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Dariusz C. Kotlewski

(Warsaw School of Economics (SGH) and Statistics Poland)

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ROLE OF INFRASTRUCTURE IN ECONOMIC GROWTH THROUGH THE LENSES OF KLEMS GROWTH ACCOUNTING

BY DARIUSZ KOTLEWSKI*

Warsaw School of Economics

Statistics Poland

Abstract

The aim of the article is to assess the role of infrastructure capital in economic growth. For this purpose, KLEMS growth accounting framework shall be used. It was found, that due to some specificity of available data structure infrastructure capital can be quite easily extracted from the total capital aggregate when it is understood broadly, and then introduced into KLEMS framework formulae. With that exercise, however, are associated some issues that will be discussed in the paper. Finally, it was found that when the proposed methodology is applied to spatial aggregations (i.e., countries and provinces of countries) rather than industries then quite sound data can be obtained even before the envisaged SNA reform.

Key words: GVA, growth accounting, decomposition, infrastructure capital.

JEL: O47, E22, E23, E24

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1. INTRODUCTION

Among economists, the view that infrastructure development has a positive impact on the rate of economic growth is quite widespread. However, it is often impossible to establish beyond doubt the economic viability of infrastructure investment (despite existing business best practices). This is because the future demand for infrastructure remains largely uncertain. It depends on strategic economic decisions that may or may not prove to be accurate. Furthermore, this demand for infrastructure in the future may depend on non-economic factors, including geopolitics - in general, the long lifespan of infrastructure facilities makes unforeseen historical events likely. Observations and analyses of this issue are usually conducted ex post, considering successful and sufficiently long periods of relatively undisturbed economic development that can be studied. These are very often analyses of a qualitative nature, and if they are quantitative, they are often based on mainly external observation.

This often happens without providing a cause-and-effect path grounded in proven economic theory. In this situation, anchoring this issue in an account based on a general, well-established, and largely tested economic theory would be an important contribution to solving many of the dilemmas posed by researchers in this area, considering of course the above-mentioned limitations in foreseeing the longer future. However, the idea of disaggregating infrastructure capital, in order to examine its actual impact on economic growth rates, faces problems related to the presently applied System of National Accounts (SNA). Growth accounts based on the index method, including the internationally most widely applied KLEMS growth accounting, use the so-termed endogenous approach. The weights associated with capital, which are assumed to be its relative remunerations at the level of individual aggregations, are calculated residually by subtracting from the GVA at the level of those aggregations the compensations of labor.

This means that the assumption is that the internal rate of return on capital is such that it leads to a total equalization of the relevant part of the gross operating surplus with the capital remuneration. The advantage of this endogenous approach is that it is consistent with neoclassical assumptions of constant returns to scale under perfect competition. However, for public capital, arising from public investment, there is a problem in determining the appropriate level of gross operating surplus – for in the National Accounts (NA) the net revenue from public capital is assumed to be zero. As a result, for the example given by M. Mas (2009, 365) gross operating surpluses presented by the NA are underestimated by up to 15 % and GVA values by around 5-6 % relative to the situation if an exogenous approach of taking data from the market, rather than calculating them residually, were used – taking the relevant data from the market on the rate of return on capital on the relevant aggregates, however, presents insurmountable difficulties.

Fortunately, these differences when only increments and contributions to increments are used become much less significant, according to Mas. We understand that the mechanism behind this is due to the fact that the underlying structures in data arrays are more permanent than the actual value levels. This circumstance means that the formulae for the decomposition of economic growth understood as GVA growth rates and their transformations can nevertheless be effectively applied to the study of the impact of infrastructure on economic growth, since only increments and contributions to increments are present in decomposition formulae. Therefore, with some modification of the formulae for KLEMS-type decompositions and a special operation on the input data from the supply and use tables (SUT), rough but sound estimates of the importance of infrastructure for economic growth can be obtained (taking the underlying neoclassical assumptions of course), although further development of the methodology in this area is required.

The paper presents e.g., results for the aggregate Polish economy and for Polish voivodeships, which demonstrate the fairly good approximate effectiveness of this approach and motivate further work on a possible reform of the SNA system (per Mas) so that the input data meet the theoretical requirements of economic growth accounting. The other possible limitations of the adopted methodology are also discussed.

2. Basic Methodology and Methodological Developments

The decomposition of economic growth into the contributions of two basic production factors has been initiated originally by Solow (1957), following a specific development of his economic growth theory (Solow, 1956). The application of this theory in regularly conducted productivity accounts was related with the introduction of Leontief concepts (1966) in statistics. Because of the relative complexity of numerous calculations to be performed its practical implementation was only possible with the advent of the computer era. The present version of economic growth accounting in the form of KLEMS growth accounting was formulated mainly by Jorgenson and associates (Jorgenson & Griliches, 1967; Jorgenson, Gollop, Fraumeni, 1987; Jorgenson, Ho, Stiroh, 2005)[1]. It is a methodology that is basically consistent with the OECD (2001) methodology, and together with it remains one of the two most often performed ways of conducting economic growth accounting using the index method, very strongly advised by Diewert (1976, 1978, 1992, 2004 and 2005)[2], a well-known expert of the trade. The starting point, then, will be the Solow's decomposition:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \alpha \frac{\Delta K}{K} + \beta \frac{\Delta L}{L} \tag{1}$$

where Y is the GDP, L – the labor factor, considered as physical counted hours (later on strictly defined as hours worked), K – the capital factor, considered as capital-stock value. The weights

[1] It is worth to see also: Jorgenson (1963 and 1989). The basic KLEMS methodology was well summarized in: Timmer et al. (2007) and O'Mahony & Timmer (2009).

[2] There exists also the econometric method developed by, e.g.: Ackerberg, Caves, Frazer (2015); Levinsohn & Petrin (2003) and Olley & Pakes (1996). This econometric method is often considered to be more appropriate for decompositions at firm level.

α and β are elasticities, that can be specified as shares of factor remunerations in total income, which requires, according to the theory, the adoption of the assumptions about the existence of perfect competition and constant returns to scale in the economy – moreover, these assumptions allow to use the formula $\beta = 1 - \alpha$ in (1). A is the *total factor productivity* (TFP). The contribution of TFP, i.e., *ΔA/A* is calculated residually by subtracting the other values in (1) – it is called as the *Solow's residual*. In this way, there is no direct need to establish the value of *A*, which remains an abstract category and its interpretation was (and to some degree still is) an issue. Solow interpreted it as technological progress. Presently, it is usually interpreted as technological or organizational progress disembodied in labor or capital.

Because the Törnqvist procedure (quantity index) is used for aggregation when the Solow-type decomposition is conducted at industry level this formula (1) was replaced in the KLEMS growth accounting by its translog approximation:

$$\Delta lnV_{jt} = \Delta lnA_{jt}^{V} + \overline{\alpha_{jt}}\Delta lnK_{jt} + \overline{\beta_{jt}}\Delta lnL_{jt} \tag{2}$$

which is consistent with this procedure. It has been established that in this procedure average shares between two time periods t and *t-1* should be used, according to formula $\bar{\alpha}_t = (\alpha_t + \alpha_{t-1})/2$ and similarly for $\bar{\beta}_t$ – subscript *j* for industries, present in (2) has been omitted here for simplicity (however, β_t is usually calculated residually in a similar way as for the Solow's formulae). By definition, these shares are shares in the gross value added (GVA) here, and it is the growth of GVA (V_{jt}) that is present on the left-hand side of formula (2). For each year and each industry (for instance represented by NACE sections and divisions) the formula (2) should be used independently. Thanks to its translog shape the formula (2) is strictly conformable with the original Cobb-Douglas production function[3].

The formula (2) can be developed by introducing an additional variable, related with the intermediate inputs, to the original production function. In the theory developed after Solow, it was established that only the decomposition of gross output growth (with an additional factor-alike contribution in the form of intermediate inputs' contribution to gross output growth) allows to establish technological or organizational progress disembodied in labor or capital. This gross-output-based MFP contribution is different than the value-added-based MFP contribution, but in an ideal situation they should be related with each other by the ratio between the gross output

[3] However, in the instance when growths are high (much over 10%) the logarithm values become discrepant with the classic relative growths from formula (1).

and the GVA. Otherwise, the formula (2) allows to establish the contribution to growth of technological or organizational progress disembodied in labor or capital only approximately – it can be inconsistent (i.e. not related by a known ratio as above mentioned) because of the phenomenon of substitution between the production factors (labor and capital) and the intermediate inputs[4]. That is why the contribution of the A variable in (2) is presently rather considered as the industry capacity to capture the value, to participate in the income (OECD, 2001, 23).

But the use of gross output decomposition is associated with data issues. Data insufficiency causes that for most countries, for which KLEMS growth accounting is performed, only the GVA decomposition according to formula (2) is being done. Fortunately, the GVA decomposition remains the central backbone of KLEMS growth accounting, providing the most essential information about the economy. Therefore, despite its limitations, it remains the basis for most analyses based on the method of decomposition in the framework of this accounting. Performing GVA growth decomposition as in (2) instead of gross output decomposition facilitates also international comparisons, since the issue of huge differences in the vertical integration of firms between the countries related with intermediate inputs is lifted. This issue is also important in the case discussed in the present paper, as those differences in vertical integration are also present between the different provinces of the given country – in case of Poland, between the different voivodships. Therefore, for the present study oriented to regional comparisons the choice of GVA decomposition in the framework of KLEMS growth accounting seems to be well justified.

In addition to the above, an important change in the KLEMS growth accounting decomposition compared to the Solow decomposition is the introduction of different definitions for the factors labor and capital. In the KLEMS growth accounting, instead of using in formula (2) the resources (stocks) of these factors, the quantities of services of these factors are used. The magnitudes of the factors' services are calculated by means of the Törnqvist quantity index aggregation procedure, in which the resources of the factors are weighted by their relative wages at the lowest aggregations adopted in the account before being added up to the total contribution of the factor. Therefore, in the KLEMS growth accounts, residual productivity is referred to as *multifactor productivity* (MFP), which can then be regarded as a more modern variant of TFP.

[4] This discrepancy is observable but not that extremely large as to totally refute the simpler GVA growth decomposition.

The difference between the contribution of labor factor services and the contribution of its resource (hours worked) is, according to the KLEMS methodology, the quality of labor, otherwise labor composition. Although it is theoretically possible to divide the contribution of capital services similarly into the contribution of capital quality and the contribution of its resource (stock), in the adopted practice of KLEMS growth accounts the capital services are divided differently, i.e. by capital type aggregates – into the contributions of ICT capital services and of non-ICT capital services. Formula (2) therefore develops into the formula:

$$\Delta lnY_{jt} = \Delta lnA_{jt} + \overline{\alpha_{Jt}}\Delta ln\left(K_{ITjt} + K_{NITjt}\right) + \overline{\beta_{Jt}}\left(\Delta lnLC_{jt} + \Delta lnH_{jt}\right) \quad (3)$$

where K_{IT} stands for ICT capital services, K_{NIT} – non-ICT capital services, LC – labor quality (otherwise called *labor composition*), H – hours worked. As it can be seen, the contribution of capital services K_{jt} from formula (2) is differently divided than the contribution of labor services L_{jt}, as there is a logarithmic expression $\overline{\alpha_{Jt}}\Delta ln$ before the parenthesis in addition to the weight of the factor, while for the labour factor there is only the weight β_{jt} before the parenthesis. Hence, equation (3) can be further transformed into:

$$\Delta lnY_{jt} = \Delta lnA_{jt} + \overline{\alpha_{ITJt}}\Delta ln\left(K_{ITjt}\right) + \overline{\alpha_{NITJt}}\Delta ln\left(K_{NITjt}\right) + \overline{\beta_{Jt}}\left(\Delta lnLC_{jt}\right) + \overline{\beta_{Jt}}\left(\Delta lnH_{jt}\right) \quad (4)$$

in which the expressions in brackets are separated. The difference in the way the capital factor has been split up is evident from the fact that the weights $\overline{\alpha_{ITJt}}$ and α_{NITjt} differ, while the weights for the components of the labour factor are identical. Thus, the capital factor has been separated into separate sub-factors, while the labour factor has only been separated into its different aspects (labour quality and labour stock).

The quality of labour is determined by the level of its hourly remuneration (it is assumed that markets function perfectly or at least correctly and that the hourly remuneration reflects the value of labour to the economy) - it is usually related to the level of education and experience (age), so according to this differentiation this quality of labour is calculated. The calculation of the quality of capital would also be related to its level of remuneration according to its types but in this case, we have the special situation that the high level of remuneration of capital is directly due to its short lifespan. If capital is short-life then the return on capital must be rapid for such capital to be of use in the economy, so the remuneration of short-life capital is high in relation to its stock value. The opposite is true for long-life capital – here a low remuneration of capital relative to its stock value is possible, as there is a long period of return on capital.

Hence, there arises the 'temptation', or just the possibility, to stimulate an increase in the application of short-life capital at the expense of long-life capital in order to accelerate economic growth on an ad hoc basis. Nevertheless, the American growth resurgence (according to Jorgenson, Ho, Stiroh (2005)) is based on a similar phenomenon, and happened not necessarily on purpose.

In the KLEMS growth accounts it was considered that there is no need to divide the service input of capital into the input of its quality and the input of its stock, since, in general, the capital with particularly high 'quality' in this sense is precisely ICT capital, while the remaining capital is capital with a rather more standard (albeit differentiated) 'quality'. While an increase in the quality of labour can and should be stimulated through an increase in the level of education, which is not controversial, in mathematical terms the same 'quality' of capital is controversial, as it may induce the above-mentioned behaviour leading to negligence in the development of infrastructure – i.e. capital of low 'quality' in the light of the definition of this term adopted here. For infrastructure capital is capital with a generally very long life and a very long period of return on capital[5].

Notwithstanding these considerations, the fact that the analysis of the contribution of capital services is carried out in the KLEMS productivity account somewhat differently from the analysis of the contribution of labour services is a fortunate circumstance for the issue at hand, since in formula (4) it is sufficient to separate the contribution of non-ICT capital services K_{NITjt} to GVA growth into the contribution of infrastructure capital services K_{INFjt} and the contribution of other capital services K_{Ojt}[6]:

$$\Delta lnY_{jt} = \Delta lnA_{jt} + \overline{\alpha_{ITjt}}\Delta ln\left(K_{ITjt}\right) + \overline{\alpha_{Ojt}}\Delta ln\left(K_{Ojt}\right) + \overline{\alpha_{INFjt}}\Delta ln\left(K_{INFjt}\right) + \overline{\beta_{jt}}\left(\Delta lnL_{jt}\right) \quad (5)$$

In formula (5), the contributions of labour services have been combined back as in formula (2) so as not to complicate our considerations beyond their essence. The contribution of capital services K_{jt}, on the other hand, was finally separated into the contribution of ICT capital K_{ITjt} with a generally shorter life-span, the contribution of other capital K_{Ojt} with a generally medium life-span and the contribution of infrastructure capital K_{INFjt} with a generally longer life-span. Now we need to solve the problem of extracting the relevant data.

[5] Such views are sometimes advanced by researchers, See: Hirschman, 1964.
[6] According to author's knowledge the only attempt to extract infrastructure capital within growth accounting has been performed by Mas (2009).

3. Extraction of ICT Capital and of Infrastructure Capital

The above positioning of infrastructure capital in the KLEMS growth accounts effectively solves the problem posed on the side of economic growth accounting methodology, as only general assumptions are sought here. However, the issue of obtaining appropriate data for equation (5) remains a problem. By analogy, we will first refer to the separation of ICT capital in the KLEMS growth accounts for the Polish economy, which has already been implemented by Statistics Poland.

The statistical data in the Polish National Accounts do not distinguish certain types of capital. Types *computer hardware* and *telecommunications equipment* are not extracted from the category *other machinery and equipment*, and type *computer software* is not extracted from the category *intangible assets*. These three types of capital not extracted under Polish conditions are aggregated in the internationally practiced (e.g., on the EU KLEMS website) KLEMS growth accounts into one super-category of ICT capital, and the remaining types of capital into one super-category of non-ICT capital using the Törnqvist quantity index. From this also follows the methodologically justified necessity to separate ICT capital in order to be consistent with the way accounts are performed for countries present on the EU KLEMS platform, to which the Polish KLEMS growth accounting results are most often compared (regardless of the fact that the importance of ICT capital for the Polish and many non-Polish economies is small).

Referring to infrastructure capital type, it can be noted that it is not separated from category *other structures and buildings*. Theoretically, an attempt could therefore be made to extract infrastructure capital in a manner analogous to the already performed extraction of ICT capital. At the same time, as infrastructure constitutes the 'lion's share' of category *other structures and buildings*, this category can be used as a first approximation in the analyses without separating 'pure' infrastructure capital from it, which would enable the accounts to be performed outright. This simplification exercise is not possible for the ICT capital, which is not the 'lion's share' of the categories from which it has been extracted, but as we will show further at this stage it is not only possible but necessary for the infrastructure capital.

The adopted operation was therefore to separate these three types of ICT capital before aggregating them into a common ICT capital category using the Törnqvist quantity index. This was done on the basis of the Supply and Use Tables (SUT), i.e. on the basis of the figures in the investment outlays column for each of the above-mentioned three types of ICT capital (in the SUT Tables up to 2007 in the NACE 1.1 system these are groups 296, 316 and 430, while in the NACE 2 system these are groups 250, 252 and 489 respectively) – see further the details of this already applied technique described in Kotlewski (2021). A similar approach could be followed for the extraction of infrastructure capital, selecting the relevant items in the investment outlays column, and using the appropriate structures to distribute their values. In the NACE 1.1 system, these would be groups: 384, 385, 387 and 389 for outlays and the structure of NACE 1.1 divisions numbered 38, 39, 40 and 42. In the NACE 2 system, on the other hand, these would be groups 444-450, i.e. the entire division numbered 42 for outlays and the structure of NACE 2 divisions numbered 49-53. In doing so, it should be noted that the representation of infrastructure capital is more accurate in the NACE 2 system.

However, the effectiveness of this method may not be much better than the simplifying assumption mentioned above, based on the observation that infrastructure capital makes up the 'lion's share' of category *other structures and buildings*, not least because this would be (especially for pre-2008 data in the NACE 1.1 system) a 'narrowly understood' infrastructure capital (i.e. without some components of it). Thus, an undertaking that was necessary in the case of ICT capital (thus 'narrowly understood' including only the most essential components such as computers, software, etc. without the rest of the equipment, including peripheral equipment), because otherwise it could not be extracted at all, may be not so necessary in the case of infrastructure capital. Furthermore, the following problem, also explained here by comparison with the performed ICT capital extraction, is presently unsolvable without going outside the SNA system.

When separating out ICT capital, the assumption was made that, since this capital is ageing rapidly, there is no need, given their very low value, to separate out the older parts of this capital from the existing broader aggregates. In order to determine the current state of fixed assets in this respect, it was considered unnecessary to consider the initial ICT capital stock from just few years before 2005 (the starting year of Polish KLEMS accounts). The total value of this initial ICT capital stock, due to its high rates of depreciation, becomes much less than 10% of its initial value after just a few years – the addition of ongoing investments and depreciation of ICT capital means that after just a few years the resulting total includes almost all ICT capital stock (albeit narrowly defined ICT capital, as only this can be effectively separated based on the SUT tables).

Unfortunately, this operation cannot be effectively conducted for infrastructural capital, as it ages very slowly. When determining the initial fixed capital stock for this capital, the time horizon for this operation would have to be extended many times – meanwhile, SUT tables for the period before 2000 are not drawn up for the Polish economy (and no initiatives to draw them up are advanced, because of unsurmountable difficulties)). Thus, the perpetual inventory method (PIM) cannot, based on data from the SUT tables, be effectively performed under Polish conditions for infrastructure capital. The other two methods of estimating the value of capital, i.e., observing the value of market transactions or the capital insurance market, also cannot be used effectively in this case, as infrastructure capital is predominantly owned by the state and is not normally traded on the market.

In this situation, it remains to check approximately how large the above-mentioned 'lion's share' can be attributed to infrastructure stricto sensu within the above-mentioned category *other structures and buildings*. This can be roughly estimated by observing the SUT tables, but only in the NACE 2 system, i.e. from 2008 onwards. It turns out that this infrastructure capital stricto sensu is rather by far the predominant part of this category. Thus, if we devise for the needs of the present analysis the category of a 'broadly understood infrastructure capital' then the above-mentioned category *other structures and buildings* can be a good approximation of it. This 'broadly understood infrastructure capital' includes all tangible capital assets that are not dwellings and are not movable capital assets. When only increments are considered in decomposition formulae, then this approach becomes even more sensible.

4. EMPIRICAL FINDINGS

In order to limit the issue at hand to its essence we will transform equation (5) into:

$$\Delta lnY_{jt} = \overline{\alpha_{INFjt}}\Delta ln(K_{INFjt}) + \sum W_{jt} \tag{3}$$

where all contributions other that infrastructure capital (broadly understood as above explained) have been added up to $\sum W_{jt}$. Thus we can perform the calculations and present the data as in Table 1.

However, one more issue should be discussed here before presenting the data. Considering 'broadly understood infrastructural capital' in this way seams appropriate at the aggregate level of the economy but remains very controversial at the industry level. At this lower aggregation level the share of infrastructural capital stricto sensu in the category *other structures and buildings* may be very different depending on the industry considered, so as to undermine entirely the validity of this analysis, not to mention that distributing pure infrastructure components such roads, railways, etc. between industries is a theoretical issue. However, this is not the case if the disaggregation is made spatially (in the geographical sense) not vertically (by industry). Therefore, the present analysis seams particularly valuable for interregional comparisons, also between the provinces of a given country, i.e., Polish voivodships in this case. Data, therefore, will be presented only at aggregated levels for total Polish economy and the 16 Polish voivodships.

Table 1.

Decomposition of GVA growth into infrastructure contribution and other contributions for total Polish economy and by Polish voivodship

		Years															
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Code	Decomposition	in % for GVA and in pp for contributions															
00	GVA growth	3.317	5.929	6.873	3.884	3.071	3.706	4.624	1.368	1.193	3.312	3.997	3.063	4.573	5.165	4.510	-2.609
	Other contributions	3.000	5.949	5.323	3.461	2.159	1.934	2.640	0.413	-0.029	1.820	3.334	2.046	3.898	4.371	3.546	-3.473
	Infrastructure contribution	0.317	-0.020	1.550	0.423	0.911	1.772	1.984	0.955	1.221	1.492	0.663	1.017	0.675	0.794	0.964	0.865
02	GVA growth	5.385	9.588	8.898	3.076	3.970	7.307	5.326	1.258	0.390	3.177	3.940	2.641	4.152	4.383	4.410	-3.260
	Other contributions	4.896	9.677	7.132	2.537	3.194	5.508	3.535	-0.025	-1.077	1.763	3.444	1.413	3.737	4.108	3.374	-4.509
	Infrastructure contribution	0.489	-0.089	1.766	0.539	0.776	1.799	1.792	1.283	1.467	1.414	0.496	1.229	0.415	0.275	1.037	1.249
04	GVA growth	1.776	6.301	6.248	4.249	1.613	3.250	2.994	0.612	1.710	2.658	3.674	2.722	3.693	5.355	2.244	-2.389
	Other contributions	2.274	6.191	5.325	3.974	0.666	1.747	0.696	0.296	0.362	1.527	2.303	2.361	3.017	4.606	1.909	-3.060
	Infrastructure contribution	-0.498	0.109	0.923	0.275	0.946	1.503	2.298	0.315	1.348	1.131	1.371	0.361	0.676	0.748	0.334	0.670
06	GVA growth	1.795	4.063	7.117	5.230	0.227	3.284	4.262	2.020	1.839	1.981	1.900	2.849	3.485	2.404	4.540	-1.716
	Other contributions	1.732	4.110	6.747	5.170	0.135	2.519	3.443	1.038	1.254	0.922	1.372	2.439	3.159	2.293	3.930	-2.121
	Infrastructure contribution	0.063	-0.047	0.371	0.059	0.092	0.765	0.819	0.982	0.585	1.059	0.529	0.410	0.326	0.111	0.611	0.405
08	GVA growth	5.557	5.538	5.907	1.143	1.533	3.370	2.167	1.556	1.781	4.400	2.721	2.971	2.295	4.374	2.979	-3.067
	Other contributions	4.903	5.305	3.701	1.567	0.231	1.703	1.026	-1.264	-1.759	3.635	1.510	1.751	1.302	3.531	2.558	-3.167
	Infrastructure contribution	0.653	0.233	2.206	-0.424	1.302	1.667	1.142	2.820	3.540	0.765	1.211	1.220	0.993	0.843	0.421	0.100
10	GVA growth	3.394	5.470	6.397	4.638	1.417	4.345	4.467	1.339	0.848	3.348	2.903	2.660	3.826	4.990	5.208	-2.580
	Other contributions	2.866	5.424	5.743	4.259	0.791	4.279	1.593	0.303	-0.281	0.851	2.518	1.798	3.195	4.658	4.450	-2.988
	Infrastructure contribution	0.528	0.045	0.654	0.379	0.626	0.066	2.874	1.037	1.129	2.497	0.385	0.862	0.631	0.331	0.759	0.408
12	GVA growth	3.451	8.167	5.752	4.611	2.582	2.946	6.365	1.256	1.491	4.132	5.494	3.966	6.072	5.962	4.194	-2.471
	Other contributions	3.117	8.304	4.716	4.519	1.553	1.562	4.876	0.315	0.373	3.381	4.668	2.915	5.784	5.604	3.750	-2.843
	Infrastructure contribution	0.334	-0.137	1.036	0.093	1.029	1.384	1.489	0.940	1.117	0.751	0.827	1.051	0.288	0.358	0.445	0.372
14	GVA growth	5.342	6.550	7.577	2.708	4.824	5.054	5.011	2.304	2.193	3.720	4.513	3.790	5.581	6.223	6.085	-2.146
	Other contributions	5.026	6.837	5.904	1.927	3.732	2.945	2.825	1.753	0.471	2.071	4.077	2.052	4.471	5.381	4.965	-3.223
	Infrastructure contribution	0.316	-0.287	1.674	0.781	1.092	2.109	2.186	0.551	1.722	1.649	0.436	1.738	1.110	0.842	1.120	1.077
16	GVA growth	1.181	3.298	9.280	5.813	-1.721	1.582	4.397	-0.415	-0.058	3.719	2.022	1.018	4.305	4.884	3.610	-2.386
	Other contributions	0.600	3.488	7.502	7.010	-2.287	-0.690	4.401	-0.309	-0.950	3.035	1.649	0.677	3.548	4.387	0.282	-2.745
	Infrastructure contribution	0.581	-0.190	1.778	-1.197	0.566	2.272	-0.004	-0.106	0.891	0.685	0.373	0.341	0.757	0.497	3.328	0.359
18	GVA growth	2.679	5.478	5.830	6.123	2.169	3.044	5.523	0.903	2.559	3.137	3.493	2.334	3.989	6.134	4.500	-2.823
	Other contributions	2.566	5.333	4.662	5.881	1.545	1.815	4.581	0.834	1.361	2.198	3.122	1.731	3.674	5.618	4.279	-3.444
	Infrastructure contribution	0.113	0.144	1.168	0.242	0.624	1.228	0.942	0.069	1.198	0.939	0.371	0.604	0.315	0.516	0.221	0.621
20	GVA growth	3.484	3.726	7.729	2.336	4.745	2.867	3.668	-0.982	2.334	3.052	1.724	1.883	4.661	4.426	4.547	-1.526
	Other contributions	3.371	3.654	7.187	2.144	4.423	1.950	2.170	-1.268	1.063	1.604	0.883	1.528	4.311	3.596	3.882	-2.229
	Infrastructure contribution	0.113	0.072	0.542	0.191	0.323	0.917	1.498	0.286	1.271	1.448	0.841	0.355	0.350	0.830	0.665	0.704
22	GVA growth	4.262	6.370	7.250	1.270	6.445	2.738	5.357	3.471	0.057	2.411	4.961	3.975	5.146	6.193	5.295	-2.776
	Other contributions	4.113	6.175	5.650	0.943	5.642	0.952	3.622	3.342	-2.131	0.722	4.328	2.955	4.591	5.248	4.872	-3.894
	Infrastructure contribution	0.149	0.195	1.600	0.327	0.803	1.786	1.735	0.129	2.189	1.688	0.633	1.020	0.555	0.945	0.423	1.118
24	GVA growth	-0.362	3.569	6.312	4.098	1.132	3.029	4.141	0.033	-0.365	2.510	4.075	2.651	3.793	4.787	2.856	-3.762
	Other contributions	-0.493	3.396	4.884	3.801	0.365	1.212	2.234	-0.107	-2.603	0.810	3.415	1.513	3.116	3.519	2.279	-5.227
	Infrastructure contribution	0.132	0.173	1.428	0.297	0.767	1.817	1.907	0.140	2.238	1.700	0.660	1.138	0.678	1.267	0.577	1.464
26	GVA growth	-0.871	7.522	7.910	7.312	-0.723	1.780	3.057	-0.667	-2.056	3.258	1.828	1.416	3.778	5.507	2.326	-2.025
	Other contributions	-0.958	7.414	6.949	7.106	-1.259	0.454	1.699	-0.763	-3.745	1.910	1.313	0.552	3.274	4.537	1.870	-3.198
	Infrastructure contribution	0.086	0.108	0.961	0.207	0.536	1.327	1.358	0.097	1.689	1.348	0.515	0.864	0.504	0.969	0.456	1.172
28	GVA growth	3.120	5.026	5.274	4.190	3.706	2.958	3.373	0.467	0.711	3.442	2.593	2.616	2.182	3.180	3.179	-2.030
	Other contributions	3.000	4.877	4.039	3.932	3.032	1.387	1.821	0.348	-1.364	1.799	1.971	1.561	1.556	2.047	2.662	-3.368
	Infrastructure contribution	0.120	0.149	1.235	0.258	0.674	1.571	1.552	0.119	2.075	1.643	0.622	1.056	0.626	1.133	0.517	1.338
30	GVA growth	4.484	5.307	6.582	4.923	5.756	1.753	4.853	2.035	2.575	3.785	5.097	3.588	5.080	4.428	5.071	-2.644
	Other contributions	4.333	5.117	5.051	4.610	4.978	-0.047	3.082	1.909	0.470	2.123	4.477	2.582	4.508	3.421	4.628	-3.787
	Infrastructure contribution	0.150	0.191	1.531	0.313	0.777	1.800	1.771	0.126	2.105	1.662	0.620	1.006	0.572	1.006	0.443	1.143
32	GVA growth	3.544	4.918	4.476	4.742	0.719	2.676	3.047	1.236	0.074	3.890	3.811	1.619	4.159	4.429	3.569	-2.451
	Other contributions	3.405	4.738	2.993	4.433	-0.068	0.871	1.218	1.101	-2.210	2.048	3.087	0.401	3.471	3.217	3.004	-3.925
	Infrastructure contribution	0.139	0.180	1.483	0.309	0.787	1.806	1.830	0.136	2.284	1.841	0.724	1.218	0.689	1.212	0.566	1.474

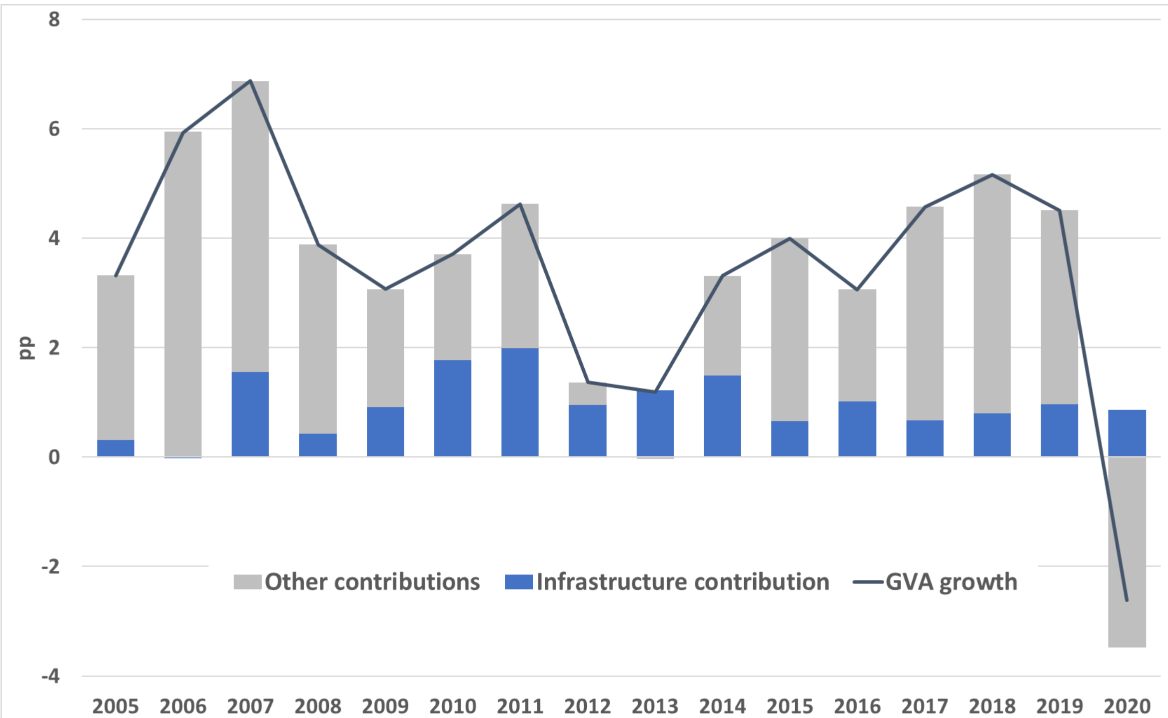
Note: Data in NACE Rev. 2 classification. Code numbers in the left-hand-side column are code numbers used in Polish statistics: 00 – for total Polish economy aggregate, 02-32 – for the 16 Polish voivodships.

Source: own elaboration based on Statistics Poland data.

As can be seen on Figure 1. it may be noted at the outset that the role of infrastructure in economic growth was greater in 2007, followed by a slump in connection with the global financial crisis of 2007-2009. The role of infrastructure was even more important in the years preceding the Euro 2012 soccer event. For the purposes of this sporting event, a number of highways and other roads were built and some other elements of infrastructure (e.g. railways) were modernised – 2010-2011 was in fact the period of the most intensive development of infrastructure in the entire adopted period of analysis (2005-2020). This investment acceleration was performed in a country very needy in this respect, and the Euro 2012 sporting event provided a good socio-political momentum for it. However, infrastructure captured in this way also includes facilities associated with infrastructure, such as hotels and other facilities. After 2012, the contribution of infrastructure to economic growth is already smaller and fluctuates in a two or three-year cycle, which may be related to the two or three-year construction preparation cycles. It can be seen also that during the Covid-19 related crisis infrastructural investments were continued, as only a slight drop against the previous year can be observed. This picture of the data seems confirming the validity of the method for the scope of the analysis.

Figure 1.

Decomposition of GVA growth into infrastructure contribution and other contributions for total Polish economy

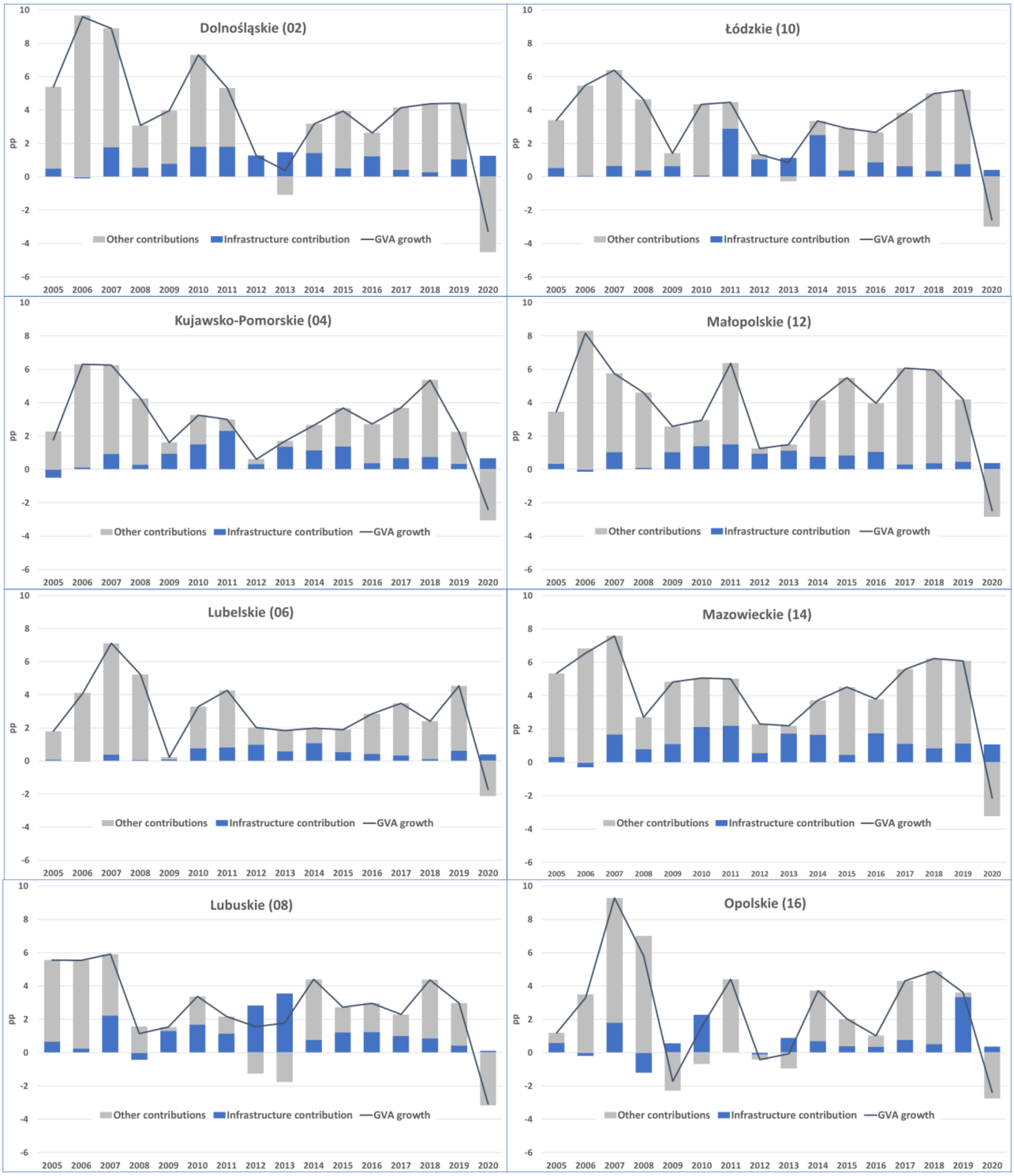


Source: as for table 1.

This analysis can very much deepened, as far as spatial distribution of infrastructural investment activity is considered, if we refer to Figure 2. where the same kind of data were presented for the 16 Polish voivodships.

Figure 2.

Decomposition of GVA growth into infrastructure contribution and other contributions for the 16 Polish voivodships



Note: Data in NACE Rev. 2 classification. Code numbers by the names of voivodships are code numbers used in Polish statistics: 00 – for total Polish economy aggregate, 02-32 – for the 16 Polish voivodships.

Source: as for table 1.

Figure 2. (cont.)

Decomposition of GVA growth into infrastructure contribution and other contributions for the 16 Polish voivodships

Note: Data in NACE Rev. 2 classification. Code numbers by the names of voivodships are code numbers used in Polish statistics: 00 – for total Polish economy aggregate, 02-32 – for the 16 Polish voivodships.

Source: as for table 1.

5. Final Discussion and Conclusion

One more issue needs to be discussed. The infrastructure capital has a very long lifespan. It delivers its value (i.e., services) to the economy over a very long period, and the flow of these services is not directly captured in the KLEMS growth accounting on a year-to-year basis. On the other hand, capital investments in infrastructure lead to conspicuous demand stimulus and this demand stimulus is not a supply side economic theory story but rather a demand side economic theory story.

However, we can try to overcome this inconsistency by referring to net present value (NPV) capital concept[7]. In NPV concept capital stock value is equal to the sum of all future revenues from that capital discounted with a percentage rate. Similarly, it is so with an investment. The idea behind NPV is to project all of the future cash inflows and outflows associated with an investment, discount all those future cash flows to the present day, and then add them together to establish the value of an investment. Here, instead of future cash flows we take general, largely invisible infrastructure future benefits delivered to the economy. In a situation of generally sensible infrastructure investments decision making (we average their accuracy, as far as future benefits are considered) the values of those investment outlays, particularly when aggregated, should be closely related to those future benefits. Therefore, the economy is presently stimulated by infrastructure investments in proportion to future benefits from them (spread and discounted over years).

Those future benefits, on the other hand, are counterbalanced by debt interest rates to be repaid (if capital is not lent, then still it has its opportunity cost). Since all rates are converging on the market (as prices do), this counterbalancing should be exhausting the mentioned benefits. Therefore, finally the present investment economic stimulus remains as the only one impacting the economy. Thus, supply side theory standing behind KLEMS growth accounting merges with demand side theory here. If we take, therefore, large aggregates and not individual cases that may individually diverge from average economic behavior and fortune, then KLEMS type growth accounting should happen to be an effective way of assessing the impact of infrastructure capital on economic growth. The presented results confirm that stand.

[7] Author's own elaboration.

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