1 Estimating Contributions to GDP Growth by Structural Decomposition of Input-Output Tables

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Introduction

This paper presents a case study to demonstrate the calculation methods of GDP growth contributions using structural decomposition analysis (SDA) of input-output tables and their Hungarian applications. Although the required data are available with a considerable time-lag, results show that taking supplier relations and value chain multipliers into account can significantly alter the picture on growth effects of industries and final demand categories by the conventional approach. This can be instructive for analysts, policy and decision makers, not only in Hungary, but also in other countries. The study was performed by using public macroeconomic and sectoral data obtained from the Hungarian Central Statistical Office's (HCSO) dissemination database and STADAT tables.[1]

Input-output tables

Input-output tables are published with a much longer time-lag than flash estimates of GDP. Therefore the case study is not on the last quarter but, according to the annual horizon and the publication schedule of input-output tables,[2] on an earlier year.

[1] This paper is a short version of *Koppány* (2016) published in the Hungarian Statistical Review, http://www.ksh.hu/statszemle_archive/2016/2016_08-09/2016_08-09_881.pdf. Full-length analysis in English is forthcoming in Acta Oeconomica. See these studies for technical background and results in detail. This research was supported by the János Bolyai Research Scholarship of Hungarian Academy of Sciences and the PADS Foundation.

[2] According to the European guidelines, input-output tables are published by HCSO every five years, with a three-year time lag.

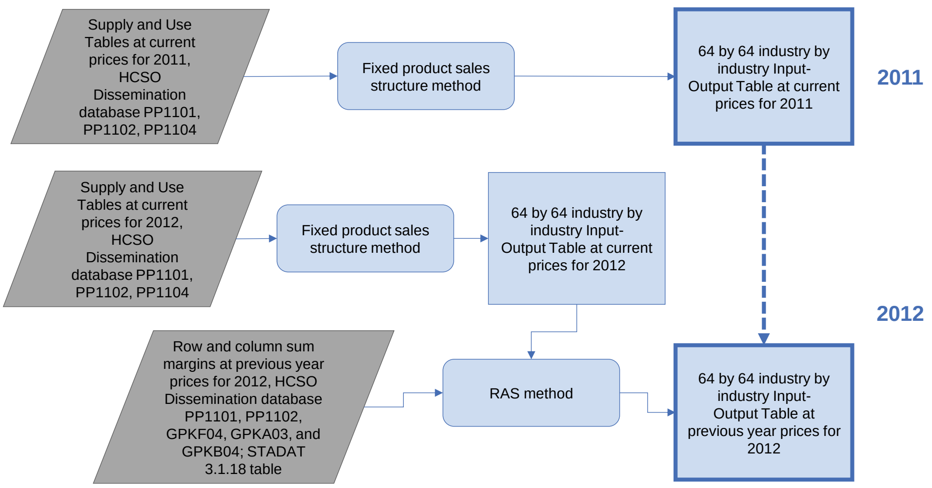
For analysing GDP volume change, two successive years' input-output tables are needed, of which, the latter is expressed at previous year prices. In Eurostat Database only three countries, Denmark, Netherlands, and Romania have industry by industry tables of this type. Estimating a constant price table is a challenge for other countries.

At the time of writing this paper, the latest input-output table published by the HCSO is valid for the year 2010.[3] This is produced from the supply and use tables[4] by the "fixed product sales structure" transformation (*Eurostat* (2008), p. 351., Model D), calculated with 88 industries and published in a 65 by 65 aggregation depth.

Supply and use tables at current prices are available also for the subsequent two years, so using these and the method referred to above I could generate current price input-output tables for 2011 and 2012, as well. Data available for next steps required unification of industries 68A: Imputed rents of owner-occupied dwellings and 68B: Real estate activities (excluding imputed rents), so from this point I worked with 64 industries.

The former detailed dataset at previous year's prices was not available, consequently a constant price table for 2012 was developed from the 2012 year current price table with the RAS method (*Miller–Blair* (2009) sections 7.4.1–3) using the previous year price margins available in the dissemination database and STADAT (see Figure 1).

Figure 1: Generating input-output tables



Although margins are available for 2013–2014 too, updating for these years, even for current price tables can only be done by RAS or other approximation techniques. This would made the results precarious. For this reason, I use 2011 current price and 2012 previous year price input-output tables (Table group 1) for the demonstration of the application of SDA, by which we can analyse GDP growth and growth contributions of the year 2012.

Due to the size of the tables, Table group 1 shows the simplified, four industry, three final demand component and only one value added row version of these, which will be of assistance to us in the demonstration and comprehension of the decomposition methods, and comparisons between the numbers by conventional and SDA techniques. In spite of the short form presentation of the data and the results as well, calculations are made on 64 industry levels.

[3] Dissemination database / National accounts, GDP / Input-output tables, supply and use tables / Symmetric input-output table (industry by industry), at current basic prices NACE Rev. 2 (ESA2010) (technical code PP1109)

[4] I.b. PP1101, PP1102 and PP1104.

Table group 1: Simplified input-output tables for Hungary
(billion HUF)

Simplified input-output table for base year 2011 at current prices

Industries	Intermediate consumption					Final use				Total use / output
	A Agriculture, forestry and fishing	B-E Mining; manufactu-ring etc.	F Construction	G-T Services	Total intermediate consumption	Household final consumption expenditures	Other domestic final demand	Export	Total final use	
A Agriculture, forestry and fishing	564	719	4	101	1 389	317	242	652	1 211	2 600
B-E Mining; manufacturing etc.	352	3 558	422	1 746	6 077	2 260	737	16 747	19 744	25 822
F Construction	3	67	63	217	349	26	1 947	98	2 071	2 420
G-T Services	256	2 382	447	6 077	9 163	7 583	6 819	3 979	18 382	27 545
Import	285	12 683	456	3 061	16 485	2 239	1 942	1 961	6 142	22 627
Taxes less subsidies on products	33	206	40	756	1 036	2 649	378	183	3 211	4 246
Total intermediate / final use	1 493	19 616	1 432	11 958	34 499	15 076	12 065	23 620	50 761	85 260
Gross value added	1 106	6 206	988	15 586	23 887					
Output	2 600	25 822	2 420	27 545	58 386					

Simplified input-output table for current year 2012 at previous year prices

Industries	Intermediate consumption					Final use				Total use / output
	A Agriculture, forestry and fishing	B-E Mining; manufactu-ring etc.	F Construction	G-T Services	Total intermediate consumption	Household final consumption expenditures	Other domestic final demand	Export	Total final use	
A Agriculture, forestry and fishing	499	721	4	90	1 314	296	82	642	1 020	2 334
B-E Mining; manufacturing etc.	353	3 153	363	1 640	5 509	2 250	677	16 158	19 085	24 593
F Construction	3	58	70	218	349	23	1 779	104	1 906	2 255
G-T Services	257	2 272	419	5 787	8 735	7 514	6 761	3 963	18 238	26 973
Import	305	12 123	436	2 905	15 769	2 015	1 899	2 218	6 132	21 901
Taxes less subsidies on products	44	198	37	741	1 021	2 622	368	188	3 178	4 199
Total intermediate / final use	1 460	18 525	1 329	11 381	32 695	14 721	11 566	23 273	49 560	82 255
Gross value added	874	6 068	926	15 592	23 460					
Output	2 334	24 593	2 255	26 973	56 155					

Conventional growth contributions

The data required for calculating growth contributions by the widely-used conventional method can be acquired from the input-output tables, as well.

Arranging industries' values added and taxes less subsidies on products (grey cells in Table 1) to Table 2, branches' value added and the whole economy's GDP changes can be obtained as the differences of constant price current and base year numbers (in the case of industry A Agriculture, forestry and fishing, for example, 874 – 1 106 = –232). Expressing these in proportion to base year gross domestic product, we have growth contributions of industries in a percentage form (–232 / 28 134 = –0,82 %), which are exactly the same as the statistics in STADAT 3.1.6 table.[5]

To quantify demand side effects, we need to assemble the components of the well-known expenditure approach GDP identity (dark blue cells in Table 1). Totals of household consumption, other domestic final use, and export can be found in the sums of the same columns. Last cells of the fifth rows is subtracted from them, which are the sums of all intermediate and final use of imports. Using these, similarly to the production approach in the upper table of group 2, we can calculate growth contributions of demand components as well. Results differ slightly from STADAT 3.1.6 only because of the variance of national account and input-output table valuation standards.[6] The method is the same.

For the compatibility of the result from the conventional method reviewed above and the SDA, some changes were made in Tables 2 that do not affect the main point. First, seeing that growth effects of industries are of great importance, we omit taxes less subsidies, and express contributions not for the GDP, but the fully industry-divisible gross value added (GVA) (Table group 3). Although

[5] http://www.ksh.hu/docs/eng/xstadat/xstadat_annual/i_qpt017a.html, for the conventional methodology see http://www.ksh.hu/docs/eng/modsz/modsz31.html

[6] Import is valued at fob (free on board) parity in national accounts, and at cif (cost, insurance and freight) in the input-output tables. Cif/fob adjustments, direct purchases abroad by residents and purchases on domestic territory by non-residents cause differences in trade and household consumption.

percentage GVA contributions somewhat differ from those based on GDP, relative weights of branches remain the same. Furthermore, these numbers are directly comparable to the results gained from the input-output model in the next section.

Table group 2: Conventional GDP growth contributions
(billion HUF and percentage)

Production approach contributions to GDP growth based on industries own value added

Industries	Base year, 2011 (at current prices)	Current year, 2012 (at previous year prices)	Change in value	Change in proportion to base total
A Agriculture, forestry and fishing	1 106	874	-232	-0,82%
B-E Mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply etc.	6 206	6 068	-138	-0,49%
F Construction	988	926	-63	-0,22%
G-T Services	15 586	15 592	5	0,02%
Taxes less subsidies on products	4 246	4 199	-48	-0,17%
Gross domestic product (at purchaser's prices)	**28 134**	**27 659**	**-475**	**-1,69%**

Expenditure approach contributions to GDP growth

Components of final use		Base year, 2011 (at current prices)	Current year, 2012 (at previous year prices)	Change in value	Change in proportion to base total
Household final consumption expenditures		15 076	14 721	-355	-1,26%
Other domestic final demand		12 065	11 566	-500	-1,78%
of which	Final consumption expenditures by non-profit organisations serving households (NPISH)	444	448	4	0,01%
	Final consumption expenditures by government	5 847	5 761	-85	-0,30%
	Gross fixed capital formation	5 569	5 324	-245	-0,87%
	Changes in inventories	206	33	-173	-0,62%
Export		23 620	23 273	-347	-1,23%
Import (-)		-22 627	-21 902	725	2,58%
Gross domestic product (at purchaser's prices)		**28 134**	**27 657**	**-476**	**-1,69%**

Table group 3: Contributions to GVA growth
(billion HUF and percentage)

Production approach contributions to GVA growth based on industries own value added

Industries	Gross value added: Base year, 2011 (current prices) (v^0)	Gross value added: Current year, 2012 (at prev year prices) (v^1)	Change in value (Δv)	Change in proportion to base total
A Agriculture, forestry and fishing	1 106	874	-232	-0,97%
B-E Mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply etc.	6 206	6 068	-138	-0,58%
F Construction	988	926	-63	-0,26%
G-T Services	15 586	15 592	5	0,02%
Gross value added total	**23 887**	**23 460**	**-427**	**-1,79%**

Expendtirus approach contributions of final demand for domestic products to GVA growth

Components of final use		Base year, 2011 (at current prices)	Current year, 2012 (at previous year prices)	Change in value	Change in proportion to base total
Household final consumption expenditures for domestic products		10 187	10 084	-103	-0,43%
Other domestic final demand for domestic products		9 745	9 299	-447	-1,87%
of which	Final consumption expenditures by non-profit organisations serving households (NPISH)	443	447	4	0,02%
	Final consumption expenditures by government	5 511	5 475	-36	-0,15%
	Gross fixed capital formation	3 784	3 488	-296	-1,24%
	Changes in inventories	7	-111	-118	-0,50%
Export from domestic products		21 476	20 867	-609	-2,55%
Intermediate use from imports and taxes less subsidies on intermediate products (-)		-17 521	-16 789	732	3,06%
Gross value added total		**23 887**	**23 460**	**-427**	**-1,79%**

A second modification is that direct import content of final demand components (dark green cells in Table 1) is ignored in the expenditure table, so only final use from domestic sources is taken into account. The import row includes only intermediate consumption henceforth.[7] Changes in the final demand for domestic products can, of course, alter the intermediate use from imports, which has an adverse effect on GVA. Thus, growth contributions of domestic product demand components indicated in Table 2 can be imprecise. Assessment of their value added effect depends on the industry mix of final demand change, domestic and foreign supply chains of the concerned industries, and companies' value added ratios. Multiplicative processes taking place can be kept track of by the input-output model, and factoring the changes can be made by a structural decomposition analysis. These techniques will be covered in the following section.

When comparing SDA and the conventional method, values of Table 3 will serve as reference points. These are the growth contributions calculated separately from the supply and demand side surface of the economy, from the margins of the input-output tables. Only such calculations can be accomplished using current GDP statistics, which ignore the interconnections between industries captured by the numbers in the light blue highlighted cells of Table 1. A more profound investigation based on these can penetrate deeper into the growth relationships and discover details that cannot be revealed from above. For this, however, we need to recall the basics of the input-output model.

Structural decomposition analysis

Using the input-output model we can draw on the well-known mechanism that

- changes in the final demand (A) affects output of industries, which in turn,
- modifies the purchases from other industries (B), i.e. intermediate consumption too, generating a circular, multiplicative process in the economy, and as a result of this,
- value added of the industries will vary (C) (see Figure 2).

Figure 2: **GVA multiplication process in the demand-pull input-output model** (billion HUF)

Simplified input-output table for base year 2011 at current prices

Industries	Intermediate consumption					Final use				Total use / output
	A Agriculture, forestry and fishing	B-E Mining; manufactu-ring etc.	F Construction	G-T Services	Total intermediate consumption	Household final consumption expenditures	Other domestic final demand	Export	Total final use	
A Agriculture, forestry and fishing	564	719	4	101	1 389	317	242	652	1 211	2 600
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Gross value added	1 106	6 206	988	15 586	23 887					
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Value added between two years can change because of three main reasons: changes in the

- final demand (D),
- domestic requirements of the supply chains (E), and
- industries' value added (F) ratios (relative to output) (see Figure 3).

These are the three terms on the right hand side of the following basic value added SDA equation

$$\mathbf{v} = \langle \mathbf{c} \rangle \mathbf{L} \mathbf{f} \ ,$$

where $\mathbf{v}$ is the vector of values added, $\langle \mathbf{c} \rangle$ is the diagonalized vector of industry value added ratios, $\mathbf{L}$ is the so-called Leontief inverse of direct requirements of intermediate inputs, and $\mathbf{f}$ is the vector of the final demand.

[7] For the sake of switching from GDP to GVA we correct with product taxes of intermediate consumption also in this row.

Figure 3: **Reasons of GVA changes**
(billion HUF)

Simplified input-output table for base year 2011 at current prices

Industries	Intermediate consumption					Final use				Total use / output
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Simplified input-output table for current year 2012 at previous year prices

Industries	Intermediate consumption					Final use				Total use / output
	A Agriculture, forestry and fishing	B-E Mining; manufactu-ring etc.	F Construction	G-T Services	Total intermediate consumption	Household final consumption expenditures	Other domestic final demand	Export	Total final use	
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Gross value added	874	6 068	926	15 592	23 460					
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Factoring the differences between two years' value added vector, $\Delta\mathbf{v} = \mathbf{v}^1 - \mathbf{v}^0$ (superscripts indicate the relating time periods: 0 is for the base, and 1 for the current year) can be done in several ways. The two so-called polar decompositions, stepping from current to base year with weights,

$$\Delta\mathbf{v} = \langle\Delta\mathbf{c}\rangle\mathbf{L}^1\mathbf{f}^1 + \langle\mathbf{c}^0\rangle(\Delta\mathbf{L})\mathbf{f}^1 + \langle\mathbf{c}^0\rangle\mathbf{L}^0\Delta\mathbf{f} \text{ ,}$$

and vice versa

$$\Delta\mathbf{v} = \langle\Delta\mathbf{c}\rangle\mathbf{L}^0\mathbf{f}^0 + \langle\mathbf{c}^1\rangle(\Delta\mathbf{L})\mathbf{f}^0 + \langle\mathbf{c}^1\rangle\mathbf{L}^1\Delta\mathbf{f} \text{ ,}$$

however, in the case of three or more components are not unique, don't cover all possible formulations. Empirical evidence suggests that the average of them still gives a good approximation. The other way for coping with the non-uniqueness problem is bracketing two adjacent terms, and make hierarchical or nested decompositions. Both of them was used in the case study.

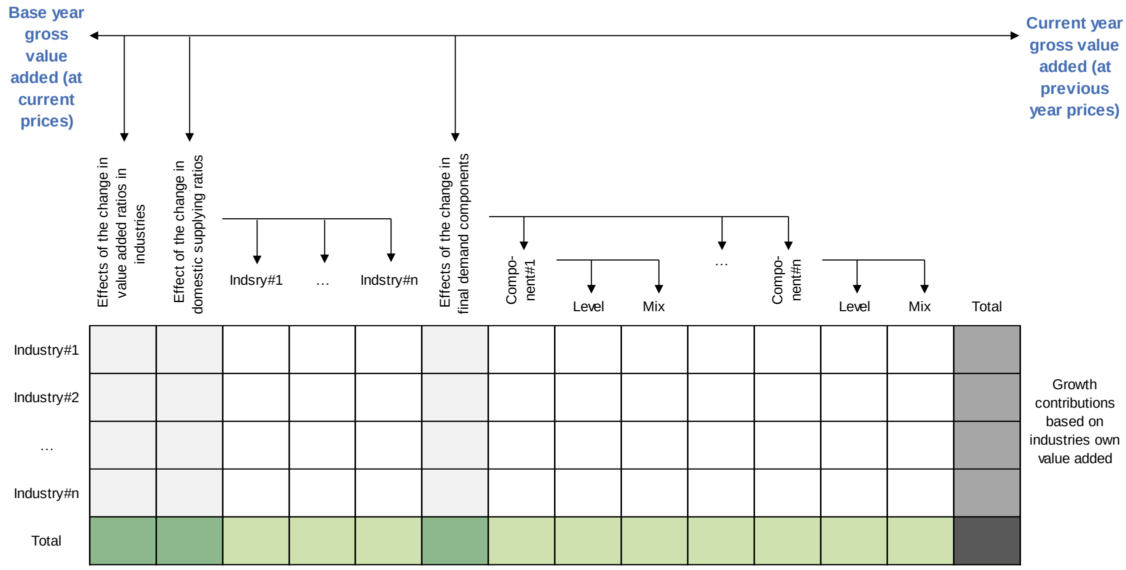
Another problem was the interdependence between value added and domestic supplying ratios, which called for a special solution.[8]

Figure 4 shows the design of the SDA. Variations between two years' value added are broken to the three main part effects mentioned above, with the second and third one divided further to sublevels. Results can be obtained in a matrix or cross-tab format, where

- column sums show the SDA version of the expenditure approach, i.e. the demand side originated effects, and
- row sums give the production approach industry break-up with exactly the same conventional growth numbers on the whole.

[8] On these problems and on the SDA itself in genereal see *Rose–Casler* (1996), *Dietzenbacher–Los* (1998, 2000), *Pei et al* (2012), and *Koppány* (2016). Detailed mathematical apparatus used in this study is also available in *Koppány* (2016).

Figure 4: SDA design



In order to reveal new aspects on growth from the supply side, as well, I performed the variance analysis with the following, modified version of the basic equation:

$$\bar{\mathbf{v}} = \left\langle (\mathbf{c})' \mathbf{L} \right\rangle \mathbf{f} .$$

Vectors $\bar{\mathbf{v}}$ in SDA#2, in contrast to former vectors **v** in SDA#1, allocate domestic value added to industries not on the basis of where they appear, but according to all the direct and indirect nationwide effects that an industry's final demand can have. So this alternative gives not the own value added of industries, but the value added of all industries contributing to a given industry's final demand through the supply chains, of course, to the extent of their contribution. Using this model, we have a different production approach, which also yields significant deviations from conventional growth contributions in certain industries. Results in the short form Table 4 serve for an easy comparison to Table 3, and will be evaluated in the next section.

Discussion of the results

Figures 5 and 6 help give an overall assessment. The waterfall chart shows that, according to the most important column sums of the SDA, the change of value added ratios have the only significant positive effect on 2012 growth. Shifts in domestic direct requirements, particularly those of manufacturing, and the fall in final demand decreased total value added.

Benchmark Tables 2 and 3 indicated export as a considerable negative factor, which was overcompensated by the more declining import. Thus from the demand side, international trade was the only positive force. SDA results indicate these differently. Taking the industry mix of export and the multiplication processes through the value chains into account and fixing the supplier structure and value added ratios at an average of two years, we can say changes in export hardly affected the growth on the whole. Cutdown of domestic final use of domestic products, mainly the decrease in investments, was the greatest retractive force. The growth effect order of the components of domestic final demand in SDA, however, is the same as in Table 3.

An in-depth discussion of the various industry part effects behind the column sums, and unfolding the complexities of the levels and mixes is beyond the limits of this paper; however, highlighting variances between industries own value added and those of their supply chains definitely deserves mention. These can be followed by a row-by-row comparison of Tables 3 and 4.

Value added production of an industry, according to the "accounting" used in SDA#2, depends, on the one hand, on its final output, and on the other hand, on its value added multiplier. Agriculture, for example, sells more for intermediate, than final use, so, despite its relatively high multiplier, it has a lower value added from final demand supply chains than its own realized measure (a part of the latter, in supply chain approach, will be accounted to other industries, for which agriculture is a supplier). Supply chain values added of manufacturing and construction, however, far exceed their own one. These are due to the prodigious production and export volumes of the key growth manufacturing sub-branches, and the high multiplier value of construction. Hence, decline of the final demand for construction, in Table 4, decreased economic growth more than the fall in its own value added in Table 3.

Table 4: Production approach growth contributions by SDA#2
(billion HUF and percent)

Production approach contributions to GVA growth based on final demand industry supply chains' value added

Industries	Gross value added		Change	
	Base year, 2011 (at current prices) $(\bar{v}^0)$	Current year, 2012 (at previous year prices) $(\bar{v}^1)$	in value $(\Delta\bar{v})$	in proportion to base total
A Agriculture, forestry and fishing	877	690	-187	-0,78%
B-E Mining and quarrying; manufacturing etc.	7 336	7 192	-144	-0,60%
F Construction	1 341	1 238	-104	-0,43%
G-T Services	14 333	14 340	7	0,03%
Gross value added total	23 887	23 460	-427	-1,79%

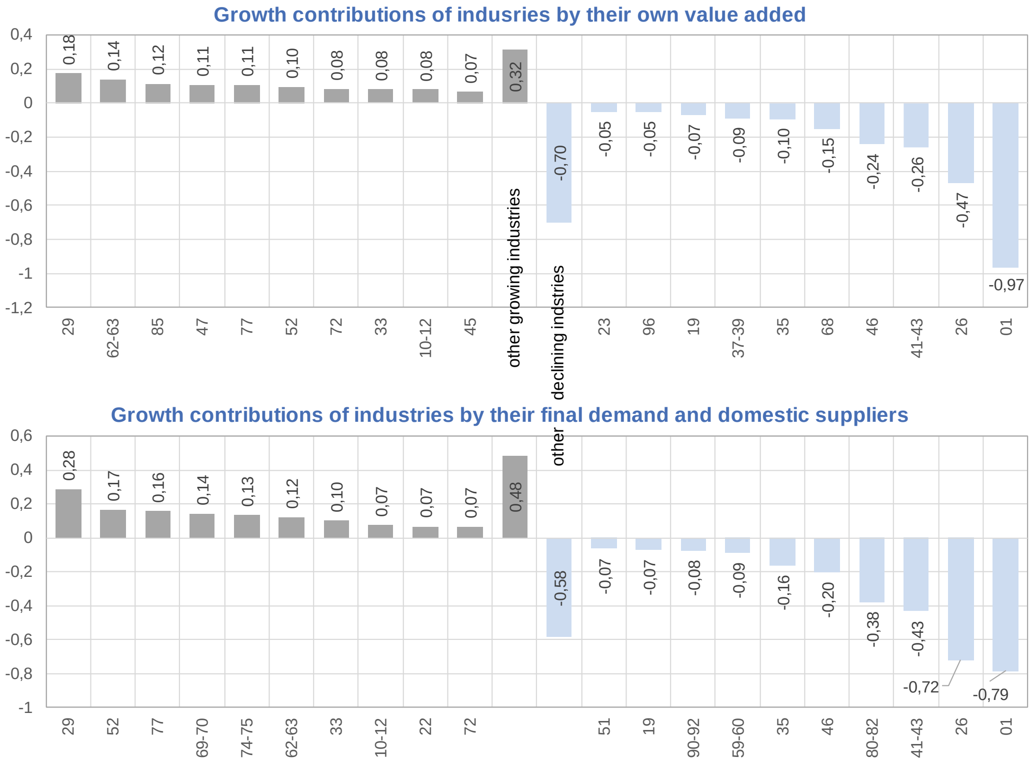
Figure 5: Column sum SDA results
(billion HUF and percentage)

Figure 6 shows the effect of the most and least growth-contributing industries in 2012 estimated by both methods. The ranking is headed by the manufacture of motor vehicle in both cases, although value according to the second approach was more than a one and a half times higher. Growth contribution of the automotive industry by its own value added was 0.176 %; however, it bore a 0.284 % effect through its suppliers, in spite of its almost minimum and somewhat decreasing multiplier value, caused by its high import, and low domestic supply and value added rates.

Nevertheless, low and declining multipliers, coupled with a high and increasing export volume, resulted in an ascent from second to first position in the ranking of final use effect, the direct and indirect consequences of which overcompensated the negative growth effects of declining domestic supplying rates.

When making a comparison of the lists of the first and last ten indusries of the upper and lower diagram of Figure 6, a significant overlap can be seen. The most and least own value added growth-contributing industries generally have the greatest effects through their supply chains, too. The ranking between them, however, is somewhat different. Warehousing and support activites for transportation, for example, is second by its supply chains, and only sixth with its own value added.

Figure 6: **Effects of the most and least growth-contributing industries in 2012** (percent)



Legend: 01: Crop and animal production, hunting and related service activities; 10-12: Manufacture of food products, beverages and tobacco products; 19: Manufacture of coke and refined petroleum products; 22: Manufacture of rubber and plastic products; 23: Manufacture of other non-metallic mineral products; 26: Manufacture of computer, electronic and optical products; 29: Manufacture of motor vehicles, trailers and semi-trailers; 33: Repair and installation of machinery and equipment; 35: Electricity, gas, steam and air conditioning supply; 37-39: Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services; 41-43: Construction; 45: Wholesale and retail trade and repair of motor vehicles and motorcycles; 46: Wholesale trade, except of motor vehicles and motorcycles; 47: Retail trade, except of motor vehicles and motorcycles; 51: Air transport; 52: Warehousing and support activities for transportation; 59-60: Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities; 62-63: Computer programming, consultancy and related activities; information service activities; 68: Real estate activities and imputed rents of owner-occupied dwellings; 69-70: Legal and accounting activities; activities of head offices; management consultancy activities; 72: Scientific research and development; 74-75: Other professional, scientific and technical activities; veterinary activities; 77: Rental and leasing activities; 80-82: Security and investigation activities; services to buildings and landscape activities; office administrative, office support and other business support activities; 85: Education; 90-92: Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities; 96: Other personal service activities.

Summary and comparison, pros and cons

The calculation of growth contributions by SDA, like any method, has both advantages and disadvantages. As a conclusion we present a brief overview of these. Theoretical and methodological limitations are not explained here, instead, difficulties evident from the choice of investigated periods are emphasized. The time-lag of several years in producing and publishing supply, use and input-output tables, the assumptions, limitations, and imprecisions of the models, updating and approximation techniques impede an up to date and accurate operation of the analysis.[9] Undoubtedly, flash estimates of quarterly GDP by statistical offices also need re-examinations and sometimes corrections; however, conventional methods of calculating growth contributions can be applied immediately, even by the most current and simple structure data, providing very quick indicators for analysis and policy.

Structural decomposition of the factors of economic growth offers extra information to the standard production and expenditure approach contributions calculated independently from the changes of own value added of industries and the levels of final demand components. Conventional methods show only the surface from two separate sides. Both methods presented here, however, consider multiplicative effects of final use from domestic output through the supply chains, and decompose them to part effects of changes in value added ratios, supplying structure and final demand, and further subcomponents. The effects are allocated between industries, as well, so the demand side and the value added generation of the producers (in SDA#1) and supply chains (in SDA#2) are connected as two dimensions of growth and shown together in a crosstab format.

Different approaches yield different insights and significant variance in the results. Consequently, SDA, in spite of the time-lag of data and the imprecision of updating techniques, can be a useful complement to standard techniques. Structural decomposition and variance analysis of input-output tables show a deeper structure of the economy, thus offering a different approach to assessing GDP generation and growth contributions of industries, supply chains and final demand components for a better understanding of the driving forces of growth. As a complementary tool for analysis, it can support economic, development and policy decisions of the private sector and the government.

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[9] The general reason of official statistics for constructing and publishing input-output tables only every five years is that the structures of the economies modify relatively slow. It might have been true for the past, but not for the future. Being round the corner of the large scale robotization, virtualization, IoT, big data and hopefully green revolution, the world, including technological and economic structures and so the driving forces of growth, will probably change faster than ever before. Statistical offices definitely perceive these phenomena and the pressure from analysts and policymakers for the most current and high quality data on economic structures, at the same time. Timely estimates of several statistical indicators, especially those of GDP, improved significantly in the last decades (see *Kokkinen–Wouters* (2016)). There must be some possibilities also in reducing the production time of input-output tables. A decrease of the time-lags will boost the applicability and the relevance of the growth decomposition analysis presented here.