & Caribbean	Upper middle income
Vietnam	VNM	East Asia & Pacific	Lower middle income
Virgin Islands (U.S.)	VIR	..	High income: nonOECD
West Bank and Gaza	WBG	Middle East & North Africa	Lower middle income
Yemen, Rep.	YEM	Middle East & North Africa	Lower middle income
Zambia	ZMB	Sub-Saharan Africa	Lower middle income
Zimbabwe	ZWE	Sub-Saharan Africa	Low income

APPENDIX 2. DESCRIPTIVE STATISTICS FOR EACH COUNTRY GROUP

LOW INCOME GROUP: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
h	506	1.7199	0.4244	1.12857	2.85849
RD	88	0.1937	0.10959	0.01748	0.53299
T	650	59.933	27.2512	10.8307	199.675
C_h	506	59.423	40.2631	3.23752	294.862
C_RD	88	7.643	8.36058	0.36935	60.486
C_T	650	2100.1	2004.63	184.185	17858.3

LOWER MIDDLE INCOME GROUP: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
h	638	2.11971	0.47096	1.16042	3.161489
RD	166	0.33191	0.28822	0.00614	1.1923
T	750	80.0499	34.4863	11.0874	209.8743
C_h	638	30.9829	32.4939	4.77096	484.0117
C_RD	166	3.31939	3.31526	0.16958	21.99467
C_T	750	1134.48	1098.36	94.7471	14978.71

HIGH MIDDLE INCOME GROUP: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
h	638	2.5044	0.32933	1.73488	3.26806
RD	320	0.5167	0.33342	0.01611	1.83704
T	870	91.435	40.4559	13.7531	223.064
C_h	638	9.3177	4.74039	2.50405	27.4385
C_RD	320	1.6381	1.4836	0.06746	7.3489
C_T	870	339.9	220.86	28.675	2023.25

HIGH INCOME GROUP: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
h	946	2.8947	0.28738	2.02183	3.61875
RD	538	1.5925	1.07536	0.01592	4.83528
T	1004	106.57	71.8216	15.924	562.06
C_h	946	1.3759	2.03658	-1.40089	7.88699
C_RD	538	0.3278	0.53134	-0.79196	2.30161
C_T	1004	143.06	1086.92	-153.369	22269.1

TESTING THE VALIDITY OF CROWDING-OUT EFFECT BASED ON TIME-VARYING PARAMETER VAR MODEL IN AGRICULTURAL SECTOR: EVIDENCES FROM AN EMERGING MARKET

Hakan SÖNMEZ[1]

1. INTRODUCTION

Public and private sector fixed capital investments are two instruments that have an impact on economic growth. Liberalization policies have gained prominence since the 1980s, leading to a decrease in public expenditures in Turkey and around the world. During this period, private sector investments have increased, which underscores the importance of assessing the effectiveness of the implemented policies. Thus, it is necessary to analyze the economic effects of investment expenditures made by the government and the private sector in Turkey. The balanced distribution of sectoral investment decisions has a significant impact on economic growth especially considering the period when the economy exhibits fluctuating performance.

Theoretical approaches regarding the impact of public investments on private sector investments are based on the fundamental concepts of crowding-out and crowding-in effects. The crowding-out effect, which is defined as the decrease in private sector investments resulting from the increased public investment expenditures financed through domestic borrowing, leads to an increase in interest rates. This effect is applicable in

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areas where the public sector can compete with the private sector, resulting in a contraction of private sector investments (Uysal & Mucuk, 2004; Altunöz, 2013). On the other hand, the positive impact of public sector investment expenditures on private sector investment expenditures is described as the crowding-in effect. In this case, public investments complement private sector investments, reducing private sector costs and increasing profitability. The nature of the relationship between these two investment tools, whether competitive or complementary, depends on the scale of the government's investment expenditures in the economy (Cural et al., 2013; Tülümce & Buyrukoğlu, 2013).

There are various assumptions regarding the concepts of crowding-out and crowding-in effects in the economic literature. The impact of public investment expenditures on private sector investment expenditures occurs directly and indirectly (Çil Yavuz, 2005; Demir, 2017). These effects vary according to classical, Keynesian, and Ricardian perspectives. According to the classical economic view, it is assumed that public investments have a crowding-out effect on private sector investments. This view can be explained through two main reasons. Firstly, when products produced by the private sector are also produced by the public sector, it diminishes the competitiveness of the private sector. In other words, if both the public and private sectors are competing to produce the same goods, the crowding-out effect is expected to be valid. Thus, when products that are substitutes for each other are produced by both the private sector and the public sector, it directly leads to a crowding-out effect. Secondly, increasing public expenditures by raising tax rates indirectly determines the crowding-out effect. This is because an increase in tax rates leads to higher costs and reduced profitability for investments made by the private sector. Lastly, the private sector’s willingness to invest decreases. Therefore, an increase in

public expenditures disrupts the free market mechanism and has negative effects on private sector investments, limiting economic growth according to the classical economic view (Dornbush & Fischer, 1994; Ahmed & Miller, 2000).

According to the Keynesian perspective, public spending, especially in areas such as infrastructure, transportation, education, healthcare, defense, energy, food, and agriculture, is believed to have a crowding-in impact on private sector investments. In contrast to the classical perspective, the Keynesian approach emphasizes the idea of synergy between public and private sector investments. Public investments create positive externalities that reduce the costs of private sector investments for these reason. Also, hhis is expected to increase the private sector's willingness to invest, thereby promoting investments. On teh other hand, it has been believed that an increase in public expenditures, whether financed through taxes or borrowing, has the same effect on private sector investments in the Ricardian approach, (Barro, 1974).

The development of the gross domestic product (GDP) value in the agricultural sector and fixed capital investments in the public and private sectors in Turkey can be observed in Figure 1. These data are important in terms of illustrating the distribution of investments made in the agricultural sector in Turkey. The agricultural sector in Turkey accounted for a significant portion of the agricultural GDP with 8.957.343 thousand Turkish Liras (TRY) in 1998. On the other hand, the lowest agricultural GDP value for the agricultural sector in 1998 was 8.9 billion Turkish Liras. It can be seen that the agricultural sector reached its highest agricultural GDP value in 2021 with 401.805.954 thousand TRY. However, the average GDP of the agricultural sector is approximately 120.000.000 thousand TRY. Based on these data, it is possible to say that agriculture is an important part of the economy, and agricultural GDP is increasing in the coming years.

Furthermore, there have been significant changes in public sector fived capital investments as seen in Figure 1. During this period, these investments show seasonal fluctuations. Public sector fived capital investments increased significantly between 1998 and 2021 in particular. The year 1999, which followed the Marmara earthquake and had a value of 433.512 thousand TRY, marked the lowest point in public sector fived capital investments. It is observed that support for public sector fived capital investments began after the 2001 local financial and banking crisis. The value of these investments has increased from 273.233 thousand TRY in 1998 to 17.013.299 thousand TRY by the year 2021. Moreover public sector fived capital investments, which began at a low level in 1998 with a value of 273,233 thousand TRY, increased relatively steadily until 2007. However, after 2007, these investments have rapidly increased. They have reached their peak value in 2018 with 14.400.370 thousand TRY. In 2019 and 2020. Furthermore, public sector fived capital investments have decreased compared to previous years but have remained above the average. This situation can be interpreted as an increased allocation of resources to infrastructure projects and economic growth.

Private sector fived capital investments have generally increased during the analysis period. The value, which has been 648.625 thousand TRY in 1998, has reached 19.145.996 thousand TRY in 2021. Especially in recent years, the rapid increase in private sector fived capital investments has been important in demonstrating the private sector's contribution to economic growth. Also, the average private sector fixed capital investment between 1998 and 2021 has been 5.039.929 thousand TRY. During the same period, the lowest private sector fixed capital investment has been in 2009, with a value of 1.411.417 thousand TRY. It is believed that the global financial crisis, which has had a significant impact worldwide, has played a substantial role in

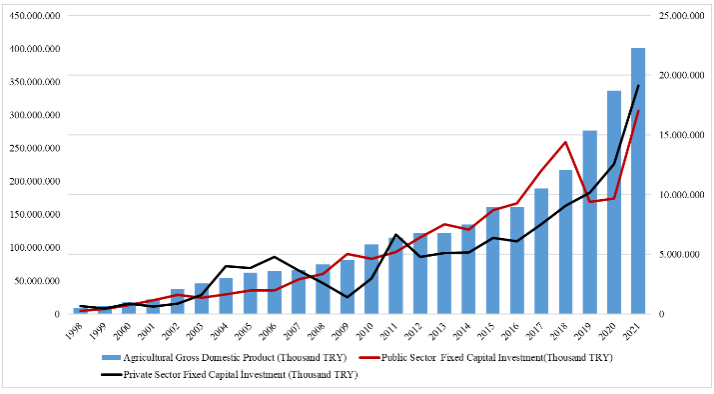
this decline. Private sector fived capital investments have reached their highest value in 2021, with 19.145.996 thousand TRY. Furthermore, private sector fived capital investments have been relatively low between 1998 and 2003, but they have started to increase from 2004 onwards rapidly. This increase has gained momentum, reaching its peak value in 2021 especially from 2010 until the onset of the COVID-19 pandemic. The data in the Figure 1 indicate a significant increase in private sector fived capital investments over the years. This result suggests that the private sector has been playing an increasingly important role in agricultural sector investments.

The agricultural sector has been a significant contribution to economic growth, alongside both public and private sector investments in Turkey. Moreover, fived capital investments in the agricultural sector, which have encompassed a range of areas such as the modernization of the sector, the acceleration of technological advancements, the strengthening of infrastructure and support, the development of transportation networks, and the renewal of storage facilities, have played a vital role in economic growth. The Turkish economy has experienced various local and global crises, as well as witnessed significant structural transformation decisions during the past 20 years, which necessitate a reevaluation of analyses in light of these changes. Hence, in order to maintain its economic growth and attain the objectives of sustainable development, Turkey has found it imperative to consider the dynamic characteristics of public and private sector investments in the agricultural sector. In this context, the central question of this study has revolved around whether public investments in the Turkish agricultural sector have excluded or included private sector investments. Furthermore, the cyclical fluctuations in the economy and the disparities specific to each sector have emphasized the necessity for detailed planning of forthcoming economic policies and investments.

Therefore, this study has undertaken an analysis to ascertain whether public sector investment expenditures have had a positive or negative impact on private sector investment expenditures. Previous research examining the impact of public investments on private sector investments in the agricultural sector has not considered the changing parameter structure over time to the best of our knowledge. In contrast to other studies, this research has analyzed the validity of the crowding-out effect using a time-varying parameter VAR (TVP-VAR) model for the first time in the agricultural sector in Turkey. Also it is believed that the study has made a significant contribution to the literature by evaluating how economic crises and structural changes in Turkey have influenced public and private sector investments in the agricultural sector.

This study is divided into five sections. The first section encompasses the introduction. Subsequently, the second section focuses on the literature review. Information is provided about econometric methods and the dataset used in the third section. The fourth section thoroughly discusses the empirical findings. In the concluding section, the study's results are presented, and potential policy recommendations are offered.

Figure 1. The Development of Agricultural GDP, Agricultural Public and Private Sector Invesments in Turkey (1998-2021)



(Source: Turkish Statistical Institute, 2023 and Republic of Turkey Presidency Strategy and Budget Office, 2023)

2. LITERATURE REVIEW

There are numerous studies in the literature, both at the national and international levels, which have analyzed the relationship between public investment expenditures and private sector investment expenditures. However, assessments need to be examined and interpreted on a country-specific basis due to variations in economic structures from one country to another and the use of different time periods in the analysis. Different findings regarding the validity of crowding-out and crowding-in effects between public investment expenditures and private sector investment expenditures have been reached when reviewing the relevant literature. From this perspective, these studies can be categorized into three main groups. The first group comprises analyses based on a single country. The second group includes studies conducted for various country groups. The third group encompasses research conducted specifically in Turkey.

The direction and causality relationship between variables have generally been analyzed in studies that focus on a single country. Also there is no complete consensus on the relationship between these variables in theoretical terms. For instance, Aschauer (1989) examined the impact of increased public spending on private investments. It was suggested that there was a crowding-in effect between these two variables using a 33 year data set for the United States. Nazmi & Ramirez (1997) has been used a broad dataset spanning 51 years and concluded that public investments increased private sector investments. In another study for the United States, Pereira (2001) found that there was a crowding-in effect of public investments on private sector investments between 1956 and 1997 using a VAR model. Mitra (2006) conducted a study that covered the period from 1965 to 2005 in India, which used the Johansen cointegration test and concluded that public investment expenditures excluded private investment expenditures. In sectoral studies, it has been observed

that public investments have a crowding-in effect on private sector investments especially related to infrastructure(Looney & Frederiken, 1997; Rossiter, 2002). As a case in point, Hossain (2010) showed that public investments had a crowding-in effect on private sector investments especially in the health and education sectors. However, some studies have identified the presence of a crowding-out effect. For example, Ghali (1998) has found a negative impact of public investments on private investments in the short term, which occurred between 1963 and 1993 in Tunisia. Voss (2002) examined the impact of public investments on private investments for the United States and Canada using a VAR model. The research indicated that public investments negatively influenced private sector investments through a crowding-out effect. Majeed & Khan (2008) used a dataset covering a 36-year period for Pakistan. The study finding concluded that public investments reduced private investments. This result indicates the presence of a crowding-out effect during the relevant period. Hatano (2010) examined the impact of public investment expenditures on private investment expenditures in Japan between 1955 and 2004 using the Johansen cointegration test. The research emphasized that public investments excluded private investments. Sahu & Panda (2012) found that there was a crowding-out effect of public investments on private sector investments in the long run during the period from 1975 to 2008 in India.

A definitive agreement has not been reached regarding whether the crowding-out or crowding-in effect has dominated in studies conducted across different country groups. Studies that have utilized panel data have often yielded results similar to those obtained for individual countries. To illustrate, Khan & Kumar (1997) have investigated the impact of public investments on private sector investments for 95 developing countries and have concluded that a crowding-in effect has been present. Odedokun

(1997) has determined that public investments in infrastructure have increased private sector investments for 48 developing countries in the long run. Argiman et al., (1997) have used panel data methodology to examine the relationship between public investments and private sector investments in 14 OECD countries, and they have found the presence of a crowding-in effect among these variables. However, some studies involving multiple countries have observed the crowding-out effect. For instance, De Gregorio (1992) has examined this effect on country groups different from other studies. Using the panel data method, he has shown that there has been a crowding-out effect between the two types of investments in 12 Latin American countries. Erden & Helcombe (2006) conducted a study, which involved the use of panel data and cointegration analysis for 16 countries in the developing country group covering a dataset that spanned 17 years. The analysis results have indicated that a crowding-in effect has been present between public investment expenditures and private investments in the long term. Atukeren (2005) examined 25 developing countries from 1970 to 2000. According to the Granger causality test result the impact of public investments on private sector investments has occurred as crowding-in in some countries and crowding-out in others. Düzgün & Bilgili (2008) have used panel data analysis for Central Asian countries from 1990 to 2003. The findings of the study have indicated that public consumption expenditures have excluded private consumption expenditures. Gjini & Kukeli (2012) have tested the exclusion effect using panel data analysis for Eastern European countries from 1991 to 2009. The test results have shown that during the relevant period, public investments have had a crowding-in effect on private sector investments.

Public investments have increased private sector investments, implying a crowding-in effect in studies conducted for Turkey. Conversely, other studies have shown the opposite situation. As an illustration, Uysal & Mucuk (2003) have demonstrated that public sector investment expenditures have excluded private sector investments between 1975 and 2000. Yavuz (2001) has utilized a dataset spanning 10 years and has concluded that public investments have reduced private investments based on the findings obtained from cointegration and vector error correction models. Furthermore, it has been deduced that public investment expenditures exhibit a crowding-out effect on private investment expenditures. Başar & Temurlenk (2007) have used a Structural Vector Autoregressive (SVAR) model over a research period of 25 years and have found a negative relationship between the two variables, with public investments weakly excluding private investments. Şen & Kaya (2014) have employed Johansen cointegration and vector error correction models to investigate the relationship between public expenditures and private investments covering the period from 1975 to 2011. The study has determined that public investments have had a negative impact on private investments, which implies the presence of a crowding-out effect. Demir (2017) has found, public investments have excluded private sector investment expenditures, indicating a crowding-out effect in the context of structural breaks between 1983 and 2013. Kaytancı (2017) has analyzed the crowding-out and crowding-in effects of public expenditures on private investments between 1985 and 2016 using the ARDL bounds testing method. The study's findings indicate the persistence of a crowding-out effect in both the short and long term. Karatay Gögül & Adıyaman (2022) have investigated the presence of a crowding-out effect using the Johansen cointegration test for the period from 1986 to 2018. The study has concluded that public fived capital investments have excluded private fived capital investments.

Research conducted in the context of Turkey has produced mixed findings, with certain studies proposing a complementary relationship between public and private investments, while others suggest a contrary effect. For instance, İyidiker & Özuğurlu (2003) have found evidence supporting the presence of a complementary effect between public and private sector investments. Çil Yavuz (2005) has employed Granger causality tests to assess the long-term impact of public spending on private sector investments and has shown that public spending has increased private sector investments. Similarly, Şimşek & Kadılar (2005) have reported the existence of a complementary effect between public and private sector investments, which implies that public spending, from 1963 to 2002, positively influences private sector investments. Kuştepeli (2005), through a study considering two different time series periods, has also provided support for the idea that public investments have positively influenced private sector investments. Günaydın (2006) has stressed that public investments have boosted both public and private sector investments over a 17-year time series. Altunç & Şentürk (2010) have examined the existence of a complementary effect between public and private sector investments in the long term from 1980 to 2009 and have found that the crowding-in effect prevails. Başar et al., (2011) have examined the presence of crowding-out effects from 1987 to 2007 using Johansen cointegration analysis. The findings have suggested a negative relationship between public investments and private investments, which indicating the presence of crowding-out effects. Cural et al., (2012) have investigated the impact of public investments on private sector investments from 1970 to 2009 using cointegration analysis. The study has indicated that public fived capital investments have exerted a crowding-in effect on private fived capital investments. Yaraşır Tülümce & Buyrukoğlu (2013), have found support for the idea that public spending excludes private investments through Granger causality tests and Johansen cointegration

results that added the interest rate variable to the model. Felor (2013) has found that public investment expenditures do not crowd out private investments but rather complement them between 1980 and 2012 using Johansen cointegration tests. Çelik (2016) has taken structural breaks into account and has investigated the crowding-in effect between public investment expenditures and private investment expenditures. The study results have revealed the validity of the crowding-in effect between the variables unlike other studies.

3. MATERIALS AND METHODS

The annual data has been used in this study covers the period from 1998 to 2021. The agricultural gross domestic product (GDP) data, which have been obtained from the database of the Turkish Statistical Institute (TÜİK), have been classified according to main activity branches. Data for public sector agricultural fixed capital investment and private sector fixed capital investment have been obtained from the database of the Presidency of the Republic of Turkey Strategy and Budget Directorate. All variables have been converted into real terms using the 2009 base-year deflator, and logarithmic transformation has been applied to all the data. Definitions related to the variables used in the model have been shown in Table 1.

Table 1. Variables and Their Descriptions

Vairable Name	Abbreviation	Source
Agricultural Gross Domestic Product (TRY)	GDPagricultural	The Turkish Statistical Institute
Public Sector Fixed Capital Investment(TRY)	INVESTMENT public	Presidency of Strategy and Budget
Private Sector Fixed Capital Investment(TRY)	INVESTMENT private	Presidency of Strategy and Budget

It is essential for the series to be stationary in the analysis of time series data. This ensures that there is no spurious regression problem, which would otherwise result in inconsistent

parameter estimates. In non-stationary time series, even when there is no statistically significant relationship among the variables included in the model, an apparent relationship is often considered. This situation can lead to the incorrect interpretation of parameters in the spurious regression equation (Baltagi, 2003:557). Therefore, making a time series stationary is crucial for the reliability of the obtained parameters (Gujarati, 2004:805). The stationarity of all series has been examined using the Augmented Dickey-Fuller (ADF) unit root test in this study. There are different tests at each stage: no constant and no trend, constant, constant and trend in the stationarity analysis of the series. The equations for these tests are expressed as (1), (2), (3) sequentially. Various criteria, which is the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SC), are used to determine the appropriate lag lengths for the series. The value that minimizes the number of lags is determined as the most suitable lag length according to both information criteria

$$\Delta y_t = \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

$$\Delta y_t = \alpha + \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \varepsilon_t \qquad (2)$$

$$\Delta y_t = \alpha + \beta\, t + \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \varepsilon_t \qquad (3)$$

Public and private sector fived capital investments have shown significant changes over the past 25 years in Turkey and worldwide. Thus, analyzing the changing structure over time requires models that can evaluate these changes. The Time-Varying Parameter VAR Model with Stochastic Volatility (TVP-VAR) is estimated based on Bayesian methods (Primiceri, 2005). The following equation is used for forecasting with the TVP-VAR model in this study.

$$Y_t = \delta_t + A_{1,t}\, Y_{t-1} + \cdots + A_{p,t}\, Y_{t-p} + u_t = X_t' \Theta_t + \varepsilon_t \qquad (4)$$

The Y_t in equation 4 is the internal variable vector of size nx1. X_t represents the matrix of explanatory variables, and δ_t represents the time-varying parameters of the explanatory variables. On the other hand u_t, represents shocks whose variance changes over time, dependent on the variance-covariance matrix denoted as Ω_t

$$\Omega_t = \beta_t^{-1} H_t (\beta_t^{-1})' \tag{5}$$

It is possible to decompose the Ω_t variance-covariance matrix into a reduced diagonal form as shown in equation 5.

$$B_t = \begin{vmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21,t} & 1 & 0 & 0 & 0 \\ a_{31,t} & a_{32,t} & 1 & 0 & 0 \end{vmatrix}$$

$$H_t = \begin{vmatrix} h_{1,t} & 0 & 0 & 0 & 0 \\ 0 & h_{2,t} & 0 & 0 & 0 \\ 0 & 0 & h_{3,t} & 0 & 0 \end{vmatrix} \tag{6}$$

The parameters located in the lower triangular part of the Bt matrix are used to determine the dynamic relationship between variables. Neglecting the time-varying structure in the VAR model can lead to upward biases in parameter estimation (Cogley & Sargent, 2005). Therefore, the variance-covariance matrix should take into account the interaction between the examined variables and the stochastic volatility arising from changing variances of shocks. It is assumed that the time-varying parameters change within the framework of equations 7, 8, and 9 (Primiceri, 2005).

$$\Theta_t = \Theta_{t-1} + v_t \quad v_t \sim N(0, Q) \tag{7}$$

$$\alpha_t = \alpha_{t-1} + \zeta_t \quad \zeta_t \sim N(0, S) \tag{8}$$

$$\ln h_{i,t} = \ln h_{i,t-1} + \sigma_i \eta_{i,t} \quad \eta_{i,t} \sim N(0,1) \tag{9}$$

The time-varying Θ_t and α_t parameters expressed in equations 7, 8, and 9 involve a random walk process without a constant. It is assumed that the probabilities follow a geometric random walk unlike the time-varying parameters. This assumption enhances the efficiency of the Markov Chain Monte Carlo (MCMC) algorithm. The vector of internal variables that will be used to explain the relationship between public and private sector fived capital investments is as described in equation number 10.

Y_t=[Δln (INVESTMENTpublic$_t$), Δln (INVESTMENTprivate$_t$), Δln (GDPagricultural$_t$)] (10)

The vector of endogenous variables contains Δ(INVESTMENTpublict) representing public sector fixed capital investments, Δ(INVESTMENTprivatet) representing private sector fixed capital investments, and Δ(GDPagriculturalt) representing agricultural gross domestic product in equation number 10. In line with the purpose of the study, two steps were followed in determining the transition effect from public sector fived capital investments to private sector fived capital investments. First, the first differences of all variables have been taken, and then the natural logarithm of all series has been calculated. Therefore, the calculated coefficients have been interpreted as elasticity values for the variables. The ordering of variables, which has been determined from the most exogenous to the most endogenous, includes public sector fived capital investments, private sector fived capital investments, and agricultural gross domestic product, as described in equation number 10 in both linear VAR and TVP-VAR models. This ordering has been determined on the assumption that public sector fived capital investments would exogenously affect private sector fived capital investments. The value of agricultural gross

domestic product, which has been considered the most endogenous variable, assumes that it is affected by fived capital investments in both sectors. 10.000 iterations have been conducted for the convergence of parameters, using the year 2.000 as a period in the predictions made with VAR models (Primiceri, 2005; Nakajima, 2011). Eviews 12 software has been used for the analysis of unit root tests. In the estimation of the TVP-VAR model, the OxMetrics program used by Nakajima (2011) has been preferred.

4. FINDINGS AND DUSCUSSIONS

Firstly, it has been determined whether the series have been stationary before moving on to the results of the Time-Varying Parameter Vector Autoregressive (TVPVAR) model predictions. The results of the widely used Augmented Dickey-Fuller (ADF) unit root test statistics have been presented in Table 2. As can be seen in Table 2, it has been found that all variables have contained a unit root at the level, which means they have not been stationary at the level. However, it has been determined that the first differences of all variables have been first-order stationary.

Table 2. ADF Test for Unit Root

Variable Name	Intercept			Trend and Intercept		
	ADF Tau (τ) Test Statistics		Decision of Stability	ADF Tau (τ) Test Statistics		Decision of Stability
	Level I(0)	First Difference I(1)		Level I(0)	First Difference I(1)	
Ln(GDPagricultural)	-0.0774	- 7.8165***	I(1)	-1.7835	- 7.7394***	I(1)
Ln(INVESTMENTpublic)	-1.7625	-4.7602***	I(1)	-1.7945	-4.7018***	I(1)
Ln(INVESTMENTprivate)	-0.4203	-4.7229***	I(1)	-2.0460	-4.5742***	I(1)

(Notes: ***, ** indicate significance at the 1%, and 5% level, respectively. The lag order determine using the Schwartz information criterion and the maximum delay length set to 9 numbers. Values in parentheses denote degree of stability) (Source: Author's computation using E-view 12)

The consecutive modified LR test statistic, final prediction error (FPE), Schwarz information criterion (SC), and Hannan-Quinn information criterion (HQ) statistics have all suggested an appropriate lag length of 1 as seen in Table 3. In contrast to other information criteria, the Akaike information criterion (AIC) has recommended a lag length of 3. Therefore, a lag length of 1 has been determined.

Table 3. Lag Length Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2.258.047	NA	0.000340	0.525805	0.675165	0.554961
1	3.904.317	66.08195*	1.37e-05*	-2.704.317	-2.106878*	-2.587691*
2	4.584.562	8.843.190	1.84e-05	-2.484.562	-1.439.044	-2.280.466
3	5.783.026	1.198.463	1.67e-05	-2.783026*	-1.289.427	-2.491.459
4	6.665.069	6.174.301	2.68e-05	-2.765.069	-0.823391	-2.386.033

Note: * denotes a significance level of 5%.

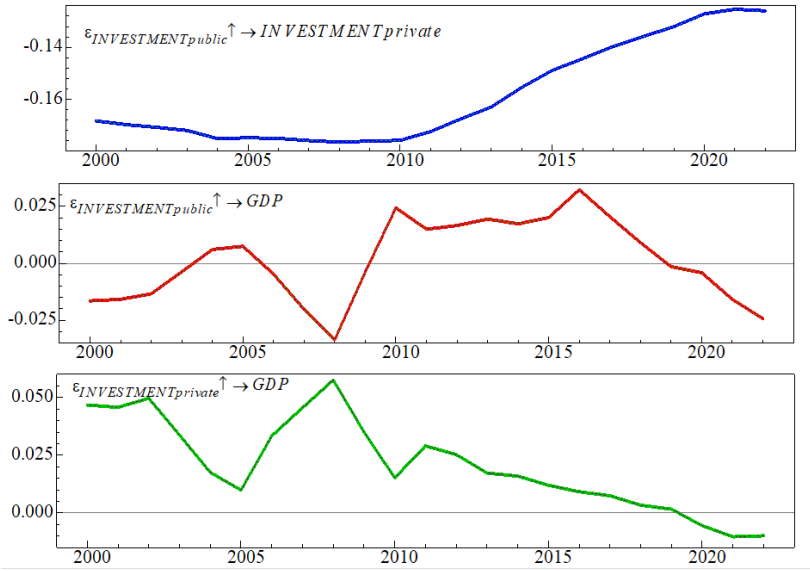
Test results related to Geweke (CD) convergence test statistics and inefficiency factor for the TVPVAR model are presented before moving on to the impulse response function results in Table 4. Firstly, the fact that all inefficiency factor values, which are less than 100, indicates that the selected sample is effective in parameter estimation. However, parameter mean values are within 5% confidence intervals. This result also implies that the coefficient estimates for the parameters within the 5% confidence interval are reliable.

Table 4. Time-Varying Parameter VAR (TVPVAR) Model Estimation Results

Parameter	Mean	Standart Deviation	95%L	95%U	Geweke (Convergence Diagnostics)	Inefficiency
S_{b1}	0.0119	0.0010	0.0102	0.0143	0.000	1.190
S_{b2}	0.0119	0.0010	0.0102	0.0139	0.660	1.260
S_{a1}	0.0925	0.0428	0.0440	0.2123	0.000	6.110
S_{a2}	0.0845	0.0370	0.0424	0.1859	0.943	18.47
S_{h1}	0.0760	0.0417	0.0246	0.1640	0.000	59.93
S_{h2}	0.1039	0.0808	0.0442	0.3603	0.004	7.750

(Note: The estimation results of the chosen parameters in the TVP-VAR model indicate that the means, standard deviations, 95% credible intervals (both upper and lower bounds), convergence diagnostics, and the count of inefficient samples constitute the diagonal elements within the covariance matrices. $S_{b1}= (\sum\beta)_1$, $S_{b2}= (\sum\beta)_2$, $S_{a1}= (\sum\alpha)_1$, $S_{a2}= (\sum\alpha)_2$, $S_{h1}= (\sum h)_1$, $S_{h2}= (\sum h)_2$) (Source: Author's Computation Using OxMetrics)

Figure 2. The Impact of Domestic Food Price Shock on Inflation in TVPVAR Models



(Source: Author's Computation Using OxMetrics)

After the estimation of parameters, the time-varying response of private sector fived capital investments to a standard deviation-positive shock in public sector fived capital investments, which is specific to the agricultural sector, is predicted using the TVP-VAR model and presented in Figure 2. The time-varying response of private sector fived capital investments (INVESTMENTprivate) to positive shocks in public sector fived capital investments (INVESTMENTpublic) is consistently negative throughout the entire analysis period as seen in Figure 2. In other words, it has been determined that there is a crowding-out effect of public sector fived capital investments on private sector fived capital investments. The results of this study confirm the findings of a study conducted by Yavuz (2001); Voss (2002); Başar &Temurlenk (2007); Majeed & Khan (2008); Hatano (2010); Sahu & Panda (2012); Şen & Kaya (2014); Kaytancı (2017); Demir (2017); Karatay Gögül &Adıyaman

(2022) found that the difference in public fixed capital investmen has a negative sign and a significant effect on the fixed capital investmnet in agricultural sector. Another noteworthy observation when looking at the time-varying responses is that the period with the lowest negative impact of public sector fived capital investments on private sector fived capital investments in the agricultural sector is between 2001 and 2010. During this period, Turkey experienced the 2001 banking crisis and the 2008 global financial crises. Therefore, it is thought that the contractions experienced during these crisis periods had an impact on both public and private sector investments. Furthermore, it has been concluded that the time-varying responses increased in a negative direction after 2010 gradually.

The impact of public sector fived capital investments (INVESTMENTpublic) on agricultural gross domestic product (GDPagricultural) varies with periods of increase and decrease. According to the findings, it has been concluded that the time-varying response has been negative during the years of the 2001 banking crisis and the 2008 global financial crisis. However, the impact is observed to be positive between 2009 and 2019. In other words, public sector fixed capital investment shocks (INVESTMENTpublic) are increasing agricultural gross domestic product (GDPagricultural) during these years. The positive time-varying response turns negative again after 2019 (post-Covid-19 period). Throughout the entire analysis period, it is possible to say that the direction of time-varying responses between the two variables varied. It has been observed that the time-varying responses obtained from giving a shock to private sector fived capital investments (INVESTMENTpublic) on agricultural gross domestic product (GDPagricultural) remained positive until the end of 2019. Especially during the periods of the 2001 local banking crisis and the 2008 global financial crisis, it has been concluded that the response of private sector fixed

capital investment shock (INVESTMENTpublic) on agricultural gross domestic product (GDPagricultural) has been most pronounced. Moreover, it has been determined that the time-varying response has been higher in the 2008 global crisis compared to the 2001 local banking crisis. Furthermore, it has been found that the responses have gradually decreased between 2009 and 2019. On the other hand, the direction of the response has shifted from positive to negative after 2019.

5. CONLUSION

This study aims to analyze the impact of changes in public sector fived capital investments in the agricultural sector on private sector fived capital investments. Unit root tests have been initially applied to determine the stationarity of variables. Non-stationary series at the level have been made stationary by taking their first differences. Subsequently, the validity of the crowding-out or crowding-in effect of public investments on private sector investments has been determined using the TVP-VAR model. As a result of the study, it has been determined that the response of private sector fived capital investments in the agricultural sector to public sector fixed capital investment shocks has changed over time. Public sector fived capital investments have a negative effect on private sector fived capital investments in agricultural sector according to the TVP-VAR model's impulse response function results. This findings indicates that public sector fived capital investments in the agricultural sector reduce private sector fived capital investments.

Furthermore, it has been found that the crowding-out effect was most pronounced between 2001 and 2010. During the 2008 global financial crisis, a 1 standard deviation positive shock in public sector fived capital investments resulted in approximately a 17.6% reduction in private sector fived capital

investments. This result reveal that the highest negative responses of private sector fived capital investments to public sector investment shocks coincided with local and global financial crisis periods. Therefore, it is possible to say that during economic crisis periods, private sector fived capital investments are more sensitive to public sector investment shocks.

There has been crowding-out effect of public sector fived capital investments on private sector fived capital investments in the agricultural sector in Turkey. Therefore, this view supports the classical economic perspective that public sector fived capital investments reduce private sector fived capital investments. On the other hand, the time-varying response of public sector fixed capital investment shocks on agricultural gross domestic product is sometimes positive and sometimes negative, making it difficult to decisively determine this effect. Furthermore, the impact of private sector fixed capital investment shocks on agricultural gross domestic product has been found to be positive, except for the period after 2019. This result indicates that private sector fived capital investments increase agricultural gross domestic product. The findings obtained at the end of the study, which highlight the necessity of increasing private sector investment incentives and infrastructure investments, suggest that the public sector in the agriculture sector is reducing private sector investments. Furthermore, it is believed that increasing access to credit facilities can enhance the private sector's investment capacity.

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EXAMINATION OF THE RELATIONSHIP BETWEEN FIXED CAPITAL INVESTMENT AND GROSS DOMESTIC PRODUCT IN TURKEY: THE EXAMPLE OF AGRICULTURAL SECTOR IN THE PRESENCE OF MULTI STRUCTURAL BREAKS

Hakan SÖNMEZ[1]

1. INTRODUCTION

Capital accumulation is one of the significant instruments for economic growth in many countries. It is well known that countries with high economic growth rates often have high levels of capital accumulation. It is also recognized that investments impact economic growth through capital accumulation. Thus, fixed capital investments play a crucial role in capital accumulation. Fixed capital investments consist of investments in machinery, equipment, buildings, roads, dams, and other infrastructure aimed at increasing the production of goods and services in an economy. Moreover, fixed capital investments not only contribute to the growth of production but also stimulate employment and income growth, thus contributing to economic development. Furthermore, they are essential elements in enhancing economic welfare and adding to a country's economic strength. Therefore, an increase in fixed capital investments is considered one of the fundamental factors in promoting growth.

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The impact of fixed capital investments on economic growth differs according to classical and Keynesian perspectives. From a classical perspective, capital accumulation is the most critical component of growth. An increase in capital accumulation leads to a more productive economy. This accumulation is related to fixed capital investments, such as the construction of new factories and infrastructure projects. As capital accumulation increases, the economy's capacity for investment also grows. Having modern and efficient production equipment allows businesses to enhance productivity and competitiveness. Additionally, capital accumulation contributes to the potential for opening new businesses and creating jobs. As a result, the reduction of unemployment rates and the increase in production become possible, directly linking economic growth and increased prosperity to capital accumulation.

Keynesian perspective offers a different outlook compared to classical economics. According to this economic view, investments are influenced by demand conditions and unexpected external factors in the economy. During periods of low demand, businesses may be reluctant to make new investments due to concerns about their ability to sell their products. In contrast, increases in income and consumer spending positively affect investments in the economy. Households with higher incomes can purchase more goods and services, which can incentivize businesses to invest in expanding their production capacity. During economic crises, policies such as stimulus measures, including increased fixed capital investments and government spending, can help revive the economy and reduce unemployment. This approach can mitigate the effects of economic crises and contribute to stabilizing the economy. Fixed capital investments are made in various sectors, and one of these sectors is the agriculture sector. Thus, investments in different sectors across a wide range can have varying effects on economic

growth. Investments in the agriculture sector can directly and indirectly contribute to increased production, employment, improved income distribution, enhanced social welfare, and ensuring food security. Additionally, given the increasing global population, the role of investments in this sector becomes crucial in shaping long-term environmental sustainability. For these reasons, the agriculture sector is considered one of the fundamental sectors for a country's economic development.

Table 1. Agricultural fixed capital investments, agricultural gross domestic product and share of Agricultural Gross Domestic Product in Turkey (1998-2021)

Year	Share of Agricultural Gross Domestic Product (%)	Agricultural Gross Domestic Product (Thousand TRY)	Agricultural Total Fixed Capital Investment (Thousand TRY)
1998	12,45	8.957.343	921.858
1999	10,46	11.229.013	903.346
2000	10,03	17.205.761	1.615.202
2001	8,79	21.729.848	1.746.138
2002	10,19	36.901.720	2.458.981
2003	9,80	46.249.933	2.945.000
2004	9,33	54.365.145	5.673.664
2005	9,17	62.349.598	5.802.587
2006	8,09	64.415.593	6.759.546
2007	7,46	66.197.107	6.539.642
2008	7,42	74.451.345	5.948.675
2009	8,07	81.234.274	6.431.322
2010	8,97	104.703.635	7.630.081
2011	8,17	114.838.169	11.849.576
2012	7,69	121.692.893	11.225.821
2013	6,68	121.733.979	12.618.915
2014	6,56	134.744.489	12.252.186
2015	6,87	161.471.476	15.077.847
2016	6,14	161.330.969	15.358.508
2017	6,04	189.232.800	19.554.978
2018	5,78	217.107.229	23.450.979
2019	6,41	276.325.464	19.538.066
2020	6,67	336.623.140	22.235.331
2021	5,54	401.805.954	36.159.295

(Source: Turkish Statistical Institute and T.R. Presidency Strategy and Budget Office 2023)

Fixed capital investments in the agricultural sector, the value of agricultural gross domestic product (GDP), and the share of agricultural GDP are shown in Table 1. When Table 1 is examined, it can be observed that the agricultural sector constituted 12.45% of the GDP value in 1998, while this ratio decreased to 5.54% in 2021. As seen, Turkey's share in the agricultural sector has been decreasing over time. This result indicates that Turkey's economic structure has been shifting away from agriculture towards industry and service sectors. Moreover, technological advancements and urbanization have been among the other key factors behind this decline.

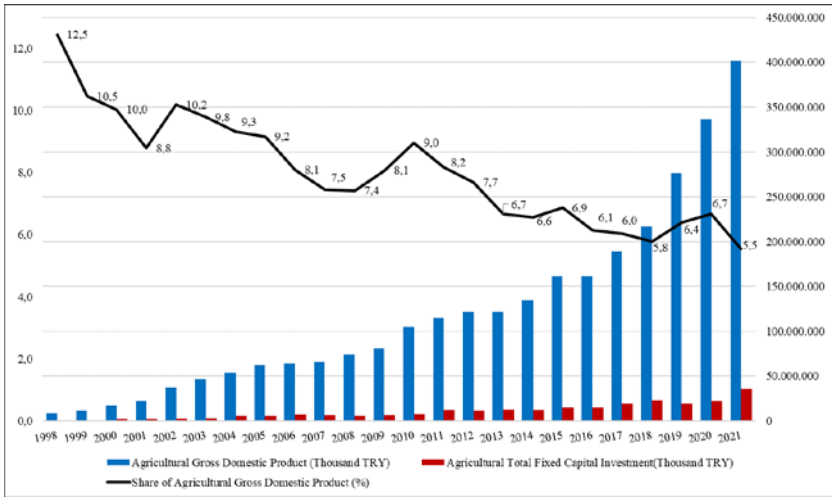
Fixed capital investments play a critical role in enhancing modernization and efficiency in the agricultural sector. Furthermore, agricultural fixed capital investments are expected to have a positive impact on agricultural gross domestic product in line with theoretical expectations. According to the data presented in Table 1, fixed capital investments have significantly increased since 1998. Also, at the beginning of the analysis period, fixed capital investments were 921.858 (Thousand TRY), while at the end of the analysis period, they reached a value of 36.159.295 (Thousand TRY). However, the value of agricultural gross domestic product was 8.957.343 (Thousand TRY) in 1998, and this figure increased to 401.805.954 (Thousand TRY) in 2021. This result indicates that during periods of increased fixed capital investments, higher agricultural gross domestic product values are achieved. Nevertheless, it has been observed that the share of the agricultural sector in the national income has continuously decreased despite the increase in fixed capital investments since the early 2000s. This situation highlights that the agricultural sector has been growing more slowly compared to other sectors and emphasizes the need to enhance its competitiveness. There was a significant increase in fixed capital investments compared to the previous year in 2011, which can be

related to the concurrent increase in public expenditures during the same period. The average value of agricultural fixed capital investments was 10.612.398 (Thousand TRY) over the 24-year analysis period, and the value of agricultural gross domestic product was 120.287.370 (Thousand TRY). However, the increase in fixed capital investments in the year 2021 stands out. In 2021, it is observed that fixed capital investments nearly doubled compared to the year 2020. The reasons and consequences of this significant increase require a more detailed examination.

Figure 1 depicts the evolution of agricultural fixed capital investments, agricultural gross domestic product, and the proportion of agricultural gross domestic product within the total gross domestic product in Turkey between 1998 and 2021. This figure holds significance in reflecting the changing dynamics of Turkey's agricultural sector and its economic development. During the period between the 1999 Marmara earthquake and the 2001 local banking and financial crisis in Turkey, the values of both series increased to a limited extent as seen in Figure 1. Moreover, the value of agricultural GDP steadily increased between the 2001 local banking and financial crisis and the 2008 global financial crisis. Furthermore, agricultural fixed capital investments displayed a somewhat fluctuating trend, albeit not very sharp during this same period. However, it is worth noting that after the 2008 global financial crisis, agricultural fixed capital investments and agricultural GDP exhibited similar developments. Particularly striking is the rapid increase in the values of both series after the year 2018. On the contrary, it is apparent that the share of agriculture in the gross domestic product has gradually decreased over time, reaching an average of 8%. Throughout the entire analysis period, agricultural fixed capital investments remained lower than the value of agricultural GDP. Additionally, it is worth highlighting that both time series

showed a consistently upward trend over the years. The presence of numerous local and global crises during the analysis period, along with various structural transformation decisions, necessitated the inclusion of these changes in the analyses.

Figure 1. Development of Agricultural Fixed Capital Investments, Agricultural GDP and Their Share in Gross Domestic Product in Turkey (1998-2021)



(Source: Prepared by the author using data from the Turkish Statistical Institute and Republic of Turkey Presidency Strategy and Budget Office, 2023)

Studies investigating the impact of fixed capital investments in the agricultural sector on economic growth have not taken structural breaks into account to the best of our knowledge. In this study, we employed a different analysis method developed by Bai-Perron, which allows for up to 5 multiple structural breaks, unlike other research. Also, the analysis of the results under multiple structural breaks constitutes the unique aspect of this study. The study is consist of five parts. Following the introductory section, the second segment furnishes details regarding the pertinent literature.The third section includes information about econometric methods and the dataset.

In the fourth section, the empirical findings are discussed. The last section presents the conclusion and offers policy recommendations.

2. LITERATURE REVIEW

Studies investigating the correlation between fixed capital investments and economic growth can be classified into three primary categories in the literature. The first group comprises analyses centered on a single country. The second group includes studies conducted for various groups of countries. The third group of studies, however, is specific to research conducted in Turkey. Studies examining the relationship between fixed capital investments and economic growth within a single country context reveal two significant outcomes. Firstly, models have been constructed using causality tests and co-integration analysis methods in most of the empirical studies. Furthermore, it has been concluded that there is a positive correlation between them. For instance, a positive relationship has been found between fixed capital investments and economic growth in the Chinese economy (Chow, 1993). It has been emphasized that a 1% increase in fixed capital investments has increased economic growth by 0.045%. Kwan et al., (1999) emphasized that fixed capital investments contributed to China's economic growth between 1952 and 1993. Qin & He (2005) identified a unidirectional and positive long-term relationship between the two variables. Harvie & Pahlavani (2006), who used quarterly data spanning 25 years, found that fixed capital investments had a substantial impact on the growth in the South Korean economy. Zhou &Yang (2007) determined that a 1% increase in fixed capital investments resulted in a 0.81% increase in GDP. Bal et al., (2016), which employed the ARDL method to investigate the relationship between variables in the Indian economy from 1970 to 2012, revealed a positive influence of fixed capital investments

on economic growth. Secondly, studies conducted at the country level have highlighted results indicating no significant relationship between the variables. For instance, Lee &Yu (2005) found that fixed capital investments did not have a significant impact on economic growth in Korea. Feasel et al., (2001) have used VAR analysis to conclude that there has been no relationship between the two variables in the long run.

Economic development, which significantly depends on adequate capital accumulation and an expansion of production capacity, are factors that positively impact economic grow. Thus, it has been established that countries with higher levels of fixed capital investments tend to experience higher growth rates. As an illustration, De Long & Summers (1991) emphasized that a positive relationship between an increase in fixed capital investments and economic growth in predictions made for 61 countries using models from different periods. Blomstrom et al., (1993), who examined the causal relationship between fixed capital investments and economic growth, found that an increase in fixed capital accumulation leads to rapid growth. Sinha (1999) has conducted research spanning 47 years to investigate the relationship between these two variables in Asian countries, which has concluded that there has been a strong relationship between them in the majority of countries. Podrecca and Caemeci (2001), who utilized the Generalized Method of Moments and panel causality methods, based on data from 104 countries spanning the period from 1960 to 1990. They demonstrated that fixed capital investments have a positive impact on economic growth. Emirkadı (2022) explored the relationship between fixed capital investments and economic growth in MIST countries from 1990 to 2019. The cointegration test results revealed that economic growth is driven by fixed capital investments. It is worth noting that results differ when various methods are employed in the analysis of different country groups. For

instance, Anwer & Sampath (1999) have examined a selected group of countries from 1960 to 1992. They have found that there has been no cointegration relationship between fixed capital investments and Gross Domestic Product in any of the included countries.

Similar to studies conducted for other countries, the nature of the relationship between the two variables varies in studies conducted for Turkey. The presence of a positive relationship between the variables is evident in some of the studies. As an illustration, Bayraktutan & Aslan (2008) have utilized a 26-year dataset with Johansen cointegration analysis. As a result of the study, it has been determined that fixed capital investments positively influence economic growth. Ateş (2013) has examined the relationship between physical capital investment and GDP. Using the Autoregressive Distributed Lag Bound Test (ARDL) boundary test approach, it has been determined that changes in the rate of physical capital investment have had short-term effects on GDP per capita in growth rate. Terin et al., (2013) have supported the hypothesis that agricultural fixed capital investments have increased agricultural growth between 1990 and 2012 in their study. Teyyare & Sayaner (2018) have examined the impact of fixed capital investments on economic growth using the Least Squares Method in the period from 1984 to 2014. The study has resulted in a conclusion based on a positive relationship between fixed capital investments and economic growth. Olgun et al., (2018) have tested the presence of a relationship between variables using Johansen Cointegration Analysis between 1983 and 2015. The findings from the study suggest that agricultural fixed capital investments have increased agricultural gross domestic product in the long term. Beşer & Kadanalı (2021) have investigated the impact of agricultural fixed capital investments in the agricultural sector using VAR Analysis and Granger Causality Test. In the long term, a positive effect from public

sector fixed capital investments on agricultural growth has been indicated. However, no relationship has been detected between the variables In some studies. For example, Arısoy (2011) has emphasized that there has been no long-term relationship between physical capital investments and economic growth for the period from 1968 to 2006. Also Şahbaz (2014) has tested panel cointegration analysis between Turkey and European Union countries from 1991 to 2011, and contrary to other studies, has found that there has been no causality relationship between the variables. Gövdere & Can (2016) have reached the conclusion that the impact of fixed capital investments on economic growth has been statistically insignificant in their study.

3. MATERIALS AND METHODS

The data used in this study has been annual and covers the period from 1998 to 2021. The agricultural gross domestic product data has been obtained from the Turkish Statistical Institute (TÜİK) database in the study. Price series classified by main activity branches have been used. The data for agricultural fixed capital ınvestment, on the other hand, has been obtained from the database of the Presidency of Strategy and Budget of the Republic of Turkey. All variables used in the study have been converted into real terms using the 2009 base year deflator, and logarithmic transformation has been applied to the data. Definitions related to the variables used in the model are presented in Table 1.

Table 1. Variables and Their Descriptions

Variable Name	Variable Abbreviation	Source	Expected Sign
Agricultural Gross Domestic Product (TRY)	GDPagricultural	Turkish Statistical Institute	
Agricultural Fixed Capital Investment (TRY)	FCIagricultural	Presidency Strategy and Budget Office of Turkey	Positive (+)

The stationarity of time series data is crucial for the consistency of results. For a time series to be stationary, it is essential that its mean, variance, and covariance remain constant over time. In the case of stationary time series, the effects arising from shocks are temporary, and the series reverts to its mean values in the long run. If the series is non-stationary, it may lead to spurious regression results, implying a statistically significant relationship among variables used in the econometric model, even when no such relationship exists (Baltagi, 2003). Thus, it is essential to first make the series stationary to forecast a time series with an appropriate econometric model (Gujarati, 2004). Also, there are numerous methods and techniques for testing the stationarity of time series, and their number continues to grow in the econometrics literature. The Augmented Dickey-Fuller (ADF) unit root test has been initially used to test the stationarity of all variables in this study. When testing the stationarity of the series, three methods are used: the non-stationary model without a constant term and trend, the model with a constant term, and the model with a constant term and trend. These models are respectively expressed by equations (1), (2), and (3).

$$\Delta y_t = \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \, \Delta y_{t-i} + \varepsilon_t \quad (1)$$

$$\Delta y_t = \alpha + \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \, \Delta y_{t-i} + \varepsilon_t \quad (2)$$

$$\Delta y_t = \alpha + \beta \, t + \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \, \Delta y_{t-i} + \varepsilon_t \quad (3)$$

Here, α represents the constant term, t denotes the deterministic trend, k stands for lag length, Δ represents the differencing operator, and ε_t represents the error term. This unit root test aims to analyze whether the parameter ρ is different from zero. Various criteria such as Akaike Information Criterion (AIC) and Schwarz Information Criterion (SC) are employed to determine the appropriate lag lengths for the series. The value that minimizes the lag count is considered the most suitable lag length according to both information criteria. Structural break unit root

tests have been employed, taking into consideration the structural transformations that the Turkish economy has undergone after the conventional unit root tests, which were initially conducted by Perron (1989), followed by Zivot & Andrews (1992), Lumsdaine & Papell (1997), and Lee & Strazicich (2003). In these tests, up to two structural breaks are allowed in the model. However, in this study, the Bai Perron (1998) multiple structural break unit root test, which differs from other unit root tests, allows for up to five structural breaks. In this method, with m structural breaks and m+1 regimes, the multiple regression model estimated is represented as follows in equation (4).

$$Y_t = \beta_1 X_t{}' + \gamma_1 Z_t{}' + \varepsilon_t \qquad t = 1, \dots T_1 \quad \text{j} = 1, \dots \dots \text{m}$$

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.

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(4)

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$$Y_t = \beta_m X_t{}' + \gamma_{m+1} Z_t{}' + \varepsilon_t, \qquad t = T_{m+1}, \dots T$$

In equation 4, Y_t represents the dependent variable, x_t is a vector of dimension $(px1)$, z_t is a vector of dimension $(qx1)$, $\varepsilon_t$represents the error terms, and $(T_{1,\dots\dots}, T_m)$ denotes the detected unknown break points. The least squares estimates of the coefficients β and γ_{i} for each of the m segments are obtained by minimizing the sum of squared errors, as shown in equation 5.

$$\sum_{i=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} (Y_t - \beta X_t{}' - \delta_i{}^2 Z_t{}') \qquad (5)$$

Bai-Perron (2003) has suggested the following three tests for determining the number of breaks in the multiple structural break model:

1) The *Sup* $F_T(k)$ test statistic, which is expressed as the null hypothesis that there are no breaks versus the alternative hypothesis that there are *k* breaks.

2) The *UDmax* and *WDmax* tests, where the null hypothesis states that there are no breaks, and the alternative hypothesis allows for up to *m* unknown breaks.

3) The consecutive *Sup* $F_T(l+1/l)$ test, where the null hypothesis is formulated as *l* breaks versus the alternative hypothesis of $l+1$ breaks.

Bai-Perron (2003) has suggested three information criteria for determining the model dimension. In the first one, they suggest using the Bayesian Information Criterion (BIC) developed by Yao (1988). In the second one, they recommend the modified version of the Schwarz criterion, known as the LWZ criterion, developed by Liu, Wu, & Zidek (1994). In the third one, they introduce the sequential information criterion based on the consecutive *Sup* $F_T\ (\ l+1\ /\ l\ )$ test, which they themselves developed. It is noted that the critical values for these tests are established for series without trends. Moreover, they emphasize that these three tests can be safely used even when the series contains trends.

$$\Delta Ln(GDP_{agricultural}) = \beta_0 + \beta_1 \Delta\, Ln(FCI_{agricultural}) + \varepsilon_t (6)$$

Agricultural gross domestic product is used as the dependent variable, and agricultural fixed capital investment is used as the independent variable in equation 6. The econometric model to be used for predictions is expressed as in equation 6. Taking the natural logarithm of the variables allows for obtaining elasticity values. The coefficient β_1 in the model represents the elasticity value for the agricultural fixed capital investment variable. Empirical findings from the estimation of the econometric model have been obtained using the Eviews 12 econometric software package.

4. FINDINGS AND DUSCUSSIONS

Unit root test analysis has been conducted for all variables before proceeding to the parameter estimation results. The results of the Augmented Dickey Fuller (ADF) unit root test statistics can be found in Table 2. The null hypothesis indicates that the series contains a unit root or is non-stationary ($H_o: \rho = 0$), while the alternative hypothesis suggests that the series does not contain a unit root or is stationary ($H_1: \rho < 0$) in the ADF test. The Tau (τ) test statistic has been utilized to test hypotheses in the models provided in equations (1), (2), and (3). The Tau (τ) test statistic is calculated using the formula $\tau = \frac{\hat{\rho}}{S_{\hat{\rho}}}$ (Dickey & Fuller, 1979). If the calculated Tau (τ) test statistic is less than the critical value, which indicates that the series is stationary, the null hypothesis is rejected. Consequently, the null hypothesis positing that all variables contain a unit root at the level has been rejected. In other words, it has been ascertained that all series are non-stationary at the level. However, when the first difference of all variables is taken, it has been observed that the series becomes stationary in the study.

Table 2. ADF Test for Unit Root

Variable Name	Intercept			Trend and Intercept		
	ADF Tau (τ) Test Statistics		Decision of Stability	ADF Tau (τ) Test Statistics		Decision of Stability
	Level	First Difference		Level	First Difference	
Ln(GDPagricultural)	0.6254	-7.8168***	I(1)	-1.7825	-3.5309*	I(1)
Ln(FCIagricultural)	-2.0742	-4.7256***	I(1)	-1.7912	-4.5596**	I(1)

(Notes: ***, ** indicate significance at the 1%, and 5% level, respectively. The lag order has been determined using the Akaike Information Criterion. Numbers in parentheses are denoted degree of stability) (Source: Author's Computation Using E-view 12)

The most significant issue with traditional unit root tests is the failure to consider structural breaks. If the analyzed variables have undergone structural changes during the examined period, unit root tests conducted without taking these structural

changes into account can yield misleading results due to the spurious regression problem. Thus, a unit structural break root test by Bai Perron was conducted to determine the break dates in this study. In addition to ensuring the stationarity condition of the series, determining the number of breaks in the series is also crucial in the decision-making process. Hence, the number of breaks has initially been determined.

Table 3. Bai-Perron Multiple Structural Break Test Results

Sup F_t (k) Test					Double Maximum Tests	
Sup F_t (1)	Sup F_t (2)	Sup F_t (3)	Sup F_t (4)	Sup F_t (5)	UD_{max}	WD_{max}
9.285*	44.317*	9641.277*	9620.084*	53866173*	107732345*	11229069*

Sequential Sup F_t [$(l+1)$ / l] Test			
Sup F_t (1/0)	Sup F_t (2/1)	Sup F_t (3/2)	Sup F_t (4/3)
9.285*	6.708*	156.369*	1.563

(Notes: * represents significance at the 5% level. The critical values for the Sup F_t (k), UD_{max}, WD_{max} ve Sup F_t [$(l+1)$ / l] tests obtain from Bai & Perron (2003) (Source: Author's Computation Using E-view 12)

Table 3 presents the results of the Bai Perron unit root test, which allows for up to 5 multiple structural breaks internally. When examining the test results, it is observed that the *SupFt(k)* Test and Double Maximum Tests (UD_{max}, WD_{max}) are statistically significant at a 5% significance level. The *SupFt(k)* test, which suggests 1, 2, 3, 4, and 5 breaks as alternatives, rejects the null hypothesis that there is no break. Similarly, the null hypothesis that there is no structural break, with an alternative hypothesis assuming at least one break, cannot be rejected. According to the results of both tests, it is determined that there is at least one break in the series. Finally, following Bai Perron's recommendation, the consecutive procedure test results are examined to precisely determine the number of breaks. Based on the SupF_t [$(l+1)$ / l] test results, 1 break is rejected against 0 breaks, 2 breaks are rejected against 1 break, and 3 breaks are rejected against 2 breaks.

Table 4. Estimates of The Multi Structural Break Model Using Bai-Perron Approach

	Regime 1		Regime 2		Regime 3		Regime 4	
	β_0	β_1	β_0	β_1	β_0	β_1	β_0	β_1
Coefficients	0.036***	0.260***	0.021**	0.054***	0.003**	0.565***	0.014***	-0.098**
t-Statistic	[3.875]	[6.400]	[2.541]	[3.062]	[2.266]	[23.229]	[3.301]	[-2.355]
Probability	(0.001)	(0.000)	(0.022)	(0.007)	(0.038)	(0.000)	(0.004)	(0.032)

(Note: *, **, *** represents significance at the 10%, 5% and 1% level. Trim % and max number of breaks 15 % and 5, respectively) (Source: Author's Computation Using E-view 12)

When the three criteria of BIC, LWZ, and consecutive information criteria are considered together to determine the number of breaks, it has been determined that there are 3 breaks in this study. The break dates are in the years 2003, 2015, and 2018. According to the determined number of breaks, the observation period is divided into 4 different sub-regimes for analysis. The identified sub-regimes include the periods (Regime 1: 1999-2002), (Regime 2: 2003-2014), (Regime 3: 2015-2017), and (Regime 4: 2018-2021). Table 4 denotes the Bai-Perron approach estimation results under different regimes. For Regime 1, 2, and 3, the coefficient of agricultural fixed capital investments is positive and significant at the 1% significance level. The structural breaks in the model are considered to be caused by events such as the 1999 Marmara earthquake, the local financial crises in November 2000 and February 2001, the decision to transition from implicit inflation targeting to explicit inflation targeting, and the 2008 global financial crisis. During the first 3 regime periods, a 1% increase in agricultural fixed capital investments increases agricultural gross domestic product by 0.260%, 0.054%, and 0.565%, respectively. The results of this study confirm the findings of previous studies conducted by Chow (1993), Kwan et al., (1999), Podrecca & Caemeci (2001), Qin & He (2005), Aslan (2008), Ateş (2013), Olgun et al., (2018), which found a positive and significant effect of differences in fixed capital investment on gross domestic product. As seen, the positive effect of agricultural fixed capital investments on agricultural gross domestic product is quite high in regime 3. On

the other hand, contradictory results were found in regime 4. Contrary to the theoretical expectation, the coefficient value is negative for Regime 4 at the 5% significance level. During Regime 4, significant changes have occurred in oil prices and exchange rates. In this period, a 1% increase in agricultural fixed capital investments has led to a 0.098% decrease in agricultural gross domestic product.

5. CONLUSION

Fixed capital investments primarily contribute positively to production and subsequently to economic growth in an economy. These investments enable the enhancement of productivity and the sustainable utilization of resources. The agricultural sector continues to play significant roles such as driving economic growth, providing employment, ensuring nutrition, and food security in Turkey. However, with changing dynamics and global economic competition, the sustainability of the agricultural sector has become a crucial concern. Despite the decreasing share of the agricultural sector in GDP over time, its importance for the country's economy remains substantial. Thus, investments in this sector need to be evaluated with a strategic perspective. For this purpose, the modernization of the agricultural sector, technological innovations, and the foundation based on environmental sustainability principles need to be established more robustly in the future. Starting from this point, this study has investigated the relationship between agricultural fixed capital investments and agricultural gross domestic product from 1998 to 2021 in Turkey.

The stationarity of the variables has been initially investigated using the ADF unit root test, and it has been determined that the variables that were not stationary became stationary after differencing them once. The local and global

economic crises experienced in the Turkish economy, as well as structural change decisions, have caused significant fluctuations in many sectors. The fluctuations, which include the 1999 Marmara earthquake, the banking and financial crisis in November 2000 and February 2001, the decision to transition from implicit inflation targeting to explicit inflation targeting, the 2008 global financial crisis, fluctuations in oil prices and exchange rates, and the Covid-19 pandemic, have caused significant disruptions in various sectors of the Turkish economy. The existence of these important economic crises in the Turkish economy necessitates evaluations to be made under the consideration of multiple structural breaks. Therefore, the stationarity of the series was analyzed using the Bai-Perron method in the study, which takes into account multiple structural breaks, unlike other studies. After applying the tests, it has been found that the 3 significant structural breaks have created 4 different regimes, and coefficient values have been calculated for each regime period from the estimations. According to the analysis results, in the first three regime periods, fixed capital investments increased gross domestic product, while fixed capital investments decreased gross domestic product in the agriculture sector in regime 4. In the first regime period, a 1% increase in fixed capital investments increased agricultural gross domestic product by 0.260%, in the second regime period, it increased it by 0.054%, and in the third regime period, it increased it by 0.565%. In the fourth regime period, however, the direction of the relationship turned negative, and the coefficient value has been calculated as -0.098%. As a result of the study, it was determined that fixed capital investments in the agricultural sector had different and varying effects on agricultural gross domestic product in different regime periods. It is considered necessary to promote technological innovations, prioritize infrastructure improvements, implement education and skill development programs, and enhance marketing and trade in order for Turkey

to harness its potential in the agricultural sector sustainably and competitively. Additionally, when making investment decisions, the contribution of agriculture to environmental sustainability and its role in combating climate change should also be taken into account.

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ANALYSIS OF ECONOMICS APPLICATIONS

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