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Decomposition of CO2 Emissions over 1980–2003 in Turkey

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Decomposition of CO2 emissions over 1980–2003 in Turkey

Summary

There is a multi-dimensional need for studying the energy situation in Turkey and to obtain insight into the development of CO2 emissions. On the one hand, recent projections of the OECD show that Turkey has a yearly GDP growth potential of over 7%. On the other hand, recent projections of UNDP and World Bank indicate that the level of CO2 emission is going to rise six-fold by 2025 with respect to the level of emissions in 1990. It is a great challenge to both meet the growth target and keep the CO2 under control. Thereupon, this paper tries to unfold factors that explain CO2 emissions by undertaking a complete decomposition analysis for Turkey over the period 1980–2003. The analysis shows, as is common to relatively fast growing economies, that the biggest contributor to the rise in CO2 emissions is the expansion of the economy (scale effect). The carbon intensity and the change in composition of the economy, which nearly move in tandem, also contribute to the rise in CO2 emissions, albeit at a slower rate. The energy intensity of the economy, which is decreasing, is responsible for a modest reduction in CO2 emissions. Hence, in congruence with the scale effect, we do not find a decoupling of carbon emissions and economic growth in Turkey over the period 1980–2003.

Keywords: Decomposition analysis, Turkey, Energy, CO2 emissions, Economic growth

JEL Classification: Q4, Q54

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1. Introduction

There is a multi-dimensional need for studying the energy situation in Turkey and to obtain insight into the development of CO_2 emissions. First, Turkey is a candidate for becoming an EU member in the near future and Turkey can strengthen her strategic position as a gas and oil transportation country (see also: Van der Linde, 2004). Second, Turkey is listed as an Annex 1 country of the UNFCCC framework, but not as an Annex B country and has not yet set a greenhouse gas emissions reduction target. Once such a reduction target is negotiated, Turkey could become a partner for Joint Implementation projects. Turkey does not qualify for projects under the Clean Development Mechanism. Finally, the Turkish economy has a boom-bust structure and it is interesting to study her development performance. A recent survey of the OECD shows that Turkey has a long-term yearly growth potential of above 7% (OECD, 2004).

UNDP and WB (2003) provide a broad policy overview of Turkey's energy situation and energy related environmental issues until 2025. They project a six-fold increase in greenhouse gas emissions by 2025 in the baseline with respect to 1990 levels (ibid. page 56). Over the period 2000–2025 an annual increase of 5.7% is foreseen, while in the same period final energy consumption is projected to increase at 5.9% (ibid. page 25). In the baseline there is already accounted for an unrestricted increase of gas imports into the energy mix, namely from 14 million tonnes of oil equivalent (mtoe) in 2000 to 73 mtoe in 2015 and 155 mtoe in 2025, almost 50% of the total energy demand (ibid.).

Yet, the level of greenhouse gas emissions in 1990 was particularly low and the energy supply has grown with 4.4% per year in the last decade. Compare this, for instance, with the situation in transition economies in Eastern European countries where the level of greenhouse gas emissions in 1990 was particularly high and emissions declined considerably with 32% in the period 1990–2000 (using CO_2 emissions with reference approach from IEA database for economies in transition).

In order to find possibilities for slowing down the expected growth in carbon emissions, Karaata and Ekmekçi (2002) and Oğulata (2003) focus on the prospects of Turkey to install wind power as a renewable energy source of the future. They conclude that there is indeed quite some potential in Turkey. Around a similar line of thought, Birol (2002) gives a national energy outlook for Turkey and a forecast of future CO_2 emissions and discusses the prospects for introducing nuclear energy into the energy mix. In relation to a possible reduction in CO_2 emissions, Şahin and Pratlong (2003) discuss the consequences for Turkey for introducing a tradable emission permit scheme.

Sari and Soytas (2004) apply a so-called generalized forecast error variance decomposition technique, which they use to shed light on the link between energy consumption and economic growth. They conclude that energy consumption is almost as important as employment in explaining the variance in the growth of national income in Turkey. This decomposition technique differs from the decomposition analysis as presented in Section 2 in the sense that it decomposes the variance in a variable, rather than decomposing the level of a variable. That is also the reason why they did not explain the variation in CO_2 emissions; we have done this in Section 3.4.

Altınay and Karagöl (forthcoming) apply a series of so-called unit root and causality tests to verify whether there is a causality between GDP and energy consumption for the period 1950–2000. Establishing that energy consumption causes GDP has important policy implications, because then a reduction in energy consumption will translate into a break on economic growth. While they show that energy consumption and GDP in Turkey do have a unit root, they also find a structural break in the data. They conclude that there is no causality between energy and GDP.

Yeldan (2002, 2004) and Voyvoda and Yeldan (2003) discuss the typical boom-bust structure of the Turkish economy. In contrary to the popular believe that bad governance caused the Turkish economic crisis in 2001, they argue that the crisis emerged due to too tight control of the IMF, which disempowered the Turkish central bank. This made an already fragile economy even more fragile to a point that short-term foreign capital fled the country with a first shock in November 2000 and a second shock in February 2001. The presence of short-term capital in the Turkish economy is sometimes ironically referred to as 'casino' capitalism (Yeldan 2002), which, once it is withdrawn overnight, can quickly destabilize the economy, with disastrous effects, as the 2001 crisis has shown.

Furthermore, Yeldan (2002, 2004) argues that due to unsustainable so-called Ponzi-schemes (a process where extra money has to be borrowed for paying the national debt service) important indicators of the Turkish economy have weakened. Moreover, the wave of growth in 2003/2004 is generated by an inflow of foreign capital to keep the Turkish lira strong. This short-term foreign capital is very volatile and this can change overnight, as the two crises in 2000 and 2001 have shown. In addition, unemployment is still high (around 10% in 2003) and there has been no growth in real wages. There is also room for optimism, however, as the diversion from hyperinflation in the 80s and 90s to the present single digit rate (in 2004). Still, for a sustainable situation to emerge, private long-term commitment in the form of fixed capital, via foreign direct investment, is needed, which goes beyond the so-called 20%–40% unsustainable arbitrage margin.[2]

Understanding long-term 'energy transitions' and 'development trajectories' is a great challenge in the move towards sustainable development in a globalising world. Energy transitions are defined as investments in possibly cleaner technologies to replace and expand the depreciating capital stock. When considered over a longer time horizon, but also across countries, significant changes in energy technologies and consumption can be observed. Development trajectories can be characterized by sectoral changes in the economy, which transform the society from traditional (agricultural/industrial sector) to modern (service/ITC sector).

Thereupon, we study the following question in this paper, using a complete decomposition analysis: Which factors –i.e. scale, composition, energy and carbon intensity– ex-

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[2] The arbitrage margin can be calculated as the end result of an operation that initially converts the foreign exchange rate into Turkish liras at the rate *ER*, and after earning the interest rate *R* offered in the domestic markets, is converted back to the foreign currency at the prevailing exchange rate. This can be expressed by the formula $(1+R)/(1+ER)-1$ (Yeldan 2002, page 7). With a somewhat negative arbitrage rate no profits can be made by this conversion and is, therefore, more sustainable.

plain changes in CO_2 emissions? In addition, the following questions are addressed: How has the sectoral composition of the economy changed over time? Which technologies are present in the energy mix over time? How has the energy and carbon intensity changed over time and per sector? What is the link between national income and carbon emissions in Turkey?

The outline of this paper is as follows. Section 2 present the method used in this paper and reviews important work on decomposition analyses. Section 3 presents and discusses the changes in the energy situation in Turkey and undertakes a complete decomposition analysis. Based on data availability, the time period 1980–2003 is considered. The final section concludes.

2. Decomposition analysis: method and literature

In studies at the country level it is customary to decompose the changes in CO_2 emissions (or energy consumption). Grossman and Krueger (1991) were about the first to decompose the change in emissions into a scale, composition and technique effect in explaining the environmental impacts of the North American free trade agreement.

Initially, it was customary to undertake a partial decomposition analysis, which led to a residual term, which could be of a considerable size. To illustrate this, let us consider a simple example. For instance, CO_2 emissions (Em) can be decomposed into CO_2 emissions per GDP and GDP. We can summarise this into the following so-called Kaya identity:

$$\text{Em} = \frac{\text{Em}}{\text{GDP}}\text{GDP} \tag{1}$$

A change in CO_2 emissions can then be decomposed into a change in CO_2 emissions per GDP weighed with GDP and a change in GDP weighed with CO_2 emissions per GDP. The following formula shows this, where 'Δ' is used to denote change:

$$\Delta\text{Em} = \text{GDP}\Delta\frac{\text{Em}}{\text{GDP}} + \frac{\text{Em}}{\text{GDP}}\Delta\text{GDP} \tag{2}$$

In equation (2) CO_2 emission are decomposed into two effects, namely the scale effect (growth in GDP) and emission intensity effect (change in emissions per GDP). This decomposition is, however, not complete, as there is a residual term, namely: $\Delta\frac{\text{Em}}{\text{GDP}} \times \Delta\text{GDP}$. To eliminate this residual term, Sun (1998) proposed a complete decomposition analysis where the residual term is distributed among the considered effects. Zhang and Ang (2001) refer to this as the *refined Laspeyres method*, which has been widely adopted due to ease of both calculation and understanding. In this paper we follow the same route as in Sun (1998), namely by equally assigning the residual term to both effects. This leads to the following extension of equation (2):

$$\Delta\text{Em} = \underbrace{\text{GDP}\Delta\frac{\text{Em}}{\text{GDP}} + \frac{1}{2}\Delta\frac{\text{Em}}{\text{GDP}}\Delta\text{GDP}}_{\text{emission intensity effect}} + \underbrace{\frac{\text{Em}}{\text{GDP}}\Delta\text{GDP} + \frac{1}{2}\Delta\frac{\text{Em}}{\text{GDP}}\Delta\text{GDP}}_{\text{scale effect}} \tag{3}$$

The principle in the example of equations (1)–(3) can also be used to decompose the level of CO_2 emissions into more effects. In this paper we have sufficient data to derive four effects. Setting up the Kaya identity as shown in equation (4) can do this:

$$\begin{aligned} \frac{CO_2\ \text{emissions}}{\text{POPulation}} &= \underbrace{\frac{\text{GDP}}{\text{POP}}}_{\text{scale effect}} \cdot \sum_i \underbrace{\frac{\text{Added value}_i}{\text{GDP}}}_{\text{composition effect}} \cdot \underbrace{\frac{\text{Energy use}_i}{\text{Added value}_i}}_{\text{energy intensity effect}} \cdot \underbrace{\frac{CO_2\ \text{emissions}_i}{\text{Energy use}_i}}_{\text{carbon intensity effect}} \\ &= P \cdot \sum_i G_i \cdot I_i \cdot E_i \end{aligned} \tag{4}$$

The total (per capita) CO_2 emissions are fully equal to the product of total (per capita) GDP (P), and the sum of the sectoral products of the added value per GDP (G_i), energy consumption per added value (I_i) and the CO_2 emissions per energy consumption (E_i).

To explain the changes in CO_2 emissions, let us define the differences (ΔP, ΔG_i, ΔI_i, ΔE_i) with respect to the base-year 1990, which is the reference year of the Kyoto protocol, for instance $\Delta P_{\text{current}}=P_{\text{current}}-P_{1990}$, and so on. Then by using the four factors from the Kaya identity in Equation (4), it is possible to decompose the change in the level of emissions into four effects, namely a scale, composition, energy intensity and emission intensity effect. Equation (5) presents the required formulas. A programme in MATLAB is developed to do the calculations.

$$\begin{aligned}
\text{scale effect} &= \Delta P\sum_i\left\{G_i\cdot I_i\cdot E_i+\tfrac{1}{2}\left(\Delta G_i\cdot I_i\cdot E_i+G_i\cdot\Delta I_i\cdot E_i+G_i\cdot I_i\cdot\Delta E_i\right)\right\}\\
&+\Delta P\sum_i\left\{\tfrac{1}{3}\left(\Delta G_i\cdot\Delta I_i\cdot E_i+\Delta G_i\cdot I_i\cdot\Delta E_i+G_i\cdot\Delta I_i\cdot\Delta E_i\right)+\tfrac{1}{4}\cdot\Delta G_i\cdot\Delta I_i\cdot\Delta E_i\right\}\\
\text{composition effect} &= \sum_i\Delta G_i\left\{P\cdot I_i\cdot E_i+\tfrac{1}{2}\left(\Delta P\cdot I_i\cdot E_i+P\cdot\Delta I_i\cdot E_i+P\cdot I_i\cdot\Delta E_i\right)\right\}\\
&+\sum_i\Delta G_i\left\{\tfrac{1}{3}\left(\Delta P\cdot\Delta I_i\cdot E_i+\Delta P\cdot I_i\cdot\Delta E_i+P\cdot\Delta I_i\cdot\Delta E_i\right)+\tfrac{1}{4}\cdot\Delta P\cdot\Delta I_i\cdot\Delta E_i\right\}\\
\text{energy intensity effect} &= \sum_i\Delta I_i\left\{P\cdot G_i\cdot E_i+\tfrac{1}{2}\left(\Delta P\cdot G_i\cdot E_i+P\cdot\Delta G_i\cdot E_i+P\cdot G_i\cdot\Delta E_i\right)\right\}\\
&+\sum_i\Delta I_i\left\{\tfrac{1}{3}\left(\Delta P\cdot\Delta G_i\cdot E_i+\Delta P\cdot G_i\cdot\Delta E_i+P\cdot\Delta G_i\cdot\Delta E_i\right)+\tfrac{1}{4}\cdot\Delta P\cdot\Delta G_i\cdot\Delta E_i\right\}\\
\text{carbon intensity effect} &= \sum_i\Delta E_i\left\{P\cdot G_i\cdot I_i+\tfrac{1}{2}\left(\Delta P\cdot G_i\cdot I_i+P\cdot\Delta G_i\cdot I_i+P\cdot G_i\cdot\Delta I_i\right)\right\}\\
&+\sum_i\Delta E_i\left\{\tfrac{1}{3}\left(\Delta P\cdot\Delta G_i\cdot I_i+\Delta P\cdot G_i\cdot\Delta I_i+P\cdot\Delta G_i\cdot\Delta I_i\right)+\tfrac{1}{4}\cdot\Delta P\cdot\Delta G_i\cdot\Delta I_i\right\}
\end{aligned}\qquad(5)$$

Equation (5) shows that in order to calculate, for instance, the scale effect we need to consider the difference in P weighed with the other three factors of the Kaya identity. This first term leaves, however, a residual. The residual is then distributed on the 'jointly created and equally distributed' principle (Zhang and Ang, 2001). This explains the halves, thirds and quarters in the formula, which has terms with respectively two, three and four deltas. All these terms are added up to obtain the scale effect. The other effects are derived in a similar way. The change in CO_2 emissions with respect to base year 1990 is the sum of the scale, composition, energy intensity and carbon intensity effect. There is no residual. This method is used to decompose the changes in the level of CO_2 emissions in Turkey over the period 1980–2003 in Section 3.4.

Another way to eliminate the residual term is suggested by Ang and Choi (1997), namely the *logarithmic mean weight Divisia method*, which can also deal with zero values in the data set. Ang (2004) extends the refined Laspeyres method and the logarithmic mean weight Divisia method to multiplicative methods. Hoekstra and Van den Bergh (2002, 2003) make a comparison between structural and index (sectoral) decomposition analyses.

In the literature a number of applications of the decomposition analysis can be found. Liaskas et al (2000) undertake a partial decomposition analysis (where a so-called residual term remains) on all European countries except Ireland and Luxembourg. They show that the decline of CO_2 emissions during the 1970s is mainly caused by measures to promote energy efficiency, as a response to the oil crisis. Kaivo-oja and Luukkanen (2004) broaden this analysis by studying energy transitions in all European countries plus Norway and they instead use a complete decomposition analysis. They show that there are large differences among the individual countries. These differences are explained by decomposing energy intensity and CO_2 intensity. Changes in energy intensity can be largely explained by structural changes in the economy (composition effect), while changes in CO_2 intensity can be explained by changes in energy intensity and fuel switching.

Bhattacharyya and Ussanarassemee (forthcoming) employ the log-mean Divisia index (Ang and Choi 1997) to decompose the changes in aggregate energy and CO_2 intensities in the industrial sector in Thailand. The transport, agricultural and services sectors are excluded from their analysis. They conclude that both the energy intensity and CO_2 intensity have declined to some extent over the period 1981–2000. The changes in energy and carbon intensities are of a cyclical type: increasing in some periods and decreasing in others.

Paul and Bhattacharya (2004) apply a complete decomposition analysis on India, as originally developed by Sun (1998). They split the data up into four sectors, namely agricultural, industrial, transport, and other sectors. With such a sectoral specification, it is necessary to apply an index decomposition analysis (Hoekstra and Van den Berg 2002, 2003). While they do find some differences among the agricultural, industrial, transport and other sectors, their main overall conclusion is that economic growth (scale effect) is the main contributor to the increase in CO_2 emissions in India. In Section 3.4 we undertake a complete index decomposition analysis of the CO_2 emissions in Turkey.

3. Results and discussion

Let us now turn to a quantitative analysis of development trajectories and energy transitions in Turkey. Energy transitions can be studied from various perspectives. This section uses a graphical presentation of this process. For this purpose, it is useful to characterize energy use by two categories, namely technologies and sectors. Technologies can be divided into fossil (coal, lignite, oil, gas) and renewable (wind, solar, hydro and bio energy). Main energy using sectors are power (and heat) generation, transport, and industry, but the agricultural and services sectors also consume energy.

3.1 Data

For Turkey, data have been collected from various sources. These data comprise yearly observations over the years 1980–2003, namely:

- Total population in millions,
- Gross domestic product in trillion 1987 TL (quarterly from 1987 onwards),
- Total primary energy supply per technology in btoe,
- Total primary energy consumption per sector per technology in btoe, and
- Total CO_2 emissions per sector in mega tonnes derived with the sectoral approach.

Energy data are collected from the Ministry of Energy as published by Altaş *et al* (2003), completed with the updated table for 2002 and 2003 (Altaş 2004, personal communication). The added value per sector and the quarterly GDP data are taken from the National Accounts as prepared by the State Institute of Statistics (Korkmaz 2004, personal communication). These data have been crosschecked with data from official sources (WDI cd-rom and IEA database). In addition, Zaim (1996) provides a sectoral overview of various emissions in Turkey over the period 1970–1991, including CO_2 emissions.

To prepare the data for undertaking a (sectoral) complete decomposition analysis, the Turkish economy has been divided into four distinct sectors, namely the primary agricultural sector, the secondary industrial sector, while the tertiary sector is subdivided into transport and services. The value added has been derived from the national accounts as provided by the State Statistical Institute (Korkmaz 2004, personal communication). In these national accounts the value added for agriculture and industry are separately specified and can be used straightaway. However, the value added for transport is only available in combination with communication. By lack of better information, we use the value added of transport and communication is as a proxy for the transport sector in this paper. The remaining value added is assigned to the services sector in the economy. To obtain an as close as possible agreement with data from other sources, i.e. World Bank WDI cd-rom and IEA data, it was necessary to distribute “imputed bank services” over the four sectors, which we have done according to the sectoral shares without “imputed bank services”.

The same sectoral division as for the value added is also possible for energy consumption. This is achieved simply by taking the numbers in billions tonnes of oil equivalents (btoe) as published in Altaş *et al* (2003), completed with the updated table for 2002 and

2003 (Altaş 2004, personal communication). It is also possible to derive the composition of fuel types in primary energy supply from these energy balances as shown in Figure 4.

To complete the data set, energy balances as published by Altaş *et al* (2003), completed with the updated table for 2002 and 2003 (Altaş 2004, personal communication) have been extended with emission factors using the IPCC guidelines II (chapter I.6) for emission inventorying (see Table 1). This extension is needed, because the UNFCCC has not published a national communication on the emissions inventory of Turkey on their web page (http://www.unfccc.int).

Table 1 Emission factors (in tonne carbon per TJ).

Coal	Secondary Coal	Lignite	Petro cokes	Asphalt	Oil	Natural gas	Coke oven gas
26.8	27.5	27.6	27.5	22.0	19.5	15.3	13.0

Source: IPCC (2000)

Table 1 shows the emission factors (in tonne carbon per TJ) per used fuel type. The carbon content of lignite is the highest with 27.6 tonne carbon per TJ, while the carbon content is lowest for coke oven gas with 13.0 tonne carbon per TJ. There are no emissions for energy generated with wood, animal waste, hydro, geothermal, wind power and traded electricity.

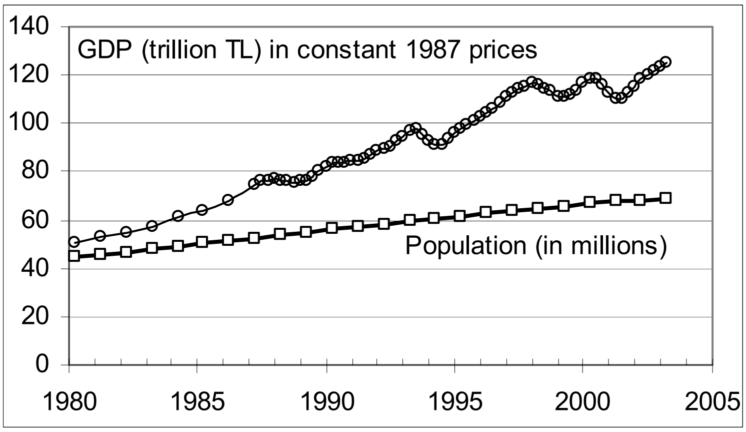
There are two ways to estimate CO_2 emissions. The first one is called the reference method. This method is based on making a carbon flow account (inputs and outputs of carbon fuels) and correcting for carbon in fuels that are not emitted. The other method is called the sectoral method. This method is based on consumption figures for different sectors. The outcomes of both methods are usually different, for various reasons (e.g. different sources of statistics). The difference is on average 5%. Here we use the level of emissions based on the generally more precise sectoral method.

In addition to the agricultural, industrial, transport and services sector, there is a fifth sector, namely power generation. This conversion sector has a very low value added in the national accounts and a separate consideration would probably yield a distorted image of the economy. Following the study by Paul and Bhattacharya (2004), the CO_2 emissions from power generation are assigned to four sectors in the economy proportional to their consumption of electricity as given in the energy balances.

3.2 GDP and population growth in 1980–2003

In order to obtain an insight into the Turkish economy, Figure 1 plots the development of GDP and population over the period 1980–2003. The economy has been growing at an average yearly per capita growth rate of 2.1%, which compares well with the expected average long-term growth rate at the world level in the B1[3] IPCC scenario (IPCC 2000; Nakicenovic *et al.* 2003; Castles and Henderson 2003). The variation in economic growth per capita is large, varying from a +7.1% boom in 1987 to a –8.4% bust in 2001.

Figure 1 Development of GDP in real terms and population in Turkey.



In order to obtain some feeling about an economy like Turkey, Table 2 compares the situation in Turkey in 1980 and 2003 with other countries in 2003. Based on the sectoral division of the economy and the per capita exchange rates base GDP in US$ 2003 prices, the situation of Turkey in 1980 is somewhere near to the situation in Albania and Guatemala in 2003. Twenty-three years later, the situation of Turkey is somewhere between Uruguay and Argentina. This shows that the Turkish economy has made a considerable advance in the previous decades in spite of its so-called boom-bust structure.

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[3] The B1 IPCC scenario envisages a globalised world with an accent on the community and conservation. The B1 storyline and scenario family describes a convergent world where the global population peaks in mid-century and declines thereafter, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives (for further information on the IPCC scenarios refer to IPCC (2000) or http://www.grida.no/climate/ipcc/emission/003.htm).

Table 2 The stage of development in Turkey in 1980 and 2003 linked to a comparable development stage of other countries in 2003.

	GDPPC in current prices	Agricultural sector	Industrial sector	Services sector	Population (millions)
Albania in 2003	1933	25.33*	18.94*	55.72*	3.2
Guatemala in 2003	2009	22.25	19.26	58.49	12.3
Turkey in 1980	**2158******	**24.25**	**21.49**	**54.26**	**44.4**
Uruguay in 2003	3308	9.50	26.97	63.53	9.9
Turkey in 2003	**3365**	**12.20**	**28.86**	**58.94**	**70.7**
Argentina in 2003	3381	11.06	34.81	54.14	38.4

* Sectoral shares for the year 2002

** GDP in US$ 2003 constant prices

3.3 Energy consumption by sector and by fuel

Before presenting the results of the complete decomposition analysis, the nature of the data is presented graphically. Figure 2 shows the development of the share of GDP in constant prices of four sectors over time.

Figure 2 Share in the Turkish economy of four considered sectors.

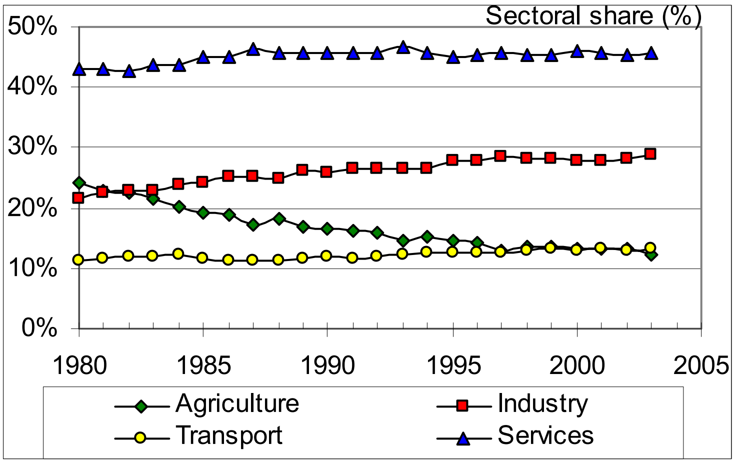


Figure 2 shows that the services (from 43% in 1980 to 46% in 2003) and transport sector (from 11% in 1980 to 13% in 2003) increase slightly in the period 1980–2003. There is a substitution between an increasing share of the industrial sector (from 22% in 1980 to 29% in 2003) and a decreasing share of the agricultural sector (from 24% in 1980 to 12% in 2003).

Based on traditional views on development trajectories (see for instance Kuik and Gupta (2003) for an overview), an economy tends to move from a traditional agricultural-based economy to an economy with an industrial dominance and finally moves towards a modern services-based economy. From that point of view, Turkey has not yet fully reached its industrialization peak, and we may expect to find growing levels of CO_2 emissions in the near future (see also UNDP and WB, 2003).

The development over time of the sectoral energy consumption per value added (energy intensity) is presented in Figure 3. The graph shows the changes of energy intensity over time, with respect to the level in the base-year 1990, which is also the reference year in the Kyoto protocol, to which has been assigned the value of 100. Table 3 presents the per cent changes over the period 1980–1990, 1990–2003 and 1980–2003.

Figure 3 Sectoral development of energy intensity (per value added) in Turkey.

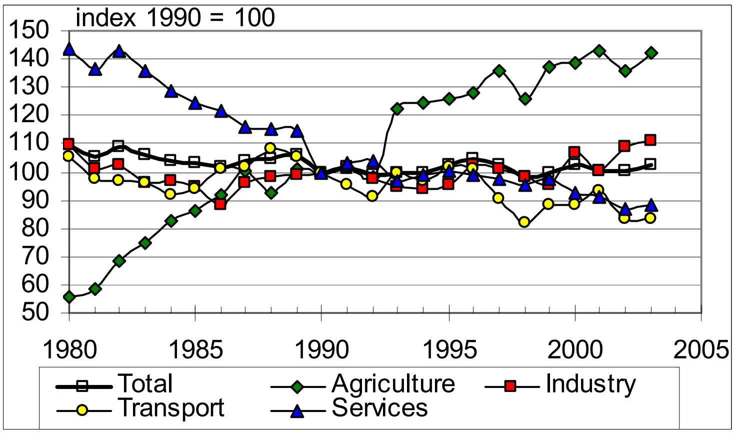


Table 3 Per cent changes in energy intensity (per value added) in Turkey.

	Total	Agriculture	Industry	Transport	Services
1980-1990	-9.0%	79.7%	-8.9%	-5.3%	-30.4%
1990-2003	2.5%	42.1%	10.8%	-16.6%	-11.7%
1980-2003	-6.7%	155.4%	1.0%	-21.0%	-38.5%

Table 3 shows that the overall energy intensity decreased with 9.0% between 1980 and 1990 and it increased again with 2.5% between 1990 and 2003. The net decrease over the period 1980–2003 is 6.7%.

For the four considered sectors in Turkey we obtain two extreme results for the development in energy intensity. Figure 3 clearly shows that the agricultural sector has become much more energy intensive over the period 1980–2003; to be precise there has been a change of +155.4% (Table 3). At the same time there has been a change in the energy intensity in the services sector of –38.5% over the 1980–2003 period. The largest decrease in the services sector took place in the 80s, it stabilized in the 90s and it is decreasing again since 2000. There is also a substantial decrease in energy intensity in the transport sector, namely an overall change of –21.0% over the period 1980–2003. The energy intensity in the industrial sector is, however, nearly constant at +1.0%.

In interpreting the result of the changes in energy intensity, we see a sharp increase in the agricultural sector. An explanation can be found by focusing on the sectoral level. Özkan *et al* (2004) give an in-depth analysis of energy use in the agricultural sector. Due to mechanisation the energy intensity has increased over the past two decades and has shifted from animal power (halving) to tractor power (doubling). This shows that there has been a transition in the agricultural sector in the form of mechanization in the past two decades. The services sector, which is an addition of all other sectors (excluding agriculture, industry and transport) has also gone through a transition, namely from an energy intensive composition towards a more energy extensive composition. It is interesting to see a decrease in the energy intensity in the transport sector. A possible explanation for this energy efficiency improvement is that the value-added of communications, which is added to the value-added of the transport sector, has grown considerably over the period 1980–2003. The energy intensity in the industrial sector fluctuates somewhat, but the level in 2003 is back at the level in 1980.

Let us now consider the composition of fuel types in primary energy supply in Turkey. Figure 4 presents this. Table 4 summarizes the shares in 1980 and 2003

Figure 4 Shares of fuel type in primary energy supply in Turkey.

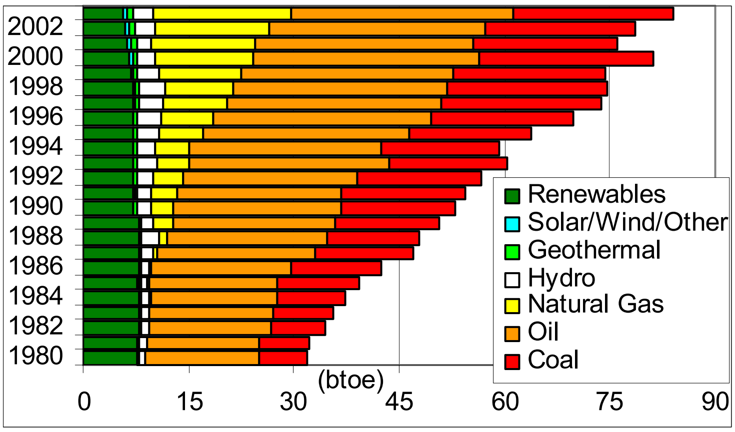


Table 4 Shares of fuel type in primary energy supply in Turkey in 1980 and 2003.

	Coal	Oil	Natural Gas	Hydro	Geothermal	Solar/Wind/Other	Renewables	Total
1980	21.3%	51.0%	0.1%	3.1%	0.2%	0.4%	24.0%	31.97
2003	27.0%	37.9%	23.2%	3.6%	1.0%	0.5%	6.8%	84.01

Figure 4 shows that the share of renewable carbon-free energy types (including hydro) is fairly constant in tonnes of oil equivalents over time. The fast growing demand for energy in Turkey is primarily met with an increase in oil and coal production and imports (not shown in Figure 4). Since 1987 natural gas started to acquire a share in the energy mix. In 1980, coal contributed 21.3%, oil 51.0%, and renewables 27.7% to the primary energy supply in Turkey (Table 4). In 2003, coal contributes 27.0%, oil 37.9%, natural gas 23.2% and renewables 11.9% to the primary energy supply in Turkey. Furthermore, the import as percentage of the total primary energy supply has increased from 47% in 1980 to 78% in 2003 (Altaş *et al* 2003; Altaş 2004, personal communication).

The development over time of the sectoral CO_2 emissions per unit of energy consumed (carbon intensity) is presented in Figure 5. Following the presentation in Figure 3, the carbon intensity is shown with respect to the level in 1990 to which has been assigned the value of 100. Table 5 shows the per cent changes over the period 1980–1990, 1990–2003 and 1980–2003.

Figure 5 Sectoral development of carbon intensity (per energy consumption) in Turkey.

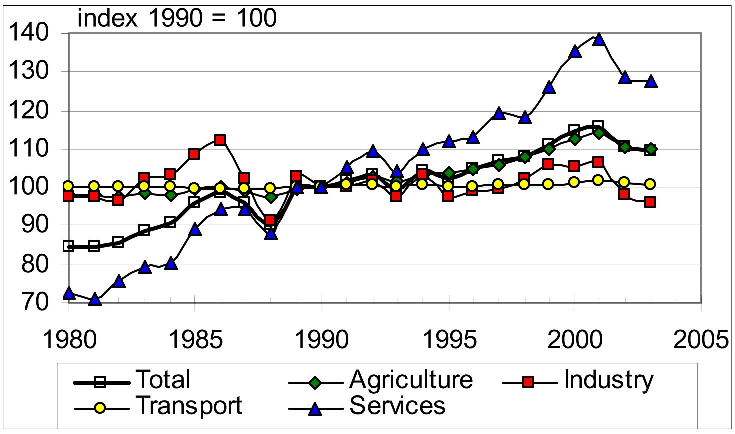


Table 5 Per cent change in carbon intensity (per energy consumption) in Turkey.

	Total	Agriculture	Industry	Transport	Services
1980-1990	18.2%	2.1%	2.8%	-0.2%	37.8%
1990-2003	9.2%	10.0%	-3.9%	0.8%	27.4%
1980-2003	29.1%	12.2%	-1.3%	0.6%	75.7%

Table 5 shows that there has been a gradual increase in the carbon intensity over time. Over the period 1980–2003, the carbon intensity increased with +29%, or +1.07% per year. The increase in carbon intensity has been most extreme in the services sector, which shows an increase of +76% over the period 1980–2003. The carbon intensity in the agricultural sector also increased with +12%, albeit at a lower than average rate. Figure 5 shows that the carbon intensity in the industrial sector is quite variable over time. The development of carbon intensity in the transport sector is very gradual over time and seems to be independent of the boom-bust structure of the economy. The overall change in carbon intensity is nearly constant in the industrial sector (–1.3%) and the transport sector (+0.6%).

Interpretation of the result in Figure 5 indicates that the services sector, which had a substantial decrease in energy intensity, has become much more carbon intensive. The 'profit' of a reduction in energy intensity is slightly more than offset by the 'loss' in an increased carbon intensity in the services sector. The aggregate effect of energy efficiency gain and the increase in carbon intensity is a gradual increase of CO_2 emissions with 10%, which is still below the average of the total economy.

There is a huge increase of carbon emissions in the agricultural sector: on top of the energy intensity increase by 155% there is another carbon intensity increase by 12%. The main conclusion is that no significant reduction in CO_2 emissions can be observed in any of the considered sectors in the Turkish economy.

3.4 Decomposition analysis

Let us now undertake a complete decomposition analysis, as originally proposed by Sun (1998). Given the data availability, changes in CO_2 emissions (per capita) over time with respect to the (non-binding) Kyoto base-year 1990 can be decomposed into a number of factors.

Figure 6 and Figure 7 present the results of the decomposition analysis for Turkey. Figure 6 decomposes the total level of CO_2 emissions at the national level, while Figure 7 looks at the per capita level of CO_2 emissions to exclude the effect of population growth. Following the presentation in Figure 3, the difference in CO_2 emissions with respect to the amount of CO_2 emissions in 1990 is given to facilitate a graphical presentation. For example, the increase of 30 million tonnes CO_2 emissions in 1995 with respect to 1990 is the sum of 23 + 5 – 1 + 3 million tonnes of CO_2 emissions, respectively, due to the scale, composition, energy intensity and carbon intensity effects. Table 6 and Table 7 show the per cent changes over the period 1980–1990, 1990–2003 and 1980–2003.

Figure 6 Decomposition of the difference in CO_2 emissions with respect to the level of emissions in 1990.

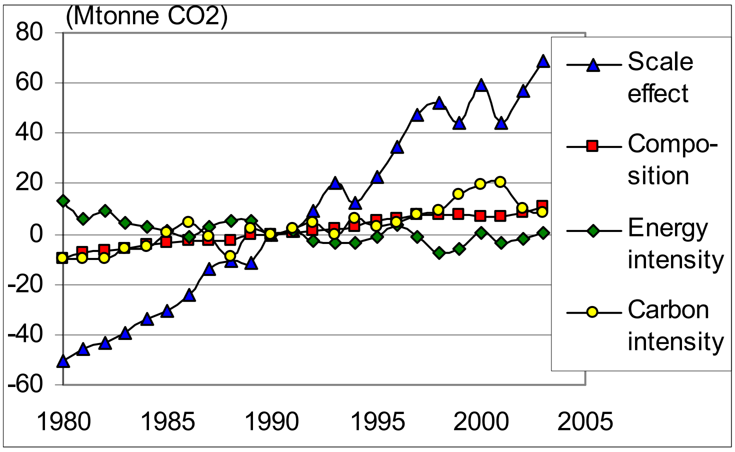


Table 6 Decomposition of the change in CO_2 emissions.

	1980-1990		1990-2003		1980-2003	
Scale effect	50.21	(+87.9%)	69.05	(+78.3%)	119.26	(+82.0%)
Composition effect	10.01	(+17.5%)	10.52	(+11.9%)	20.54	(+14.1%)
Energy intensity effect	-13.12	(–23.0%)	0.27	(+0.3%)	-12.86	(–8.8%)
Carbon intensity effect	10.04	(+17.6%)	8.39	(+9.5%)	18.43	(+12.7%)

Figure 7 Decomposition of the difference in the per capita CO_2 emissions with respect to the level of emissions in 1990.

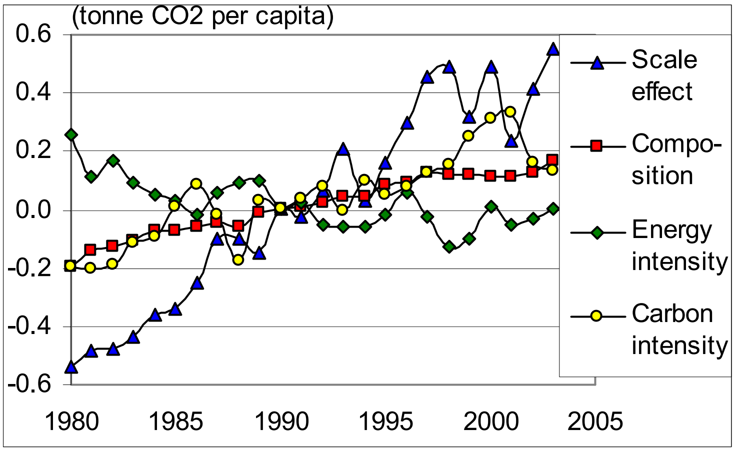


Table 7 Decomposition of the change in per capita CO_2 emissions.

	1980-1990	1990-2003	1980-2003
Scale effect	0.536 (+79.4%)	0.551 (+64.4%)	1.087 (+71.0%)
Composition effect	0.196 (+29.1%)	0.167 (+19.5%)	0.363 (+23.7%)
Energy intensity effect	-0.255 (–37.7%)	0.005 (+0.6%)	-0.250 (–16.3%)
Carbon intensity effect	0.197 (+29.2%)	0.133 (+15.6%)	0.331 (+21.6%)

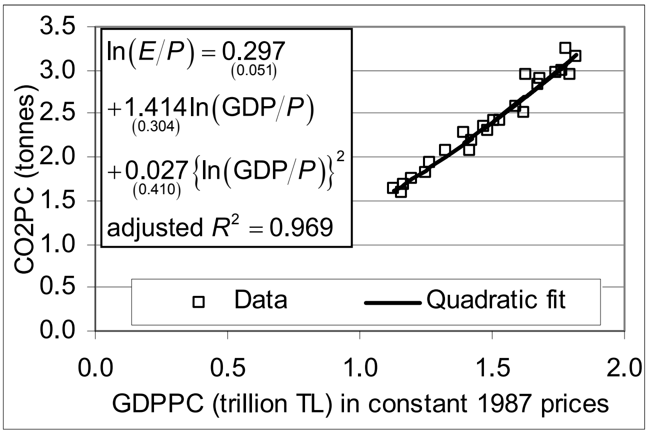
From Figure 6 we can see that the scale effect (growth in the economy in real terms) is the main explaining factor for the increase in CO_2 emissions in the Turkish economy. More specifically, Table 6 shows that the scale effect accounts for +82.0% of change in CO_2 emissions over the period 1980–2003. The composition effect (+14.1%) and carbon intensity effect (+12.7%) nearly move in tandem. However, the variation in the carbon intensity effect is much larger, than the gradual increasing composition effect. This means that the composition of the Turkish economy has become somewhat dirtier over time and the CO_2 emissions have increased over time, due to the carbon intensity effect. The opposite is true for the energy intensity effect, according to that effect the CO_2 emissions would be decreasing during the first five years. After that the change in CO_2 emissions with respect to the level in 1990 varies cyclically according to the energy intensity effect. In 2003 there is no increase in CO_2 emissions with respect to the 1990 level of emissions according to the energy intensity effect. Over the period 1980–2003 the energy intensity effect accounts for a change of –8.8% in CO_2 emissions (Table 6).

The result in Figure 7 is qualitatively the same; only the relative differences between the effects are now more accentuated. The overall scale effect is lower and accounts for an increase of +71.0% in CO_2 emissions over the period 1980–2003 (Table 7). Overall the conclusions that we derived for Figure 6 also hold for Figure 7. Furthermore, during economic crises (characterized by a negative economic growth) the scale effect works in the opposite direction, which is clearly demonstrated by the downward jumps in 1993, 1999 and 2001 in Figure 6 and Figure 7. However, an important difference between Figure 6 and Figure 7 is that the scale effect is less dominating once the growth in population is excluded from the analysis. Figure 7 shows for the years 1988 and 2001 that the carbon intensity effect is even higher than the scale effect. This difference eliminated as soon as the economy continues to grow.

3.5 Link CO_2 emissions and GDP

To verify the link between CO_2 emissions and GDP, it is also possible to test whether Turkey has a so-called environmental Kuznets curve (EKC) with respect to the greenhouse effect as measured by CO_2 emissions. Figure 8 presents a graphical plot of the data and an estimation result together with the fitted curve.[4]

Figure 8 The link between GDP and CO_2 emissions in Turkey.



While the goodness of fit (adj R^2) is good, we do not find an EKC for Turkey, as the estimate of the quadratic term is not significant (error term in the brackets is much larger than the estimated coefficient, which is then not statistically different from zero) and does not have the right sign. This means that based on the yearly data over the period 1980–2003, the CO_2 emissions per capita have been linearly increasing in the level of GDP per capita and there is no EKC in CO_2 emissions for Turkey. Hence, so far there is no decoupling of carbon emissions and economic growth in Turkey. This result is in line with the conclusion from the decomposition analysis that GDP growth (scale effect) is the main determinant of increase in CO_2 emissions in Turkey over the period 1980–2003. Moreover, the carbon intensity per GDP has increased with 20.5% over the period 1980–2003, which is equivalent a yearly increase in carbonisation of 0.78%. That there is no decarbonisation in Turkey can also be seen from Figure 8, which shows a convex function. Hence, in order to reach a rate of decarbonisation of 2%, key to meeting long term climate change targets, an improvement of at least 2.78% is required in the future.

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4 A more advanced way to do the EKC test is to verify whether the variables GDP and *E* are integrated (Stern, 2004) or to consider efficient frontier models (Zaim and Taskin 2000a,b; Zaim 2004). This interesting line of research is not further explored here. The scatter plot is sufficient to support our argument.

4. Conclusions

This paper undertook a quantitative analysis of development trajectories and energy transitions for the energy situation in Turkey. A decomposition analysis was undertaken to answer the following question: Which factors –i.e. scale, composition, energy and carbon intensity– explain changes in CO_2 emissions? In addition, the following questions were addressed: How has the sectoral composition of the economy changed over time? Which technologies are present in the energy mix over time? How has the energy and carbon intensity changed over time and per sector? What is the link between national income and carbon emissions in Turkey?

In order to demonstrate the progress within the Turkish economy a comparison is made with levels of development and sectoral shares in other countries. I concluded that Turkey has undergone a transition from 1980, which is comparable to the situation in Albania and Guatemala in 2003, to a situation in 2003, which is comparable to the economy in Uruguay and Argentina in 2003. From that perspective, there has been a considerable progress in the Turkish economy in spite of its boom-bust structure. In addition, a per capita yearly growth rate in GDP in constant prices of 2.1 per cent has been realized over the period 1980–2003, which is comparable to the long-term growth level of the world economy in the B1 IPCC scenario.

The share of the agricultural sector halved, but the share in 2003 is still considerable, while the industrial and services sectors have grown over the period 1980–2003. Furthermore, the overall energy intensity dropped somewhat over the period 1980–2003. There has been a considerable increase of energy use in the agricultural sector, representing a mechanization process in the past two decades. On the contrary, the services sector had a considerable reduction in energy intensity. Finally, there has been a reduction of energy intensity in the transport sector, indicating an introduction of more efficient transport technologies.

In contrary to the changes in energy intensity over time, the amount of CO_2 emissions per unit of energy consumed increased in the past two decades. The highest increase is found in the services sector (total GDP minus added value of agricultural, industrial and transport sector) offsetting the gain achieved by the reduction in energy intensity. The main conclusion is that no significant reduction in carbon emissions is observed in any of the considered sectors in the Turkish economy.

The decomposition analysis indicates that the largest increase in CO_2 emissions is caused by the expansion of the economy (scale effect). In per capita terms, the scale effect is more dominant in the 80s than in the 90s in explaining the increase in CO_2 emissions. The composition of the economy and the carbon intensity has also contributed to the increase in CO_2 emissions. The energy intensity of the economy is decreasing and is responsible for a modest reduction in CO_2 emissions.

The link between energy and carbon emissions is a monotonic increasing one. Hence, in the absence of carbon policies, no significant reduction in CO_2 emissions can be observed in the Turkish economy.

This study has shed light on possible development trajectories and energy transitions in a country with a high potential for growth. Turkey is still in the middle of her transition towards a modern society. This speed of transition also differs regionally within Turkey. On the one hand, The Western region is highly industrialized and developed quite comparable to other European countries, on the other hand, the Eastern region, but also Central Anatolia, is still largely based on traditional agriculture and livestock rearing. To complete the transition into a modern society, a path with a particularly high level of carbon emissions is foreseen. Future policy research is needed to find ways for Turkey to 'leapfrog' these emissions.

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