

Assessing the contribution of infrastructure to economic growth for total Polish economy and by Polish voivodship in light of KLEMS growth accounting

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Abstract

The aim of this paper is to demonstrate the possibility of assessing the role of infrastructure in economic growth with the use of the KLEMS growth accounting (otherwise called the KLEMS productivity accounting). A theoretical justification is provided for the validity of the adopted procedure – it was found that in light of Jorgenson’s rationale (between others) the KLEMS accounting is quiet fit for this exercise, and it accords with some developments of the mainstream economic theory. Then the methodology and issues related to the extraction of infrastructure data are presented. Finally, a demonstration is provided with some interpretation based on Statistics Poland’s data used and processed in the KLEMS productivity accounting for the Polish economy. It was found that when the proposed methodology is applied to spatial aggregations (i.e. countries and provinces) rather than industries then quite sensible data can be obtained even before the envisaged SNA reform.

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

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 to impact the future demand for infrastructure. Observations and analyses of this issue are usually conducted ex post, considering successful and sufficiently long periods of relatively

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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 into 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 – this is the gap in the literature that is to be addressed in the present paper.

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 widely applied KLEMS growth accounting, use the so-called endogenous approach². The weights associated with capital, which are assumed to be its relative remunerations at the level of individual aggregations, are calculated residually by subtracting the compensation figures for labor from the GVA at the level of those aggregations³.

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, the problem emerges of 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)⁴ gross operating surpluses presented by NA are underestimated by up to 15% and GVA values by around 5-6% relative to the situation in which an exogenous approach of taking data from the market rather than calculating them residually would have been used – taking the relevant data from the market on the rate of return on capital for the relevant aggregates, however, presents insurmountable difficulties.

² This is not to be confused with the use of the term ‘endogenous’ for the theory of endogenous growth of Barro and Sala-i-Martin (2004), Romer (1994) or Lucas (1988). We use this term in Mas (2009) sense, who also directly addressed the issue of the role of infrastructure in economic growth for the Spanish economy.

³ One problem in the System of National Accounts (SNA) is that the return to self-employed labor is not differentiated from the return to self-employed capital, therefore gross operating surplus could be overstated. However, in the KLEMS productivity accounting performed for Poland the shares of self-employed labor have been assessed and labor values adjusted accordingly, and the residual values for self-employed capital added to main capital values (see: Kotlewski 2021, p. 67).

⁴ The literature overview shows that the mentioned Mas’ work is the only recent attempt to solve this issue on general theoretic platform.

Fortunately, these differences when only increments and contributions to increments are used become much less significant, according to Mas (2009). 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 the 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).

The paper starts in the next section with a discussion on the validity of using a growth accounting methodology such as the KLEMS framework for the issue at hand and on some related problems. Then, in the third section the KLEMS growth accounting methodology is presented with the necessary alterations. In the following section the problem of extracting data for infrastructure capital is developed and compared to the already solved problem of ICT capital data extraction as done with the Statistics Poland KLEMS framework for the Polish economy⁵ – here, we find that this problem of data extraction can be better solved for countries with much longer time series of data than that available for the Polish economy. However, in the final section estimates for the aggregate Polish economy and for Polish voivodeships are presented, which demonstrate the fairly good approximate effectiveness of this approach and motivate further work on a possible reform of the SNA system (per Mas, 2009) so that the input data meet the theoretical requirements of economic growth accounting. The paper ends with a conclusion section.

2. Feasibility and Outcomes of Using KLEMS Growth Accounting

One issue needs to be discussed first – it is why there is a gap in the literature about infrastructure. The objective of this section is to explain the difficult economic context for studying the role of infrastructure in economic growth, and why the use of the KLEMS accounting is relevant to overcoming some of these difficulties (only to some extent presently, before the possible future reform of the SNA). Grasping infrastructure role in economic growth remains difficult also because of some theoretical controversies discussed here.

⁵ <https://stat.gov.pl/en/experimental-statistics/klems-economic-productivity-accounts/methodology-of-decomposition-in-klems-productivity-accounts-for-the-polish-economy,2,2.html>.

The infrastructure capital has a very long lifespan⁶. 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 by analogy to the net present value (NPV) capital concept. In the NPV concept capital stock value is supposed to be equal to the sum of present and all future revenues from that capital discounted with a percentage rate (so it is about wealth stocks). Similarly, it can be argued that 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 with the current ones to establish the value of an investment. Here, by analogy⁷, instead of accountable future cash flows we take general, largely invisible infrastructure future benefits (and costs) delivered to the economy, although not always clearly reported. In a situation of a 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).

The fact that these future benefits are not the ones that are clearly accounted for allows us to include all potential spillovers (that are ignored when regular accounting is carried out as for usual private investments). Some may argue that investment in infrastructure may not follow the economic logic that lets us equate the marginal cost of an asset to its marginal product, as the state is not typically seen as cost minimizing (let alone profit maximizing). But this argument is only true at individual investment level – here, the state is able to cover huge cost overruns. When we consider aggregate investment in infrastructure (and historical periods) the state should also seek to balance them (if it wishes not to encounter insurmountable issues later on). As we are seeking a general (but sound) assessment here, this issue should not contradict the use of a growth accounting methodology such as KLEMS.

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 cost⁸, therefore this process should be treated together with the remaining opportunity cost). Since all rates are converging in the market (as prices do), this counterbalancing should exhaust the

⁶ Generally, despite huge differences between the different strands of it as Fraumeni (2022) finds it.

⁷ Author's own elaboration about it, although perhaps already developed by someone (?).

⁸ We can say here that debt is nothing else than the 'revealed' part of the opportunity cost.

above-mentioned benefits (in equilibrium). Therefore, finally the present investment economic stimulus remains the only one impacting the economy. Thus, supply side theory standing behind KLEMS growth accounting merges with demand side theory here (we only need to acknowledge the problem of the difference between investments and capital stock increase). 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 results presented further on seem to confirm that stand⁹.

This situation generates ambivalent behavior on the part of economic decision-makers not only at the microeconomic level (which is part of the inherent nature of each individual investment decision), but also at the aggregate, i.e. macroeconomic and mesoeconomic levels. The fact that infrastructure investments may be unprofitable for the economy (in the above-mentioned opportunity cost terms), for example, for up to 10-20 years, but at the same time may become profitable, for example, over a period of much longer than 20 years, causes hesitation of decision-makers when making strategic investment decisions. Thus, considering both the above-mentioned demand and supply effects, the following two modes of action happen to be adopted by strategic decision makers.

One is the attitude of forcibly investing “in anything” to stimulate demand. With this approach, it can be assumed that with rapid growth of the economy as a whole (as in China, for example, or as in Japan earlier), almost any infrastructure investment, even a not-quite-hit one, will eventually pay off in the very long term – rapid economic growth will contribute so much to the demand for infrastructure services that even wrong investment decisions will often not manifest their negative impact on economic activity in the long run.

Analysis by Ansar *et al.* (2016) shows that infrastructure investment in China is extremely often characterized by cost overruns, execution time overruns (although in this matter China is no worse than developed Western countries) and failure to meet expected benefits. Similarly to the global trend, cost overruns reach 30.6% in China (Ansar *et al.*, 2016) – the costs of infrastructure investments are therefore systematically underestimated at the stage of their planning and acceptance. The timeliness of infrastructure investments is relatively better, as according to the above-mentioned authors, in Western democracies, decision-makers tend to promise too much. On the other hand, for example, observation of traffic volume in China indicates the frequent phenomenon of weak traffic on most roads, with heavy congestion on a small number of them. The aforementioned researchers conclude that China's model of forcible investment, fueled by unwarranted optimism, should not be emulated in other

⁹ This view can be extended to other investment, not only infrastructural.

countries as it leads to a buildup of debt throughout the economy, debt that is not covered by the expected benefits. According to these researchers, unless China changes its policies toward a smaller stream but higher quality of infrastructure investment, economic problems, mainly related to financial inefficiency, are in store¹⁰.

At the same time, these researchers point out (although this approach is criticized by them) that, in light of neo-Keynesian economic thought, cost overruns and insufficient benefits from performed investments are not a serious problem, since excess spending only increases the power of the (Keynesian) investment multiplier. Other researchers (Du, Zhang and Han, 2022) also point out that the so-called new infrastructure investments, related to information technology (telecommunications infrastructure), increase their overall share among infrastructure investments, thus having a positive impact on the quality of economic growth (which includes, in addition to GDP growth, improvements in living standards and other qualitative socio-economic aspects, among other things). As a result, the change in the structure of infrastructure investment in favor of IT-related investment due to the effect associated with ICT capital (this issue is also discussed further below) may overshadow the negative effects on economic growth of the earlier more “reckless” infrastructure investment policy. More generally, it can be argued that China's economic growth may nevertheless prove to be sustainable, with the result that the initial intuitive statement of a fairly likely return on investment over the very long term may come true.

The second mode of action is to refrain from “excessive” investment in infrastructure. With this approach, funds can be saved in the economy at the aggregate level for other investments with shorter payback periods (as in the U.S. – more on this below) and periodically accelerate economic growth in this way. The opportunity cost principle perceived in the shorter term is behind this approach, but in the very long term, this approach, if not changed, can lead to economic problems and eventually stifle economic growth due to infrastructure scarcity. This does not necessarily mean that there is a long-term misguided policy, since, given the very long term, it is possible to evolutionarily change the policy by adapting it to changed circumstances. But it does imply a growing need over time to change the development paradigm to one that is more amenable to infrastructure investment.

The example of the U.S. economy is telling here. In 1956, thanks to a decision made by President D. Eisenhower, a period of intensive development of road infrastructure (including the Interstate Highway System) began in this country. It is believed that this decision was a source of growth stimulation for the economy in the short term (demand-side economics), and it became the basis for long-term prosperity in this country thanks to the increase in productivity in the long term (supply-side economics). However, infrastructure development was later neglected, which,

¹⁰ We are not going to dwell here to much on the issue whether this is actually happening in this country now.

according to Aschauer (1989) led to a slowdown in the productivity growth of the U.S. economy in the 1970s and 1980s¹¹.

A new economic policy referring to neoclassical thought subdued the importance of public spending on infrastructure. This was based, among other things, on the alleged crowding out effect, which is that public investment pushes out private investment from the market because it takes resources away from the private sector (direct crowding out) and because, through taxation, it takes away the private sector's incentive to expand economic activity and, through an increase in public debt, deprives the private sector of financing for its investments, not to mention the possible inflationary effects of increased public activity in the economy (these last three phenomena are termed indirect crowding out). According to Aschauer, a similar phenomenon (of neglecting infrastructure development) has been observed to some extent in other G7 countries, but it has been less intense, and, therefore, in these years (1970s and 1980s), among other reasons, Western Europe was generally catching up with the U.S., i.e. the gap in the level of economic development on both sides of the Atlantic has narrowed (according to this author of course).

However, the U.S. experienced an IT revolution in the 1990s, parallel in time to a significant acceleration of economic growth. According to Jorgenson, Ho and Stiroh (2005), the reason for this sudden increase in the productivity of the U.S. economy and consequently faster GDP growth is to be found in the expansion of ICT capital, i.e. short-lived capital that gives its value back to the economy faster than long-lived capital. Although not at the same time, but in a consequential way, there has been a shift in the structure of investment in the U.S. economy in favor of faster growth-boosting investments. After the earlier withdrawal from “excessive” investment in infrastructure, there was increased investment in capital related to information technology – the opportunity cost principle perceived in the short term clearly favored such an investment policy. This phenomenon was not replicated to such an extent on the other side of the Atlantic, hence the reiteration of the U.S. becoming far ahead of Western Europe in the level of economic development during the 1990s. In the first decade of the 21st century, however, this economic effect wore off, but in the meantime new information technologies were applied to the rapid trading of financial instruments, which somewhat prolonged the period of good growth until the financial crisis of 2007-2009. Nowadays, the problem of inadequate infrastructure, which is relatively outdated and insufficient in the U.S., is returning as one of the main topics of discussion among economic researchers (e.g. the mentioned Fraumeni's works). From the point of view of the present paper,

¹¹ During the 1980s and particularly the 1990s we can observe a recovery of some infrastructural investments. As Fraumeni (2022) points out, such was the case with highways and streets but their benefits were in this case subdued by increased costs. It must be pointed out here that Aschauer's analyses are now considered to overstate the role of infrastructure. It is believed in the present paper that the growth accounting methodology can restore the appropriate balance.

the Jorgenson, Ho and Stiroh (2005) interpretation of this economic evolution is strongly supporting our stand to use the KLEMS growth accounting framework to study the role of infrastructure in economic growth.

From the conceptual standpoint we can divide attitudes towards infrastructural investments into two types. The 'reactive' attitude would be about observing the state of congestion and undertaking infrastructure investments with the sole purpose of relieving that congestion. Unloading congestion in communications and transportation produces effects similar to the effect of trade creation due to the reduction or abolition of customs duties between some countries. Thus, not only are there material benefits resulting from a decrease in the unit resultant gross transportation costs for existing transports and shipments but also benefits resulting from an increase in the transport flow with new transports and shipments that would not have been carried out at all without the above-mentioned infrastructure investments being undertaken. The results of these phenomena are the benefits to the economy described in the case of foreign exchange by the theory of international trade, which, with certain reservations, can also be applied to internal trade within a country. This attitude is most characteristic of the second of the above-mentioned modes of action, which is to refrain from "excessive" investment in infrastructure. To a lesser extent than in the case of the 'developmental' attitude described below, there is a trade diversion effect in this case, but it, too, is present and can be in some specific cases sufficiently intense to produce competition between regions in the pace of infrastructure development – even in this 'reactive' attitude, therefore, there can be competitive forcing of infrastructure investments between regions.

On the other hand, the 'developmental' attitude would be about putting one's faith in the effect of induced traffic created by infrastructure investments in relatively undeveloped areas. In this case, decongestion in congested old centers of economic activity can also be achieved, thanks to the effect similar to the effect of trade diversion known from trade theory. However, the trade creation effect is the most fundamental here, as the economic impact of new investments in infrastructure is multi-layered. Increased initial demand attracts new economic activity, not least because new infrastructure investment is usually accompanied by other new investments. Newly developed land as a result of a new infrastructure investment usually means the mobilization of new growth resources for the economy and usually has some comparative advantage over old economic centers. This 'developmental' attitude is more characteristic of the first of the above-mentioned modes of action.

In light of the above, a turn towards a balanced (sustainable) approach may be advised, in which a balance is sought between the various effects of infrastructure investment. The short-term effect of stimulating demand at the macroeconomic level

remains important, which, by constantly maintaining an adequate level of infrastructure investment, can also be continued in the long term. But the planning should also take sufficient account of the rather likely return on investment at the microeconomic level, inevitably in the very long term (even if only potential, under conditions of a fortunate and favorable course of historical events). In this approach, therefore, the preservation of solid microeconomic foundations of neoclassical provenance (in order to avoid future infrastructural benefits falling below the debts and opportunity costs mentioned above) becomes co-essential with the aforementioned demand stimulation (which is the unbalanced impact on economic growth). The end result should be an overall increase in the productivity of the economy as a result of infrastructure improvements that reduce the costs of existing operations and encourage the expansion of new activity, under conditions of a corresponding increase in demand for infrastructure services. A growth accounting procedure with an extracted contribution of infrastructure could be helpful in this, particularly for some countries with long detailed-data time series, also for infrastructure disaggregated components.

3. 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 to 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 the KLEMS growth accounting was formulated mainly by Jorgenson and associates (Jorgenson and Griliches, 1967; Jorgenson, Gollop and Fraumeni, 1987; Jorgenson, Ho and Stiroh, 2005)¹². 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)¹³, a well-known expert of the trade. The starting point, then, will be the Solow decomposition:

$$\frac{\Delta Y}{Y} = \alpha \frac{\Delta L}{L} + \beta \frac{\Delta K}{K} + \frac{\Delta A}{A} \quad (1)$$

¹² It is also worth seeing Jorgenson (1963 and 1989). The basic KLEMS methodology was well summarized in: Timmer et al. (2007) and O'Mahony and Timmer (2009).

¹³ There is also an econometric method developed by, e.g.: Akerberg, Caves and Frazer (2015); Levinsohn and Petrin (2003) and Olley and Pakes (1996). This econometric method is often considered to be more appropriate for decompositions at firm level.

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 α and β are elasticities, which 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)¹⁴. A is the *total factor productivity* (TFP). The contribution of TFP, i.e. $\Delta A/A$ is calculated residually by subtracting the other values in (1) – it is called as the *Solow 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 a technological progress. Presently, it is usually interpreted as a technological or organizational progress disembodied in labor or capital.

Because the Törnqvist procedure (quantity index) is used for aggregation, Formula (1) was replaced in the KLEMS growth accounting by its translog approximation:

$$\Delta \ln V_{jt} = \bar{\alpha}_{jt} \Delta \ln L_{jt} + \bar{\beta}_{jt} \Delta \ln K_{jt} + \Delta \ln A_{jt}^V, \quad (2)$$

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 $\bar{\alpha}_{jt} = (\alpha_{jt} + \alpha_{j(t-1)})/2$ and similarly for $\bar{\beta}_{jt}$ (however, β_{jt} is usually calculated residually (i.e. by subtraction of $\bar{\alpha}_{jt}$ from unity) in a similar way as for the Solow formulae). By definition, these shares are shares in the gross value added (GVA) here, and it is the growth rate of GVA (V_{jt}) that is present on the left-hand side of formula (2).

In addition to the above, the 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 the resources (stocks) of these factors in formula (2), 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 factor growths are weighted by their relative shares in total income before being added up to the total contribution of the factor (at the given aggregation, including industry aggregations j). Therefore, in the KLEMS growth accounts, residual productivity is referred to as *multifactor productivity* (MFP), which is a variant of TFP. Thanks to its translog shape formula (2) is strictly conformable with the original Cobb-Douglas production function¹⁵.

¹⁴ In the original work of Solow (1957), the symbol α refers to the capital factor and the symbol β refers to the labor factor.

¹⁵ However, in the instance when growths are high (much over 10%) the logarithm values become more discrepant with the classic relative growths from formula (1).

Formula (2) can be developed by introducing an additional variable, related to 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 rate (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 and GVA. Otherwise, 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 to a known ratio as mentioned above) because of the phenomenon of substitution between the production factors (labor and capital) and the intermediate inputs¹⁶. That is why the contribution of the *A* variable in (2) is presently rather considered as the industry capacity to capture the value. *Rather than technical change itself, the value-added based measure reflects an industry's capacity to translate technical change into income and into a contribution to final demand* (OECD, 2001, p. 27–28).

But the use of gross output growth rate decomposition is associated with data issues. Data insufficiency means that for most countries, for which the KLEMS growth accounting is performed, only the GVA growth rate decomposition according to formula (2) is being done¹⁷. Fortunately, it 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 the GVA growth rate decomposition as in (2) instead of gross output growth rate 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 a given country. Therefore, for the present study oriented towards regional comparisons the choice of the GVA decomposition in the framework of the KLEMS growth accounting seems to be well justified.

The difference between the contribution of labor factor services and the contribution of its resource (hours worked) is, according to the KLEMS methodology,

¹⁶ This discrepancy is observable but not that extremely large as to totally refute the simpler GVA growth rate decomposition.

¹⁷ In the last EU KLEMS 2021, 2023 and 2025 releases (<https://www.rug.nl/ggdc/productivity/eu-klems/>) despite the use of extended decomposition framework with intangibles there is no mention about gross output growth decomposition. For the theoretical basics of these releases see: Bontadini et al (2023) and Corrado (2005 and 2009).

the quality of labor, otherwise-called 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 the 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.¹⁸ Formula (2). Therefore, develops into the formula:

$$\Delta \ln Y_{jt} = \overline{\alpha}_{jt}(\Delta \ln LC_{jt} + \Delta \ln H_{jt}) + \overline{\beta}_{jt} \Delta \ln(K_{ITjt} + K_{NITjt}) + \Delta \ln A_{jt}, \quad (3)$$

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

$$\Delta \ln Y_{jt} = \overline{\alpha}_{jt} \Delta \ln LC_{jt} + \overline{\alpha}_{jt} \Delta \ln H_{jt} + \overline{\beta}_{ITjt} \Delta \ln K_{ITjt} + \overline{\beta}_{NITjt} \Delta \ln K_{NITjt} + \Delta \ln A_{jt}, \quad (4)$$

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 $\overline{\beta}_{ITjt}$ and $\overline{\beta}_{NITjt}$ differ, while the weights for the components of the labor factor are identical. Thus, it can be said that the capital factor has been separated into separate sub-factors, while the labor factor has only been separated into its distinct aspects (labor quality and labor stock).

The quality of labor 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 labor to the economy) – it is usually related to the level of education and experience (age), so according to this differentiation this quality of labor 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 lengthy period of return on capital. Hence, the ‘temptation’ arises, 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. The American growth resurgence

¹⁸ For the standard KLEMS growth accounting, i.e. for all releases before the last 2021, 2023 and 2025 releases, where (as above mentioned) intangible capital contributions have been extracted. The additional extraction of intangible capital lastly performed on EU KLEMS site is omitted here as not relevant for the issue at hand.

(Jorgenson, Ho and Stiroh, 2005)) is based on a similar phenomenon, and happened not necessarily on purpose but because of technological evolution (or revolution according to some).

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 labor 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 behavior leading to negligence in the development of infrastructure – i.e. capital of low ‘quality’ in light of the definition of this term in this instance, for infrastructure capital is capital with a generally very long life and a very long period of return on capital¹⁹ because of low yearly remuneration against its stock value.

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 labor services is a fortunate circumstance for the issue at hand since in formula (4) it is sufficient to divide the contribution of non-ICT capital services K_{NITjt} to the GVA growth into the contribution of infrastructure capital services K_{INFjt} and the contribution of other capital services K_{Ojt} ²⁰:

$$\Delta \ln Y_{jt} = \overline{\alpha}_{jt} \Delta \ln L_{jt} + \overline{\beta}_{ITjt} \Delta \ln K_{ITjt} + \overline{\beta}_{Ojt} \Delta \ln K_{Ojt} + \overline{\beta}_{INFjt} \Delta \ln K_{INFjt} + \Delta \ln A_{jt}. \quad (5)$$

In formula (5), the contributions of labor services have been combined back as in formula (2) because the focus of this article is not on separating out the quality of labor. 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 lifespan, the contribution of other capital K_{Ojt} with a generally medium lifespan and the contribution of infrastructure capital K_{INFjt} with a generally longer lifespan. Now, we need to solve the problem of extracting the relevant data.

4. Infrastructure Capital Extraction compared to ICT Capital Extraction

The above positioning of infrastructure capital in the KLEMS growth accounts effectively solves the problem posed on the side of economic growth accounting

¹⁹ Such views are sometimes advanced by researchers, see: Hirschman (1964).

²⁰ According to the author’s knowledge the only attempt to extract infrastructure capital within growth accounting has been performed by Mas (2009). However, a large work on infrastructural data (which could end by a possible growth accounting exercise) has been performed also by Fraumeni (e.g. 1999, 2007, 2009 and 2022).

methodology, as only general estimates 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 distinguish 6 capital types: *dwelling, other structures and buildings, transport equipment, other machinery and equipment, cultivated assets, intangible assets*. However, three ICT types of capital are not distinguished. The *computer hardware* and *telecommunications equipment* types are not extracted from the *other machinery and equipment* type, and the *computer software* type is not extracted from the *intangible assets* type. These three types of capital not extracted under Polish conditions are aggregated in the internationally practiced (e.g. on the EU KLEMS website) standard 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.²¹ 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 platform²², 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 the infrastructure capital type, it can be noted that it is not separated from the *other structures and buildings* wider capital type already used in the KLEMS accounting. 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 hard infrastructure constitutes the 'lion's share' of the *other structures and buildings* type, it can be used as a first approximation in the analyses without separating 'pure' hard infrastructure capital from it (i.e. without separating other non-residential structures contained in it, such as offices, warehouses and factory buildings), which in turn can enable the accounts to be performed outright. This simplification turn 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 in the Polish KLEMS accounts 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

²¹ With the exception of 2021, 2023 and 2025 EU KLEMS releases mentioned above, where additionally intangible capital has been extracted.

²² The lastly performed extraction of intangible capital contribution on EU KLEMS site is planned to be implemented in Statistics Poland's KLEMS accounts in the next round of data release.

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 Rev. 2 system these are groups 250, 252 and 489 respectively) – see further details of this already applied technique described in Kotlewski (2021).

A similar approach could be followed for the extraction of the infrastructure capital type, 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 investment outlays and the structures 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 investment outlays and the structures 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 Rev. 2 system.

However, the effectiveness of this method may not be much better than the simplifying assumption mentioned above, based on the observation that the infrastructure capital type makes up the ‘lion's share’ of the *other structures and buildings* capital type, 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 by Statistics Poland, is presently unsolvable without going outside the SNA system.

When separating out ICT capital, the assumption was made that, since this capital has a short life in general, 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 has a very long life. When determining the initial fixed capital stock for this capital as negligible (in a similar way as for the ICT 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, based on data from the SUT tables, the perpetual inventory method (PIM) cannot 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 *sensu stricto* 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 *sensu stricto* 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 *other structures and buildings* capital type can be a good approximation of it. When only increments are considered in decomposition formulae, then this approach becomes even more sensible. Therefore, in the following analysis, this capital type data are used as data source on infrastructure capital.

Before continuing, however, we need to make one important remark. It is true that for the Polish economy there are no SUT tables from before the year 2000 and no reliable data on capital stocks from before 2000 (not to mention the requirement for these data to be conformable with SNA 2008 or ESA 2010 systems). But there are countries where this kind of data collection and processing have started earlier²³. In such a case the method suggested above (and applied in the Polish KLEMS growth accounts only for the ICT capital extraction) could become an effective tool for infrastructure capital extraction. KLEMS sites’ data for some countries begin from the 1970s, awaiting also to be used for this purpose.

5. Empirical Findings

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

$$\Delta \ln Y_{jt} = \overline{\alpha_{INFj}} \Delta \ln K_{INFjt} + \sum W_{jt} \quad (6)$$

²³ Direct data on capital stock, using the perpetual inventory method (PIM) are more available for some countries. This is the case for instance for the U.S. and they have been largely processed by Fraumeni (1999, 2007, 2009 and 2022). With quite rich, although disparate, array of data for this country, it is possible to choose narrow infrastructure components to be studied more closely as in the case of Fraumeni's works cited here, where strong evidence is provided for that *more disaggregated approach*. It is plausible to advance that a growth decomposition exercise could possibly be performed on those data.

where all contributions from equation (5) other than infrastructure capital (broadly understood as above explained) contribution have been added up to $\sum W_{jt}$. Thus, we can perform the calculations and present the data as in Table 1 – firstly, for the aggregate Polish economy (code “00”) and later for the 16 Polish voivodships (codes “02” – “32”).

Table 1. Decomposition of GVA growth into infrastructure contribution and other contributions for total Polish economy and by Polish voivodship

Specification		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	3.32	5.93	6.87	3.88	3.07	3.71	4.62	1.37	1.19	3.31	4.00	3.06	4.57	5.17	4.51	-2.61		
	Other contributions	3.00	5.95	5.32	3.46	2.16	1.93	2.64	0.41	-0.03	1.82	3.33	2.05	3.90	4.37	3.55	-3.47		
	Infrastructure contribution	0.32	-0.02	1.55	0.42	0.91	1.77	1.98	0.95	1.22	1.49	0.66	1.02	0.68	0.79	0.96	0.86		
02	GVA growth	5.38	9.59	8.90	3.08	3.97	7.31	5.33	1.26	0.39	3.18	3.94	2.64	4.15	4.38	4.41	-3.26		
	Other contributions	4.90	9.68	7.13	2.54	3.19	5.51	3.53	-0.02	-1.08	1.76	3.44	1.41	3.74	4.11	3.37	-4.51		
	Infrastructure contribution	0.49	-0.09	1.77	0.54	0.78	1.80	1.79	1.28	1.47	1.41	0.50	1.23	0.41	0.27	1.04	1.25		
04	GVA growth	1.78	6.30	6.25	4.25	1.61	3.25	2.99	0.61	1.71	2.66	3.67	2.72	3.69	5.35	2.24	-2.39		
	Other contributions	2.27	6.19	5.33	3.97	0.67	1.75	0.70	0.30	0.36	1.53	2.30	2.36	3.02	4.61	1.91	-3.06		
	Infrastructure contribution	-0.50	0.11	0.92	0.27	0.95	1.50	2.30	0.32	1.35	1.13	1.37	0.36	0.68	0.75	0.33	0.67		
06	GVA growth	1.79	4.06	7.12	5.23	0.23	3.28	4.26	2.02	1.84	1.98	1.90	2.85	3.49	2.40	4.54	-1.72		
	Other contributions	1.73	4.11	6.75	5.17	0.13	2.52	3.44	1.04	1.25	0.92	1.37	2.44	3.16	2.29	3.93	-2.12		
	Infrastructure contribution	0.06	-0.05	0.37	0.06	0.09	0.77	0.82	0.98	0.59	1.06	0.53	0.41	0.33	0.11	0.61	0.40		
08	GVA growth	5.56	5.54	5.91	1.14	1.53	3.37	2.17	1.56	1.78	4.40	2.72	2.97	2.30	4.37	2.98	-3.07		
	Other contributions	4.90	5.30	3.70	1.57	0.23	1.70	1.03	-1.26	-1.76	3.63	1.51	1.75	1.30	3.53	2.56	-3.17		
	Infrastructure contribution	0.65	0.23	2.21	-0.42	1.30	1.67	1.14	2.82	3.54	0.77	1.21	1.22	0.99	0.84	0.42	0.10		
10	GVA growth	3.39	5.47	6.40	4.64	1.42	4.34	4.47	1.34	0.85	3.35	2.90	2.66	3.83	4.99	5.21	-2.58		
	Other contributions	2.87	5.42	5.74	4.26	0.79	4.28	1.59	0.30	-0.28	0.85	2.52	1.80	3.20	4.66	4.45	-2.99		
	Infrastructure contribution	0.53	0.05	0.65	0.38	0.63	0.07	2.87	1.04	1.13	2.50	0.38	0.86	0.63	0.33	0.76	0.41		
12	GVA growth	3.45	8.17	5.75	4.61	2.58	2.95	6.37	1.26	1.49	4.13	5.49	3.97	6.07	5.96	4.19	-2.47		
	Other contributions	3.12	8.30	4.72	4.52	1.55	1.56	4.88	0.32	0.37	3.38	4.67	2.92	5.78	5.60	3.75	-2.84		
	Infrastructure contribution	0.33	-0.14	1.04	0.09	1.03	1.38	1.49	0.94	1.12	0.75	0.83	1.05	0.29	0.36	0.44	0.37		
14	GVA growth	5.34	6.55	7.58	2.71	4.82	5.05	5.01	2.30	2.19	3.72	4.51	3.79	5.58	6.22	6.09	-2.15		
	Other contributions	5.03	6.84	5.90	1.93	3.73	2.95	2.82	1.75	0.47	2.07	4.08	2.05	4.47	5.38	4.97	-3.22		
	Infrastructure contribution	0.32	-0.29	1.67	0.78	1.09	2.11	2.19	0.55	1.72	1.65	0.44	1.74	1.11	0.84	1.12	1.08		
16	GVA growth	1.18	3.30	9.28	5.81	-1.72	1.58	4.40	-0.42	-0.06	3.72	2.02	1.02	4.31	4.88	3.61	-2.39		
	Other contributions	0.60	3.49	7.50	7.01	-2.29	-0.69	4.40	-0.31	-0.95	3.03	1.65	0.68	3.55	4.39	0.28	-2.75		
	Infrastructure contribution	0.58	-0.19	1.78	-1.20	0.57	2.27	0.00	-0.11	0.89	0.68	0.37	0.34	0.76	0.50	3.33	0.36		

Table 1. Decomposition of GVA growth into infrastructure contribution and other contributions for total Polish economy and by Polish voivodship (cont.)

Specification		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																
18	GVA growth	2.68	5.48	5.83	6.12	2.17	3.04	5.52	0.90	2.56	3.14	3.49	2.33	3.99	6.13	4.50	-2.82	
	Other contributions	2.57	5.33	4.66	5.88	1.55	1.82	4.58	0.83	1.36	2.20	3.12	1.73	3.67	5.62	4.28	-3.44	
	Infrastructure contribution	0.11	0.14	1.17	0.24	0.62	1.23	0.94	0.07	1.20	0.94	0.37	0.60	0.31	0.52	0.22	0.62	
20	GVA growth	3.48	3.73	7.73	2.34	4.75	2.87	3.67	-0.98	2.33	3.05	1.72	1.88	4.66	4.43	4.55	-1.53	
	Other contributions	3.37	3.65	7.19	2.14	4.42	1.95	2.17	-1.27	1.06	1.60	0.88	1.53	4.31	3.60	3.88	-2.23	
	Infrastructure contribution	0.11	0.07	0.54	0.19	0.32	0.92	1.50	0.29	1.27	1.45	0.84	0.36	0.35	0.83	0.67	0.70	
22	GVA growth	4.26	6.37	7.25	1.27	6.45	2.74	5.36	3.47	0.06	2.41	4.96	3.97	5.15	6.19	5.29	-2.78	
	Other contributions	4.11	6.18	5.65	0.94	5.64	0.95	3.62	3.34	-2.13	0.72	4.33	2.95	4.59	5.25	4.87	-3.89	
	Infrastructure contribution	0.15	0.19	1.60	0.33	0.80	1.79	1.74	0.13	2.19	1.69	0.63	1.02	0.56	0.95	0.42	1.12	
24	GVA growth	-0.36	3.57	6.31	4.10	1.13	3.03	4.14	0.03	-0.36	2.51	4.07	2.65	3.79	4.79	2.86	-3.76	
	Other contributions	-0.49	3.40	4.88	3.80	0.36	1.21	2.23	-0.11	-2.60	0.81	3.41	1.51	3.12	3.52	2.28	-5.23	
	Infrastructure contribution	0.13	0.17	1.43	0.30	0.77	1.82	1.91	0.14	2.24	1.70	0.66	1.14	0.68	1.27	0.58	1.46	
26	GVA growth	-0.87	7.52	7.91	7.31	-0.72	1.78	3.06	-0.67	-2.06	3.26	1.83	1.42	3.78	5.51	2.33	-2.03	
	Other contributions	-0.96	7.41	6.95	7.11	-1.26	0.45	1.70	-0.76	-3.74	1.91	1.31	0.55	3.27	4.54	1.87	-3.20	
	Infrastructure contribution	0.09	0.11	0.96	0.21	0.54	1.33	1.36	0.10	1.69	1.35	0.52	0.86	0.50	0.97	0.46	1.17	
28	GVA growth	3.12	5.03	5.27	4.19	3.71	2.96	3.37	0.47	0.71	3.44	2.59	2.62	2.18	3.18	3.18	-2.03	
	Other contributions	3.00	4.88	4.04	3.93	3.03	1.39	1.82	0.35	-1.36	1.80	1.97	1.56	1.56	2.05	2.66	-3.37	
	Infrastructure contribution	0.12	0.15	1.24	0.26	0.67	1.57	1.55	0.12	2.07	1.64	0.62	1.06	0.63	1.13	0.52	1.34	
30	GVA growth	4.48	5.31	6.58	4.92	5.76	1.75	4.85	2.03	2.58	3.78	5.10	3.59	5.08	4.43	5.07	-2.64	
	Other contributions	4.33	5.12	5.05	4.61	4.98	-0.05	3.08	1.91	0.47	2.12	4.48	2.58	4.51	3.42	4.63	-3.79	
	Infrastructure contribution	0.15	0.19	1.53	0.31	0.78	1.80	1.77	0.13	2.11	1.66	0.62	1.01	0.57	1.01	0.44	1.14	
32	GVA growth	3.54	4.92	4.48	4.74	0.72	2.68	3.05	1.24	0.07	3.89	3.81	1.62	4.16	4.43	3.57	-2.45	
	Other contributions	3.40	4.74	2.99	4.43	-0.07	0.87	1.22	1.10	-2.21	2.05	3.09	0.40	3.47	3.22	3.00	-3.92	
	Infrastructure contribution	0.14	0.18	1.48	0.31	0.79	1.81	1.83	0.14	2.28	1.84	0.72	1.22	0.69	1.21	0.57	1.47	

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

Source: own work based on Statistics Poland data.

As can be seen in Figure 1, concerning the total Polish economy, in the year 2006 there was almost no contribution of infrastructure to economic growth. This can be explained by the fact that economic actors were waiting for the EU funds to be approved, as Poland accessed the European Union (EU) in May 2004. Following that, the

role of infrastructure in economic growth became 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 modernized – 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 others.

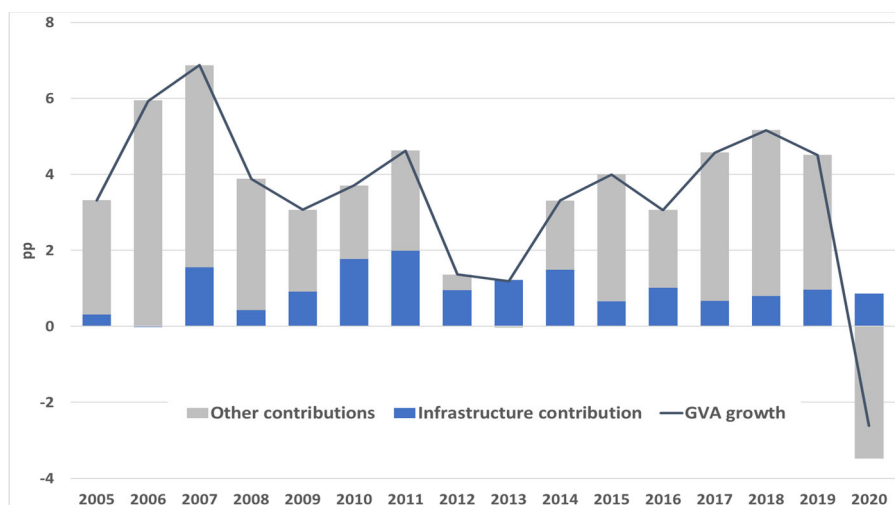


Figure 1. Decomposition of GVA growth into infrastructure contribution and other contributions for the total Polish economy.

Source: as for Table 1.

After 2012, the contribution of infrastructure to economic growth becomes smaller and fluctuates in a two or three-year cycle, which may be related to the two or three-year construction cycles (planning and preparation and then construction). In general, in the period after the above-mentioned soccer event the role of infrastructure in economic growth shows a decreasing trend. A parallel, unpublished yet, research conducted by the author of this paper indicates that this is probably due to the slower price increase in investment goods in Poland during that period, compared to consumer goods. It can be also seen that during the Covid-19 related crisis infrastructural investments were rather continued, as only a slight drop against the previous year can be observed, which is conformable to observation. This picture of the data seems confirming the validity of the method for the scope of the analysis.

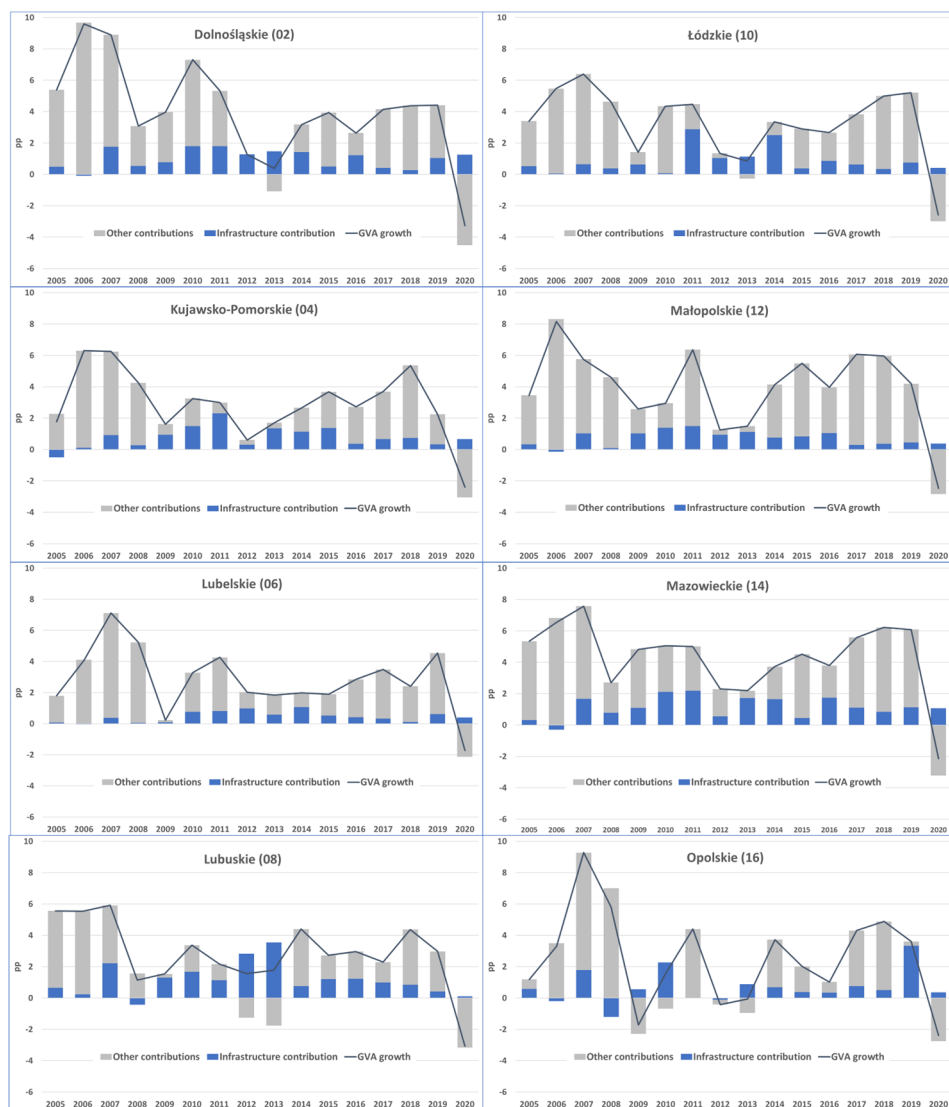


Figure 2. Decomposition of GVA growth into infrastructure contribution and other contributions for the 16 Polish voivodships.

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

Source: as for Table 1.

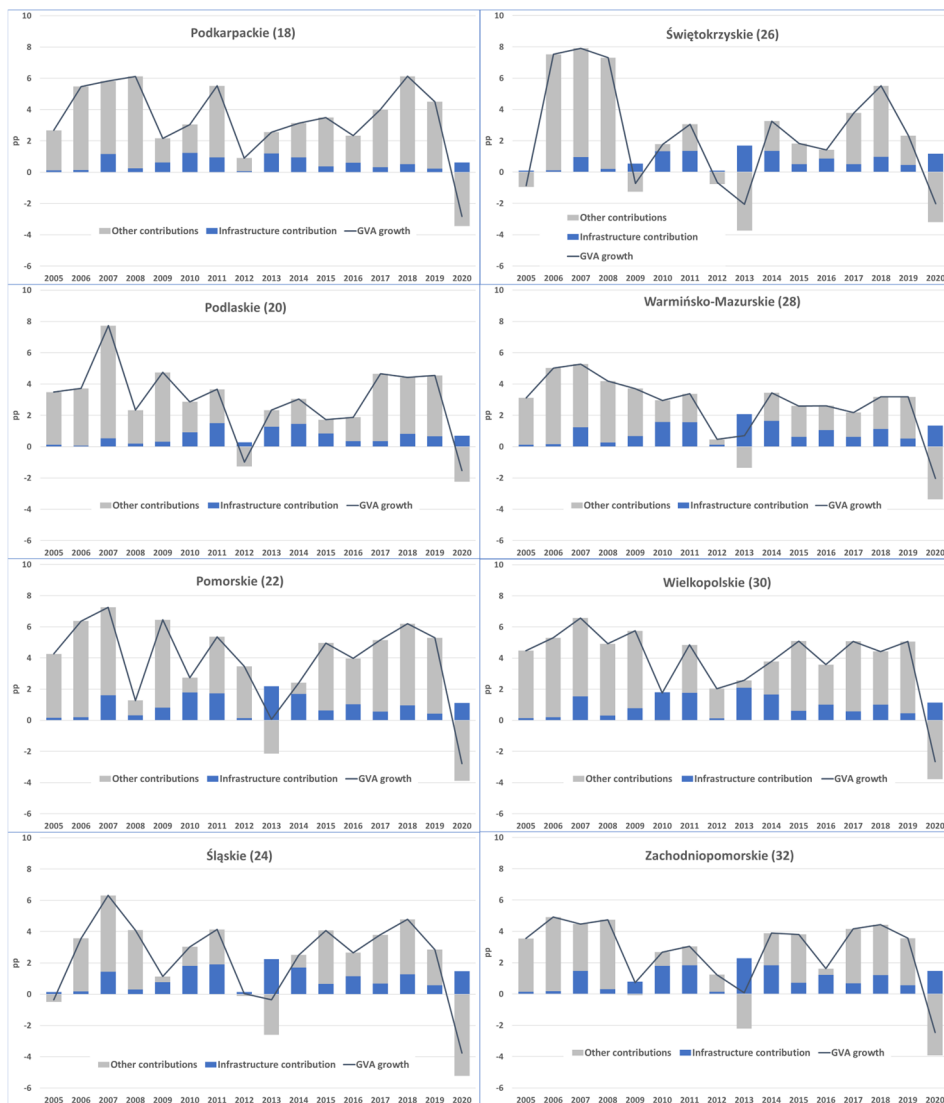


Figure 2. (cont.) Decomposition of GVA growth into infrastructure contribution and other contributions for the 16 Polish voivodships.

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

Source: as for Table 1.

However, one problem remains, namely that the presented data are not at the industry level but only at the aggregate level. This does not mean that the computations have not been done at the industry level, but that their validity is debatable, and therefore data at the industry level have not been included in the analysis. The question arises as to how to attribute shares in infrastructure components such as highways, railroads, etc., to individual industries distinguished in the KLEMS framework. Do industries participate equally, i.e. proportionally, in infrastructure services? Should individual consumers be treated differently from businesses? Which part of the tax revenue should be considered as infrastructure capital remuneration in growth accounting, as infrastructure fees are rather not directly charged on users (with some exceptions), etc.

However, despite difficulties in conducting the KLEMS type decomposition exercise by industry, as far as infrastructure contribution is considered, it remains nevertheless possible to develop it spatially. Therefore, the analysis based on Figure 1 can be significantly deepened if we refer to Figure 2, where the same kind of data from Table 1 were presented for the 16 Polish voivodships. It can be observed that the voivodships more involved in the above-mentioned 2012 soccer event and also those more centrally located, contrary to the more peripheral ones, have greater infrastructure contributions, which is conformable to expectations and is once again confirming the validity of the adopted method. It is well known that government's investments (and government supported or promoted ones) translate into SNA data reported in Statistics Poland. These data enter the KLEMS growth accounting and impact the contributions to economic growth with different effectiveness (some of the investment may not translate effectively into economic growth). They can be nevertheless traced qualitatively.

Three new stadiums were built in Gdańsk (Pomorskie voivodship), Wrocław (Dolnośląskie voivodship) and Warsaw (Mazowieckie voivodship). One stadium was utterly modernized in Poznań (Wielkopolskie voivodship). Around these soccer 2012 locations airports and train stations and lines were modernized, and more road connections established (more on this in Sobiera, 2012). Hotels were also built. Zachodniopomorskie (with Szczecin) and Lubuskie voivodships are important entry hubs to Poland from Western Europe. Kujawsko-Pomorskie and Łódzkie voivodships are centrally located, Śląskie (the most industrial voivodship) and Małopolskie (with Kraków, a renown touristic destination) are the remaining hubs that also participated in the infrastructure development momentum, as this event was also considered to be an occasion to promote Poland. We can observe that in many cases infrastructure investments were almost stopped dead in 2012 itself – this is the case for 11 out of 16 voivodships. The intention was not to annoy soccer participants (road and other works were temporarily restrained) and to deviate resources to withstand the additional soccer

event expenditures. Other differences from Figure 1 at the voivodship level are related to local circumstances and developmental needs.

A profound study of government and provincial policy documents could produce an ample book-size report but, nevertheless, it can be asserted that a sensible initial assessment of the role of infrastructure in economic growth was achieved – it is important but should not be overstated at the same time.

6. Conclusion

The main issue of the paper was to demonstrate the viability of a growth accounting methodology, the KLEMS growth accounting in particular, to study the role of infrastructure in economic growth, and an empirical case study for the Polish economy has been conducted for this purpose.

The paper demonstrates that there are strong theoretical premises for the use of this accounting methodology in this context, including the work of Jorgenson, Ho and Stiroh (2005). The specific interrelation between demand-side and supply-side impacts of infrastructure and its very long life-span lead to different attitudes of policy makers in regard to infrastructure investments – one is to forcibly invest in it in order to stimulate the economy on the demand side, the other one is to refrain from “excessive” investment in infrastructure in order to avoid the negative crowding out effect of those investment on business activity. A turn towards ICT capital investment in the U.S. during the 90s, as explained by Jorgenson, Ho and Stiroh (2005), was the reason for the U.S. economic growth resurgence in those years, and this is another justification to see this issue through the lenses of the KLEMS growth accounts.

As shown in the paper, it is possible to slightly alter the KLEMS formulae in order to distinguish the contribution of infrastructure to economic growth. There is, however, the issue of extracting appropriate data. This can be done thanks to the use of structures from the supply and use tables (SUT) but only for countries with very long time series of data conformable with the system of national accounts (SNA). However, despite the fact that this kind of data is not available for the Polish economy, it is still possible to make an acceptable assessment of the role of infrastructure in economic growth for Poland thanks to adopting the notion of a ‘broadly understood infrastructure capital’. The obtained results do sensibly explain the impact of infrastructure on economic growth in the years 2005-2020, which is the period for which the KLEMS growth accounting exercise for the Polish economy has been conducted.

The most important limitation of the study is at the sectoral level of aggregation. Infrastructure, contrary to private capital owned by firms, is owned in Poland (as in many other countries) by the state, and therefore it is difficult to attribute it to industries or sectors. The solution to this problem could be to conduct a growth accounting

exercise at the firm level, using econometric methods that would allow to attribute infrastructure shares to firms and therefore also to industries. But this still remains a matter of future research. Fortunately, the lack of industry results does not affect the aggregate results. The second limitation is the measurement of infrastructure types. It would be interesting to analyze the contribution of different types of infrastructure – not treated *en bloc* – to economic growth. Innovative research is also required in this area.

Further research should extend the analysis in two directions. Firstly, it should compare the Polish infrastructure contributions with other countries using the EU KLEMS data, although the availability of data limits such comparisons, as only limited result data are available for other countries. Secondly, it should combine the KLEMS results with firm-level data in order to identify differences between groups of firms and, consequently, industries.

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