Economic Convergence of the Countries in 1992-2022

Maria-Yana Maykhrovich

Maria-Yana Maykhrovich — expert at the Centre for Economic Expert Analysis, Institute for Public Administration and Governance, HSE University; laboratory assistant at the Centre for Comprehensive European and International Studies, HSE University.

ORCID: 0000-0003-0324-9664
ResearcherID: HLP-7799-2023

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Abstract

Economic science has always been concerned with the catch-up effect: are developing countries really catching up to technologically developed countries, and is the economic gap between rich and poor countries narrowing over the long run? The goal of this article is to test the hypothesis of economic convergence of countries as one of the primary research problems within the field of cross-country inequality. The objective of this research is to gain a deeper understanding of the factors that contribute to economic cross-country inequality. This article seeks to ascertain the impact of country convergence, as postulated by R. Solow in his model of economic growth, utilizing R. Barro's equations for the period from 1992 to 2021/22. The paper reveals the existence of economic convergence, but at a rate that is insufficient for developing countries to catch up to developed countries in a meaningful way. The dynamics of convergence by decade is analyzed separately. It is found that convergence was as slow as possible in the period between 2002 and 2011 and as fast as possible in the period between 2012 and 2022. The economic shocks of 2020-2022 may undermine

the catching-up potential of many developing countries, which may result in a slowing of further convergence.

Introduction

The term "convergence" first appeared in ancient Greece in the 5th century BC, as postulated by Heraclitus of Ephesus. He proposed that the world should be conceptualized in terms of the unity and unification of the whole [Dementieva 2021. P. 509]. The concept of "convergence" was first used in the field of economics in the 1960s and 1970s.

In 1961, J. Tinbergen's work "Do Communist and Free Economies Show a Converging Pattern?" was published [Dementieva 2021. P. 509]. In this work, the author posits that under the influence of civilizational processes and in the context of scientific-technological progress and rational management of economic activity over time, disparate economic systems, though fundamentally opposed to each other, converge toward a singular trajectory of development [Dementieva 2021. P. 509]. Subsequently, numerous economists and sociologists, including J. Galbraith (2004), R. Barro and X. Sala-i-Martin (1990), expanded and refined convergence theory. Galbraith identified investment, production expansion, and the development and use of advanced technology as the main drivers of convergence between developed and developing countries [Dementieva 2021. P. 509–511].

The theory of economic convergence is a major area of research in the field of cross-country inequality. The concept of the "catch-up effect" has been the subject of considerable debate within the field of economic theory.[1] Some researchers argue that countries are diverging, leading to a widening of the economic gap between developing and developed countries over time [Pritchett 1997; Mazumdar 2003]. Conversely, others argue that international convergence occurs over time [Barro & Sala-i-Martin 1990; Kónya & Guisan 2008; Jorda & Sarabia 2014].

The question of whether convergence between rich and poor countries is possible remains a topic of debate among economists. Recent calculations, carried out between 2018 and 2023 by researchers affiliated with international organizations, have produced mixed results. K. Daly and T. Gedminas of Goldman Sachs, S.A. Solarin, S. Erdogan, and U.K. Pata—researchers at the OECD—examined the convergence process in different samples of countries and concluded that economic convergence between developed and developing countries is a real phenomenon and that international inequality tends to decrease [Daly & Gedminas 2022. P. 2; Solarin et al. 2023]. However, J. Rebello and D. Young of the World Bank come to a different conclusion, namely that the effect of convergence between countries is slowing down [Rebello, Young 2022]. If economic convergence is indeed a reality, it is puzzling why there have been no significant cases of convergence between emerging and developed economies since the 1950s [Grigoryev et al. 2022.

[1] The catch-up effect means that developing countries grow faster, as a result of which (and in the course of transformation of the socio-economic system) they try to catch up with technologically advanced economies.

Chapter 1]. Convergence can also be studied at the regional level. For example, S. Golovina and S. Pugin (2014) tested the hypothesis of convergence for the subjects of the Russian Federation.

As with the question of the reality of convergence or divergence in the world, there is a major debate about the reasons for "why some countries are poor and others are rich," i.e. the factors that directly affect economic divergence among countries. Institutionalists argue that the quality and type of institutions that influence citizens' incentives (e.g., education, entrepreneurship, technology adoption, investment) are the primary drivers of economic divergence [Acemoglu & Robinson 2015. P. 105]. Economic institutions are directly responsible for creating these incentives, but they are highly dependent on political mechanisms and structures, the continuity and stability of which can guarantee the effective functioning of the economic mechanism. It is reasonable to conclude that the quality of institutions depends on the characteristics of public administration. For example, the existence of a centralized democratic system, ensuring the protection of citizens' rights and freedoms, as well as the existence of checks and balances, are factors that contribute to the quality of institutions [Samarasinghe 2019].

The theory of geographic determinism posits that a country's wealth is influenced by its geographic location. Low-income regions are predominantly located in areas with equatorial, sub-equatorial, and tropical climates, while wealthy regions are predominantly located in areas with temperate climates [Diamond 1997]. The theory of sociocultural codes posits that divergent values lead to the development of different principles and approaches to various aspects of economic, social, and political life [Inglehart & Welzel 2009].

Another factor influencing economic disparity and, consequently, cross-country inequality is the discrepancy in income distribution among citizens within a given country [Grigoryev, Salmina 2013. P. 9]. It is observed that the rate of economic growth slows down in countries with high levels of national inequality. This phenomenon can be attributed to the lack of incentives and opportunities for individuals to climb the social ladder [Grigoriev, Salmina 2013. P. 10]. Moreover, technological progress not only improves and optimizes the production capabilities of enterprises but also contributes to the development of technology within the national economy [Romer 1990]. Human capital, which has a higher rate of return than physical capital, has also been identified as a significant divergence factor [Lucas 2015]. In addition, environmental damage during production has been highlighted as a potential impediment to economic growth [Nordhaus 2017].

The aim of this paper is not to study the drivers of economic growth. The objective of this study is to empirically test the convergence hypothesis. This paper aims to replicate R. Barro's equations that test the existence of convergence in per capita income over a thirty-year time horizon, between 1992 and 2021/22.

The first section presents the basic concepts associated with the concept of convergence and provides an overview of R. Barro's seminal work on the subject. Section 2 presents a contemporary discussion of economic convergence. Section 3 presents the empirical test of the hypothesis of convergence of countries since 1992. The paper concludes with a summary of the key findings.

1. History of the concept of economic equalization between developed and developing countries

The study of economic growth recognizes a number of different types of convergence [Galor 1996]. The first type is absolute convergence, which implies that developed and developing countries will eventually converge in terms of per capita income. The second type, conditional convergence, implies that countries will converge provided that a number of other factors remain constant. The structural characteristics of an economy, including the level of human capital and technology and the quality of institutions, determine the long-run equilibrium state of the economy. The greater the discrepancy between a country and its potential equilibrium state, the faster its growth. It is not the case that per capita incomes are equalized in an absolute sense. Finally, club convergence, like absolute convergence, reflects the convergence of countries in terms of per capita income, but not across the whole population, rather within distinct groups of countries defined by one or more specific criteria. These groups of countries, or "clubs," are thus characterized by similar trajectories of economic growth.

In the context of absolute convergence, two different forms of convergence can be identified: "beta-convergence" and "sigma-convergence" [Paprotny 2021. P. 194-195]. The concept of "beta-convergence" is based on the theoretical framework proposed by R. Solow [Solow 1956], according to which poorer countries tend to experience higher rates of economic growth, eventually leading to convergence with developed countries over time. "Sigma-convergence" refers to the equalization of the dispersion of GDP per capita levels in developing and developed countries [Paprotny 2021. P. 194-196].

Expectations of beta-convergence are based on the model of economic growth proposed by R. Solow. The model posits that wealthy economies quickly reach a stationary level of labor capitalization, after which economic growth slows down as it can only be sustained through total factor productivity growth. In contrast, developing economies have the potential to exploit all growth factors, especially capital growth [Solow 1956]. A limitation of the Solow model is its universalist nature. The model assumes that the patterns of economic growth in both developed and developing countries are identical, with the only difference being the quantitative parameters of certain sources of GDP growth [Mozias 2023. P. 44-45]. Therefore, the qualitative, sectoral, and individual parameters of each country are not considered.

A significant contribution to the study of catch-up development was made by R. Barro and X. Sala-i-Martin, who actually established the concept of "beta-convergence," which describes the negative relationship between the rate of economic growth and the initial level of development [Dementieva 2021. P. 511]. The beta convergence hypothesis reflects R. Solow's idea that emerging economies have higher rates of economic growth, which leads to economic equalization over time. Barro and Sala-i-Martin (1990; 1992) used a replication of Solow's neoclassical growth model to analyze economic convergence among countries between 1840 and 1988. The authors constructed a linear regression model from which they obtained a negative coefficient between the rate of economic growth per capita and the initial level of per capita income. As a result, economic inequality between the southern and northern states of the United States has decreased.

The poorer southern states have experienced faster growth than the richer northern states [Barro, Sala-i-Martin 1990, 1992].

In 1991, R. Barro et al. conducted a similar study for 73 European regions in seven countries from 1950 to 1985, and also attempted to calculate the speed of convergence of rich and poor regions across countries. The results showed that the trend of economic convergence in European regions is almost identical to the trend of equalization in US states. "The gap between the typical poor and rich state [in the US] diminishes at roughly 2% per year. We apply the same framework to patterns of convergence across 73 regions of Western Europe... The rate of convergence is again about 2 percent a year" [Barro et al. 1991. P. 108].

In subsequent studies, R. Barro shifted his focus from regional to national-level analysis. In particular, he tested the hypothesis of beta-convergence between rich and poor countries using panel data for 98 countries [Barro 1999]. As a dependent variable, Barro continued to consider the growth rate of real GDP per capita, which is the average for each of the three periods: 1965-1975, 1975-1985, and 1985-1995. The author considered the logarithm of real GDP per capita as an independent variable to identify economic convergence. In addition, the following variables were included as control variables: government consumption as a percentage of GDP, rule of law index, investment as a percentage of GDP, democracy index, and inflation rate.

Barro also found that economic growth slows down when the level of inequality within a country increases. In order to reduce international inequality, it is first necessary to address the issue of inequality within countries. "With limited access to credit, the exploitation of investment opportunities depends, to some extent, on individuals' levels of assets and incomes. Specifically, poor households tend to forego human-capital investments that offer relatively high rates of return. In this case, a distortion-free redistribution of assets and incomes from rich to poor tends to raise the average productivity of investment. Through this mechanism, a reduction in inequality raises the rate of economic growth" [Barro 1999. P. 2]. In other words, Barro noted that the reduction of intranational inequality, by increasing economic growth rates in developing countries, can ensure the reduction of the international economic gap.

2. Continuing the debate on convergence in the 21st century

The debate on economic equalization continues. The "shock distortions" of 2020-2022 raise questions about the ability of developing countries to maintain their rapid economic growth to sustain economic convergence. Grigoryev (2023) identifies four main shocks: (a) The COVID-19 pandemic shock in the form of lockdowns and its impact on the healthcare sector; (b) The shock of unique (in scale and time) anti-crisis responses by governments and central banks in 2020–2021, employing fiscal and monetary incentives; (c) An early recovery in the commodity markets and rising raw material prices under (a) and (b) in 2021–2022; (d) The sanctions shock in 2022 as a global economic issue and the EU energy collapse as a key component of it or as an individual shock.

The differing degrees of vulnerability to external shocks (the likelihood that the country's economic development will be slowed down because of them) experienced by countries in 2020-2022 led to different rates of recovery from the crisis [Morozkina et al. 2024, in press]. In the Morozkina et al. study (in press), three linear regression models were constructed. In these models, economic growth in 2020, 2021, and 2022 compared to 2019 was considered as the dependent variable, while the country's vulnerability index, indicators of macroeconomic stability, social development, and the quality of public administration were considered as independent variables. The model for economic growth in 2020 compared to 2019 was the most successful, while the models for 2022 and 2021 (compared to 2019) demonstrated poor results following the same scheme. This can be explained by the fact that the vulnerability and stability of economies determine only the first reaction [Morozkina et al. 2024, in press]. In other words, it seems likely that developing countries were only able to respond to the first shock (a) (in the form of lockdowns and health initiatives in 2020), which probably did not significantly slow their economic growth rates and thus did not lead to a halt in the convergence of developed and developing countries. However, the shocks (b), (c), and (d) that immediately followed the emergence of the coronavirus, as well as the transition of the global economy into a period of high inflation in 2022/23 [Podrugina, Lysenko 2023], reduced the fiscal and financial capacity of developing countries to cope with macroeconomic shocks, which may have hindered economic equalization across countries.

However, despite the occurrence of macroeconomic shocks between 2020 and 2022, some studies indicate that the trend of convergence between developed and developing countries remains unchanged [Daly, Gedminas 2022. P. 3]. According to the Goldman Sachs report, China, the United States, India, Indonesia, and Germany are expected to become the five largest economies in the world by 2050 in terms of gross domestic product (GDP) at purchasing power parity (PPP). Indonesia is expected to push Brazil and Russia out of the top five. By 2075, Nigeria, Pakistan, and Egypt will also be among the world's largest economies [Daly, Gedminas 2022. P. 2].

An empirical study by Solarin et al. (2023) found that both conditional and absolute economic equalization occurred in OECD countries from 1870 to 2018. Consequently, in order to achieve a reduction in inequality among OECD countries, national governments must continuously invest in education and skills development (human capital investment), thereby reducing the socio-economic gap between their citizens. In other words, the above studies have shown that there is a tendency for income inequality between countries to decrease in the long run [Daly, Gedminas 2022; Solarin et al. 2023], but income inequality within countries increases over time. This poses a significant challenge for future research, as intranational inequality hinders the narrowing of the gap between wealthy and impoverished countries [Daly, Gedminas 2022. P. 2].

Conversely, some studies have questioned the existence of convergence, even before the 2020-2022 crises. For example, the IMF report examined beta-convergence for a sample of 12 EU founding countries from 1960 to 2015, a sample of 19 EU countries from 1990 to 2015, and a sample of 28 EU countries from 1992 to 2015 [Franks et al. 2018. P. 12]. From 1960 to 1992, the EU-12 countries with relatively low GDP per capita experienced

higher economic growth rates, catching up with more developed economies. However, from 1999 to 2015, the rate of income convergence among EU-12 countries slowed and stalled, coinciding with the introduction of the euro [Franks et al. 2018. P. 11-12]. However, the economic equality of the new EU member states that joined after 2007 with their predecessors was established [Franks et al. 2018. P. 12-13]. Convergence among the EU-19 countries was maintained between 1993 and 2015, while divergence among them was observed between 1990 and 1998. In other words, the hypothesis of convergence among the 12 member states of the European Union was confirmed until the introduction of the common currency. Convergence has continued at a slow pace between the "old" and "new" EU members that joined the Union after 2007. This is partly due to the Maastricht criteria, which serve as a condition, or at least a benchmark, for EU accession.

Pritchett (1997) showed that despite the existence of examples of regional economic convergence (rapid growth of some Asian countries), developing and lagging markets diverge due to the presence of "forces" in poor countries that generate economic stagnation. Using econometric techniques, he demonstrated that "a quarter of the 60 countries with initial per capita GDP of less than $1000 in 1960 have had growth rates less than zero, and a third have had growth rates less than 0.05 percent" between 1870 and 1990 [Pritchett 1997. P. 15].

Mazumdar (2003) came to a similar conclusion using a sociological approach. He conducted a study of the living standards of countries from 1960 to 1995. The author reasoned that the studied developed and developing countries are divergent. "The convergence tests for the indicators reflecting quality of life of human beings, such as, infant survival rate, life expectancy at birth, adult literacy rate, calorie intake as percentage of requirement for the full sample as well as for three income groups indicate that in almost for all the cases for all the indicators divergence is observed rather than convergence" [Mazumdar 2003. P. 29-30].

A recent World Bank study predicts that global economic growth will slow by 2024, potentially hindering the continued progress of emerging economies [Rebello, Young 2022]. The cessation of economic growth can be attributed to the shocks that occurred between 2020 and 2022. Achieving economic convergence between developed and developing countries requires a unified international approach, which is difficult to implement due to prevailing global geopolitical tensions. This is consistent with the findings of Morozkina (2019), who suggests that it is difficult for poor nations to maintain high economic growth rates without financial support from developed nations. In the aftermath of the 2008 global financial crisis, a significant portion of this assistance became conditional.

Examining the impact of shocks in 2020-2022, Morozkina et al. (in press) conclude that "the level of fiscal measures, which has been cited in the literature as one of the main factors limiting the 2020 downturn in advanced economies, has no impact on 2020 economic growth in the sample of developing countries compared to 2019, which is likely primarily due to the relatively small amounts of fiscal support in developing countries." The lack of sufficient resources within the developing countries themselves prevented them from providing the necessary support.

3. Search for convergence in 1992-2021/2022 using the methodology of R. Barro

In this section, we apply Robert Barro's approach to identifying the economic convergence of developing and developed countries to a sample of countries for the period 1992-2021/22 (the sample is presented in Appendix 1). The objective is to test the hypothesis of a negative relationship between economic growth rate and GDP per capita in the base year. The relationship can be expressed as follows: the higher the income of the population in the base period, the lower the economic growth of the country. This confirms the assumption that wealthy countries experience a lower rate of economic growth, as postulated by R. Solow in his model of economic growth.

If there is convergence between developing and developed countries, this will be reflected in the linear regression equations for panel data. There is likely to be a negative relationship between GDP per capita for the initial period and the rate of economic growth, as in Barro's equations. Barro used a specific list of independent variables in his papers when examining the issue of convergence between developing and developed countries. Table 1 on p. 50 compares the economic analysis presented in the author's two articles, 1999 and 2013.[2]

Table 1. Comparison of two articles by R. Barro on key characteristics of equations

	"Education and Economic Growth" (2013)	**"Inequality and Growth in a Panel of Countries" (1999)**
Time period	three periods (1965-1975; 1975-1985, 1985-1995)	three periods (1965-1975;1975-1985;1985-1995)
Number of observations in complete national dataset	81, 84, 81	79, 87, 84
Dependent variable	Real GDP per capita growth rate. Growth rates averaged per period: 1965-1975; 1975-1985; 1985-1995	Real GDP per capita growth rate. Growth rates averaged per period: 1965-1975; 1975-1985; 1985-1995
Independent variables	• Logarithm of real GDP per capita at the beginning of each period. • The square of the logarithm of real GDP per capita at the beginning of each period. • Average number of years of middle and high school completed by men aged 25 and over. • Government spending, measured by education and defense spending, compared to GDP. • Trade openness coefficient, measured by the relation of the sum of export and imports to GDP. • The sum of private and state investments to GDP. • Rule of Law Index. • Inflation rate (for consumer prices). • Logarithm of the birth rate. • Average growth rate of the terms of trade (export compared to import prices) for each period.	• Logarithm of real GDP per capita at the beginning of each period. • The square of the logarithm of real GDP per capita at the beginning of each period. • Average number of years of middle and high school completed by men at the beginning of each period. • Government spending (excluding education and military spending) to GDP. • The sum of private and state investments to GDP. • Democracy Index. • Latest available value of the Rule of Law Index (1982 and 1985) for the first two equations, and the average value over the period for the third equation. • Inflation level. • Logarithm of the birth rate. • Average growth rate of the terms of trade (export compared to import prices) for each period.

[2] Frequently used independent variables in the author's equations. In the present study, two works by Barro 15 years apart were taken as examples: Barro, R., 2013. Education and Economic Growth. P. 306, 313-319; Barro, R., 1999. Inequality and Growth in a Panel of Countries. P. 28.

Coefficient of determination (examined separately for each time period)	0.62, 0.50, 0.47	0.67, 0.49, 0.41
Resulting equation	Y(1965-1995) = 0.107*log(per capita GDP) – 0.0084*log(per capita) squared + 0.0044*male upper school – 0.157*government expenditures/ GDP + 0.0138* rule of law index + 0.133*openness ratio – 0.0137*inflation rate – 0.0275*log(total fertility rate) + 0.033*investment/GDP – 0.0142*openness ratio*log(GDP)	Y(1965-1995) = 0.123*log(per capita GDP) – 0.0095*log(per capita) squared – 0.149*government expenditures/GDP + 0.0173* rule of law index + 0.053*democracy index – 0.037*inflation rate + 0.0072*years of schooling – 0.0250*log(total fertility rate) + 0.059*investment/GDP + 0.164*growth rate of terms of trade

Source: complied by the author on the basis of: Barro, R., 2013. Education and Economic Growth. P. 306, 308; Barro, R., 1999. Inequality and Growth in a Panel of Countries. P. 28, 37, 38.

Thus, by analyzing the various indicators from Table 1 that Barro used in two different equations 15 years apart, we can identify the set of determinants of economic growth that he used. In Table 2 on p. 51 they are compared with the variables used in this study.

Table 2. Independent variables in R. Barro's articles and in this study

Determinants of economic growth in Robert Barro's articles									
Labor		Capital	Quality of institutions		Economic liberalization		Indicators of macroeconomic stability		
Fertility	Education among men	Sum of private and state investments	Democracy Index	Rule of Law Index	Growth rate of the terms of trade	Openness of the economy	Inflation	Government spending on education and defense	Government spending except education and defense

Determinants of economic growth used in the model of this study					
Volume of fixed capital	Quality of institutions	Economic liberalization	Indicators of macroeconomic stability		
Gross capital formation	Rule of Law Index	Openness of the economy	Inflation	Public expenditure on education and defense	Unemployment

Source: compiled by the author on the basis of: Barro, R., 2013. Education and Economic Growth. P. 306, 308; Barro, R., 1999. Inequality and Growth in a Panel of Countries. P. 28, 37, 38.

There are several peculiarities to note about this study. The first is the time period. Barro's studies looked at data between 1960 and 1995. The present study covers the last 30 years: from 1992 to 2021/22, including the coronavirus shock and the geopolitical crisis of 2022. Additionally, the data in this paper are divided into three separate decades: 1992-2001, 2002-2011, and 2012-2021. The periods have been chosen to cover the full business cycle (rather than the "round" decades in Barro's works). This eliminates the influence of crises, which may have been unevenly distributed across the periods [Grigoryev 2023]. In addition, the 2012-2022 cycle and the panels for the entire period (1992-2021 and 1992-2022) are considered separately.

Another feature is the relatively simplified equation form. In practical works, Barro considered the effect of two independent logarithmic variables on the average growth rate of real GDP simultaneously: the logarithm of GDP per capita for the base period and the square of the logarithm of GDP per capita (see Table 1 on p. 50). In this study, only the log of GDP per capita is used to simplify the explanation of convergence.

Two models are based on panel data for the entire period under consideration (1992-2021 and 1992-2022 models). Another four models are based on spatial data for individual decades (the last decade is represented in the 2012-2021 and 2012-2022 versions).

The dependent variable is the calculated average economic growth rate of countries based on the annual GDP (PPP) in 2017 in constant international US dollars on average over decades: GDP (1992–2001), GDP (2002–2011), and GDP (2012–2021).

The independent variables considered are:

- Unemployment or total employment (% of total labor force).
- Consumer price index (2010 = 100).
- Gross capital formation (% of GDP).
- Openness of the economy (sum of exports and imports as % of GDP).
- Rule of law (-2.5 to 2.5).[3]
- Government spending on education and defense (% of GDP).[4]
- Logarithm of GDP per capita for the base (reference) year.

All independent variables are calculated as decade averages for each country. The independent variable "logarithm of GDP" is given in the models for 1991, 2001, and 2011.

Table 3. Correlation matrix of dependent and independent variables for the period 1992-2021

	Average economic growth rate (y)	Log (GDP 1991)	CPI	Unemployment	Gross capital formation	Openness of the economy	Rule of law	Government spending
Average economic growth rate (y)	1							
Log(GDP 1991)	-0.148*	1						
CPI	-0.063	-0.050	1					
Unemployment	-0.003	0.121*	-0.023	1				
Gross capital formation	0.428***	0.056	-0.109*	-0.044	1			
Openness of the economy	0.156**	0.364***	-0.005	-0.019	0.154*	1		
Rule of law	-0.22	0.707***	-0.091	-0.035	0.073	0.335***	1	
Government spending	-0.076	0.254***	-0.022	0.004	0.095	0.083	0.059	1

Source: calculated by the author on the basis of World Bank data (n.d.).

Note: * $p \le 0{,}05$, ** $p \le 0{,}01$, *** $p \le 0{,}001$.

[3] Reflects the quality of institutions and mechanisms for governing society in a country as well as the degree to which people trust and abide by rules.

[4] According to Barro's relatively "new" 2013 paper "Education and Economic Growth."

The growth rate of real GDP per capita may be correlated with the explanatory variables "in two directions," creating an endogeneity problem that can lead to low explanatory power of the model and biased estimates. The 1992-2021 panel model passed all tests (Appendix 6) except the cross-sectional dependence test, which confirms the "endogeneity problem." To avoid the "endogeneity problem" in the present study, the models are calculated using two-stage least squares (2SLS) with lagged values (lag of 5 years) of the independent variables used as instrumental variables [Barro 2016. P. 3]. All tests (for heteroscedasticity, multicollinearity, model specification, autocorrelation of residuals, cross-sectional dependence, and serial correlation in panels) are presented in Appendices 2-7.[5]

The 1992-2022 model failed the tests for serial correlation and model specification (Appendix 7). In general, it turned out to be of lower "quality" than the 1992-2021 model. Obviously, the deterioration in the quality of the model is caused by the addition of the crisis year 2022. Moreover, there is a decrease in the estimate of the coefficient of log GDP from 0.09 to 0.08, i.e., a slowdown in convergence. This decrease is not significant, but it can be explained either by the sanctions and counter-sanctions of 2022, which could be a catalyst to slow down the convergence of developing and developed countries, or by the sharp decline in China's economic growth, which showed continuous growth during 2001-2019. The average real GDP growth rate in China from 2001 to 2019 is about 9%.[6] If in 2018 and 2019 China maintained stable economic growth rates of 6.6 and 6.1%, respectively, the country's real GDP growth rates were 2.3 and 3% during the 2020 coronavirus and the 2022 geopolitical crisis, respectively [IMF 2019, 2020, 2022, 2021, 2023]. On average, the PRC's economic growth rate for 2020-2023 was 4.65, compared with 6.62% for 2016-2019.[7]

The results of the regression models are shown in Table 4 on page 54. In all models, the coefficient on log GDP per capita for the base year is significant, confirming the convergence hypothesis.

So why is there no visible success in closing the development gap? The question of convergence is not a question of its presence or absence but of the "speed of convergence" of developing and developed countries [Grigoryev et al. 2022. Chapter 1]. "According to the 'iron law of convergence,' countries eliminate gaps in levels of real per capita GDP at a rate around 2% per year. Convergence at a 2% rate implies that it takes 35 years for half of an initial gap to vanish and 115 years for 90% to disappear" [Barro 2012. P. 3]. Grigoryev and Maykhrovich (2023) have already tried to calculate the number of years

[5] Models in which heteroscedasticity was detected by the Breusch-Pagan test are considered taking into account robust errors. For panel models, the Lagrange multiplier test was applied. In the case of the 1992-2021 panel model, the p-value was found to be 0.04, below the 5% significance level but above the 1% significance level, while the other 1992-2022 panel passed the test for any reasonable significance level. Autocorrelation of residuals according to the results of the Durbin-Watson test is not present in the models. The specification of the models, according to the results of the Ramsey test, is correct except for the model for spatial data for 2012-2021, although the 2012-2022 model passed the specification test. There is no multicollinearity of the variables. The series are stationary by the Dickey-Fuller test. Inspection of the Hausman test shows that the fixed effects model has the best quality. Serial correlation by the Breusch-Godfrey test is absent in the 1992-2021 panel series, while it is present in the 1992-2022 model.

[6] Calculated on the IMF data (World Economic Outlook).

[7] Calculated on the IMF data (World Economic Outlook).

of lag between developing and developed countries by calculating the number of years needed to double GDP. The poorest countries in the sixth and seventh income clusters (seven clusters in total) need 47 and 100 years, respectively, to double GDP per capita at these average annual GDP growth rates (1.49% for the sixth cluster and 0.7% for the seventh cluster). GDP growth rates are much higher for clusters 3-5, but even they take decades to move to a higher cluster. "Developing countries are growing faster than the most developed countries, but they are 'not catching up'..." [Grigoryev, Maykhrovitch 2023. P. 31, 34].

Table 4. Results of regression model building

	Panel regression using the 2SLS method		Linear regression model built on average spatial data, 2SLS			
	Fixed effects model 1992-2021. Including instrumental variables	Fixed effects model 1992-2022. Including instrumental variables	Model 1992-2001	Model 2002-2011	Model 2012–2021 taking into account robust errors	Model 2012–2022 taking into account robust errors
Constant	0.174*** (0.009)	0.282*** (0.01)	0.058** (0.021)	0.11*** (0.019)	0.119** (0.045)	0.118* (0.049)
Log GDP base	-0.09*** (0.018)	-0.081*** (0.018)	-0.008** (0.002)	-0.005** (0.002)	-0.0089• (0.005)	-0.0088• (0.005)
Gross capital formation	0.197*** (0.02)	0.157*** (0.02)	0.001*** (0.0003)	0.002*** (0.0002)	-	-
Rule of law	0.028• (0.016)	0.026• (0.015)	0.014*** (0.003)	-	0.013* (0.006)	0.014* (0.006)
Openness of the economy	0.082*** (0.023)	0.074*** (0.022)	-	-	-	-
Unemployment	-	0.028• (0.017)	-	-	-	-
CPI	-	-	-	-0.001*** (0.0002)	-	-
Public expenditure	-	-	-	-	-0.0091* (0.004)	-0.0086* (0.004)
N	405	405	115	147	143	143
R^2	0.246	0.188	0.3	0.403	0.197	0.157
R^2_{adj}	0.238	0.178	0.281	0.390	0.180	0.138
Residual standard error	0.057	0.056	0.02	0.02	0.029	0.032

Source: calculated by the author on the basis of World Bank data (n.d.).
Note: significance score *** 0.001, ** 0.01, *0.05, • 0,1.

Comparing the equations by decade, we find a decrease in the coefficient for log GDP per capita in base year in the second decade (-0.005 compared to -0.008) and an increase in the third decade (-0.009). This implies that the speed of convergence of countries has increased in the 2012-2021 period compared to the 2002-2011 period. Perhaps the reason for the slowdown in convergence between developed and developing countries between 2002 and 2011 was the global financial crisis of 2008-2009. Perhaps the subsequent

strengthening of convergence is attributable to the slowdown in the growth rates of developed countries in the last decade.

The fourth equation for 2012-2022 is not very different from the third equation for 2012-2021. Therefore, the conclusion about the slowdown in convergence in 2022 can only be drawn from the panel series analysis. In the spatial data, the addition of the crisis year 2022 has no significant effect on the slowdown of economic convergence across countries.

Let us also look at the evolution of the contribution of capital investment to economic growth. In two decades (1992-2001 and 2002-2011) it is significant, while in the equation of the third decade (2012-2021 and 2012-2022) it is insignificant. The lack of significance of the factor of gross capital formation in the third decade can be explained by two reasons. The first is the long recovery within 5-10 years after the Great Recession. Gross capital formation "collapsed" during the 2008 crisis, but it was not reflected in the equation until the third period: 2012-2021. "The economic crisis of 2008-2009... posed a challenge to established growth patterns... The reduced rate of accumulation in all major developed economies has not yet resulted in growth rates comparable to those of the 1990-2000s. Perhaps this was evidence of the transition to a new stationary regime, with relatively low growth rates, relatively high volatility, greater dependence of economic dynamics on developing countries" [Grigoryev, Makarova 2019. P. 51].

The second possible reason for the disappearance of the importance of investment in the third period (2012-2022) is the appearance of a significant coefficient before government spending (probably also due to large anticrisis injections in 2020-2022) and its displacement of investment. In general, there is a lot of debate on the issue of private versus public investment and the nature of its impact on economic growth. Barro, for example, found a significant negative impact of government spending on education and defense [Barro 2013. P. 313].

The rule of law factor is significant in 1992-2001 and 2012-2021, and insignificant in 2002-2011. During global recessions, economic decline can have a number of political consequences: an increase in the level of corruption within government bodies, a weakening of institutional mechanisms, and a decrease in support for the democratic order [Gasiorowski 1995]. In 2009, incumbent parties lost elections, including in countries (such as Iceland, Japan) where they had been in power for decades; in Latvia and Greece, distrust of governments and economic regulators led to mass protests [Olafsson 2016; Katada 2013; Aslund 2009; Kanellopoulos & Kousis 2018]. Several large countries, including Brazil and Russia, fell into the middle-income development trap for a long time after the 2008-2009 crisis for institutional reasons [Grigoryev, Makarova 2019. P. 33].

Conclusion

Economic convergence as one of the key issues within the topic of cross-country inequality is currently hotly debated among economists and social scientists: some believe that countries are absolutely divergent, and therefore, the gap between the rich and poor economies of the world will grow over time; others express the opposite view and believe that, on the contrary, countries are converging and the economic divergence between nations tends to decrease in the long run.

This paper has been able to reproduce Robert Barro's equations and illustrate the existence of an economic equalization effect between developed and developing countries over the period 1992-2021 and even 1992-2022. However, convergence does not mean that developing countries are catching up with developed countries. The catch-up effect is not visible in practice because the speed of convergence between these groups of countries is too slow. Barro said the same thing about regions ("...if the histories of the US states and European regions are useful guides, then the convergence process will occur, but only at a slow pace" [Barro et al. 1991. P. 108]). This is even more true for countries where absolute convergence is complicated by differences in institutions.

A separate regression analysis was carried out for ten-year periods. The slowest convergence was observed between 2002 and 2011, despite the impressive growth rates of the leading emerging economies (including the BRICS) in the first half of this period. The main reason for the slowdown is likely to be the economic crisis of 2008-2009. Convergence accelerates in 2012-2021, mainly due to the slowdown in economic growth in developed economies. Economic shocks in 2020-2022 are expected to undermine the catching-up potential of developing economies (especially poor countries), and as a result convergence may slow down in the future.

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APPENDICES

Appendix 1

Countries for which statistical data was available between 1991 and 2001									
1	Albania	26	Chad	51	Haiti	76	Morocco	101	Sudan
2	Algeria	27	Chile	52	Honduras	77	Nepal	102	Sweden
3	Angola	28	China	53	Hungary	78	Netherlands	103	Switzerland
4	Argentina	29	Colombia	54	India	79	New Zealand	104	Tajikistan
5	Armenia	30	Comoros	55	Indonesia	80	Nicaragua	105	Tanzania
6	Australia	31	DR Congo	56	Iran	81	Niger	106	Thailand
7	Austria	32	Costa Rica	57	Ireland	82	Nigeria	107	Togo
8	Azerbaijan	33	Côte d'Ivoire	58	Italy	83	North Macedonia	108	Tunisia
9	Bahamas	34	Cyprus	59	Jamaica	84	Norway	109	Turkey
10	Bahrain	35	Czech Republic	60	Japan	85	Oman	110	Uganda
11	Bangladesh	36	Denmark	61	Jordan	86	Pakistan	111	Ukraine
12	Belarus	37	Dominican Republic	62	Kazakhstan	87	Panama	112	UK
13	Belgium	38	Ecuador	63	Kenya	88	Paraguay	113	US
14	Belize	39	Egypt	64	Korea, Rep.	89	Peru	114	Uruguay
15	Benin	40	El Salvador	65	Kyrgyzstan	90	Philippines	115	Vietnam
16	Bhutan	41	Eswatini	66	Laos	91	Poland		
17	Bolivia	42	Finland	67	Luxembourg	92	Portugal		
18	Botswana	43	France	68	Madagascar	93	Romania		
19	Brazil	44	Gabon	69	Malaysia	94	Russia		
20	Brunei	45	Gambia	70	Mali	95	Rwanda		
21	Bulgaria	46	Germany	71	Malta	96	Saudi Arabia		
22	Burkina Faso	47	Ghana	72	Mauritania	97	Senegal		
23	Burundi	48	Greece	73	Mauritius	98	Singapore		
24	Cameroon	49	Guatemala	74	Mexico	99	Spain		
25	CAR	50	Guinea-Bissau	75	Mongolia	100	Sri Lanka		
Countries for which statistical data was available for the period 2001-2011									
1	Albania	31	Chile	61	Honduras	91	Mauritius	121	Senegal
2	Algeria	32	China	62	Hungary	92	Mexico	122	Serbia
3	Angola	33	Colombia	63	Iceland	93	Moldova	123	Sierra Leone
4	Argentina	34	Comoros	64	India	94	Mongolia	124	Singapore
5	Armenia	35	DR Congo	65	Indonesia	95	Montenegro	125	Slovakia
6	Australia	36	Congo, Republic of.	66	Iran	96	Morocco	126	Slovenia
7	Austria	37	Costa Rica	67	Iraq	97	Mozambique	127	South Africa
8	Azerbaijan	38	Côte d'Ivoire	68	Ireland	98	Myanmar	128	Spain

9	Bahamas	39	Croatia	69	Israel	99	Namibia	129	Sri Lanka
10	Bahrain	40	Cyprus	70	Italy	100	Nepal	130	Sudan
11	Bangladesh	41	Czech Republic	71	Jamaica	101	Netherlands	131	Sweden
12	Belarus	42	Denmark	72	Japan	102	New Zealand	132	Switzerland
13	Belgium	43	Dominican Republic	73	Jordan	103	Nicaragua	133	Tajikistan
14	Belize	44	Ecuador	74	Kazakhstan	104	Niger	134	Tanzania
15	Benin	45	Egypt	75	Kenya	105	Nigeria	135	Thailand
16	Bhutan	46	El Salvador	76	Korea, Rep.	106	North Macedonia	136	Togo
17	Bolivia	47	Equatorial Guinea	77	Kuwait	107	Norway	137	Tunisia
18	Bosnia and Herzegovina	48	Estonia	78	Kyrgyzstan	108	Oman	138	Turkey
19	Botswana	49	Eswatini	79	Laos	109	Pakistan	139	Uganda
20	Brazil	50	Finland	80	Latvia	110	Panama	140	Ukraine
21	Brunei	51	France	81	Lebanon	111	Paraguay	141	UAE
22	Bulgaria	52	Gabon	82	Lesotho	112	Peru	142	UK
23	Burkina Faso	53	Gambia	83	Libya	113	Philippines	143	US
24	Burundi	54	Georgia	84	Lithuania	114	Poland	144	Uruguay
25	Cape Verde	55	Germany	85	Luxembourg	115	Portugal	145	Vietnam
26	Cambodia	56	Ghana	86	Madagascar	116	Qatar	146	Zambia
27	Cameroon	57	Greece	87	Malaysia	117	Romania	147	Zimbabwe
28	Canada	58	Guatemala	88	Mali	118	Russia		
29	CAR	59	Guinea	89	Malta	119	Rwanda		
30	Chad	60	Guinea-Bissau	90	Mauritania	120	Mauritius		
Countries for which statistical data was available for the period 2011-2021									
1	Albania	30	Chile	59	Honduras	88	Mauritania	117	Saudi Arabia
2	Algeria	31	China	60	Hungary	89	Mauritius	118	Senegal
3	Angola	32	Colombia	61	Iceland	90	Mexico	119	Serbia
4	Argentina	33	Comoros	62	India	91	Moldova	120	Sierra Leone
5	Armenia	34	DR Congo	63	Indonesia	92	Mongolia	121	Singapore
6	Australia	35	Congo, Republic of.	64	Iran	93	Morocco	122	Slovakia
7	Austria	36	Côte d'Ivoire	65	Iraq	94	Mozambique	123	Slovenia
8	Azerbaijan	37	Cyprus	66	Ireland	95	Myanmar	124	South Africa
9	Bahamas	38	Czech Republic	67	Israel	96	Namibia	125	Spain
10	Bahrain	39	Denmark	68	Italy	97	Nepal	126	Sri Lanka
11	Bangladesh	40	Dominican Republic	69	Jamaica	98	Netherlands	127	Sudan
12	Belarus	41	Ecuador	70	Japan	99	New Zealand	128	Sweden
13	Belgium	42	Egypt	71	Jordan	100	Nicaragua	129	Switzerland
14	Belize	43	El Salvador	72	Kazakhstan	101	Niger	130	Tanzania

15	Benin	44	Equatorial Guinea	73	Kenya	102	Nigeria	131	Thailand
16	Bhutan	45	Estonia	74	Korea, Rep.	103	North Macedonia	132	Togo
17	Bosnia and Herzegovina	46	Eswatini	75	Kuwait	104	Norway	133	Tunisia
18	Botswana	47	Finland	76	Kyrgyzstan	105	Oman	134	Turkey
19	Brazil	48	France	77	Laos	106	Pakistan	135	Uganda
20	Brunei	49	Gabon	78	Latvia	107	Panama	136	Ukraine
21	Bulgaria	50	Gambia	79	Lebanon	108	Paraguay	137	UAE
22	Burkina Faso	51	Georgia	80	Lesotho	109	Peru	138	UK
23	Burundi	52	Germany	81	Lithuania	110	Philippines	139	US
24	Cape Verde	53	Ghana	82	Luxembourg	111	Poland	140	Uruguay
25	Cambodia	54	Greece	83	Madagascar	112	Portugal	141	Vietnam
26	Cameroon	55	Guatemala	84	Malaysia	113	Qatar	142	Zambia
27	Canada	56	Guinea	85	Maldives	114	Romania	143	Zimbabwe
28	CAR	57	Guinea-Bissau	86	Mali	115	Russia		
29	Chad	58	Haiti	87	Malta	116	Rwanda		

Appendix 2: Tests for the 1992-2001 model

Heteroscedasticity test

Studentized Breusch-Pagan test

data: model9201_new_2
BP = 7.5072, df = 3, p-value = 0.05737

Ramsey test for model specification

RESET test

data: model9201_new_2
RESET = 2.6331, df1 = 2, df2 = 109, p-value = 0.07643

Durbin-Watson test for autocorrelation of residuals

log	Autocorrelation	D-W Statistic	p-value
1	0.01875309	1.81539	0.354

Alternative hypothesis: rho ! = 0

Checking multicollinearity

lngdp91	gcf9201	rule9201
2.083574	1.104772	2.012376

Appendix 3: Tests for the 2002-2011 model

Heteroscedasticity test

Studentized Breusch-Pagan test

data: model0211_new

BP = 0.91876, df = 3, p-value = 0.8209

Ramsey test for model specification

RESET test

data: model0211_new_2

RESET = 0.92956, df1 = 2, df2 = 141, p-value = 0.3971

Durbin-Watson test for autocorrelation of residuals

log	Autocorrelation	D-W Statistic	p-value
1	-0.0286838	2.047328	0.758

Alternative hypothesis: rho ! = 0

Checking multicollinearity

lngdp01	cpi0211	gcf0211
1.301415	1.303965	1.020979

Appendix 4: Tests for the 2012-2021 model

Heteroscedasticity test

Studentized Breusch-Pagan test

data: model1221_new

BP = 15.728, df = 3, p-value = 0.001289

Ramsey test for model specification

RESET test

data: model1221_new_2

RESET = 6.751, df1 = 2, df2 = 137, p-value = 0.001599

Durbin-Watson test for autocorrelation of residuals

log	Autocorrelation	D-W Statistic	p-value
1	-0.004291123	2.00379	0.986

Alternative hypothesis: rho ! = 0

Checking multicollinearity

lngdp11	rule1221	gov1221
2.253413	2.216129	1.099163

Appendix 5: Tests for the 2012-2022 model

Heteroscedasticity test

Studentized Breusch-Pagan test

data: model1222_new

BP = 15.728, df = 3, p-value = 0.003214

Ramsey test for model specification

RESET test

data: model1221_new_2

RESET = 2.0589, df1 = 2, df2 = 135, p-value = 0.1316

Durbin-Watson test for autocorrelation of residuals

log	Autocorrelation	D-W Statistic	p-value
1	-0.01250238	2.019042	0.946

Alternative hypothesis: rho ! = 0

Checking multicollinearity

lngdp11	rule1222	gov1222
2.155528	2.164836	1.069975

Appendix 6: Tests for the 1992-2021 model

Stationarity test

Augmented Dickey-Fuller Test

data: consol$GDPch

Dickey-Fuller = -11.567, Lag order = 2, p-value = 0.01

alternative hypothesis: stationary

Hausman test for model selection with fixed or random effects

Hausman Test

data: GDPch ~ logGDP + gross_capital_formation + trade_gdp + rule_of_law

chisq = 275.13, df = 4, p-value < 2.2e-16

alternative hypothesis: one model is inconsistent

Lagrange multiplier test for heteroscedasticity verification

Lagrange Multiplier Test - (Breusch-Pagan)

data: GDPch ~ logGDP + CPI + gross_capital_formation + trade_gdp + ...

chisq = 4.1253, df = 1, p-value = 0.04225

alternative hypothesis: significant effects

Breusch-Godfrey test for serial correlation

Breusch-Godfrey/Wooldridge test for serial correlation in panel models

data: GDPch ~ logGDP + CPI + gross_capital_formation + trade_gdp + …

chisq = 1.7608, df = 1, p-value = 0.1845

alternative hypothesis: serial correlation in idiosyncratic errors

Pesaran CD test for cross-sectional dependence in panels

Pesaran CD test for cross-sectional dependence in panels

data: GDPch ~ logGDP + CPI + gross_capital_formation + trade_gdp + rule_of_law

z = 23.679, p-value < 2.2e-16

alternative hypothesis: cross-sectional dependence

Ramsey test for model specification

RESET test

data: iv_model_stage_fe

RESET = 2.1535, df1 = 2, df2 = 411, p-value = 0.1174

Durbin-Watson test for autocorrelation of residuals

Durbin-Watson test

data: iv_model_stage_fe

DW = 1.9015, p-value = 0.1552

alternative hypothesis: true autocorrelation is greater than 0

Appendix 7: Tests for the 1992-2022 model

Dickey-Fuller stationarity test

Augmented Dickey-Fuller Test

data: consol$GDPch

Dickey-Fuller = -11.567, Lag order = 2, p-value = 0.01

alternative hypothesis: stationary

Hausman test for model selection with fixed or random effects

Hausman Test

data: GDPch ~ logGDP + CPI + gross_capital_formation + trade_gdp + unemployment + rule_of_law + …

chisq = 155.98, df = 5, p-value < 2.2e-16

alternative hypothesis: one model is inconsistent

Lagrange multiplier test for heteroskedasticity verification

Lagrange Multiplier Test - (Breusch-Pagan)

data: GDPch ~ logGDP + gross_capital_formation + unemployment + rule_of_law + …

chisq = 0.63775, df = 1, p-value = 0.04245

alternative hypothesis: significant effect

Breusch-Godfrey test for serial correlation

Breusch-Godfrey/Wooldridge test for serial correlation in panel models

data: GDPch ~ logGDP + gross_capital_formation + unemployment + rule_of_law + …

chisq = 81.767, df = 1, p-value < 2.2e-16

alternative hypothesis: serial correlation in idiosyncratic errors

Pesaran CD test for cross-sectional dependence in panels

Pesaran CD test for cross-sectional dependence in panels

data: GDPch ~ logGDP + gross_capital_formation + unemployment + rule_of_law + … trade_gdp

z = 7.8186, p-value = 5.34e – 15

alternative hypothesis: cross-sectional dependence

Ramsey test for model specification

RESET test

data: iv_model_stage_fe

RESET = 45.973, df = 2, df2 = 407, p-value < 2.2e-16

Durbin-Watson test for autocorrelation of residuals

Durbin-Watson test

Data: iv_model_stage_fe

DW = 1.9778, p-value = 0.4057

alternative hypothesis: true autocorrelation is greater than 0