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Firm-Level Decomposition of Energy Consumption in Turkish Manufacturing

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Abstract

Energy efficiency in industry is a crucial topic for Turkey, as the country has an import dependency of 80 percent in energy. Although the importance of enhancing energy efficiency in industry is widely acknowledged, there has not been any study examining the energy efficiency in Turkish industry at micro level. Employing a sound decomposition methodology on a firm-level data set of manufacturing firms, this paper documents that there was a significant decrease in the energy intensity of firms over 2005–12. In contrast, structural change across manufacturing sectors and across firms within sectors had positive but limited effects on the overall energy efficiency over the period.

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Firm-Level Decomposition of Energy Consumption in Turkish Manufacturing Industry[#]

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I. INTRODUCTION

Energy efficiency in industry is a crucial topic for Turkey. The country has a structural trade deficit, which in some years in the last two decades reached as much as 9% of its GDP[1]. Among the contributors of the trade deficit, oil and natural gas imports have the lion's share. Having an import dependency of around 80% in energy, US$55 billion of a total of US$84 billion trade deficit in 2014 was due to energy imports (Turkstat). A significant factor underlying such a high energy dependency is that Turkey's manufacturing industry is relatively energy intensive. While every US$1,000 of GDP requires 0.18 ton of oil equivalent (toe) energy consumption in the OECD, it takes 0.26 toe in Turkey (WB, 2012). Therefore, there is large room for and great benefits associated with policy effort to increase energy efficiency in Turkish manufacturing industry.

The importance of energy efficiency is recognized by both the Turkish government and the World Bank. The 2012-2014 Medium-Term Program of the government states that "…The systematic pursuit of energy efficiency is therefore a priority and critical for Turkey's energy security, macro/fiscal stability, competitiveness, climate change mitigation and environmental sustainability…" (Ministry of Development, 2012). Identifying the energy efficiency one of the priority areas the Country Partnership Strategy, the World Bank considers greater energy efficiency and diversification of energy sources keys to reducing Turkey's reliance on external finance (WB, 1012).

Although the energy inefficiency problem in Turkey is broadly acknowledged, there is a lack of credible studies to be consulted for designing policies aiming at increasing energy efficiency in the country. This is particularly a problem for energy use in industry, which accounted for 33.5% of total final energy use in Turkey in 2014 (GDEA)[2]. Being one of a few studies on the topic, Turkay et al. (2012) compares sectors by their share of energy consumption in total manufacturing costs. The study lists a long series of recommendations to increase energy efficiency in manufacturing facilities. The World Bank report (2015), on the other hand, outlines an institutional and legal framework to enhance energy efficiency in Turkey.

[1] In fact, the unsustainable current account deficit was the main reason for severe financial crises in the country in 1994 and 2001.

[2] Shares of other areas of energy use are as follows: Residential, commercial and public buildings (35%), transportation (29%), and agricultural production (2%).

Motivated by the importance of energy efficiency for Turkey, the lack of credible studies in this area and the existence of a unique firm-level data set that covers all manufacturing industry over the 2005-2012 period, this study aims to understand how energy efficiency evolved in Turkish manufacturing industry by its components.

Implementing a decomposition analysis, specifically, this study examines the roles of:

- Change in energy intensity of firms (technical efficiency, firm intensity effect),
- Shift of production across firms in the same sub-sector (within sector reallocation - firm structural effect),
- Shift of production across sub-sectors (across sector reallocation – sector structural effect)
- Production change (activity effect)

in the change in energy consumption of Turkish manufacturing industry over 2005-2012.

The first and second components above can be calculated only by using firm level data. To our knowledge, there is only one study (Petrick, 2015) that used a firm level data set (for Germany) and investigated these two components in the literature. Moreover, to our knowledge, this is the first decomposition analysis for Turkish manufacturing industry in the literature.

Findings in this paper are expected to provide useful insights to design more effective and focused policies to increase energy efficiency in Turkish manufacturing. Therefore, the study aims to indirectly serve to policies for more favorable external balances and better climate results of the energy consumption in the country.

The organization of the paper is as follows: The second section discusses the literature. The third section describes the data set and provides several preliminary figures. The fourth section introduces the firm level decomposition methodology. The fifth section presents the decomposition findings. Finally, the sixth section discusses the findings.

II. LITERATURE

Since their first application in late 1970s, index decomposition analyses have been increasingly used to study the impacts of structural change (i.e. changes in industry product mix) and sectoral energy intensity change in the energy economics literature. They are also widely used by national energy institutions around the world for policy-making purposes.

Decomposition methods can be broadly categorized in two groups: methods based on the Laspeyres index and methods based on the Divisia index.

Employing a Laspeyres index based decomposition, Jenne and Cattell (1983) report that during 1973-1982, structural change accounted for half of the 18% decrease in energy intensity of UK industry. The remaining residual of 9% implies a 1% annual improvement in energy efficiency. Following a similar methodology, Marlay (1984) finds that part of the reduction in the energy consumption of US industry over 1973-1983 resulted from improvements in the efficiency of industrial process technologies. Most is attributed, however, to slower growth in industrial economic activity and unprecedented changes in the composition of industrial output away from industries that consume large amounts of energy.

In another study, Howarth et al. (1991) examine trends in manufacturing energy use in eight OECD countries, decomposing the changes that occurred between 1973 and 1987 into the effects of changes in aggregate manufacturing activity, industry structure and energy intensities measured at the industry level. They conclude that structural change led to modest reductions in most countries studied.

Underlining theoretical weaknesses of decompositions based on the Laspeyres index, Boyd et al. (1987) propose the Divisia index approach as an alternative to the Laspeyres in energy decomposition analysis. They present substantial empirical support for the hypothesis that sectoral shift in manufacturing production is an important factor in explaining changes in energy intensity. Moreover, Boyd et al. (1988) make some comparisons between energy intensity decomposition and the formulation of economic indices. They illustrate the useful properties of the Divisia index in performing energy intensity decomposition.

Thereafter, extensions and refinement of methods based on the Divisia index were made. Liu et al. (1992) develop two general parametric Divisia index methods. They also extend the Divisia based index methodology to the environment field. To overcome the two commonly encountered problems - existence of a residual after decomposition and the handling of the value zero - with the existing Divisia index based decompositions; Ang and Choi (1997) modify the Divisia index decomposition method by replacing the arithmetic mean weight function by a logarithmic one. This transforms the Divisia index method into a perfect decomposition with no residual. The Logarithmic Mean Divisia Index decomposition is formalized by Ang and Liu (2001) in multiplicative form.

As for empirical applications of decompositions based on the Divisia index, to decompose the reduction in energy intensity in China between 1978 and 1995 into technical change and various types of structural change, Garbaccio et al. (1999) employ input-output tables. They conclude that between 1987 and 1992, technical change within sectors accounted for most of the fall in the energy output ratio and structural change actually increased the use of energy. An increase in the import of some energy-intensive products also contributed to the decline in energy intensity.

Greening et al. (1998) apply the Adaptive Weighted Divisia rolling base year index to total carbon emissions from the manufacturing sector of 10 OECD countries for the period 1971–1991. They find that declines in aggregate carbon intensity for these countries may be primarily attributed to decreases in energy intensity, i.e. increases in the average factor productivity of energy.

Using data of 2,582 large and medium-size Chinese enterprises over the period 1997-1999 and employing the multiplicative Divisia index, Fisher-Vanden et al. (2004) decompose the intensity of three types of energy – coal, refined oil, and electricity into the contributions of sectoral shift (i.e., changes in the sectoral composition of total industrial output) and subsector productivity change (i.e. changes in energy intensity within individual industrial sectors). They document that while subsector productivity change emerges as the dominant factor driving declines in oil and electricity intensities, sectoral shift plays a near equal role in declining coal and refined oil intensities.

Applying logarithmic mean Divisia index (LMDI) techniques, Ma et al. (2008) investigate the role of inter-fuel substitution in the decline in energy intensity or the causes of the rise in energy intensity in the period 1980-2003 for Chinese manufacturing industry. They find that technological change is the dominant contributor to the decline in energy intensity and structural change at the industry and sector (sub-industry) levels actually increased energy intensity over the period. On the other hand, structural change involving shifts of production between sub-sectors decreased overall energy intensity with inter-fuel substitution contributing little to the changes in energy intensity[3].

Finally, being the only firm level study in the literature, Petrick (2015) decomposes changes in total CO_2 emissions in German manufacturing industry to changes in activity level, structural change between sectors, shifting market shares within sectors, energy intensity at the firm level, fuel mix, and emission factors, applying an LMDI index decomposition technique. He reveals that shifts in production across firms in manufacturing sub-sectors and shift of production across sub-sectors play larger roles in determining the path of energy use

[3] Please see Liu and Ang (2007) and Ang (2015) for a detailed review of the related literature.

in German manufacturing industry over the 1995-2007 period than the change in firm energy intensity does.

Although there has been no attempt so far to decompose energy consumption/CO_2 emissions in the Turkish economy by using firm level data in the literature, there are several papers that covered the topic for Turkey by employing data at more aggregated levels. Following the LMDI methodology, Turut Asik et al. (2008) reveal that the main cause of the change in the energy intensity in Turkish manufacturing intensity over the 1992-2001 period is change in the energy intensity at the sub-sector (industries at 4 digits) level instead of a structural effect, i.e. production shift, across sub-sectors. In another study, Tunc et al. (2009) document that over the 1970-2006 period, economic activity was the main component that determined the changes in CO_2 emissions in Turkey. Moreover, the sectoral intensity effect had a significant role in the CO_2 change, unlike the sectoral structural effect.

Employing a refined Laspeyres methodology, Kumbaroglu (2011) show for the 1990-2007 period that the energy intensity effect has a dominant impact on CO_2 emissions in Turkish manufacturing industry. Applying the LMDI methodology on a Turkish manufacturing industry data set at the ISIC 4-digit level, Yilmaz et al. (2016) document that the activity effect was by far the most contributing effect in the increase in energy consumption in Turkish manufacturing industry over the 1981-2011 period. The structural effect had a slightly negative effect and the intensity effect had a slightly positive impact on energy consumption during the period.

III. DATA SET AND PRELIMINARY ANALYSIS

This study makes use of Annual Industry and Services Surveys (AISS) of the Turkstat for the 2005-2012 period. AISS is divided into two parts, based on firm employment size: (i) a census of firms with at least 20 employees in that year and (ii) a large sample of firms with fewer than 20 employees with sampling based on region and NACE 4-digit sector.

The variables used for this study are:

- Firm random codes to identify firms (codes change across firms in a year but are the same over time for the same firm),
- Year and 2-digit NACE sector codes,
- Value of energy consumption,
- Value of production (gross output).

In order to prepare the data set for computations, monetary variables were deflated by applying sector level wholesale price indices and energy price indices. Table 1 below presents some annual key figures from the data set. The figures are consistent with those officially announced by Turkstat.

Table 1: Key Figures of the Turkish Manufacturing Industry over Time (All Firms)

Period	Number of Establishments (1,000x)	Employment (million)	Energy Consumption (2005 billion TL)	Value of Production (2005 billion TL)
2005	302	2.58	11.4	322
2006	310	2.68	12.9	359
2007	317	2.78	14.0	372
2008	322	2.78	13.4	392
2009	325	2.50	11.6	350
2010	300	2.79	12.8	415
2011	333	3.08	14.0	488
2012	310	3.32	14.6	495
Average	315	2.25	13.1	399

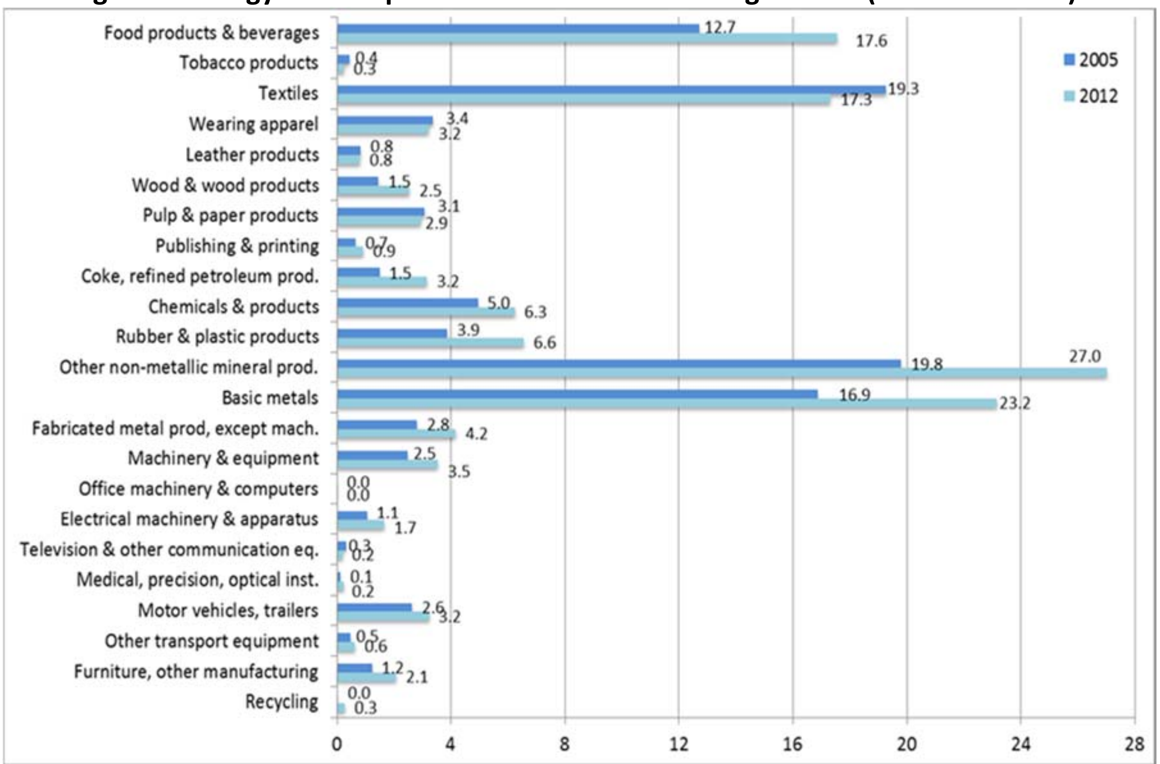
Since we can properly track only firms that employ 20+ employees every year within the period (due to the fact that firms with fewer than 20 employees are not subject to the census sample), we have to limit the firm level decomposition to firms existing in the data set every year over the period. The number of these firms (all period 20+ firms) is 9,379. Although they represent a very small share of all firms by count (3%), their average shares over the 2005-2012 period in total manufacturing employment, energy consumption and production are 45.6%, 72.5% and 66.5%, respectively. (Corresponding figures of 20+ firms and those of 9,379 all period 20+ firms are provided in the Appendix.)

Next, we provide sector level statistics in the following three figures. First, Figure 1 provides an Index that compares total energy consumption of sectors in 2005 and 2012 and also shows how energy consumption of each sector changed over the 2005-2012 period. In the figure, the total energy consumption of all sectors is set to 100. The total of all sectors in 2012 is computed as 127.8, indicating a 27.8% increase in the total energy consumption of the manufacturing industry over the 2005-2012 period. (This can be verified in Table 1 as well.)

As for sectors, classified by NACE (rev.1.1) 2-digit sectors, other non-metallic mineral products (cement, glasses, ceramics etc.) manufacturing, textile manufacturing and basic metals manufacturing were leading sectors in terms of energy consumption with a total share of 56%

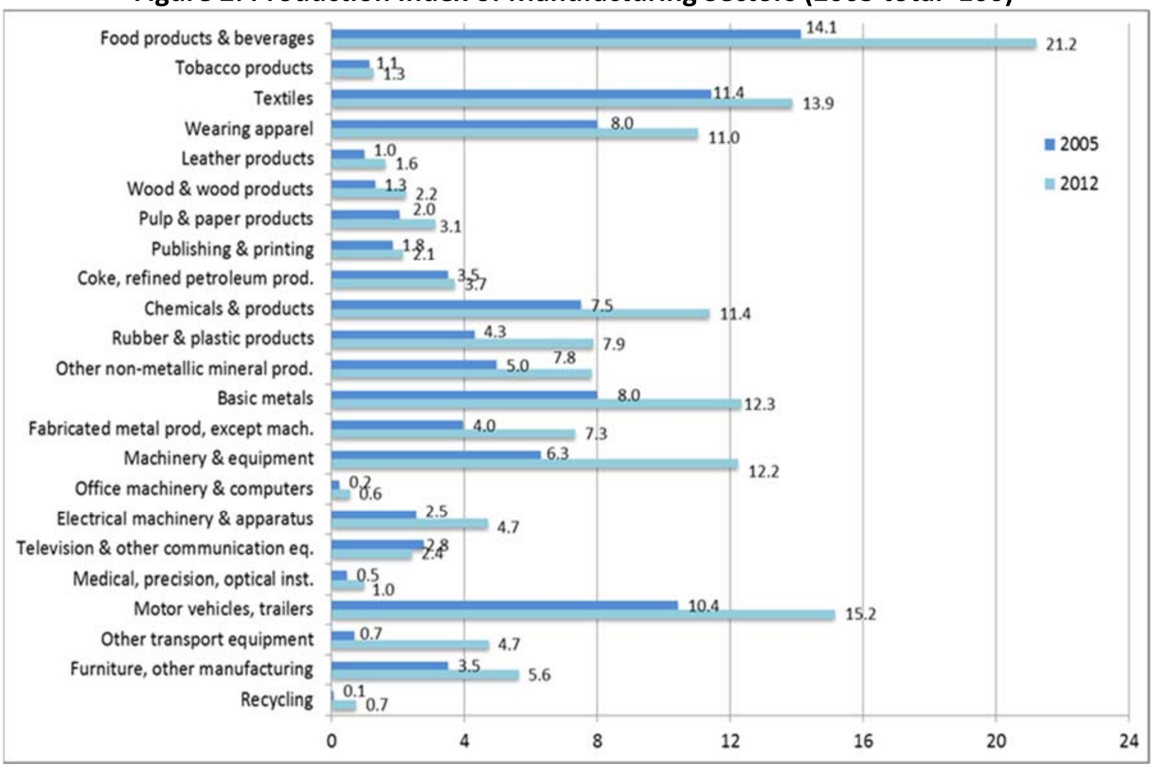
in 2005. Increasing their energy consumption by around 35% over the period (e.g. from 19.8 to 27.0 and 16.9 to 23.2), other non-metallic products and basic metals manufacturing strengthened their leadership position in energy consumption. Besides, recording a 39% increase (from 12.7 to 17.6), food products and beverages sector became the third sector in terms of energy consumption in 2012. On the other hand, the share of textiles in manufacturing industry energy consumption decreased significantly over the period.

Figure 1: Energy Consumption Index of Manufacturing Sectors (2005 total=100)



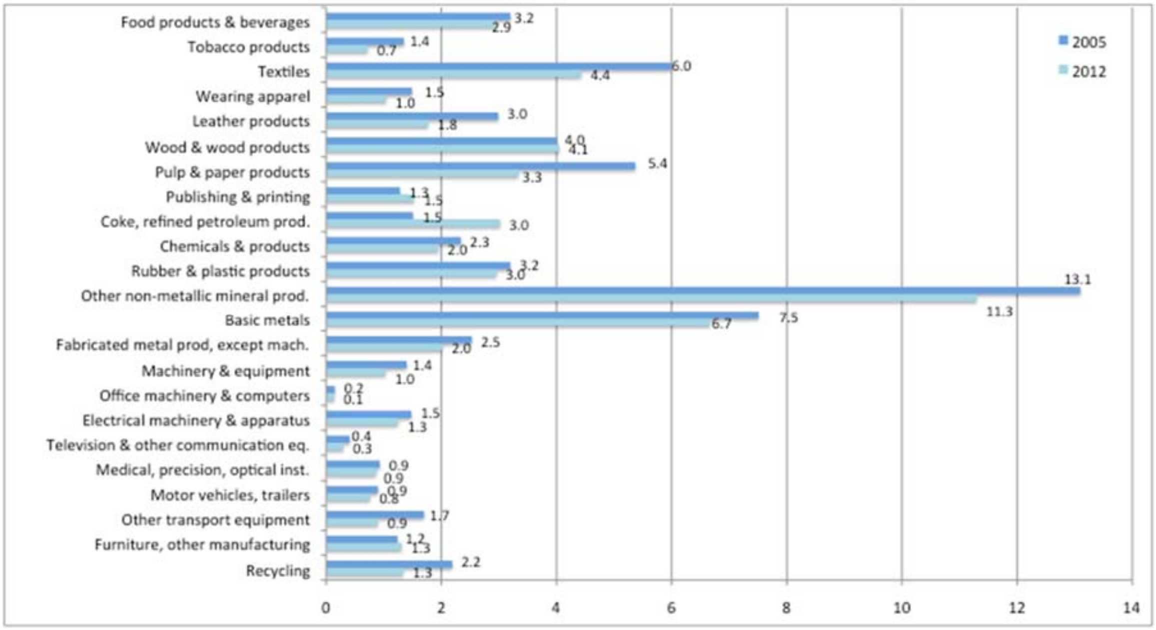
In parallel to Figure 1, Figure 2 below demonstrates the production index values of sectors. Once the total manufacturing production index is set to 100, the corresponding index is computed as 154.0, indicating a 54% increase in the manufacturing industry production over the period. As for sectors, food products and beverages was the sector with the highest production share (14.1%) in 2005. It was followed by textiles (%11.4) and motor vehicles (10.4%) manufacturing sectors. Recording an increase from 14.1 to 21.2, the food products and beverages sector strengthened its leading role in the manufacturing industry production over the period. While the motor vehicles and trailers manufacturing maintained its position, textile manufacturing lost momentum as its index value increased only from 11.4 to 13.9, an increase less than that is observed in the manufacturing industry. On the other hand, other transport equipment, machinery and equipment, recycling, electrical machinery and apparatus, rubber and plastic products manufacturing sectors increased their share in the manufacturing industry production as the growth in the production of these sectors have been higher than the average growth of the production of the manufacturing industry during the 2005-2012 period.

Figure 2: Production Index of Manufacturing Sectors (2005 total=100)



Finally, we present energy intensity by sector in Figure 3. Energy intensity is calculated as 100*energy consumption value divided by the production value. In 2005, other non-metallic mineral products were the most energy intensive sector (13.1%) by a wide margin. It was followed by basic metals, textiles and pulp and paper products. On the opposite end, office machinery & computers, television & other telecommunications equipment, motor vehicles & trailers, and medical, precision and optical instruments had an energy intensity of less than 1%. Out of 23 sectors, only in 3 of them energy intensity increased over the 2005-2012 period. The increase was particularly significant in coke and refined petroleum products manufacturing, from 1.5% to 3.0%. Although the energy intensity of the other non-metallic mineral products decreased by 1.8% points, it continued to be the highest energy intensive sector with 11.3%.

Figure 3: Energy Intensity (%) by Sectors



IV. METHODOLOGY

As for the methodology, we develop an extension of the multiplicative version of the Log-Mean Divisia Index Method-I (LMDI-I) decomposition introduced by Ang and Liu (2001). There are three main reasons for preferring this method over some others in the literature[4]:

- The Divisia index uses logarithmic change, unlike the Laspeyres index, which makes use of the concept of percentage change. Tornqvist et al. (1985) present the merit of using the log change and point that it is the only symmetric and additive indicator of relative change, whereas the ordinary percentages are asymmetric and non-additive.
- Among those based on Divisia, the Arithmetic Mean Divisia Index (AMD) methods fail the factor reversal test and can yield a large residual, which may significantly limit the usefulness of the decomposition for policy purposes[5].
- Although the log-mean Divisia Index Method-II (LMDI-II), proposed by Ang and Choi (1997), solves the problem of the residual, it is not consistent in aggregation[6].

[4] See Ang et al. (2009) for other desirable properties of LMDI-I.
[5] The factor reversal test requires that multiplying a price index and a volume index of the same type should be equal to the proportionate change in the current values.
[6] Introduced by Diewert (1980), consistency in aggregation implies that an index value calculated in more than one step is equal to that calculated in a single step. See Ang and Liu (2001) for the proof that LMDI-I is consistent in aggregation.

LMDI-I has all the desirable properties of perfect decomposition and consistency in aggregation. Perfect decomposition ensures that the decomposition results obtained do not contain a residual term[7].

Adapting the Log-Mean Divisia Index-I decomposition, originally developed for sector level analysis, to firm level data, the general formula of our decomposition methodology becomes the following[8]:

$$E = \sum_{s} \sum_{f} Q \frac{Q_S}{Q} \frac{Q_f}{Q_S} \frac{E_f}{Q_f}$$

where s, f, E and Q stand for sector, firm, energy consumption and production, respectively.

Then, change in the energy consumption of the manufacturing industry between the base year (^{0}) and the end year (^{T}) can be decomposed into components as follows:

$$E^T / E^0 = D_{man} = D_{act} D_{strs} D_{strf} D_{\text{int}f}$$

In the equation above:

- D_{man} is the total change in the energy consumption in the manufacturing industry,
- D_{act} is the activity effect, the change in the aggregate associated with a change in the overall level of the activity in the manufacturing industry,
- D_{strs} is the sector structural effect, the change in the aggregate associated with a change in the relative shares of sectors in overall manufacturing,
- D_{strf} is the firm structural effect, the change in the aggregate associated with changes in the relative shares of firms within sectors,
- D_{intf} is the intensity effect, the change in the aggregate associated with changes in the firm energy intensities.

[7] See Ang (2004, 2015) for a detailed comparison of different decomposition methods.
[8] For the mathematical derivation of the formula please see Ang and Liu (2001).

Formula to compute components of decomposition are as follows:

$$D_{man} = \exp\left(\sum_f w_f \ln(E^T / E^0)\right)$$

$$D_{act} = \exp\left(\sum_f w_f \ln(Q^T / Q^0)\right)$$

$$D_{strs} = \exp\left(\sum_s \sum_f w_f \ln((Q_s{}^T / Q^T)/(Q_s{}^0 / Q^0))\right)$$

$$D_{strf} = \exp\left(\sum_s \sum_f w_f \ln((Q_f{}^T / Q_s{}^T)/(Q_f{}^0 / Q_s{}^0))\right)$$

$$D_{\mathrm{int}\,f} = \exp\left(\sum_f w_f \ln((E_f{}^T / Q_f{}^T)/(E_f{}^0 / Q_f{}^0))\right)$$

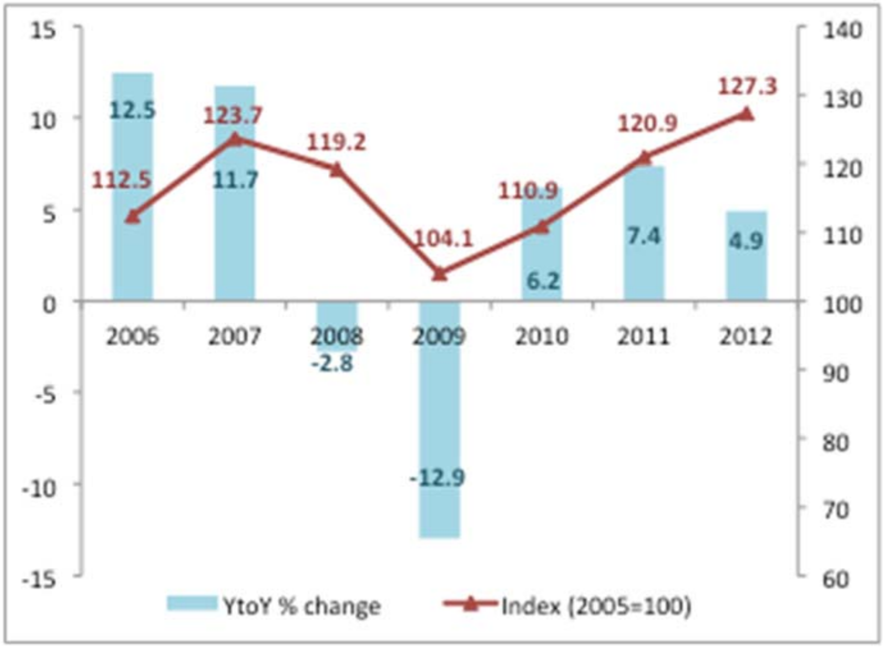
where the weight of each firm is computed as:

$$w_f = \left[(E_f^T - E_f^0)/(\ln E_f^T - \ln E_f^0)\right] / \left[(E^T - E^0)/(\ln E^T - \ln E^0)\right]$$

V. DECOMPOSITION RESULTS

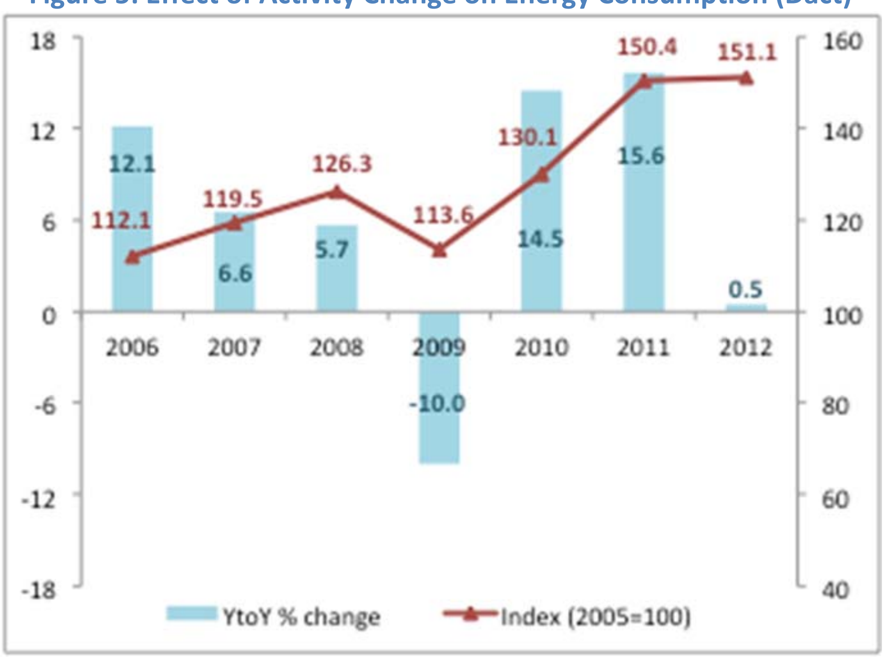
Firm level decomposition results are provided in Figures 4 to 8. Over the 2005-2012 period, energy consumption in Turkish manufacturing industry increased by 27.3% (Figure 4). Out of 7 years covered, energy consumption decreased only in 2008 and 2009, by 2.8% and 12.9%, respectively. This is not surprising because the Turkish economy contracted in the Q4 of 2008 and the whole 2009 in parallel to the global economic crisis.

Figure 4: Change in Aggregate Energy Consumption (Dman)



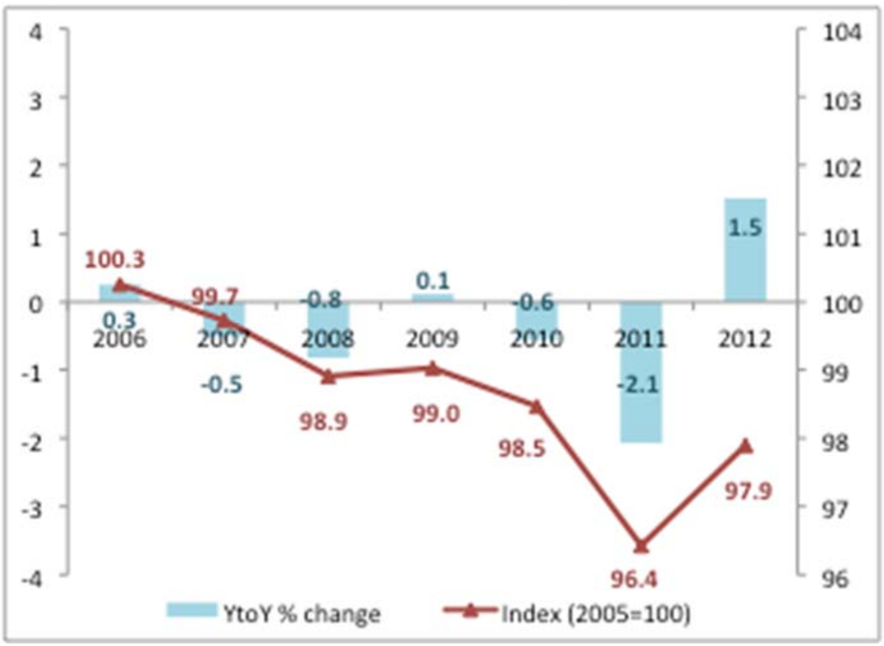
The sharp increase in production activity was the main factor behind the rise in energy consumption in the manufacturing industry. Over the whole period, production activity increased by 51.1%. The increase was particularly noteworthy in 2010 (14.5%) and 2011 (15.6%), following a 10.0% decrease in 2009.

Figure 5: Effect of Activity Change on Energy Consumption (Dact)



On the other hand, sectoral structural effect (Figure 6), change in the aggregate energy consumption due to shift of production across sectors with different energy intensity/efficiency levels, and firm structural effect (Figure 7), change in the aggregate energy consumption due to the shift of production across firms with different energy intensity/efficiency levels within sectors were both very small over the period. Specifically, the shift of production towards more energy efficient sectors in the manufacturing industry and more efficient firms within sectors had a 2.1% and 1.6% contractionary impact on the aggregate energy consumption in 2012 relative to the aggregate energy consumption in year 2005.

Figure 6: Sectoral Structural Effect on Energy Consumption (Dstrs)

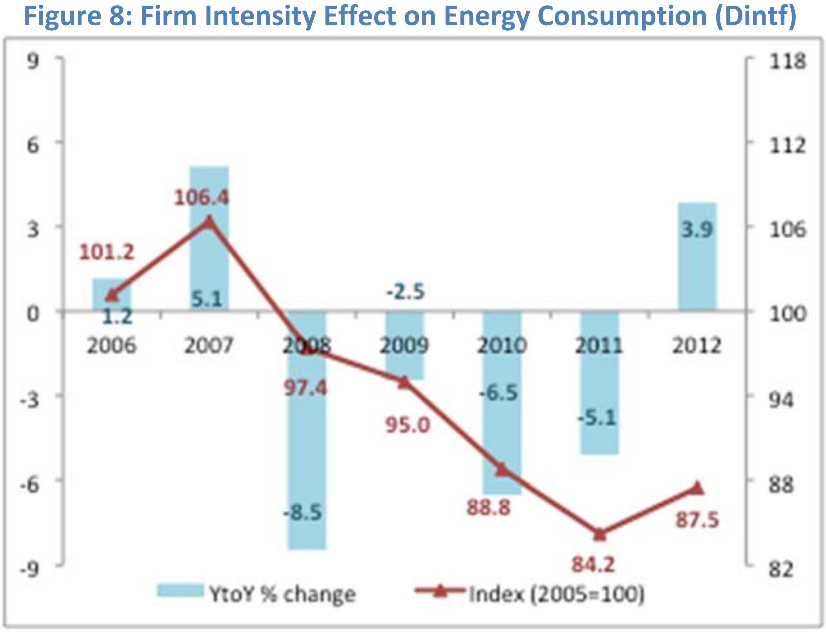


We do not detect a statistically significant correlation between the sectoral structural effect index and the firm structural effect index, indicating that these two effects do not necessarily act in coordination.

Figure 7: Firm Structural Effect on Energy Consumption (Dstrf)

Finally, Figure 8 presents the firm intensity effect. As we define the energy intensity as energy consumption*100 divided by the energy consumption, energy intensity is the opposite of the energy efficiency term. Figure 8 demonstrates that the decrease in the energy intensity of firms had a significant contractionary impact on the aggregate energy consumption over the 2005-2012 period. Specifically, the same firm, on average, produced the same value of output by using 12.5% less energy in 2012 relative to 2005. In fact, among all four effects covered, the intensity effect has been by far the most contractionary effect on energy consumption in the manufacturing industry.

Figure 8: Firm Intensity Effect on Energy Consumption (Dintf)



Effect of Firm Selection on Firm Level Decomposition Findings

Remember that for conducting firm level analysis we had to work only with 9,379 specific firms that exist every year over the 2005-2012 period. One consideration pertaining to the firm level decomposition findings is the degree to which they are representative of the energy patterns of the whole manufacturing industry. Since these firms account for 72.5% of energy consumption and 66.5% of production the manufacturing industry, we do not expect firm selection has a significant negative impact on the quality of our findings above. However, in order to get an educated idea about this, we below run traditional sector level decomposition by first using the whole universe of firms and second by using only those specific 9,379 firms[9].

The decomposition findings presented in Table 2a and Table 2b are very similar. Therefore, we conclude that not being able to cover all firms in the firm level decomposition does not pose a big problem for the representativeness of that decomposition of the whole manufacturing industry.

Table 2a: Decomposition Results at Sector Level for the 2005-2012 Period (including all firms)

D_{man}	D_{act}	D_{strs}	D_{ints}
1.278	1.538	0.981	0.847

Table 2b: Decomposition Results at Sector Level for 2005-2012 Period (including only 9,379 firms existing in the data set over the whole period)

D_{man}	D_{act}	D_{strs}	D_{ints}
1.273	1.520	0.971	0.862

VI. DISCUSSION OF FINDINGS

In this section, we first discuss our firm level decomposition findings by comparing with the findings of the only firm level study in the literature - Petrick (2015) for the German manufacturing industry. Although the time period of that study is different from ours, we still conduct such a comparison as it is the only firm level decomposition analysis in the literature and we believe that energy dynamics in an industry is not likely to change significantly over a short period of time. Comparison by each decomposition component is given in Table 3. First, unlike a significant 27% increase in the energy consumption in Turkey over the 2005-2012 period, energy consumption in Germany increased by a much smaller amount (5%) over the 2000-2007 period.

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[9] We use the multiplicative version of the Log-Mean Divisia Index Method-I decomposition introduced by Ang and Liu (2001).

Table 3: Comparison of Turkey and Germany Findings

	Turkey (2005-2012)	Germany (2000-2007)
Activity Effect	51%	15%
Sectoral Structural Effect	-2%	-6%
Firm Structural Effect	-2%	-4%
Intensity Effect	-13%	1%
Aggregate Energy Consumption[10]	*27%*	*5%*

Second, although their magnitudes by country differ significantly, the activity effect has been the main driver of the change in aggregate energy consumption in both countries with 51% for Turkey and 15% for Germany. Third, both the sectoral structural effect and the firm structural effect had a more contractionary effect on aggregate energy consumption for Germany (-6% and -4%, respectively) than for Turkey (-2% for both effects). This implies that, although across-sector and across-firm within-sector production reallocation has been towards energy efficient sectors/firms in both Germany and Turkey, these effects were much stronger in Germany. Finally, while the energy intensity effect for Germany was almost stagnant over 2000-2007 with a mere 1% increase, the energy intensity of a specific firm decreased by on average an impressive 13% over the 2005-2012 period.

To recap, using a firm level decomposition methodology, we documented that, rather than across sectors structural change, and within sector across-firm structural change, the activity effect and the firm intensity effect were the drivers of the change in energy consumption in Turkish manufacturing industry over the 2005-2012 period. With the superiority of firm level analysis over sector level analysis, we could show in this study that the energy efficiency increases within sectors seen in Table 2a and Table 2b are from the increase in firm level efficiency rather than shift of production towards more energy efficient firms within sectors.

As for policy implications, we believe that there are two areas that need to be investigated further for designing policies aiming at higher energy efficiency in Turkey. First, the very small role of the production shift from higher energy intensive sectors to lower energy intensive sectors (sector structural effect) as well as from higher energy intensive firms to lower energy intensive firms within-sectors (firm structural effect) might be indicating serious market failures and barriers that prevent more energy efficient firms from increasing their share in total production in Turkish manufacturing industry. Therefore, addressing the source of this low-level dynamism could yield useful results for enhancing energy efficiency.

[10] In Petrick (2015), the aggregate CO_2 emissions is decomposed, instead of the aggregate energy consumption. We calculated aggregate energy consumption for that study by deducting the effects of fuel mix change and emission factor of fuels from the aggregate CO_2 emissions presented in that study.

Second, and in contrast to the structural change, the significant decrease in the firm level energy intensity over the 2005-2012 period can be considered an impressive progress towards energy efficiency in the manufacturing industry. Although there are several potential candidates as the source of this progress such as increasing openness to trade and technological development[11], exact reasons can only be revealed by research designed and conducted solely for this purpose.

[11] See for example Fisher Vanden et al. (2013) for the reasons behind the energy intensity decrease in some industries in China.

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APPENDIX:

Table A1: Key Figures of 20+ Manufacturing Companies

Period	Number of Establishments	Employment (million)	Energy Consumption (2005 billion TL)	Value of Production (2005 billion TL)
2005	18,904	1.77	10.5	283
2006	19,925	1.88	11.7	319
2007	19,513	1.94	12.8	329
2008	18,777	1.95	12.3	344
2009	15,881	1.68	10.4	298
2010	21,271	1.98	11.5	363
2011	23,892	2.22	12.8	431
2012	26,111	2.41	13.5	444
Average	20,534	1.98	11.9	351

Table A2: Key Figures of All Period 20+ Manufacturing Companies

Period	Number of Establishments	Employment (million)	Energy Consumption (2005 billion TL)	Value of Production (2005 billion TL)
2005	9,379	1.13	8.2	211
2006	9,379	1.19	9.2	237
2007	9,379	1.27	10.3	253
2008	9,379	1.32	10.0	267
2009	9,379	1.22	8.7	240
2010	9,379	1.30	9.2	275
2011	9,379	1.39	9.9	319
2012	9,379	1.45	10.4	320
Average	9,379	1.28	9.5	265