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Unraveling the Energy use Network of Construction Sector in Turkey using Structural Path Analysis

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ABSTRACT

Input-output (I-O) analysis provides a useful framework for examining the direct and the indirect changes in the energy use. The purpose of this study is to gain a better understanding of the energy use network in Turkish construction (CON) sector. To do this, a particular type of network analysis, structural path analysis is conducted. Sectoral energy use data provided by World I-O database is used for the elaboration of energy paths. Mediating sectors underlying backward energy linkages are identified. Results show that energy use of CON increased both in absolute terms and that of rank among other industries. The magnitude and complexity of the coke and refined petroleum path decreased. Due to the expansion in natural gas powered energy production, relative importance and complexity of the electric, gas and water supply path increased. Energy use paths are discussed with reference to current account deficit and growth issues in Turkey.

Keywords: Energy Use, Input-output Modelling, Structural Path Analysis, Construction Sector, Turkey
JEL Classifications: C67, L74, Q43

1. INTRODUCTION

The radical increase in the emission of greenhouse gases within the last three decades produced by usage of fossil fuels has been identified as the main factor behind the change in the temperature of the planet. Reduction of the energy consumption as a global warming solution has become a challenge for many of the industrialized and developing countries. As the scientific comprehension of global climate change and its likely impacts become clearer, how to reduce energy use has become a topic of high interest and an increasing number of empirical studies are conducted covering a wide range of areas from consumption and demand for energy to embodied energy in imported products and energy-related policies (Liu et al., 2014).

One of the most convenient techniques of studying the relationship between energy use and other economic activities is the input-output (I-O) analysis (Gowdy and Miller, 1987). Unless the relations between all energy inputs and all economic outputs are examined simultaneously, it is impossible to determine how much energy input should be devoted to a specific economic output. As the I-O tables cover the exact quantitative economic relationships between industrial sectors, the technique is widely used in energy related studies (Zhang et al., 2013). In particular, total energy use per unit of final consumption can be calculated using transactions between sectors together with multipliers of direct energy use and emissions in each sector. The technique can also reallocate emissions from production to consumption, including indirect contributions from an unlimited number of upstream sectors (Nassen et al., 2007).

Suggested by Defourny and Thorbecke (1984) and Crama et al. (1984) structural path analysis (SPA) is an I-O based approach which enables tracing the intricate chain of production processes instigated by a given final demand (Peters and Hertwich, 2006). Using SPA, an analyst can explore impacts that are caused directly by final consumption (such as energy use) or the entire network of impact paths that are caused in higher orders (such as CO_2 emissions in electricity for steel production for a train taken by the consumer for a train journey) (Wood and Lenzen, 2009). SPA is used in life-cycle assessment studies by Treloar (1997), Treloar and Love (2000), and Lenzen (2001). Lenzen (2007) used the technique for measuring flows in ecological and linked ecological-economic networks. Lenzen and Murray (2010) conducted SPA to conceptualise downstream responsibility for carbon emissions and established a framework for quantifying downstream carbon footprints. Mo et al. (2011) used the approach to develop an embodied energy model of surface water and groundwater supply options. Wood and Lenzen (2009) combined the technique with structural decomposition analysis (SDA) under the name of structural path decomposition (SPD). Oshita (2012) and Gui et al. (2014) used SPD to model supply chain paths that drive changes in CO_2 emissions in Japan and China.

Findings for major developed countries show that, with the emergence of technology and service intensive sectors, the input composition of construction sector changed in time (Giang and Pheng, 2011). As interactions with the rest of the economy are becoming more complex, any construction related injection into the economy induces demand for a larger variety of economic activities. Pietroforte and Tullio (2003) put that construction sector can be a driver of growth and development provided that it supports productive capacity in the form of fixed capital formation. This function is especially important for developing countries like Turkey where construction is a main component in government spending and also in public driven institutionalisation.

Following reforms after 2001 crisis, Turkish economy experienced impressive economic growth rates. Yet, high levels of current account deficit remained as a major threat on the sustainability of this growth. High reliance on imported energy and intermediate goods has often been addressed as the main factor behind this trade imbalance (Özata, 2014). Energy is seen as a limiting factor to economic growth in Turkey and shocks to energy supply are expected to have a negative impact on economic growth (Erdal et al., 2008). Aşıcı (2014) showed that, in post-2002 era, the composition of the thirteen growth leading sectors has changed towards more energy and pollution intensive sectors which resulted in not only widening of the current account deficit but also increased environmental degradation.

Under the authorisation of central and local public bodies, construction sector in Turkey has grown remarkably in the last decade. As a major investment sector, construction has been an important component of the final demand. The employment and GDP shares of the sector have increased in the same period. Major forces behind this growth were infrastructure upgrading for residential and commercial buildings as well as urban transport, gentrification and rehabilitation projects in most city centres, capacity enhancements in inter-city railways and highways, reconstruction in regions affected by natural disasters, and public sector housing construction. In other words, public promotion of construction sector was at a large scale in the last decade. This policy of injection is expected to trigger direct and indirect input demand. The injection process would also stimulate labour, imports, and energy demand (Günlük-Şenesen et al., 2012a; 2012b).

The World I-O database (WIOD) has been established to examine the effects of globalization on trade patterns, environmental pressures and socio-economic development across a broad group of countries (Timmer, 2012; Timmer et al., 2015). WIOD provides time-series of world I-O tables for 40 major countries worldwide and a model for the rest-of-the-world for the period from 1995 to 2011 (WIOD, 2016). In order to expand the analytical potential of the dataset to wider range of research topics, a set of Socio-economic Accounts (SEA) and environmental accounts (EA) are developed for the period from 1995 to 2009. The variables in EA cover: Use of energy; emission of greenhouse gases; emission of other air pollutants; use of mineral and fossil resources; land and water use. Other environmental accounts, such as waste generation are excluded due to significant gaps in data (Genty et al., 2012).

The purpose of this study is to explore the energy use paths driven by the final demand of construction sector in Turkey. To do this, energy use linkages of the construction sector is modelled using SPA. The model is based on the National I-O and Gross Energy Use tables provided in WIOD for Turkey for the years 1995, 2002, and 2009. Employment generation potentials and import linkages of Turkish construction sector were previously modelled by Günlük-Senesen et al. (2012a; 2012b) using I-O framework. Findings of these studies indicated that labour linkages of CON declined from 2002 to 2009 whereas import linkages of CON increased in the same period. Unravelling the channels of inter industrial energy use interactions, a secondary purpose of this study is to complete the overall picture drawn by these previous studies.

The rest of the paper is organised as follows: Section 2 provides an overview of the studies on energy use. Section 3 presents the SPA methodology used to reveal the energy use paths driven by the construction sector in Turkish economy. Section 4 focuses on the data used in the study. In Section 5, SPA of energy use is conducted. Findings are presented. Path structures are demonstrated. Section 6 is devoted to the concluding remarks.

2. LITERATURE REVIEW

In recent years, increasing number of studies is devoted to the relationship between economic activities and energy use. Jayanthakumaran et al. (2012) conducted a comparative analysis of China and India in terms of energy consumption, CO_2 emissions, trade and income. Sadorsky (2012) examined the relationship between energy consumption, output, and trade in seven American counties covering the period 1980 to 2007. Martinez and Silviera (2012) used data envelopment analysis and panel data econometrics to explore the trends in energy use and CO_2 emissions in Swedish services sector. Hasanbeigi et al. (2013) examined the relationship between energy use and the economic structure of the Chinese manufacturing sector. Adom and Kwakwa (2014) investigated the effects of changing trade structure and changing technical characteristics of the manufacturing sector alongside the effects of foreign direct investment and urbanization on energy intensity in Ghana. Examples of studies specifically focus on energy use and carbon emissions in the manufacturing sector are, but not limited to, those of Theriault and Sahi (1997), Mahmud (2000), Ramirez et al. (2005), Salta et al. (2009), Al-Ghandoor et al. (2010), Tarancón et al. (2011), and Hammond and Norman (2012).

As Gowdy and Miller (1987) noted, one of the most meaningful ways to look at energy use in the economy is to use I-O tables. Developed by Leontief (1936), I-O framework has been widely used in examining the energy embodied in goods and services. Liu et al. (2010) evaluated the energy embodied in goods produced in China during 1992–2005 and used I-O SDA to identify the key factors causing the changes of energy embodied in exports. Ferguson and McLean (2011) used I-O to compare energy use and greenhouse gas emissions associated with total household expenditures and activities in Canada and US. Fan and Xia (2012) used a hybrid energy I-O model to decompose the factors driving the increase in energy intensity and estimated the potential for decreasing energy demands. Zhang et al. (2013) presented a multi-regional I-O analysis of China's regional energy uses embodied in final demand and interregional trade. They identified significant net transfers of embodied energy flows from the central and western areas of China to the eastern area via inter regional trade. Zeng et al. (2014) used I-O SDA to investigate the contributions of changes in energy mix, sectoral energy efficiency, production structure, final demand structure, and final demand category composition to China's energy intensity fluctuation during 1997-2007. Using I-O analysis, Park and Heo (2007) investigated the direct and indirect household energy requirements in the republic of Korea from 1980 to 2000. Kuhtz et al. (2010) compared the energy use structures of Italian and Chinese tile manufacturers using an enterprise I-O model. Su and Wang (2012) evaluated the new methodological developments in SDA applications in energy and emission issues. Golley and Meng (2012) investigated the relationship between income inequality and emissions embodied in energy using an I-O framework.

In I-O literature, very few studies are devoted to energy usage and emissions linked to construction sector. Nassen et al. (2007) explored direct and indirect energy use and carbon emissions in the production phase of Swedish buildings. Using SPA, Treloar (1997) derived a set of embodied energy paths for the residential building sector from Australian I-O data. Later, Treloar et al. (2000) presented an I-O based hybrid SPA algorithm for systematically extracting energy paths in Australian construction sector.

Finally, a limited number of studies focus on energy use issues in Turkish economy. Ozkan et al. (2004) examined the energy use in Turkish agricultural sector for the period of 1975-2000. Using DEA and focusing on small and medium enterprises (SMEs), Önüt and Soner (2007) conducted an analysis of energy use and efficiency in Turkish manufacturing sector. Hepbasli and Özalp (2003) evaluated the development of industrial energy efficiency and management studies in Turkey. Providing a case study for Antalya region, Canakci et al. (2005) examine energy use patterns in agriculture sector. Tunç et al. (2009) used Log Mean Divisia Index (LMDI) method to identify the factors that contribute to changes in CO_2 emissions for the Turkish economy. Unakitan et al. (2010) provided an analysis of energy use efficiency of canola production in Turkey. Akbostancı et al. (2011) used LMDI technique to decompose the changes in the CO_2 emissions of manufacturing industry in Turkey. Halicioglu (2011) examined the relationship between aggregate output, energy consumption, exports, capital, and labour in the case of Turkey using time series data for the period 1968-2008. However, none of these studies made use of I-O analysis. Moreover, to the author's knowledge, there is no study which uses either SPA or SPD framework to investigate energy consumption paths driven by the construction sector in Turkey.

3. METHODOLOGY

The most straightforward of the energy extensions to the Leontief framework is to explicitly account for energy use by simply adding a set of linear energy coefficients that define energy use monetary unit's worth of output of industrial sectors. According to basic Leontief model, total output of an economy can be evaluated as,

$$X=AX+F \tag{1}$$

$$X=(I-A)^{-1} F=BF \tag{2}$$

Where A is n×n domestic direct input coefficients matrix, X is the n×1 total output vector, AX is intermediate consumption and F is the n×1 final demand vector. B is the Leontief inverse which is equal to $(I-A)^{-1}$ (Miller and Blair, 2009).

In order to obtain the total energy use in an economy, the following approach can be used [1]:

$$E+R=G \tag{3}$$

Where E is the matrix of energy flow from energy sectors to all other sectors. R is the vector of final energy demand and G is the vector of total energy use measured in physical units, terajoules (TJs). Energy coefficients can be calculated as ratios of direct energy use (in physical units) to total input (in monetary units), expressed in TJs per million US dollars (TJ/10^6 USD),

$$e_i = \frac{\sum_{k=1}^{c} E_{k,i}}{X_i} \tag{4}$$

Where e_i is the direct primary energy coefficient of sector i and E is the n×n diagonal direct primary energy coefficients matrix (e_i in the main diagonal and zeros elsewhere). As the total primary intensities of a product is the sum of its total secondary energy intensity, energy conversion lost, and energy used for other purposes, it can be obtained as the product of direct primary energy coefficients and Leontief inverse Liu et al. (2010):

$$L=\hat{e}B \tag{5}$$

L is the n×n total energy intensity matrix. Using equation (5), total domestic energy consumption D to produce final demand F can be found as follows:

$$D=\hat{e}BF=LF \tag{6}$$

Using Taylor series Equation (6) can be written as follows:

$$D=\hat{e}BF=\hat{e}(I-A)^{-1} F=\hat{e}IF+\hat{e}AF+\hat{e}A^2 F+\hat{e}A^3 F+\hat{e}A^4 F+ \tag{7}$$

In equation (7), $\hat{e}A^tF$ represents the energy requirements generated by the t^{th} production layer. Using equation (7), energy demand path structure can be expressed as a tree where each tier represents a production layer and each node gives the contribution to total intermediate energy requirements (in physical terms) induced by final demand F. Since the number of nodes in a layer grows exponentially, there are n^{t+1} nodes in each tier (Peters and Hertwich, 2006).

The energy demand produced at the zeroth tier (t=0) can be obtained as,

$$e_{kk} f_k \tag{8}$$

Energy requirements generated in any of the n^2 nodes of the first tier can be found using

$$e_{jj}\, a_{jk}\, f_k \tag{9}$$

And this product represents the path k→j. Similarly, the n^3 nodes of the second tier can be obtained using the following expression which represents energy use generated in the path k→j→i.

$$e_{ii}\, a_{ij}\, a_{jk}\, f_k \tag{10}$$

There are an infinite number of paths between a given set of sectors and the pattern described above holds for all levels of tiers. By calculating the contributions of all branches, SPA determines the most important nodes from all tiers (Peters and Hertwich, 2006).

Using the procedure explained above, the direct energy influence, $\mathrm{Inf}^{D}_{(k\to j)_p}$ generated along a path can be captured. On the other hand, to capture the extent to which direct energy influence along a path is amplified through the effects of adjacent feedback circuits (the effect of an industry on itself), Defourny and Thorbecke (1984) suggests calculating the total influence, $\mathrm{Inf}^{T}_{(k\to j)_p}$ which can be expressed as

$$\mathrm{Inf}^{T}_{(k\to j)_p} = \mathrm{Inf}^{D}_{(k\to j)_p} M_p \tag{11}$$

Where M_p is the path multiplier (j,k=1,…,n; path,p=1,…,P). If an energy path has no feedback circuits, than the multiplier will be 1. The calculation procedure of total energy influence, $\mathrm{Inf}^{T}_{(k\to j)_p}$ with respect to different path structures can be found in Defourny and Thorbecke (1984). Lastly, the global influence $\mathrm{Inf}^{G}_{(k\to j)}$ of all the paths between two sectors can be computed as follows:

$$\mathrm{Inf}^{G}_{(k\to j)} = \sum_{p=1}^{P} \mathrm{Inf}^{T}_{(k\to j)_p} = \sum_{p=1}^{P} \mathrm{Inf}^{D}_{(k\to j)_p} M_p \tag{12}$$

The above procedure is used to calculate the overall impact of the most significant energy usage paths once determined by the SPA methodology.

4. DATA

WIOD consists of a series of databases and covers 27 EU countries and 13 other major countries in the world for the period from 1995 to 2011. The Database contains four main sections: World I-O tables (WIOT), national I-O tables (NIOT), SEA, and EA. Since the latest available I-O table published by Turkish Statistical Institute is for the year 2002, the more recent 2009 I-O table provided in NIOT for the Turkish economy is used. As the latest available EA data in WIOD is for the year 2009, to ensure consistency in time, even more recent 2011 I-O table could not be used. To obtain two equal periods of comparison, analyses are repeated for the years 1995 and 2002.

The core of the environmental database in WIOD consists of energy accounts. Energy accounts are first obtained using energy balances from the International Energy Agency (IEA). Additional information was used to relate territory and residence principles and to assign IEA accounts to the target classification and accounting concepts consistent with WIOT. To derive energy accounts from international energy balances provided by IEA, a correspondence link is established between the energy balance items and the NACE entries. The details of the data compilation procedures for EA can be found in technical reports of Timmer (2012) and Genty et al. (2012).

NIOT are prepared for 35 industries (in current US$ million). Sector based energy use data is provided in Terajoules (TJs). The abbreviations used for the sector names can be found in Table 1.

5. SPA OF ENERGY USE IN CONSTRUCTION SECTOR IN TURKEY

In 1995, with 146.6 petajoules (PJs) of energy use, CON sector was the seventh among 35 sectors. Table 2 shows the gross energy use in PJs (1 PJ=1000 TJs) by industries for the years 1995, 2002 and 2009. As it is seen in Table 2, from 1995 to 2002, total energy use in Turkish economy increased by 19%. In the same period, energy use of the CON sector increased by 13% to 166.3 PJs. From 2002 to 2009, energy demand in the economy increased by another 20%. In this period, energy usage of CON sector increased by 26%. Following EGW, PET, BMA and AGR, (with 209.3 PJs) CON became the fifth most energy consuming sector in 2009. From 1995 to 2009, total energy use of CON increased by 43%.

In the SPA analysis, 0.1% of the total energy use induced by CON sector in the whole economy is used as the threshold in deciding whether to follow a path in the tree structure or not. Using Equation (6) energy use induced by CON sector for 1995, 2002, and 2009. In 1995, one million US$ (in current prices) increase in the final demand of CON would induce 15.992 TJs of energy demand in the whole economy. Therefore, the threshold for 1995 is taken as 15.992 gigajoules (GJs) (1 TJ=1000 GJs). The threshold values used for 2002 and 2009 are 20.136 and 9.298 (in GJs), respectively.

The bar charts in Figures 1-3 summarise condensed findings for paths for 1995, 2002, and 2009. The total length of a bar represents the sectoral backward energy use linkage of a path. The bars are ranked by the size of the backward linkages. The dark grey part of a bar represents the captured direct influence. The light grey part shows the multiplier effect which can be computed using

Table 1: Sectors in the WIOD database

Sector name	Abbreviation	Sector name	Abbreviation
Agriculture, hunting, forestry and fishing	AGR	Construction	CON
Mining and quarrying	MIN	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	MVH
Food, beverages and Tobacco	FOD	Wholesale trade and commission trade, except of motor vehicles and motorcycles	WTR
Textiles and textile products	TEX	Retail trade, except of motor vehicles and motorcycles; repair of household goods	RTR
Leather, leather and footwear	LET	Hotels and restaurants	HRE
Wood and products of wood and cork	WOD	Inland transport	ITN
Pulp, paper, paper, printing and publishing	PAP	Water transport	WTN
Coke, refined petroleum and nuclear fuel	PET	Air transport	ATN
Chemicals and chemical products	CPR	Other supporting and auxiliary transport activities; activities of travel agencies	OTN
Rubber and plastics	RUB	Post and telecommunications	PTE
Other non-metallic mineral	NMA	Financial intermediation	FIN
Basic metals and fabricated metal	BMA	Real estate activities	REA
Machinery, Nec	MCH	Renting of M&Eq and other business activities	MEQ
Electrical and optical equipment	EOE	Public admin and defence; compulsory social security	PAD
Transport equipment	TNE	Education	EDU
Manufacturing, Nec; recycling	MAN	Health and social work	HSW
Electricity, gas and water supply	EGW	Other community, social and personal services	CSP
		Private households with employed persons	HHE

Figure 1: Direct, multiplier and uncaptured influences of major paths in 1995

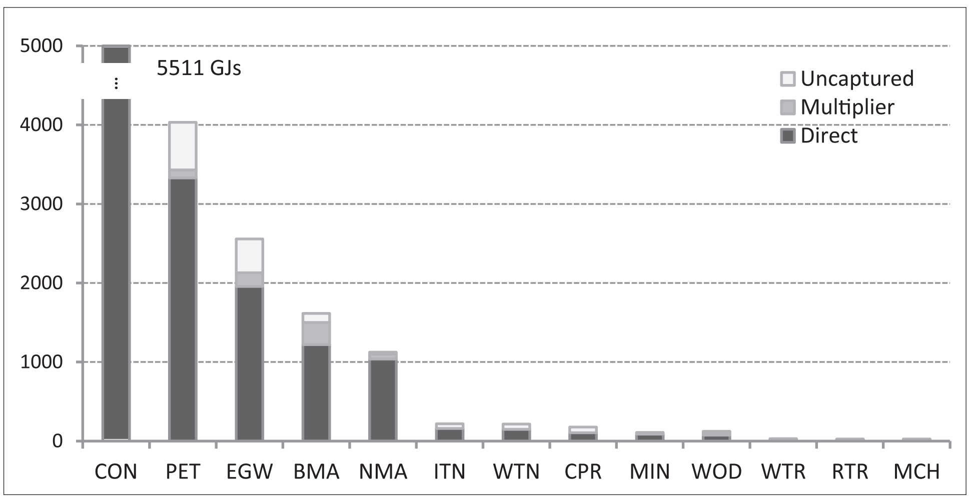


Figure 2: Direct, multiplier and uncaptured influences of major paths in 2002

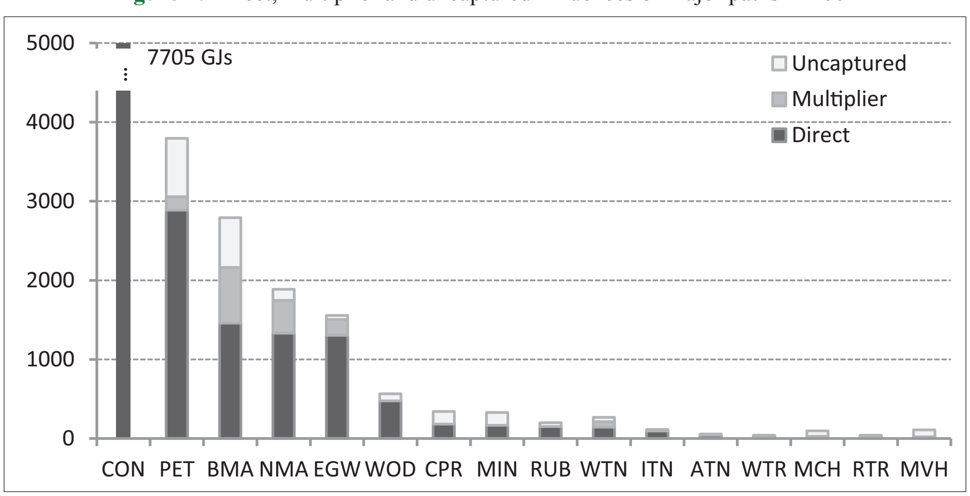


Figure 3: Direct, multiplier and uncaptured influences of major paths in 2009

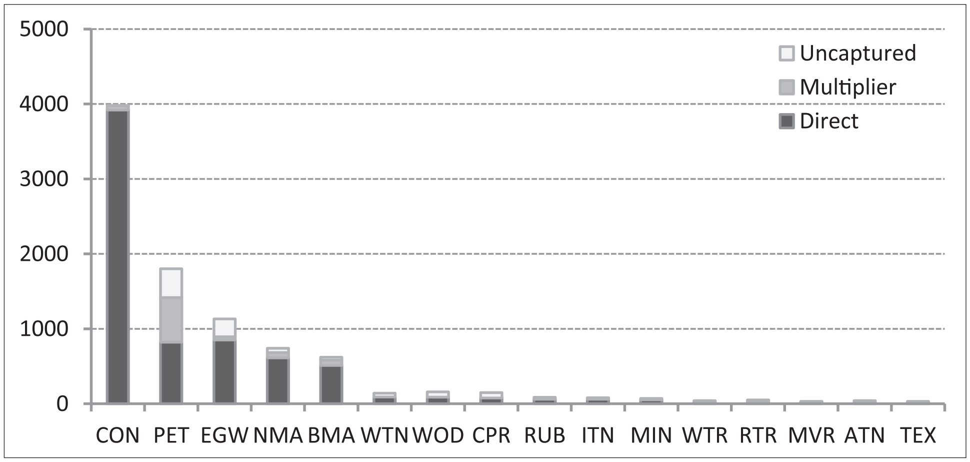


Table 2: Gross energy use (1000 TJs) by industries (1995, 2002, and 2009)

Sector	1995	Rank (1995)	2002	Rank (2002)	% change (02 vs. 95)	2009	Rank (2009)	% change (09 vs. 02)	% change (09 vs. 95)
AGR	165.2	5	185.6	0	12	248.7	4	34	51
MIN	17.0	14	27.7	16	63	28.2	18	2	66
FOD	54.6	12	83.5	12	53	129.2	10	55	136
TEX	66.2	10	139.4	8	111	125.1	12	−10	89
LET	2.3	34	5.1	32	122	5.0	34	0	121
WOD	14.8	15	56.3	14	281	23.0	22	−59	56
PAP	27.8	13	25.0	17	-10	25.4	20	2	-9
PET	1212.8	1	1176.3	1	-3	912.2	2	−22	-25
CPR	162.6	6	211.1	4	30	197.0	6	−7	21
RUB	10.2	21	75.5	13	639	77.6	13	3	660
NMA	57.5	11	111.6	9	94	125.9	11	13	119
BMA	300.0	3	270.7	3	-10	368.8	3	36	23
MCH	10.3	20	16.9	21	64	14.5	28	−14	42
EOE	5.9	28	9.6	29	63	10.1	32	5	72
TNE	11.2	18	23.7	18	111	21.5	24	−9	91
MAN	6.2	26	11.8	25	90	14.2	29	20	128
EGW	638.1	2	916.0	2	44	1525.6	1	67	139
CON	146.6	7	166.3	6	13	209.3	5	26	43
MVH	4.0	32	13.0	23	226	24.5	21	89	514
WTR	12.1	17	17.1	20	41	35.6	16	109	193
RTR	13.8	16	13.7	22	-1	29.1	17	112	111
HRE	10.5	19	18.6	19	77	46.7	15	151	343
ITN	105.1	8	96.1	11	-9	137.4	9	43	31
WTN	79.2	9	106.5	10	34	165.2	7	55	109
ATN	176.8	4	143.6	7	-19	146.2	8	2	-17
OTN	9.8	22	9.8	28	0	13.4	30	37	36
PTE	5.3	29	10.5	26	96	16.3	27	55	205
FIN	8.2	23	5.9	31	-29	12.6	31	114	52
REA	4.0	31	4.6	33	16	17.1	26	268	326
MEQ	3.3	33	2.6	34	−22	7.9	33	210	140
PAD	7.4	25	29.1	15	292	52.1	14	79	602
EDU	7.6	24	11.8	24	56	26.5	19	124	251
HSW	4.5	30	9.4	30	111	21.7	23	131	387
CSP	6.0	27	10.0	27	66	21.3	25	114	256
HHE	0.0	35	0.0	35	-	0.0	35	-	-
Economy	3367.2		4014.2		19	4837.1		20	44

Equations (11,12). The white part of a vertical bar stands for the influence uncaptured by SPA. As the size of the energy influence of CON on itself is very large, in Figures 1 and 2, it is shown with dots and a broken bar.

Tables 3-5 (Table 3 for 1995, Table 4 for 2002, and Table 5 for 2009) show every captured path with its routes above the threshold. The tables are identically structured. First column shows the captured direct energy influence in GJs. Column (2) lists the captured total energy influence (in GJs). Column (3) shows the multiplier effects. Column (4) demonstrates the overall influences which include the uncaptured part by the path analysis. The fifth column gives the percentage of the captured direct influence in overall influence. Finally, the percentage of the captured total influence in overall influence is listed in Column (6).

As an example, the first path in Table 3 shows that a million USD increase in the final demand of CON sector has 5450 GJs of direct and 5511 GJs of overall energy use influence on itself. Column (2) shows that 5509 GJs of this overall influence is captured by the SPA. The row of Path 2 "CON→PET" demonstrates the sum of the energy use induced by the routes below it. If a route has CON and an energy consumption sector only, such as CON→PET on the third row in Table 3, it is a simple route. A million USD increase

Table 3: Energy influences of construction sector in Turkey (1995) Direct and total influences captured

The routes of energy use		Captured direct influence	Captured total influence	Multiplier (total/direct)	Overall influence	Captured direct in overall influence (%)	Captured total in overall influence (%)
		(1)	(2)	(3)	(4)	(5) = (2)/(4)	(6) = (2)/(4)
1	CON→CON	5450.0	5509.0	1.011	5511	98.9	100.0
2	CON→PET	3330.5	3430.6		4033	82.6	85.1
	CON→PET	1879.6	1904.0	1.013			
	CON→ITN→PET	485.0	485.0	1.000			
	CON→NMA→PET	404.6	430.0	1.063			
	CON→BMA→PET	211.8	262.1	1.237			
	CON→WTN→PET	69.0	69.0	1.000			
	CON→MIN→PET	49.9	49.9	1.000			
	CON→WTR→PET	39.4	39.4	1.000			
	CON→EGW→PET	31.3	31.3	1.000			
	CON→CPR→PET	20.3	20.3	1.000			
	CON→RTR→PET	19.9	19.9	1.000			
	CON→NMA→MIN→PET	25.5	25.5	1.000			
	CON→NMA→ITN→PET	61.9	61.9	1.000			
	CON→NMA→EGW→PET	32.3	32.3	1.000			
3	CON→EGW	1957.2	2129.5		2557	76.5	83.3
	CON→EGW	723.1	742.3	1.027			
	CON→NMA→EGW	745.9	813.8	1.091			
	CON→BMA→EGW	358.7	443.8	1.237			
	CON→RTR→EGW	32.9	32.9	1.000			
	CON→WOD→EGW	29.0	29.0	1.000			
	CON→WTR→EGW	26.0	26.0	1.000			
	CON→PET→EGW	23.0	23.0	1.000			
	CON→MIN→EGW	18.6	18.6	1.000			
4	CON→BMA	1220.2	1499.7		1616	75.5	92.8
	CON→BMA	1177.3	1456.8	1.237			
	CON→NMA→BMA	22.8	22.8	1.000			
	CON→MCH→BMA	20.1	20.1	1.000			
5	CON→NMA	1038.5	1103.7	1.063	1124	92.4	98.2
6	CON→ITN	159.9	159.9		219	72.9	72.9
	CON→ITN	141.8	141.8	1.000			
	CON→NMA→ITN	18.1	18.1	1.000			
7	CON→WTN	149.1	149.1		215	69.2	69.2
	CON→WTN	130.2	130.2	1.000			
	CON→BMA→WTN	19.0	19.0	1.000			
8	CON→CPR	106.2	106.2		177	60.0	60.0
	CON→CPR	81.5	81.5	1.000			
	CON→NMA→CPR	24.7	24.7	1.000			
9	CON→MIN	87.5	87.5		110	79.9	79.9
	CON→MIN	58.0	58.0	1.000			
	CON→NMA→MIN	29.5	29.5	1.000			
10	CON→WOD	75.1	111.2	1.481	124	60.4	89.4
11	CON→WTR	20.2	20.2	1.000	30	67.9	67.9
12	CON→RTR	17.6	17.6	1.000	27	66.1	66.1
13	CON→MCH	16.5	16.5	1.000	27	61.1	61.1
	CON→Economy	13628	14341		15992	85.2	89.7

Table 4: Energy influences of construction sector in Turkey (2002) direct and total influences captured

The routes of energy use		Captured direct ınfluence	Captured total ınfluence	Multiplier (total/direct)	Overall influence	Captured direct in overall influence (%)	Captured total in overall influence (%)
		(1)	(2)	(3)	(4)	(5) = (2)/(4)	(6) = (2)/(4)
1	CON→CON	7546.0	7693.2	1.020	7704.6	97.9	99.9
2	CON→PET	2887.7	3056.7		3795.1	76.1	80.5
	CON→PET	2218.0	2358.4	1.063			
	CON→ITN→PET	217.0	217.0	1.000			
	CON→NMA→PET	218.0	246.6	1.131			
	CON→BMA→PET	80.2	80.2	1.000			
	CON→MIN→PET	56.0	56.0	1.000			
	CON→WTR→PET	40.0	40.0	1.000			
	CON→MVH→PET	27.3	27.3	1.000			
	CON→NMA→MIN→PET	31.2	31.2	1.000			
3	CON→EGW	1304.2	2007.8		2636.1	49.5	76.2
	CON→EGW	797.6	1219.3	1.529			
	CON→NMA→EGW	170.2	260.1	1.529			
	CON→BMA→EGW	205.9	397.8	1.932			
	CON→WOD→EGW	24.1	24.1	1.000			
	CON→WTR→EGW	25.9	25.9	1.000			
	CON→MIN→EGW	32.1	32.1	1.000			
	CON→RUB→EGW	21.2	21.2	1.000			
	CON→MVH→EGW	27.2	27.2	1.000			
4	CON→BMA	1458.8	1872.6		2013.8	72.4	93.0
	CON→BMA	1433.4	1847.3	1.289			
	CON→MCH→BMA	25.3	25.3	1.000			
5	CON→NMA	1332.0	1532.1		1583.2	84.1	96.8
	CON→NMA	1304.7	1504.9	1.153			
	CON→BMA→NMA	27.2	27.2	1.000			
6	CON→ITN	94.4	94.4	1.000	184.9	51.1	51.1
7	CON→WTN	143.1	143.1		303.7	47.1	47.1
	CON→WTN	117.3	117.3	1.000			
	CON→RTR→WTN	25.7	25.7	1.000			
8	CON→CPR	181.3	181.3		342.1	53.0	53.0
	CON→CPR	123.0	123.0	1.000			
	CON→NMA→CPR	30.3	30.3	1.000			
	CON→RUB→CPR	28.0	28.0	1.000			
9	CON→MIN	168.2	168.2		216.4	77.8	77.8
	CON→MIN	108.0	108.0	1.000			
	CON→NMA→MIN	60.2	60.2	1.000			
10	CON→WOD	475.8	546.0	1.148	599.5	79.4	91.1
11	CON→RUB	151.7	151.7	1.000	221.3	68.6	68.6
12	CON→WTR	29.8	29.8	1.000	51.0	58.5	58.5
13	CON→RTR	25.3	25.3	1.000	40.1	63.0	63.0
14	CON→MCH	27.3	27.3	1.000	39.0	70.0	70.0
15	CON→MVH	22.5	22.5	1.000	38.8	57.9	57.9
16	CON→ATN	42.0	42.0	1.000	129.3	32.5	32.5
	CON→Economy	15890	17594		20136	78.9	87.4

in the final demand of CON sector produces input demand from PET and therefore induces 1880 GJs of direct energy usage in PET. If there is a third sector between the target and base sector, such as ITN on the route CON→ITN→PET just below this simple route, it is a mediating sector, that is the input demand induced by CON from ITN generates input demand of ITN from PET which induces energy demand by PET. Some paths, such as path 5 "CON→NMA" are direct energy paths. 1 million USD increase in the final demand of CON sector yields 1038.5 GJs of direct energy use in NMA sector.

The last rows of Tables 3-5 show that the SPA captures the induced total energy demand in the Turkish economy by 90% in 1995, 87% in 2002, and 87% in 2009. The top rows of Tables 3-5 also show that 99% (in 1995), 98% (in 2002) and 99% (in 2009) of the self-influence of CON is direct and the rest of it is through multipliers. There is no evidence for strong indirect influence as the corresponding multipliers are slightly above 1 (1.011 in 1995, 1.020, and 1.014 in 2009). The fifth columns in Tables 3-5 show that almost the entire total self-influence of CON is captured by SPA.

In 1995 and 2002, CON→PET path is the second most important path in terms of overall influence. Due to increasing share of natural gas fired energy production, the path is exceeded by CON→EGW path in 2009. In 1995, CON→PET path consisted of one direct route and 12 indirect routes. In 2002 and 2009, the number of indirect routes decreased to 7 and 6, respectively. In

Table 5: Energy influences of construction sector in Turkey (2009) direct and total influences captured

The routes of energy use		Captured direct influence	Captured total influence	Multiplier (total/direct)	Overall influence	Captured direct in overall influence (%)	Captured total in overall influence (%)
		(1)	(2)	(3)	(4)	(5) = (2)/(4)	(6) = (2)/(4)
1	CON → CON	3920.8	3975.7	1.014	3980.1	98.5	99.9
2	CON → PET	821.6	864.9		1102.7	74.5	78.4
	CON → PET	646.5	689.8	1.067			
	CON → ITN → PET	61.7	61.7	1.000			
	CON → NMA → PET	55.5	55.5	1.000			
	CON → BMA → PET	16.1	16.1	1.000			
	CON → MIN → PET	20.8	20.8	1.000			
	CON → WTR → PET	10.1	10.1	1.000			
	CON → NMA → MIN → PET	10.9	10.9	1.000			
3	CON → EGW	851.2	1446.4		1831.2	46.5	79.0
	CON → EGW	553.1	953.6	1.724			
	CON → NMA → EGW	98.4	188.9	1.919			
	CON → BMA → EGW	87.6	172.1	1.963			
	CON → WOD → EGW	15.9	15.9	1.000			
	CON → WTR → EGW	14.7	14.7	1.000			
	CON → MIN → EGW	27.3	47.0	1.724			
	CON → RUB → EGW	13.0	13.0	1.000			
	CON → MVH → EGW	15.8	15.8	1.000			
	CON → RTR → EGW	11.0	11.0	1.000			
	CON → NMA → MIN → EGW	14.3	14.3	1.000			
4	CON → BMA	513.0	584.2	1.139	639.9	80.2	91.3
5	CON → NMA	613.5	683.0	1.113	721.6	85.0	94.7
6	CON → ITN	60.5	60.5	1.000	112.8	53.6	53.6
7	CON → WTN	90.0	90.0		160.2	56.2	56.2
	CON → WTN	67.5	67.5	1.000			
	CON → RTR → WTN	12.8	12.8	1.000			
	CON → WTR → WTN	9.7	9.7	1.000			
8	CON → CPR	76.8	76.8		150.1	51.2	51.2
	CON → CPR	51.8	51.8	1.000			
	CON → NMA → CPR	12.3	12.3	1.000			
	CON → RUB → CPR	12.8	12.8	1.000			
9	CON → MIN	53.1	53.1		78.3	67.8	67.8
	CON → MIN	34.8	34.8	1.000			
	CON → NMA → MIN	18.3	18.3	1.000			
10	CON → WOD	88.1	101.2	1.148	108.9	80.9	92.9
11	CON → RUB	61.9	61.9	1.000	88.1	70.2	70.2
12	CON → WTR	28.7	28.7	1.000	47.3	60.6	60.6
13	CON → RTR	24.6	24.6	1.000	37.8	65.1	65.1
14	CON → MVH	19.6	19.6	1.000	32.7	60.1	60.1
15	CON → ATN	15.5	15.5	1.000	42.6	36.4	36.4
16	CON → TEX	10.4	10.4	1.000	32.2	32.3	32.3
	CON → Economy	7249	8096		9298	78.0	87.1

all of the 3 years examined, the most important route of this path was the direct route. In 1995, the sectors mediating between CON and PET were MIN, EGW, some manufacturing sectors such as NMA, BMA, and CPR, two of the transportation sectors, i.e., ITN and WTN, and service sectors like WTR and RTR. In 2002, the number of mediating sectors decreased to 6: ITN, NMA, BMA, MIN, WTR and MVH. In 2009, the mediating sector MVH also diminished. SPA captured 85% (in 1995), 81% (in 2002) and 78% (in 2009) of the overall energy influence produced in this path. As an example, the development of CON→PET path can be illustrated as in Figures 4a-c.

In Figure 4, circular arrows above (or next to) some sectors stand for the adjacent feedback circuits. It can be seen in Tables 3-5 that the multipliers of the routes with the circular arrows are >1.

Another significant path is CON→EGW path. Mostly due to the growing share of natural gas powered energy production, the overall influence of the CON→EGW path became the second (was the third in 1995 and 2002) highest among all paths in 2009. In 1995, CON→ EGW path consisted of one direct route and 7 indirect routes. In terms of captured total influence, CON→NMA→EGW route (814 GJs) was the most significant route followed by

CON→EGW (742 GJs) and CON→BMA→EGW (444 GJs) routes. In 2002, the number of routes remained the same. However, the mediating sectors RUB and MVH appeared instead of PET and RTR. CON→NMA→EGW route lost its relative importance. CON→EGW direct route became the most intense energy use route. In 2009, CON→ EGW path consisted of one direct route and 9 indirect routes (Figure 5). CON→EGW (954 GJs), CON→NMA→EGW (189 GJs) and CON→BMA→EGW (172 GJs) were the most important routes. In 2002 and 2009, multipliers of these routes were >1.5 indicating that more than one third of the impact of these routes was indirect.

CON→BMA and CON→NMA are the next most important paths. In 1995, CON→BMA path consisted of one direct route and two indirect routes. The magnitude of the captured total influence for the direct route was 1457 GJs with a multiplier of 1.237. The two indirect routes were CON→NMA→BMA and CON→MCH→BMA. In 2002, CON→NMA→BMA route diminished. The CON→BMA direct route had a magnitude of 1847 GJs with a multiplier of 1.289. In 2009, CON→MCH→BMA route also dropped. CON→BMA direct route remained with a captured magnitude of 640 GJs. SPA captured 93% (in 1995), 93% (in 2002) and 91% (in 2009) of the overall energy influence produced in this path.

In 1995, CON→NMA path consisted of a direct route only. Captured total influence for the path was 1104 GJs with a multiplier of 1.063. In 2002, CON→ BMA→NMA route appeared. The influence of the CON→NMA direct route increased to 1505 GJs. In 2009, the route CON→BMA→NMA diminished leaving the

Figure 4: The routes of CON→PET path in (a) 1995, (b) 2002, and (c) 2009

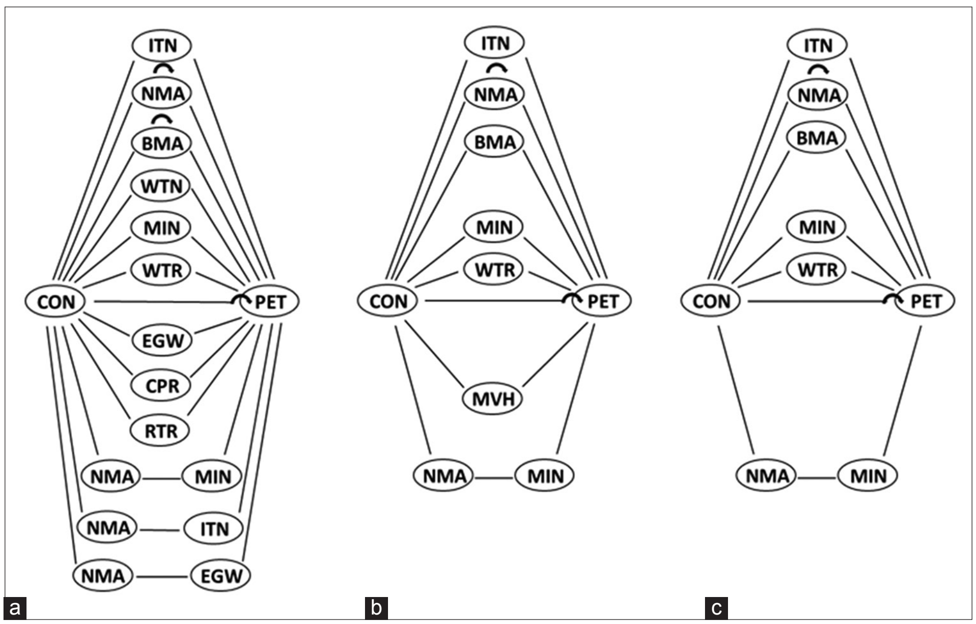
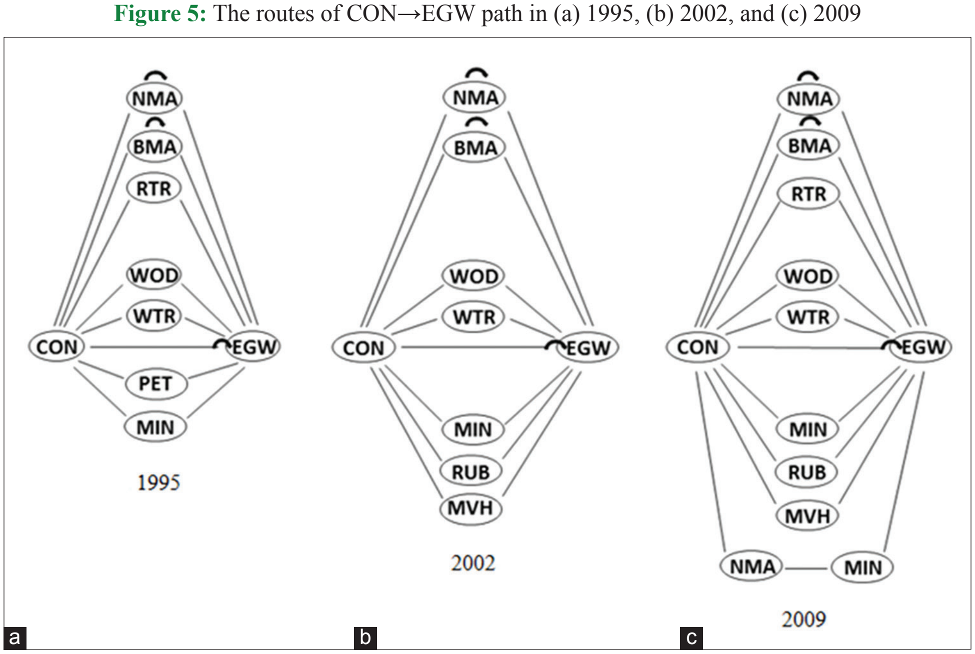


Figure 5: The routes of CON→EGW path in (a) 1995, (b) 2002, and (c) 2009



CON→NMA as the one and only route of the path again. Although decreasing in absolute terms, in 2009, the total influence of the path exceeded that of CON→BMA path. 98% (in 1995), 97% (in 2002) and 95% (in 2009) of the overall influence generated by this path is captured by the SPA.

Two transportation paths, namely CON→ITN and CON→WTN were the next most significant paths in all of the 3 years. In 1995, CON→ITN consisted of a direct route and an indirect route: CON→ITN and CON→NMA→ITN. In 2002 CON→NMA→ITN dropped and did not appear in 2009. In 1995, CON→WTN also consisted of a direct route and an indirect route. The indirect route was CON→BMA→WTN. In 2002, this route dropped and CON→RTR→WTN appeared. In 2009, CON→WTR→WTN route also showed.

CON→CPR and CON→NMA→CPR were the routes of CON→CPR path in 1995. In 2002, CON→RUB→CPR indirect route emerged and did not diminish in 2009. In all of the 3 years, CON→MIN path consisted of CON→MIN direct route and CON→NMA→MIN indirect route. In 1995, the remaining significant energy paths were CON→WOD, CON→WTR, CON→RTR and CON→MCH direct paths. In 2002, CON→RUB, CON→MVH and CON→ATN simple paths also appeared. In 2009, CON→MCH dropped and CON→TEX path came out.

Out of infinite number of inter-sectoral energy consumption routes, with 38 most significant routes, SPA captured 90% of the total energy use induced by CON in 1995. In 2002 and 2009, with 36 routes, SPA captured around 87% of the total energy use induced by CON.

6. DISCUSSION AND CONCLUSION

As the likely consequences of global warming become clearer, a growing number of studies are devoted to sectoral energy consumption issues. Heading towards the usage of renewable energy technologies and minimization of energy consumption as a global climate change solution have become a common agenda for many of the developed and developing countries.

In post-2001 era, following structural reforms, Turkish economy enjoyed high growth rates. Yet, due to Turkish economy's heavy dependence on imported intermediate goods and energy, this growth was accompanied by an ever-increasing current account deficit. Energy use of growth sectors in the economy has remarkably increased in 2000s. In the last decade, under large scale promotion of central and local public bodies, construction sector in Turkey had become an important tool of public policy injection. This policy of injection had some consequences on labor, imports, and energy use patterns. The purpose of this study was to unravel the inter-industry energy usage paths driven by the changes in the final demand of construction sector in Turkey. To do this, an I-O based methodology, SPA is used.

The results of the study showed that, in absolute terms, total energy use of CON increased in both 2002 and 2009 (relative to previous study year). In 2009, among 35 sectors, CON became the fifth (was seventh in 1995) most energy consuming sector. SPA is conducted for the years 1995, 2002 and 2009. 0.1% of the total energy use induced by CON (in the corresponding study year) is used as the threshold value. The routes that have an impact less than this threshold were not followed by the tree structure algorithm. Significant energy consumption paths and routes are determined. In all of the three study years, SPA captured more than 85% of the total energy use induced by the construction sector.

SPA revealed that, from 1995 to 2009, the magnitude and complexity of CON→EGW path increased. The most significant mediating sectors in this path were non-metals and basic metals. In the same period, the relative importance and complexity of CON→PET path decreased. The most important part of the energy use in response to a unitary final demand change took place at CON→CON initial path. In all of the 3 years, paths of two manufacturing sectors, namely CON→BMA and CON→NMA were the next most significant paths. Number of routes above the threshold remained close in all of the 3 years, whereas number of paths slightly increased (from 13 in 1995 to 16 in 2009).

As a sector of policy injection, construction sector in Turkey became more dependent upon imported gas powered energy production in post-2002 era. With limited indirect employment generation potentials and a dependence upon imported intermediate goods, CON demonstrated most of the symptoms of the overall economy. The insistence on high growth rates came at the expense of a higher contribution to widening current account deficit and degradation in environmental conditions. In 2020s, instead of energy and pollution intensive sectors like CON, Turkey should promote growth with more environment-friendly sectors with higher value-added. The focus of the energy policies should shift from meeting the increasing energy demand towards using energy more efficiently. A stable policy with a long term view, which is consistent with the international climate change commitments would be a benefit for the country.

An alternative to this long-term perspective could be to accept the current composition of the growth industries as given and promote local coal based energy production in order to decrease current account deficit. If this second path is pursued, CON→PET path may regain its importance as in 1995 to 2002 period. Yet, this short term growth perspective will have serious environmental consequences in water pollution, air pollution, land use and solid waste management areas.

The recent announcements of the big infrastructure projects like Third Bosphorus Bridge and Northern Marmara Highway, The Third International Airport of Istanbul, Çanakkale Bridge, suspension bridge of Izmit Bay and Kanal Istanbul (an artificial sea-level waterway connecting the Black Sea to the Sea of Marmara) show that, in the next decade, the public promotion of construction sector will still be at a large scale in Turkey. Moreover, declaration of action plans like The New Investment Incentives Scheme Act indicate that Turkish government will be promoting strategic sectors like coal mining and local coal based thermal energy production in the next years. These initial signs show that Turkey will follow the second path and accelerate the public policy of injection into the economy via the construction sector in the following years.

In future studies, the methodology used in this study can be applied to examine the energy usage structures of other sectors like manufacturing, services and transportation. Using WIOD, construction sectors of other countries could also be examined. With some modifications, the technique can be used to elaborate the emissions of CO_2 and other greenhouse gases. Finally, using SPD, energy use and emission analyses could be expanded so as to decompose the final demand side.

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