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Interdependence of Innovations and Institutions: Consequences for GDP Growth

Introduction

Innovativeness – in feedback with institutions – is the basic determinant of competitiveness on micro-, meso-, macroeconomic and global levels. The literature shows significant and positive relationships between the results of enterprises, sectors, regions and countries in rankings of innovativeness and their results in studies of competitiveness. Economic growth based on innovations assures a high level of competitiveness and is relatively permanent and stable in nature.

The main objective of this paper is the identification of the determinants of GDP growth based on innovations with special attention paid to institutions supporting this growth and testing the relationships between variables that reflect innovativeness, institutional environment and economic growth in EU countries in the years 2005–2014. We examine the combined effect of innovations and institutions.

We start with a brief review of growth and innovation nexus literature and the importance of institutions in economic processes. The second part of this paper presents a composite measure of creative economy (as proposed in: Żelazny, Pietrucha 2017), in which innovations and institutions constitute a common element of the environment for pro-efficiency solutions, i.e. the creative economy index – CEI. We have chosen a different approach than that used in previous studies (e.g. Balcerzak 2009) – a method proposed by OECD (2008). The third part describes the analysis of the relationship between CEI and GDP growth, taking into consideration control variables. This study covered 29 countries from 2005 to 2014.

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1. Modern determinants of economic growth

Economic growth is clearly a central economic category. The pace of long-term economic growth determines, among others, to what extent needs are being met and the standard of living. Therefore, studies of the determinants of economic growth have been carried out since scientific study of the economy began. There are, generally, two approaches in the theory of economics concerning the factors that determine growth, resulting from different methodological assumptions, namely: the classic and the Keynesian approach. These two approaches describe economies functioning under different conditions and over different time periods. In both approaches – although to different degrees – attention is paid to the role of the so-called "modern growth factors", which increase the productivity of traditional factors (capital, labour and land). Knowledge, technical progress and innovations are just some of the terms used to define modern factors.

Studies on the effect of modern factors on economic growth have been conducted in many areas. Within growth theory and total factor productivity (TFP) measurement, an attempt was made to discover the share of technological progress in the increase of production (Solow 1956, 1957; Swan 1956). However, technical progress, along with the savings rate and birth rate, is the exogenic variable in Solow's model. The exogenic approach, which appeared in the Mankiw-Romer-Weil model, is similar when considering technological progress, although it is supplemented with human capital included in the production function, which is the bridge between growth theories and the new growth theory (Mankiw, Romer, Weil 1992). The first attempts to explain sources of technological progress were recorded in literature in the late 1950s, but also in the 1960s and 1970s (von Neumann 1945; Knight 1944; Arrow 1962; Uzawa 1965; Schmookler 1966). In the 1980s and 1990s, a number of seminal works were published in the field of the so-called new growth theory, which, to a greater or lesser extent, contested the assumptions adopted within the neoclassical theory of growth and indicated the endogenous nature of the so-called fourth factor (Romer 1986, 1990; Aghion, Howitt 1992; Lucas 1988).

When identifying sources of innovations that allow for a decrease in the marginal productivity of production factors to be prevented, the following must be mentioned (Balcerowicz, Rzońca 2010; Żelazny, Pietrucha 2017):

- increase in human capital resource and/or its productivity, especially committed in R&D activities,
- increase in quantity and/or quality of intermediate goods that are innovations used in the production of final goods,
- expanding the resource of final goods with a higher level of usability for consumers,
- the presence of positive external effects related to the benefits rendered by innovations.

For the needs of this paper, knowledge, technical progress and innovation have been defined as follows. The increase in the set of the possible production techniques

resulting from the increase in the resource of knowledge (e.g. inventions, discoveries) is technical progress. Technical progress, being the derivative of the increasing resource of knowledge, contributes in return to the expansion of this resource. Innovation means the implementation of new techniques to solve specific problems in practice; this also becomes a source of new knowledge. This is why the relationship between knowledge, technological progress and innovation are of feedback in nature.

Growth based on innovations is potentially a universal and permanent mechanism until the time of the appearance of innovations that increase production factors' productivity (Balcerowicz, Rzońca 2010, pp. 39–45). The activation and/or sustaining of this mechanism of growth requires the functioning of relevant institutions. Institutions are, according to representatives of the so-called "new institutionalism", limitations devised by people that define and limit the system of choices made. Their main objective is to reduce uncertainty by way of creating a stable order (North 1990). Institutions contribute to the determination of the direction of the search for knowledge and skills – this direction is the decisive factor in the long-term development of the society (North 1990). The institutional environment of specific features thus creates conditions for increasing the resource of knowledge and its effective use in the form of innovations (cf. Carlsson, Jacobson 2005). On the other hand, the increasing set of possible production techniques resulting from the increase in the resource of knowledge is the determinant of institutional changes. Mutual interactions between the knowledge resource and the institutional framework will gradually shape transformations of the latter (North 1990). Innovations, therefore, imply changes in behaviours, habits and institutions (Nelson, Winter 1982). Institutions do not always keep up with changes in the technology of manufacturing, thus they can impede growth (Veblen 1998). Relationships of feedback nature can also be identified between the categories of knowledge and institutions. Acemoglu (2013) emphasises that technological changes stimulate economic growth, but institutions (inclusive and extractive) determine the nature, pace and reach of technological changes. The key institutions for growth driven by innovations include the structure and protection level of rights of ownership, the degree of competition between producers, and the fiscal position of the state in the economy (Balcerowicz, Rzońca 2010). The literature confirms the important and positive effect of institutions on economic growth (Góes 2016; Nawaz 2015; Acemoglu, Robinson 2010; Kacprzyk 2014).

All in all, one has to conclude that using innovative solutions that enhance the productivity of production factors is necessary in business activities in order to achieve continuous economic growth, and these production factors in turn are the derivative of a specific institutional environment and mutually interact. As a result of feedback between institutions, human capital and technology, conditions arise that are conducive to the development of creativity which is the accelerator for innovations at micro-, meso- and macroeconomic levels – therefore, the creative economy develops. It must be noted that this approach is different and broader than that used in studies related to creative industries proposed by Caves (2000) and Florida (2002).

Taking into account the interdependence of innovations and institutions, a composite measure has been proposed in the form of the creative economy index.

2. Creative economy index (CEI)

We have defined the creative economy as an economy where, as a result of feedback between institutions, human capital and technology, conditions facilitating the development of creativity are created. The proposed new composite indicator (Creative Economy Index) is a result of empirical meta-analysis of indicators characterising innovativeness and institutional environments.

The methodology of the development of the creative economy index consisted of several steps, presented in Fig. 1 (Żelazny, Pietrucha 2017).

Figure 1

Methodology of the creative economy index

Step 1	Literature review as regards composite indexes construction
Step 2	Placing the analysed phenomenon in the theoretical framework of economic sciences
Step 3	Selection of variables
Step 4	Supplementing missing data
Step 5	Standardisation of data
Step 6	Factor analysis applying the principal component method
Step 7	Selecting subindexes of the composite index and calculation of weights
Calculation of CEI (creative economy index)	

Source: own elaboration.

Step 1
Based on literature studies, benefits and problems related to the development and use of composite indexes in studying economic phenomena have been analysed (Grupp, Schubert 2010; OECD 2008; Żelazny 2016). Then, the stages of the composite index construction most often distinguished in literature were identified. These stages are presented in steps 2–7.

Step 2
Studies of economic growth factors have a significant role in the economic theory. Innovations and institutions that are linked mutually are regarded to be extremely important factors that support growth. Based on this relationship, the so-called creative economy has been distinguished, in which innovations and institutions constitute a common element of pro-efficiency and pro-growth solutions, and freedom of creation plays a key role (Żelazny, Pietrucha 2017). The creative economy index is the proposed method of measuring these dependences.

Step 3
Defining the essence of creative economy allowed for the selection of the variables that characterise the innovativeness of economies and their institutional environment. In the case of innovativeness, the Innovation Union Scoreboard Database was used. Several databases were used in the case of the institutional environment. For details see Appendix 1.

Step 4
The database was supplemented with the values from the last year covered by the available data in the case of a lack of current data or from the first year of the available data in the case of a lack of data at the beginning of the time period.

Step 5
The procedure of data standardisation was conducted.

Step 6
It was assumed that factors explaining at least 60% of the initial database variance should be taken into consideration (criterion advocated by OECD 2008, p. 89 or Nicoletti, Scarpetta, Boylaud 2000, p.20), which enabled the selection of 4 factors. In the next step, the factors were rotated (varimax normalised and biquartimax normalised), which did not produce any basically different results. Following names were adopted for the factors considered: inventive economy (*IE*), political institutions (*PI*), business regulations (*BR*) and fiscal institutions (*FI*).

Step 7
On the basis of the matrix of factor loadings of the individual variables received as a result of varimax and biquartimax rotation, the shares for the total variance of a given variable (which is explained by the ratio of the squared value of the factor load to the value of the explained variance) were calculated. The weights for the particular factors, which are at the same time the subindexes of the composite index (ICI – intermediate composite indicators), are determined according to the share of the given factor in the explanation of the total variance. When such weights do not add up to one, they should be rescaled taking into account the total value of the explained variance in the given set of factors. Finally, the creative economy index will be expressed with the formula (1):

$$CI = \sum_{i=1}^{n} w_i ICI_i \quad (1)$$

where:
w_i – the weights of subindexes ICI_i that meet the conditions $0<w_i<1$ and $\sum w_i = 1$,
n – the number of subindexes ICI.

The creative economy index assumed the form consistent with the formula (2):

$$CEI = 0.57IE + 0.19PI + 0.11BR + 0.13FI. \quad (2)$$

Factor analysis reduces a large number of initial variables into a smaller set of uncorrelated variables and removes redundancy or duplication of information from the set of initial variables. The creative economy index consists of four sub-indexes (four factors) that explain at least 60% of the variability of the whole variable set. The proposed names of the four factors resulted from the constituent variables of the matrix of factor loading analysis. It should be noted that our standardization methodology (which converts variables to a common scale with a mean of zero and standard deviation of one) produced negative and positive values of CEI. The same approach is used by the European Commission in the Innovation Union Scoreboard Database. It is possible to rescale the values in a different way (e.g. from 0 to 10) to avoid negative values but it is only an alternative way of presenting the same data.

3. Innovations and institutions as determinants of economic growth: empirical analysis

We estimate the following baseline model in line with R. Barro:

$$y = \alpha + \beta \log Y_{t-1} + \phi X_t + \pi Z_t + u_t \quad (3)$$

where: y – GDP growth, Y – GDP per capita (to check the convergence process), X – variables resulting from the models of growth, Z – additional variables (in this paper, e.g. CEI). This class of models constitutes the basis for numerous empirical studies of non-structural nature (cf. Kacprzyk 2014; Goczek, Kurowska, Zduniuk 2014).

Our set of control variables (in compliance with Kacprzyk 2014) comprises the logarithm of GDP per capita (delayed by one period), investments and trade openness.

The study covered panel data for the period 2005–2014 and 29 countries of the EU and others from the European Economic Area and Switzerland (for details see Appendix 1). The panel is balanced. The size of the panel (the number of countries and the length of the series) depends on the possibility of calculation of CEI according to the method stated above. Unfortunately, this imposes limitations on the possibility of drawing conclusions and verifying the hypothesis. Another problem is that the time period of the available data includes, unfortunately, the years of the crisis in the real sector that was the consequence of the 2007+ financial crisis, which was dramatic in many EU countries and mostly

brought about a long-term weakening of the GDP growth rate. Two countries which had a significantly different economic course in the audited period were excluded from the panel, i.e.; Greece and Poland. Taking into account all these shortcomings it was decided that some basic regressions be run in order to make preliminary observations.

The data related to CEI comes from the paper of Żelazny, Pietrucha (2017). Eurostat is the source of the data related to GDP and investments. Detailed information about the data is given in Table 1.

Table 1
Characteristics of variables and sources of data

Short name	Variable	Source
Growth of GDP	$\log GDP_t - \log GDP_{t-1}$	Eurostat, Main GDP aggregates per capita [nama_10_pc] (access date 2016-07-01)
GDP pc	Log of gross domestic product per capita	Eurostat, Main GDP aggregates per capita [nama_10_pc] (access date 2016-07-01)
Investments	Gross fixed capital formation as % GDP	Eurostat, GDP and main components (output, expenditure and income) [nama_10_gdp] (access data 2016-07-01)
Openness	Trade openness: the sum of import and export as % GDP	World Bank, World Development Indicators (access date 2016-01-17)
CEI_1 CEI_2	CEI (biquartimax rotation) CEI (varimax rotation)	Żelazny, Pietrucha 2017
CEI_a	CEI of the most important country of origin of foreign direct investments in the case when it is higher than of the given country, otherwise the CEI of the given country	Żelazny, Pietrucha 2017 the data related to direct investments UNCTAD (access date 2016-07-01)

Source: own elaboration.

In the first step, the stationarity of time series was analysed (the Harris-Tzavalis, Im-Pesaran-Shin unit root tests), which showed a rejection of the hypothesis of non-stationarity of all the time series of the dependent variable, which significantly reduces the risk of occurrence of apparent correlation with independent variables. The standard procedure in the case of economic growth is using 5-year means (to eliminate accidental fluctuations). Unfortunately, the length of the CEI time series does not allow for the use of this procedure. Therefore, another solution was adopted: the data related to GDP were smoothed with the Hodrick-Prescott filter, with the smoothing parameter equal to 6.25. However, the consequences of the 2007+ crisis persisted, which may constitute some limitation for drawing clear conclusions with regards to economic growth.

In all cases, the two-step difference GMM estimator was used with country- and time-specific dummies. The set of instruments consisted of the lagged dependent variable and differences of the lagged CEI measures (first lag only), and other regressors including the time dummies (Baltagi 2013). The robust White method for the estimation of standard errors which takes into account potential autocorrelation and heteroscedasticity of random components of the model was used. The models passed the basic tests of model specification correctness (the Arellano-Bond test for presence of 2-level autocorrelation, and the Hansen's over-identifying restrictions tests) verifying the correctness of the selection of the instruments and moments. Sargan's test suggests that the instruments are not chosen correctly. However, the test is not robust to heteroscedasticity of the error term, so the results for the robust version developed by Hansen are also reported. Table 2 presents the results of the estimation.

Table 2

Results of the estimation

	Model 1	Model 2	Model 3
GDP growth ($t-1$)	0.561** (2.64)	0.642*** (3.20)	0.478* (1.99)
CEI_11	0.027** (2.20)		0.024* (1.70)
CEI_2		0.027* (2.00)	
CEI_a			–0.007 (–0.47)
GDP pc ($t-1$)	–0.028** (–2.24)	–0.026** (–2.20)	–0.030** (–2.57)
Investments	0.0002 (0.55)	0.00003 (0.07)	0.0003 (0.61)
Openness	0.00008** (2.32)	0.00009*** (2.84)	0.00009* (2.01)
AR(1)	–0.52	–0.69	–0.44
AR(2)	–0.96	–1.03	–0.92
Sargan	129.97	128.78	110.73
Hansen	21.29	20.60	22.19
Hansen exc.	13.11	11.81	15.10
# Instruments	38	38	39

In parentheses standard errors are reported. Significant coefficients are denoted with stars (* – $p < 0{,}1$; ** – $p < 0{,}05$; *** – $p < 0{,}01$). AR(1) and AR(2) contain the results of the Arellano-Bond autocorrelation tests in first differences; Sargan and Hansen contain the results of the overidentifying restrictions tests developed by Sargan and Hansen. Hansen exc. shows the results of the Difference-in-Hansen test for excluding the exogenous instruments.

Source: own elaboration.

Both CEI specifications show a similar, statistically significant relation with the increase in GDP (the models 1 and 2). Thus, irrespective of the method of calculation, CEI shows a positive relationship with an increase in GDP, but in the case of CEI based on biquatratic rotation, the relationship is more distinct.

In the next step, the CEI variable was modified so as to take into account the external effects (spill-over effects) of the CEI of the given country. The CEI level of the given country may affect the situation (economic growth) of another country through, among others, direct foreign investments. A new CEI_a variable was created to test this channel of dependence: the CEI of the given country was replaced with the CEI of the most important supplier of foreign investments, when it was higher. For example, if, in the case of Hungary, Germany is the most important country of origin of investments, the value of the CEI for Germany was adopted. However, a new variable does not show a statistically significant effect on economic growth. One of the possible causes may be the quality of the data related to the direction of investment inflow. In many studied countries, especially in transformation economies, among the sources of inflow of direct investments, Cyprus, Luxembourg and the Netherlands dominate. These countries are the de facto place of "repackaging" the capital coming from other countries.

Conclusion

The subject matter of this paper were the relationships between the Creative Economy Index (CEI) and GDP growth. CEI was constructed based on empirical meta-analysis of variables that characterise innovativeness and the institutional environment. The interdependence of innovations and institutions has been assumed. Innovations and institutions constitute a common element of pro-effective and pro-growth solutions, in which a crucial role is played by the free creativity factor – what we call "a creative economy". We understand this in the way that innovations require inclusive institutions which provide opportunities and incentives for the development of innovations and economic activity. These incentives are based on, inter alia, aligned property rights, while opportunities are enhanced by absence of entry barriers and the provision of basic public services. Economic inclusive institutions are reinforced by political inclusive institutions characterised by a wide distribution of political power (restriction of the monopolisation of political and economic power) and the state which allows for the performance of its basic functions.

To examine the relationship between creative economy and GDP growth, regression analysis was conducted on panel data for the group of 29 economies. The results indicate a significant positive impact of creative economy (measured with CEI) on real GDP growth, with control variables taken into account. The possibilities of interpretation and drawing conclusions are limited due to the relatively short time period covered by the data and the inclusion of the financial and eco-

nomic crisis years. Nevertheless, the obtained results make our initial conjecture about the positive effect of CEI on the increase of GDP probable and constitute a stimulus for further, in-depth studies.

Received: 2 February 2017
(revised version: 6 July 2017)

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Appendix 1

List of initial variables

Database	Indicator	Variable No.
Innovation Union Scoreboard Database 2015	New doctorate graduates (ISCED 6) per 1000 of the population aged 25–34	V1
	Percentage of the population aged 30–34 having completed tertiary education	V2
	Percentage of youth aged 20–24 having attained at least upper secondary level education	V3
	International scientific co-publications per million population	V4
	Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country	V5
	Non-EU doctorate students as a % of all doctorate students	V6
	Public R&D expenditures as % of GDP	V7
	Venture capital (early stage, expansion and replacement) as % of GDP	V8
	Business R&D expenditures as % of GDP	V9
	Non-R&D innovation expenditures as % of turnover	V10
	SMEs innovating in-house as % of SMEs	V11
	Innovative SMEs collaborating with others as % of SMEs	V12
	Public-private co-publications per million population	V13
	PCT (Patent Cooperation Treaty) patent applications per billion GDP (in PPS €)	V14
	PCT patent applications in societal challenges per billion GDP (in PPS €)	V15
	Community trademarks per billion GDP (in PPS €)	V16
	Community designs per billion GDP (in PPS €)	V17
	SMEs introducing product or process innovations as % of SMEs	V18
	SMEs introducing marketing or organisational innovations as % of SMEs	V19

	Fast-growth in innovative industries	V20
	Employment in knowledge-intensive activities (manufacturing and services) as % of total employment	V21
	Medium and high-tech product exports as % of total product exports	V22
	Knowledge-intensive services exports as % of total service exports	V23
	Sales of new to market and new to firm innovations as % of turnover	V24
	License and patent revenues from abroad as % of GDP	V25
Worldwide Governance Indicators	Voice and accountability	V26
	Political stability and absence of violence/terrorism	V27
	Government effectiveness	V28
	Regulatory quality	V29
	Rule of law	V30
	Control of corruption	V31
Index of Economic Freedom	Property rights	V32
	Freedom from corruption	V33
	Fiscal freedom	V34
	Government spending	V35
	Business freedom	V36
	Labor freedom	V37
	Monetary freedom	V38
	Trade freedom	V39
	Investment freedom	V40
	Financial freedom	V41

Appendix 1 cont.

Economic Freedom of the World	Size of government	V42
	Protection of property rights	V43
	Legal system & property rights	V44
	Sound money	V45
	Freedom to trade internationally	V46
	Regulation	V47
Global Competitiveness Report	Property rights	V48
	Intellectual property protection	V49
	Diversion of public funds	V50
	Public trust in politicians	V51
	Judicial independence	V52
	Favoritism in decisions of government officials	V53
	Wastefulness of government spending	V54
	Burden of government regulation	V55
	Efficiency of legal framework in settling disputes	V56
	Efficiency of legal framework in challenging regulations	V57
	Transparency of government policymaking	V58
Doing Business	Starting a business	V59
	Dealing with construction permits	V60
	Registering property	V61
	Getting credit	V62
	Protecting minority investors	V63

	Paying taxes	V64
	Trading across borders	V65
	Enforcing contracts	V66
	Resolving insolvency	V67
Polity IV	Polity	V68
Freedom in the World	Political rights	V69
	Civil liberties	V70
Freedom of the Press	Freedom of the press	V71

Appendix 2

List of countries

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom

WSPÓŁZALEŻNOŚĆ INNOWACJI I INSTYTUCJI A ICH WPŁYW NA WZROST GOSPODARCZY

Streszczenie

Artykuł bada zależność pomiędzy wskaźnikiem gospodarki kreatywnej (CEI) a wzrostem PKB. Autorzy zakładają, że w rezultacie sprzężenia zwrotnego zachodzącego między instytucjami a kapitałem ludzkim i technologią powstają warunki sprzyjające działalności kreatywnej, która jest czynnikiem przyspieszającym innowacje na poziomie mikro-, mezo- i makroekonomicznym, czego efektem jest wzrost gospodarczy. Skonstruowany przez autorów syntetyczny wskaźnik CEI jest oparty na 71 zmiennych mierzących stopień kreatywności gospodarczej oraz współzależność innowacji i instytucji. Analiza, przeprowadzona za pomocą modelu regresji wypełnionego danymi panelowymi dla 29 krajów Europy w okresie 2005–2014, potwierdziła znaczący dodatni wpływ CEI na tempo wzrostu realnego PKB.

Słowa kluczowe: innowacje, instytucje, gospodarka kreatywna, wskaźnik syntetyczny, wzrost gospodarczy, Unia Europejska

JEL: O30, E02, P16, O43

INTERDEPENDENCE OF INNOVATIONS AND INSTITUTIONS: CONSEQUENCES FOR GDP GROWTH

Summary

This paper examines the relationship between the creative economy index (CEI) and GDP growth. The authors assume that as a result of feedback between institutions, human capital and technology, conditions for creativity development arise, which is the accelerator for innovations at micro-, mezo- and macroeconomic levels – therefore, the creative economy develops. CEI is a composite index of creative economy developed by the authors. It is based on 71 variables measuring creative economy and interdependence of innovations and institutions. A significant, positive effect of CEI on real GDP growth has been confirmed using a regression model filled with panel data for 29 countries of Europe in the period 2005–2014.

Key words: innovation, institution, creative economy, composite indicator, economic growth, European Union

JEL: O30, E02, P16, O43

ВЗАИМОЗАВИСИМОСТЬ МЕЖДУ ИННОВАЦИЯМИ И ИНСТИТУТАМИ И ИХ ВЛИЯНИЕ НА ЭКОНОМИЧЕСКИЙ РОСТ

Резюме

В статье исследуется зависимость между показателем креативной экономики (CEI) и ростом ВВП. Авторы полагают, что в результате обратной связи между институтами с одной стороны и человеческим капиталом и технологией с другой, возникают усло-

вия, способствующие креативной деятельности. Эта деятельность является фактором, ускоряющим инновации на микро-, мезо- и макроэкономическом уровне, и в результате, способствует экономическому росту. Построенный авторами синтетический показатель CEI опирается на 71 переменную, измеряющую степень экономической креативности и взаимозависимость инноваций и институтов. Анализ, проведенный с помощью модели регрессии на базе панельных данных для 29 стран Европы в период 2004–2014 гг., подтвердил значительное положительное влияние CEI на темпы реального роста ВВП.

Ключевые слова: инновации, институты, креативная экономика, синтетический показатель, экономический рост, Евросоюз

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