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TFP AND GLOBAL GROWTH: SHAPING CROSS-COUNTRY INCOME INEQUALITY, 1960–2019

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Abstract

This study examines global economic growth and cross-country income inequality from 1960 to 2019 using a stochastic dynamic general equilibrium model. Total factor productivity (TFP), captured through the efficiency wedge, primary drives global output growth and shapes income disparities. Distortions in capital and labour markets —represented by the investment and labour wedges— play secondary, context-specific roles, notably reducing growth in middle-income countries. Two major waves of global growth —post-war industrialization and globalization-driven technological diffusion— can explain TFP predominance. Cluster analysis confirms the central role of TFP in both growth miracles and failures. Global shocks like the 1973 oil crisis and 2008 recession slowed growth, particularly in high-income countries, narrowing cross-country income disparities. Since the 2000s, TFP gains in emerging economies reduced inequality. These findings highlight the theoretical and policy relevance of TFP-centered growth models and the importance of policies promoting trade openness, institutional quality, and innovation to enhance TFP and foster inclusive growth and convergence.

Keywords: Total Factor Productivity; Economic Growth; Income Inequality; Cross-Country Analysis; Business Cycle Accounting; Efficiency Wedge; Structural Distortions; Institutions and Development; Global Convergence; σ-Convergence

JEL classification: C68, E13, E17, E25, O40, O41, O47.

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1 Introduction

Attempts to describe world economic growth synthetically and to establish stylized facts have a long tradition in economics going back at least as far as Kaldor (1957) and his famous stylized facts. More recently, Jones and Romer (2010) have extended and established new facts by taking into consideration not only physical capital accumulation, but also ideas, institutions, population and human capital. Jones (1997) analysed world economic growth and characterized the evolution of cross-country income distribution between 1950 and 1988.

Our purpose is to analyse world economic growth from 1960 to 2019 identifying its driving forces and its consequences on the distribution of world income across countries with the aim of finding some remarkable features that can guide future research on economic growth and development. To do so, we follow an accounting approach: we use the standard Dynamic Stochastic General Equilibrium (DSGE) model to extract empirical regularities on the driving forces of economic growth. Therefore, the facts are stated explicitly in the light of the theory. In particular, we perform a *Business Cycle Accounting* (BCA) exercise according to the method developed by Chari et al. (2007), Brinca et al. (2016), and applied to long-run growth as in Hansen et al. (2021). Del Río and Lores (2021, 2023) perform similar exercises on economic growth with emphasis on the factorial distribution of income using the neoclassical growth model in its perfect foresight version. Brinca et al. (2024) review the BCA literature.

The adaptation of the BCA method to our objective involves several steps. The first stage of the method consists of formulating a model and using the linear decision rules of the model to estimate by maximum likelihood, using the Kalman filter, a VAR that governs the stochastic variables of the model in each country. The second stage consists of obtaining the wedge measure for each country using the model's decision rules to reproduce the model's observable variables. These wedges mainly reflect market distortions and frictions and reconcile the equilibrium conditions of the DSGE model with the evolution of the main macromagnitudes of the national accounts of each country. In the third stage, experiments are conducted by simulating the behaviour of each country's economy with a single wedge, leaving the other wedges constant at their steady state value. This makes it possible to calculate the contribution of each wedge to the evolution of each country's output and resource allocation. Finally, statistics characterising the evolution of world growth and its distribution across countries are constructed using the components obtained for each country. By doing so, we can characterize world economic growth and the evolution of the cross-country distribution of income per capita in terms not only of the behaviour of the observed variables, but also in terms of the underlying wedge contribution.

This method of empirical exploration is a natural continuation of the growth accounting carried out in Solow's (1957) pioneering article. In this work, the author uses the production function as well as output, input and price data to infer the change rate of Total Factor Productivity (TFP). The author concludes that what was called the Solow Residual accounts for a significant part of the productivity growth rate. Solow's work was of extreme importance for the Theory of Economic Growth because the fact established by Solow served as a guide to future researchers, who realized that, if they wanted to understand economic growth in both the short and long term, they had to theorize about the determinants of the evolution of TFP. Jorgerson and Vu (2015) perform a growth accounting exercise *à la* Solow (1957) for the world economy.

In our work we do something similar and derive the evolution of TFP for each country, which we call the efficiency wedge. But we do not stop there. We also simulate the standard DSGE model for the calculated evolution of the efficiency wedge. This allows us to know the response of the endogenous variables (investment, hours worked and output) to the observed changes in the efficiency wedge. Knowing this response is something that traditional growth accounting *à la* Solow (1957) does not allow. Moreover, using the rest of the equilibrium conditions of the standard DSGE model, we infer four additional wedges (investment, labour, resources, and population) whose behaviour may also be relevant for understanding global economic growth. We also simulate the model for the calculated evolution of each of these wedges.

Like the work of Solow (1957), our analysis aims at finding some empirical regularities that can serve as a guide for future research. Our main result extends Solow's result. He found that a large part of output growth is due to growth in TFP. We find that not only is this the case, but that global growth was mainly driven by changes in the TFP because, as the simulation of the model shows, changes in the factors of production, capital and labour, and hence in output, are mainly the endogenous response to changes in the TFP. The relevance of the other wedges in explaining the evolution of world output per capita is small.

We use data of the Penn World Table 10.0 (Feenstra et al. 2015) for a large sample of countries since 1960. The country sample grows over time. In 1960, it includes 91 countries, in 1970, 43 new countries enter, and in 1990, 23. Some other countries enter the sample in other years, but they represent a small number (see Figure 1). We analyse world economic growth since 1960 because it is from this year that most of countries and world population are represented in the sample. The sample starts in 1950 with only 55 countries and, in 1960, 26 new countries enter. Before 1960, there is an over-representation of rich countries and the analysis would probably be biased. India is already in the sample in 1950 and China enters in 1952. In 1960, many African countries and all the large countries are included in the sample. Thus, since 1960, the sample includes most of the world's population and a broad selection of developed and developing countries. In particular, in 1960 it includes about 86% of world population and in 2019 about 98%. The country with the largest population that enters the sample after 1960 is Russia in the year 1990.

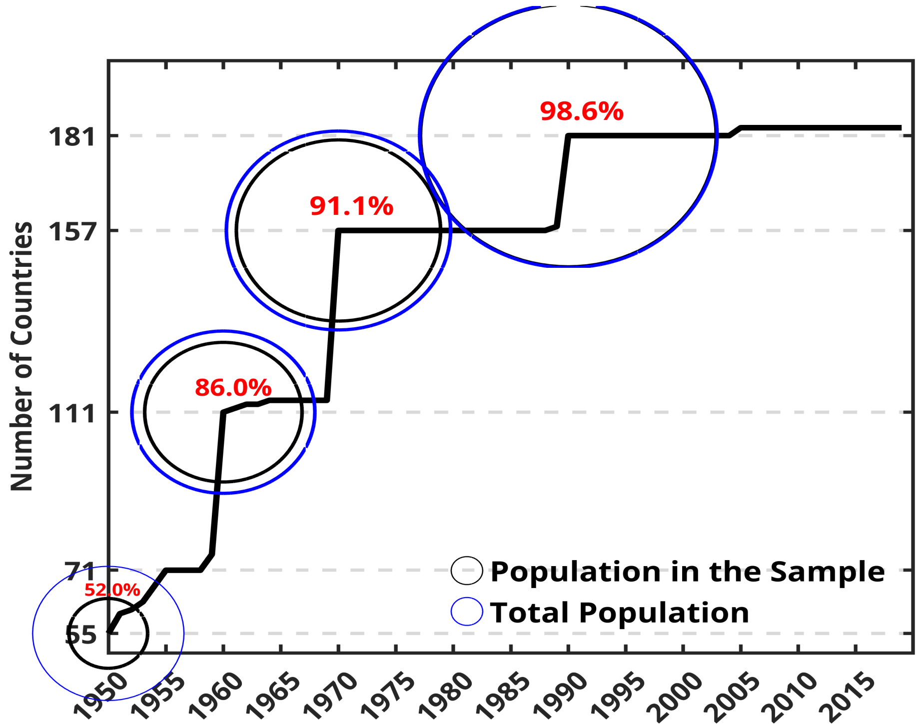


Figure 1: Countries in the sample and their coverage of the total population.

Note: The solid line indicates the number of countries in the sample over time. The numbers inside the circles are the percentages of the total population whose countries were part of the sample in the years 1950, 1960, 1970 and 1990. The total population source is UN, World Population Prospects (2024).

In this paper, we will focus our attention on four statistics that summarize world economic growth across countries: (i) the world income per capita, whose evolution reflects the world economic growth; (ii) the standard deviation of the cross-country distribution of income per capita, which reflects the dispersion of growth across countries and its evolution the so-called σ-convergence (resp. divergence) if the standard deviation decreases (resp. increases); (iii) the interquartile range, which indicates the polarisation of the cross-country distribution of income per capita; and, finally, (iv) a Theil index of the population-weighted cross-country distribution of income per capita, which is a measure of inequality in the distribution of world income across countries.[1]

Our analysis reveals that the two great growth waves that swept the world between 1960 and 2019 —the first between 1960 and 1994, with a peak in 1973 (the oil crisis), and the second between 1995 and 2019, with a peak in 2011 (the European debt crisis)— were conducted almost exclusively by the efficiency wedge both in their upturn and downturn, although all other wedges contributed to reducing the pace of global economic growth. During the first period of high growth (1960-1973), the investment wedge drove the increase in the cross-country dispersion of income per capita, while, during the second period of high growth (1995-2011), the efficiency wedge —which had driven the increase in dispersion between 1985 and 1995 —, primarily drove the rapid decline in dispersion, although the investment wedge also played a significant, but secondary, role. The efficiency wedge also was the main driving force of the increase in polarisation in the cross-country distribution of income per capita until the beginning of the 21st century as well as of its rapid decline thereafter. Likewise, the efficiency wedge was responsible for the rapid decline in inequality so far in the 21st century.

In our view, during the first wave, the improvement in TFP may have reflected the benefits of the second industrial revolution and the new international order that emerged after the Second World War.[2] But these benefits were concentrated in rich countries, leading to increased dispersion, polarisation and inequality. In some developing countries, barriers to productive investment —reflected in the investment wedge— made matters worse. In the second wave, the improvement in TFP reflected the benefits of two processes that gained particular momentum from the mid-1980s onwards: globalisation and new information technologies. It was not until the end of the last century that the benefits of these processes reached many populous emerging economies, even though globalisation and new technologies had previously made investment conditions in poor countries more flexible . All this led to a reduction in dispersion, polarisation and inequality.[3]

[1]Global income inequality can be decomposed into between-countries and within-countries components. Our analysis focuses on the between-country dimension. Chancel and Piketty (2021), using the World Inequality Database construct world income distribution estimates from 1820 to 2020 and find that within-countries inequality dropped in 1910–1980 (while between-countries inequality kept increasing) but rose in 1980–2020 (while between-countries inequality started to decline). Amarante et al. (2024) find that higher levels of economic complexity are associated with improvements in within-country income equality after certain tresholds, and Song et al. (2021) find higher foreign direct investment and remittances raise income inequality, while economic growth reduces.

[2]Xiao et. al. (2024) explore the dynamics of TFP in 40 advanced economies and its implications for economic stability, growth patterns, and technological integration.

[3]Based on the panel data of 127 developing economies around the world from 2000 to 2021, Wang and Yang (2025) find that China's foreign digital aid has significantly reduced income inequality among recipient economies.

We have divided our sample of countries into several groups based on their initial level of income and the subsequent growth of their GDP per capita. In particular, we have divided the sample into four quartiles (high-, upper-middle-, lower-middle- and low-income countries) and then divided each quartile into high-growth and low-growth countries. To do this, we ran a regression between the log of initial GDP and the growth rate of countries. We classified countries above the regression line as high-growth countries and those below the line as low-growth countries. In the end, we analysed eight different groups of countries.

The cluster analysis confirmed the main result derived from the analysis of the full sample: the efficiency wedge drives growth, while the importance of the other wedges is secondary. However, there are other lessons we can draw from the cluster analysis. From the analysis of high and low income groups, we can conclude that both growth miracles and disasters are led by the efficiency wedge, which means that if we want to understand these phenomena, we must focus on the study of the technological, institutional and economic factors that influence the growth of TFP. Nakamura et al. (2019) find that the reasons for the productivity slowdown in Japan are due to factors that determine TFP: technology, as well as capital and labour, are not used efficiently, and capital and labour are not allocated efficiently across firms. We have also found that in middle-income countries, especially those with the highest growth rates, the investment and labour wedges have contributed to slowing the growth of GDP per capita. We attribute this to the fact that countries embarking on the process of economic development often tighten investment and labour regulations in order to reconcile economic growth with other social goals, such as distributive justice or the protection of workers and the environment. Finally, it should also be noted that the investment wedge has significantly boosted GDP per capita growth in low-income countries, especially since the early 1990s. This suggests that low-income countries (even those with low growth) have taken advantage of globalisation and technological change to access better investment opportunities, and explains why, especially since the early 1990s, the investment wedge has contributed significantly to reducing the dispersion, polarisation and inequality in the distribution of GDP per capita across countries.

We also examine three global events: the oil crisis (1973), the Iraq War (1990), and the Great Recession (2008). Our analysis reveals that there was a significant slowdown in global economic growth in the years immediately following the outbreak of all three events, driven by the efficiency wedge. However, we also found that the slowdown in per capita output growth affected primarily high-income countries. As a result, the slowdown in global per capita output growth was accompanied by a decline in the dispersion and inequality in the global distribution of income per capita across countries.

The remainder of this article is organized as follows. Section 2 describes the model, while Section 3 briefly describes the accounting procedure. Section 4 is a description of the economic background to wedges and their implications for economic policy. Section 5 presents our findings. Finally, Section 6 concludes.

2 The model

The prototype economy is the DSGE model with labour and savings decisions and five random wedges that represent the distortions in the equilibrium conditions: the efficiency wedge, $\pi_{y,t}$, the labor wedge, $\pi_{l,t}$, the investment wedge, $\pi_{x,t}$, the resource wedge, $\pi_{g,t}$, and the population wedge, $\pi_{n,t}$. The efficiency wedge captures distortions in the optimal use of productive resources, primarily reflecting detrended TFP. The labour wedge reflects distortions in the consumption-leisure choice of the representative household, primarily driven by labour market frictions. The investment wedge indicates distortions in the intertemporal allocation of resources, arising from differences between returns to saving and investment, and is heavily influenced by capital market imperfections. The resource wedge represents the discrepancy between production and the allocation of resources to consumption and investment. Finally, the population wedge reflects the gap between current and projected population levels.

The equilibrium in the economy is therefore pinned down by (i) the production function,

$$y_t = \pi_{y,t} f\left(k_t, l_t\right), \tag{1}$$

where y_t is detrended output per capita, k_t is detrended capital per capita and l_t are hours worked per capita. The efficiency wedge, $\pi_{y,t}$, represents the detrended TFP. The detrending factor is $(1+\gamma)^t$, where $\gamma \geq 0$ is the rate of labour-augmenting technical progress; (ii) the resource constraint,

$$\pi_{g,t} y_t = c_t + x_t, \tag{2}$$

where c_t is detrended consumption per capita and x_t is detrended investment per capita. The resource wedge, π_g equals one minus the ratio of net exports to the output. Therefore, it decreases when the degree of foreign openness increases;(iii) the evolution law of population,

$$N_{t+1} = \pi_{n,t+1} N_t, \tag{3}$$

where N_t is population at time t and $\pi_{n,t+1}$ represents the divergence between the population at t and $t+1$; (iii) the accumulation law of detrended capital per capita

$$(1+\gamma)\pi_{n,t+1} k_{t+1} = x_t + (1-\delta)\, k_t, \tag{4}$$

where $0 < \delta < 1$ is the depreciation rate of capital at time t and γ is the trend growth rate of capital, output, investment and consumption (all variables per capita); (iv) the labour-income choice

$$-\frac{u_{l,t}}{u_{c,t}} = \pi_{l,t}\pi_{y,t} f_{l,t} \tag{5}$$

where u_l and u_c are the derivatives of the utility function with respect to c and l and $f_{l,t}$ the derivative of the production function with respect to l. The labour wedge, $\pi_{l,t}$, represents the distortion between the marginal rate of substitution between consumption and labour and the marginal productivity of labour; (v) the savings optimality condition

$$\frac{1+\gamma}{\pi_{x,t}} u_{c,t} = \beta E\left[u_{c,t+1}\left(\pi_{y,t+1} f_{k,t+1} + \frac{1}{\pi_{x,t+1}}(1-\delta)\right)\right], \tag{6}$$

where β is the discount factor and f_k is the derivative of the production function with respect to k. The investment wedge, $\pi_{x,t}$, represents the distortion between the returns to saving and investment.

The exogenous states follow a five dimensional vector autoregressive of order one where the error process is assumed to be multivariate normal with mean zero and variance and covariance matrix $Q = BB'$, as described below:

$$\log \pi_{t+1} = P_0 + P \log \pi_t + \varepsilon_{t+1} \tag{7}$$

in which $\log \pi_t = (\log \pi_{n,t}, \log \pi_{y,t}, \log \pi_{l,t}, \log \pi_{x,t}, \log \pi_{g,t})^T$.

The system of equations (1)-(7) characterizes the equilibrium of the economy.

3 The accounting procedure

Utility and production functions. The utility function is additive separable in labour and logarithmic consumption,

$$u(c_t, l_t) = \log c_t - \frac{l_t^{1-\nu}}{1-\nu},$$

where $-\frac{1}{\nu}$ is the Frisch elasticity of the labour supply. The production function is Cobb-Douglas

$$f(k_t, l_t) = k_t^{\theta} l_t^{1-\theta}$$

Parameters. For all countries, we set $\nu = -3$, which implies a Frisch elasticity of $1/3$, $\beta = 0.97$, $\delta = 0.05$, $\theta = 0.35$, and $\gamma = 0.021$, which is the average of the growth rate of world output per capita in the period $1950 - 2019$. All values of the parameters are standard in the literature (see Brinca 2014 and Del Río and Lores 2023). Table 1 summarizes the parameters.

Table 1
PARAMETERS HELD FIX ACROSS COUNTRIES.

Parameter	Description	Value
γ	Growth Rate of Labour-Aumenting Technical Progress	0.0210
δ	Depreciation Rate of Capital	0.0500
θ	Production Function Parameter	0.3500
ν	Frisch Elasticity Parameter	-3
β	Discount Factor	0.9700
$E[\pi_n]$	Steady State Population Growth Rate	1

Equilibrium decision rules are derived by log-linearization around the steady state, assuming that the exogenous states follow the five dimensional vector auto-regressive process (7).

The data are used as observables and the Kalman filter used to back out the wedges. The procedure involves (i) solving the model for steady state quantities; (ii) compute decision rules by log-linearization around the steady state; and (iii) build a state space representation of the model,with a matrix for the laws of motion for the state variables, which are subject to gaussian innovations and a matrix with the optimal choices for output, labour, and investment as a function of the states.

Following Chari et al. (2007), we set measurement errors equal to zero. The likelihood of the wedges being jointly normal is computed and the optimization program concerns the choice of the parameters of the VAR, i.e., the matrices P and B, such that the likelihood is maximized. The vector P_0 is set such that $P_0 = (I - P)^{-1}E[\log \pi_t]$. This process is repeated for each country. For a detailed list of different MLE estimation methods see Adjemian et al. (2022) and the references contained therein.

We assume that world population remains constant as well as the relative size of all countries, thus we set $E\left[\log \pi_{n,t}\right] = 0$ for all countries. The remaining mean values of exogeneous states $E\left[\pi_t\right]$ are calculated by solving the equation system (1)-(7) when $\varepsilon_t = E[\varepsilon_t] = 0$ to reproduce for each country the sample averages for detrended hours worked per capita, investment rate, and consumption to output rate in the period $2015 - 2019$. In addition, for each country, we set the steady value of detrended GDP per capita, y^*, estimating by OLS the following convergence equation $\log y_t = \alpha_0 + \alpha_1 x_t$, which approximates the transition dynamics of the neoclassical growth model and where $\alpha_0 = \log y_{t_0}$, $\alpha_1 = \log y^* - \log y_0$ and $x_t = \left(1 - \mathrm{e}^{-\lambda t}\right)$ with $\lambda = 0.103$ being the speed of convergence implied by the model.[4] From each country, we use data from the first year that the country appears in the sample to 2019. Tables in section II in the online appendix present the values of the estimated P and B matrices, as well as the values of $E[\pi_t]$ for each country.

We measure the resource and the population wedges directly from the data. To obtain the values of the other wedges, we use the data and the model's decision rules. With y_t^d, l_t^d, x_t^d, $\pi_{g,t}^d$, and $\pi_{n,t}^d$ denoting the data for the model variables. $y(k_t, \pi_t)$, $l(k_t, \pi_t)$, and $x(k_t, \pi_t)$ denoting the decision rules of the model and being k_0^d an initial condition for capital, the realized wedge series π_t solve the system given by

$$y_t^d = y(k_t^d, \pi_t), \quad l_t^d = l(k_t^d, \pi_t), \quad x_t^d = x(k_t^d, \pi_t) \tag{8}$$

with $\pi_{g,t} = \pi_{g,t}^d$, $\pi_{n,t} = \pi_{n,t}^d$ and

$$\pi_{n,t}\left(1+g\right)k_{t+1}^d = x_t^d + \left(1-\delta\right)k_t^d, \quad \text{given } k_0^d$$

where k_0^d is

$$k_0^d = \frac{x_0}{y_0}\frac{1}{\left(1+g\right)\pi_{n,0} - \left(1-\delta\right)}y_0,$$

where $x_0/y_0 = \frac{1}{T_x}\sum_{t=0}^{t=T_x-1}\frac{x_{t_0+t}}{y_{t_0+t}}$, $\pi_{n,0} = \frac{1}{T_n}\log\frac{N_{t_0+T_n}}{N_{t_0}}$ and $y_0 = y_{t,0}$ with $T_x = 10$ and $T_n = 20$. We use these values for the wedges in our experiments.

Finally, we perform simulations to see to what extent models with just one wedge

[4] Although the residuals present autocorrelation, the OLS estimates are unbiased.

or a combination of wedges can replicate observed data. Hence, new decision rules are computed, setting the wedges, that are excluded in a specific simulation exercise, to their unconditional mean values throughout the simulation procedure. Since they no longer are random variables in the simulations, the computation of new equilibrium decision rules and allocations in the simulated economies ensures that the agent's expectations are consistent with the model.

4 The wedges: economic background and policies

In this section we discuss the underlying rationale for the main wedges of the model: the efficiency wedge, the investment wedge and the labour wedge. We also point out policy recommendations in the light of the analysis and empirical evidence.

4.1 Efficiency wedge

The *efficiency wedge* reflects TFP, which measures the efficiency with which inputs (labour and capital) are used in the production process. Cross-country differences in TFP can be due to different factors.

Barriers to Technological Adoption. Barriers to technological adoption are a key factor explaining cross-country differences in TFP. These barriers can arise from institutional weaknesses, regulatory constraints, lack of infrastructure, and human capital deficits, all of which slow down the diffusion of productivity-enhancing technologies. Some papers have analysed the theoretical relationship between barriers to technology adoption and TFP. Parente and Prescott (1994) argue that institutional and policy-related barriers prevent countries from adopting existing technologies, creating persistent productivity gaps. Comin and Hobijn (2004) provide a framework showing that differences in technology adoption lags significantly contribute to cross-country TFP variation. Acemoglu et al. (2005) link barriers to technological adoption to poor institutions, which create disincentives for innovation and productivity growth. There is some empirical evidence on the relationship between barriers to technological adoption and TFP. Caselli and Coleman (2006) find that countries closer to the technological frontier experience higher TFP growth if they have fewer barriers to adopting new technologies. Comin and Mestieri (2018) provide evidence that countries with faster technology diffusion rates tend to experience higher long-run productivity growth, emphasizing the role of trade openness and financial development. Hall and Jones (1999) show that institutional quality plays a crucial role in TFP disparities, with more business-friendly environments facilitating technology adoption. Some policy implications emerges from the analysis: (i) reducing regulatory barriers and strengthening property rights can enhance technology diffusion and improve TFP; (ii) investing in human capital and digital infrastructure helps countries absorb and implement new technologies faster;[5] and (iii) improving governance and reducing corruption lowers institutional barriers, fostering TFP convergence across countries.

Human capital. Human capital –defined as the education, skills, and health of the workforce– plays a crucial role in shaping cross-country differences in TFP. Empirical research suggests that variations in human capital explain a significant share of TFP differentials across countries, primarily through its impact on technological adoption, innovation, and efficiency in resource allocation. Nelson and Phelps (1966) propose that human capital facilitates the diffusion of technology, allowing countries with a more educated workforce to catch up with technological leaders.[6] Hall and Jones (1999) find that differences in human capital explain a substantial portion of TFP variation across countries. Their study highlights the importance of education and institutional quality in driving productivity. Caselli and Coleman (2006) show that human capital influences both technology adoption and efficiency in utilizing existing technologies, leading to cross-country TFP disparities. Vandenbussche et al. (2006) argue that the effect of human capital on TFP depends on a country's position relative to the technological frontier: developing economies benefit more from human capital in terms of technology adoption, while advanced economies require higher-skilled human capital for innovation-driven growth. Policy implications of the analysis are that countries lagging in TFP should focus on education and skill development to accelerate technology adoption, while advanced economies should emphasize higher education and R&D to sustain innovation-driven productivity growth.

Institutions and Governance. Institutions and governance are fundamental drivers of TFP across countries. Strong institutions —including property rights, the rule of law, and government effectiveness— create an environment where resources are allocated efficiently, innovation is rewarded, and technology adoption is accelerated. In contrast, weak institutions and poor governance can lead to rent-seeking, misallocation of resources, and stagnant productivity growth. Informal institutions also matter

[5] Lei et al. (2024) find a nonlinear relationship between digitalization and Green TFP

[6] Romer (1990) and Lucas (1988) emphasize that human capital also drives innovation in advanced economies, contributing to endogenous growth.

for economic growth and development. They facilitate cooperation and reduce transaction costs (Zak and Knack, 2001 and Gao and He, 2023). North (1990) argues that institutions shape the incentives for economic actors, influencing investment decisions and long-term growth, and secure property rights and contract enforcement are essential for innovation and technological diffusion. Acemoglu et al. (2001) propose that extractive institutions stifle productivity by discouraging productive investments, while inclusive institutions promote entrepreneurship and technological progress. Del Río (2019, 2021) argues that the inadequate protection of property rights encourages rent-seeking, which reduces TFP and productivity because it discourages business entry and capital accumulation and encourages resource wastage. He also assesses the quantitative impact of these effects on cross-country differences in per capita income and finds that this can be very significant. There is a growing body of empirical evidence on the role of institutions in the explanation of cross-country differences in TFP and productivity. Hall and Jones (1999) develop a framework showing that differences in social infrastructure –the quality of institutions and policy environments– explain much of the variation in cross-country TFP levels. Acemoglu et al. (2001) show that historical institutional differences, shaped by colonialism, have long-lasting effects on TFP and economic performance: countries with more inclusive institutions have significantly higher productivity. Easterly and Levine (2003) find that institutional quality is a stronger determinant of TFP than geographic or cultural factors, emphasizing the importance of governance in driving long-term growth. Djankov et al. (2002) show that better governance and reduced regulatory barriers lead to more efficient business operations and higher TFP. Rodrik et al. (2004) argue that institutions trump other factors (like trade or geography) in explaining income and productivity differences across countries. Bazzi and Clemens (2013) provide evidence that institutional fragility is associated with lower TFP growth, as unstable governance disrupts economic activity and slows down technology adoption. Several mechanisms link institutions and TFP: Property Rights Protection encourages investment and technological innovation (Acemoglu et al. 2005); Contract Enforcement reduces transaction costs and promotes specialization (North 1990); Political Stability minimizes uncertainty, facilitating long-term investments (Hall and Jones 1999); Reduced corruption improves resource allocation and market efficiency (Djankov et al. 2002). The analysis provides some lessons for economic policy: (i) strengthening property rights and legal systems boosts investor confidence and encourages technological adoption; (ii) reducing corruption and enhancing regulatory quality improves resource allocation and supports productivity growth; and (iii) promoting political stability and government accountability creates a more predictable environment for long-term investments in innovation and human capital.

Infrastructure. Infrastructure –comprising transportation networks, energy supply, telecommunications, and digital connectivity– is a key determinant of TFP across countries. Well-developed infrastructure reduces production costs, improves efficiency, and facilitates technological diffusion, thereby enhancing TFP growth. Conversely, inadequate infrastructure leads to inefficiencies, bottlenecks, and lower productivity. Barro (1990) argues that public infrastructure investment can boost productivity by complementing private capital and labour, though excessive government spending may create distortions. Aschauer (1989) shows that public capital, particularly in transportation and utilities, plays a crucial role in improving TFP by lowering transaction costs and increasing economic efficiency. Canning and Pedroni (2008) emphasize the role of infrastructure in enhancing long-run economic growth by improving the allocation of resources. Irshad et al. (2023) find that that investment in telecommunication, electricity power consumption, and transportation contributes to economic growth in lower-middle-income countries. Some works have explored the empirical links between infrastructure and TFP. Hajamini and Falahi (2018) analyse the impact of different types of public spending on growth and explore the optimal size of government.Calderón and Servén (2004) find that both the quantity and quality of infrastructure significantly affect TFP across countries, with stronger effects in low-income economies. Esfahani and Ramírez (2003) provide evidence that electricity and telecommunications infrastructure enhance productivity by reducing inefficiencies in production. Röller and Waverman (2001) show that telecommunications infrastructure has a strong impact on productivity growth, particularly in advanced economies. Donaldson (2018) demonstrates how historical infrastructure projects, such as railroads in India, significantly improved market integration and TFP growth. Zhang et al. (2025) show that public investment in agriculture not only increases agricultural productivity in China by improving irrigation infrastructure and increasing the number of agricultural machines, but also by encouraging larger farms. A number of implications for economic policy emerge from the analysis: (i) increasing investment in infrastructure enhances TFP by improving market access and reducing production costs; (ii) ensuring infrastructure quality (not just quantity) is crucial, as poorly maintained infrastructure can negate productivity gains; and (iii) leveraging digital infrastructure (e.g., broadband expansion) fosters knowledge diffusion and innovation, further boosting TFP.

Trade openness and global integration. Trade openness and global integration are pivotal factors influencing a country's TFP. By facilitating the exchange of goods, services, and technologies, open trade policies enhance resource allocation, stimulate innovation, and promote efficiency, thereby boosting TFP. International trade enables the dissemination of technological advancements and managerial expertise across borders. Countries engaging in global markets can absorb and implement foreign innovations, leading to productivity enhancements. Grossman and Helpman (1991) highlight that trade serves as a conduit for knowledge transfer, which is essential for technological progress and TFP growth. Trade openness allows countries to specialize based on comparative advantage, leading to more efficient resource utilization. This specialization enhances overall productivity, as resources are allocated to sectors where they are most effective. Melitz (2003) demonstrates that exposure to international competition forces firms to optimize operations, thereby increasing aggregate productivity. The literature on the empirical relationship between trade openness and productivity is extensive. Empirical studies have consistently found a positive relationship between trade openness and TFP growth. Alcalá and Ciccone (2004) provide evidence that countries with higher trade intensity experience significant productivity gains, attributing this to increased competition and access to larger markets, and Wacziarg and Welch (2008) analyse the impact of trade liberalization on economic performance and find that countries adopting open trade policies witness substantial improvements in TFP. Their research suggests that reducing trade barriers fosters a competitive environment conducive to productivity enhancements. Bajo-Rubio and Ramos-Herrera (2024) find a bi-directional relationship between both international trade and GDP.Ma (2022) finds that the economic integration promoted by the Belt and Road Initiative has had a positive impact on economic performance, especially in low-income countries, through increased foreign trade and foreign direct investment. Manwa and Wijeweera (2016) find that trade liberation increased growth in South Africa. Le et al. (2024) analyses the positive interaction between foreign direct investment, TFP and productivity growth in middle-income countries. Policies that promote trade liberalisation, such as reducing tariffs and non-tariff barriers to trade, can improve market access, stimulate competition and encourage innovation. In addition, the development of trade-supporting infrastructure such as ports, transport networks and communication systems can facilitate smoother integration into global markets, thereby increasing productivity.

R&D and innovation. The role of R&D in cross-country differences in TFP is particularly evident in the work of Jones (1995), who explores the role of technology diffusion and knowledge spillovers. More advanced economies with greater R&D investment are able to adopt and adapt new technologies more efficiently, leading to higher productivity growth. In contrast, less developed economies may struggle to harness the benefits of innovation due to limited access to new technologies or insufficient domestic R&D capabilities. R&D can act as a catalyst for catching up with more technologically advanced countries, as evidenced by the experiences of East Asian economies that have rapidly increased their TFP growth rates through strategic investments in technology and innovation (Kim, 1997). The economic policy measures suggested by the literature are many and varied:(i) Investment in education, particularly in science, technology, engineering, and mathematics (STEM) fields, should be prioritized as well as programs that foster entrepreneurship and technological skills should be designed to prepare the workforce for innovation-driven industries and policies that encourage lifelong learning can help workers adapt to rapidly evolving technological landscapes; (ii) Governments should adopt policies that promote openness to foreign technologies and encourage Foreign Direct Investment, which can include reducing tariffs, simplifying regulations, creating favourable conditions for technology licensing, and implementing policies that promote knowledge exchange and cross-border collaborations to impulse faster diffusion of innovation; (iii) Enhancing the quality of governance and strengthening intellectual property rights are key steps for promoting innovation, which involves building robust legal frameworks, ensuring transparency in the regulatory environment, and reducing corruption as well as clear and enforceable intellectual property laws incentivise firms to invest in new technologies by protecting their innovations from unauthorized use; and (iv) Developing countries should focus on policies that enhance technology transfer from developed economies, including participating in international research collaborations, creating incentives for foreign firms to invest in local R&D, and improving infrastructure for technology adoption.

Financial development. Financial development, which refers to the evolution and efficiency of a country's financial markets and institutions, plays a crucial role in facilitating economic growth and improving productivity by enabling better allocation of resources. A well-developed financial system provides the necessary capital for firms to invest in new technologies, adopt innovations, and expand production capacity. Financial markets channel savings into productive investments, while financial institutions help mitigate the risks associated with investment by providing loans and insurance.

This leads to higher investment in R&D and technological innovations, which directly enhance TFP. Moreover, financial development promotes entrepreneurship by providing access to credit, particularly for small and medium-sized enterprises, which often drive innovation. These firms can access funding to develop new products and services, leading to productivity improvements. As argued by King and Levine (1993), financial markets improve the efficiency of capital allocation, enabling better resource distribution and fostering economic growth. Cross-country differences in financial development can explain variations in TFP growth (Levine, 2005). Countries with more developed financial systems tend to exhibit higher TFP growth because they are better able to support technological innovation and facilitate efficient resource use. In contrast, countries with underdeveloped financial markets may face greater obstacles in financing innovation, resulting in slower productivity growth. Fengju and Wubishet (2024) analysis the impact of financial development on economic growth in East Africa and the role played by institutions. Ma et al. (2024) find that financial inclusion enhances human capital investment in Chinese households by easing financing constraints, increasing property income, and reducing income uncertainty. The relationship between financial development and TFP growth has important policy implications: (i) Governments should implement policies that promote financial inclusion, reduce barriers to credit access, and support the development of venture capital and angel investment networks; (ii) Establishing financial products tailored to the needs of small businesses and startups can also encourage innovation and productivity growth; (iii) Policymakers should strengthen the regulatory environment to ensure that financial institutions are sound, transparent and able to manage risk effectively; strengthening corporate governance, improving credit information systems and ensuring better enforcement of contracts are key to building confidence in financial institutions; (iv) Public education campaigns on financial literacy should be promoted, focusing on entrepreneurship and the use of financial products for innovation, as training in financial management and investment strategies will help small and medium-sized enterprises to manage resources effectively and contribute to growth.(v) Governments should aim to improve financial market openness by reducing barriers to foreign investment, promoting international capital flows and ensuring the efficient transfer of technology and knowledge between countries; in particular, international agreements on finance and investment can help facilitate these processes.

4.2 Investment wedge

The *investment wedge* refers to distortions or inefficiencies in the allocation of capital that lead to differences between the marginal rate of substitution between present and future consumption and the rate of return on investment. This wedge can arise from various sources, including financial frictions, taxation, institutional weaknesses, and policy distortions. Investment wedges vary significantly across countries due to differences in financial development, tax policies, and institutional frameworks. Developed economies with well-functioning financial markets, stable macroeconomic conditions, and strong institutions tend to have smaller investment wedges, facilitating capital accumulation and productivity growth. In contrast, many developing countries face larger wedges due to financial repression, policy distortions, and governance issues, leading to inefficient capital allocation and slower economic growth.

Financial Frictions. Financial frictions –such as borrowing constraints, imperfect financial markets, and asymmetric information– can significantly impact investment decisions, leading to the formation of an investment wedge. The severity of financial frictions and investment wedges varies across countries depending on financial market development, regulatory frameworks, and institutional quality. Developed economies with well-functioning financial systems typically experience smaller investment wedges, while developing economies with weak financial institutions suffer from larger distortions. Financial frictions can create investment wedges in different ways. (i) Bernanke et al. (1999) argue that firms (especially small and medium enterprises and startups) with limited access to external finance must rely on internal funds, leading to suboptimal investment decisions. (ii) High collateral requirements and risk premiums increase the cost of borrowing, widening the investment wedge by making capital more expensive for financially constrained firms (Kiyotaki and Moore, 1997). (iii) Buera et al. (2011) argue that in countries with underdeveloped financial systems, capital may not be allocated efficiently, leading to persistent investment wedges across firms and sectors. (iv) Stiglitz and Weiss (1981) argue that asymmetric information between borrowers and lenders leads to adverse selection and moral hazard, restricting access to credit and exacerbating investment distortions. Addressing financial frictions through financial sector reforms, improved access to credit, and enhanced financial regulation can help reduce investment inefficiencies and promote economic growth. Adeniyi et al. 2012 find that financial development matters for the benefits of foreign direct investment to register on economic growth in some African countries. There is a wide variety of economic policy recommendations to mitigate financial frictions. (i) Well-developed financial markets reduce borrowing constraints by providing diverse sources of financing, such as equity markets, corporate bonds, and venture capital. Governments should focus on improving banking sector competition, enhancing credit availability, and fostering capital market development (Beck et al 2000). (ii) High collateral requirements limit firm investment, especially for small and medium firms. Policies that promote credit guarantee schemes and alternative lending mechanisms (e.g., fintech lending, microfinance) can help mitigate this issue. For example, governments can establish credit guarantee programs to support lending to startups and small and medium firms (Banerjee and Duflo, 2014). (iii) Asymmetric information between lenders and borrowers leads to credit rationing. Strengthening credit reporting systems, expanding financial data access, and improving corporate transparency can help mitigate these frictions (Djankov et al. 2007). (iv) Digital financial technologies can lower transaction costs, expand access to financial services, and improve capital allocation. Encouraging fintech innovation and mobile banking can reduce barriers to investment. For example, governments can provide regulatory sandboxes for fintech startups to test new financial products (Philippon, 2019).

Taxation and Regulatory Distortions. Tax policies, including corporate tax rates, capital gains taxes, and depreciation rules, play a significant role in shaping investment incentives and capital allocation. Tax policies significantly impact investment decisions by influencing the cost of capital and expected returns. High corporate tax rates and capital gains taxes widen the investment wedge, while favorable depreciation policies can mitigate distortions. (i) Higher corporate income taxes reduce the after-tax return on investment, discouraging capital accumulation and creating a larger investment wedge. Firms facing high corporate taxes may delay or reduce investment, particularly in industries with long-term capital commitments (Djankov et al. 2010). (ii) Capital gains taxes reduce the incentives for investors to provide equity financing, increasing the cost of capital for firms. Higher capital gains taxes can lead to capital lock-in, where investors hold assets longer than optimal to defer tax payments, reducing market liquidity and investment efficiency (Poterba, 2004). (iii) Depreciation policies determine how quickly firms can deduct capital expenditures from taxable income, affecting the after-tax cost of investment. More generous depreciation allowances, such as accelerated depreciation or full expensing, reduce the investment wedge by lowering effective tax rates on capital (Auerbach, 1983). Governments can implement targeted tax policies to reduce distortions in capital allocation and encourage investment. (i)Reducing corporate income tax rates lowers the cost of capital and encourages business investment. However, to maintain government revenue, tax bases should be broadened by minimizing loopholes and unnecessary exemptions. Many OECD countries have reduced corporate tax rates while maintaining tax revenue through base-broadening measures (Devereux and Griffith, 2003). (ii) Lowering capital gains taxes or offering deferral options can reduce investment lock-in effects and encourage more dynamic capital allocation (Poterba, 2004). (iii) Allowing firms to fully deduct capital expenditures immediately (full expensing) or accelerating depreciation schedules lowers the effective tax rate on new investments, increasing capital accumulation (Zwick and Mahon, 2017). (iv) Multinational firms often shift profits to low-tax jurisdictions, exacerbating investment distortions. Strengthening anti-avoidance measures while keeping rates competitive can ensure fair tax collection without discouraging investment (Clausing, 2020). (v) Frequent tax policy changes create uncertainty, discouraging long-term investment. A stable and predictable tax environment fosters business confidence (Keen and King, 2002).

Policy Uncertainty and Macroeconomic Stability. Policy uncertainty –stemming from unpredictable changes in fiscal, monetary, or regulatory policies– can significantly distort investment decisions by increasing risk, delaying capital allocation, and raising borrowing costs. A lack of macroeconomic stability exacerbates these effects, widening the investment wedge. There are several channels through which political uncertainty and macroeconomic instability increase the investment wedge. (i) Firms postpone investment when future policies (e.g., tax rates, interest rates, or regulations) are uncertain, leading to lower capital accumulation (Bloom, 2009). (ii) Uncertainty raises the cost of borrowing, as lenders demand higher risk premiums. This disproportionately affects firms reliant on external financing, widening the investment wedge (Pastor and Veronesi, 2012). (iii) Policy instability often leads to inflationary shocks and currency fluctuations, reducing investor confidence and discouraging long-term investment (Aizenman and Marion, 1993). (iv) Unstable regulatory environments and frequent policy reversals lead to inefficient capital allocation, reinforcing investment wedges across industries (Julio and Yook, 2016). Nguyen et al. (2022) find that geopolitical risk has a significant and robust negative impact on foreign direct investment and TFP.There is a number of policies that can reduce the investment wedge from policy uncertainty. (i) Governments should commit to clear, rules-based policies to reduce uncertainty, particularly in taxation, trade, and financial regulation (for example, independent central banks enhance policy credibility and reduce uncertainty). (ii)

Fiscal discipline and predictable monetary policy (inflation targeting, fiscal responsibility laws) reduce macroeconomic instability and risk (Taylor, 1993). (iii)Governments should limit abrupt policy shifts and regulatory overhauls to maintain investor confidence (for example, the European Union's Stability and Growth Pact aims to reduce fiscal volatility across member states). (iv) Policies such as investment tax credits, risk-sharing mechanisms, and infrastructure guarantees can help mitigate the negative effects of uncertainty (Rodrik 1991).

Institutional Quality and Property Rights. When institutions fail to protect property rights, enforce contracts, or prevent corruption, firms face higher risks and transaction costs, discouraging investment and innovation. (i) Uncertain ownership and lack of legal enforcement discourage long-term investments, particularly in physical and intellectual capital (Acemoglu et al. 2001). (ii) Corrupt institutions increase the cost of doing business, reduce investor confidence, and lead to inefficient capital allocation (Mauro, 1995). (iii) Strong legal institutions encourage credit availability, reducing borrowing constraints and lowering the investment wedge (La Porta et al. 1998). (iv) Stable institutions foster predictable economic policies, reducing uncertainty and encouraging investment (North 1990). Some policies can improve institutional quality and foster investment. (i) Governments should ensure clear land titles, enforce intellectual property rights, and reduce expropriation risks. De Soto (2000) argues that land titling reforms in Peru improved credit access for small businesses. (ii) Reducing court delays, increasing judicial independence, and digitizing legal processes can lower transaction costs. (iii) Policies that increase government accountability, transparency, and rule of law reduce uncertainty and distortions (Kaufmann et al. 2009). (iv) Stable institutions reduce policy uncertainty and long-term investment risks.

4.3 Labour wedge

The *labour wedge* –the discrepancy between the marginal rate of substitution of consumption for leisure and the marginal product of labor– is a critical factor in understanding labour market inefficiencies and business cycle fluctuations. This wedge indicates deviations from the optimal allocation of labour resources, often resulting from various frictions and distortions.

Search and Matching Frictions. Search and matching frictions in the labour market arise from imperfect information, hiring costs, and the time required to match workers with suitable jobs, leading to inefficient labour allocation and wage rigidities. These frictions can affect the labour wedge in a number of ways. (i) When job seekers and vacancies do not align efficiently, unemployment persists even when jobs are available, increasing the labor wedge. (Mortensen and Pissarides, 1994). (ii) Collective bargaining, minimum wages, and unemployment benefits can prevent wages from adjusting flexibly, leading to distortions in labour supply and demand (Shimer, 2010). (iii) High recruitment costs and limited worker mobility slow job creation and matching, widening the labour wedge (Diamond, 1982). (iv) Economic downturns exacerbate matching inefficiencies, as firms reduce hiring and job seekers become more selective, further increasing the labor wedge. The frictions caused by searching and matching, and their consequences, can be mitigated by certain policies. (i) Policies that enhance labor market information (e.g., digital job platforms, career counseling) can reduce mismatch and shorten unemployment durations.(ii) Lowering bureaucratic barriers to hiring and firing can improve labor reallocation and reduce inefficiencies. (iii) Unemployment benefits should be designed to provide support while maintaining incentives for job search. (iv) Policies promoting performance-based pay and worker retraining can help align wages with productivity and reduce structural unemployment.

Wedge Rigidity and Bargaining Power. Wage rigidity –the resistance of wages to adjust to labour market conditions– plays a crucial role in labour market inefficiencies. It is often driven by bargaining power, where strong labour unions, collective agreements, or minimum wage laws prevent wages from responding flexibly to supply and demand. These rigidities can contribute to unemployment, widen the labour wedge, and slow economic adjustments during business cycles.Wage rigidities can create a labour wedge in several ways. (i) When wages do not adjust downward during economic downturns, firms reduce hiring or lay off workers, increasing unemployment (Shimer, 2005). (ii) Strong unions may negotiate higher wages for insiders (employed workers) at the expense of outsiders (unemployed or new entrants), making it harder for firms to hire (Blanchard and Summers, 1986). (iii) Workers resist nominal wage cuts due to fairness concerns and psychological effects, leading to employment adjustments instead (Bewley, 1999). There are some policies that can reduce the labour wedge. (i) Policies that allow wage adjustments based on productivity and market conditions can reduce unemployment risks. For example, Germany's Kurzarbeit system allows temporary wage reductions instead of layoffs during downturns. (ii) Decentralized wage bargaining (firm-level negotiations instead of nationwide agreements) can better reflect economic conditions. (iii) Governments can support performance-based pay structures and labour mobility programs to mitigate wage rigidities. (iv) Instead of across-the-board increases, adjusting minimum wages by region or industry can balance worker protection and employment growth.

Taxation. Taxation affects labour supply decisions by influencing the incentives for individuals to work. High labour taxes reduce the after-tax wage, discouraging work and creating a labour wedge. There are a number of ways in which taxation affects labour supply and the labour wedge. (i) When labor income taxes increase, workers may reduce hours worked or exit the labour force, widening the labour wedge (Prescott, 2004). (ii) Highly progressive tax systems reduce incentives for additional work, especially for high-skilled workers, discouraging human capital accumulation (Saez, 2001). (iii) Payroll and social security taxes increase the cost of hiring, potentially leading firms to reduce employment or shift towards informal labour markets (Feldstein, M., 1995). To assess the effects of taxation, it is important to consider that the responsiveness of labour supply to tax changes varies across demographic groups, with secondary earners (e.g., married women) being more sensitive to tax rates (Meghir and Phillips, 2010). The analysis suggests some economic policy implications for reducing the labour wedge. (i) Reducing high-income tax rates can encourage labour participation and effort, boosting productivity. (ii) Earned Income Tax Credits can offset distortions by incentivizing lower-income workers to enter the labour force. (iii) Moving from labour taxes to consumption or property taxes can improve labour market efficiency. (iv) Lowering employer payroll taxes can encourage job creation and reduce informal employment.

Market Power and Price Markups. When firms possess significant market power, they set prices above marginal costs, reducing labor demand and suppressing wages relative to productivity. This distortion leads to inefficiencies in the labor market, contributing to a larger labor wedge.Policies aimed at enhancing competition, promoting labor mobility, and reducing entry barriers for new firms can help mitigate these effects, leading to more efficient labor market outcomes. Market power and price markups affect the labour wedge by different channels. (i) Firms with greater market power extract higher profits by keeping wages lower than the marginal product of labour, widening the labor wedge (De Loecker et al. 2020). (ii)As markups increase, a smaller share of economic output is allocated to labour, exacerbating income inequality and reducing overall employment incentives (Karabarbounis and Neiman, 2014). (iii) Firms with market power can impose downward pressure on wages due to reduced competition for labour, making wage adjustments sluggish and increasing unemployment (Berger et al. 2022). (iv) High market concentration limits new firms from entering, reducing job opportunities and making labour markets less dynamic (Gutiérrez and Philippon, 2023). Some policies can be implemented to reduce the labour wedge. (i) Enforcing stricter antitrust laws can reduce excessive market concentration, fostering competition and improving labour outcomes. (ii) Reducing employer monopsony power by supporting job mobility and banning restrictive non-compete clauses can help workers earn wages closer to their marginal productivity. (iii) Policies that promote startup creation and reduce regulatory burdens can increase competition, leading to more labour demand. (iv) Implementing wage-setting policies that reflect productivity improvements can help align wages with the marginal productivity of labour.

Financial Frictions. Financial frictions –such as borrowing constraints, limited access to credit, and inefficient capital allocation– can also significantly impact labour markets and contribute to the labour wedge. Financial frictions influence firms' hiring decisions, wage-setting processes, and workers' ability to smooth consumption, exacerbating inefficiencies in the labour market. In particular, workers with limited access to credit may be forced to accept lower wages or fewer hours, increasing labour market inefficiencies (Jermann and Quadrini, 2012) and during downturns, financial frictions can amplify employment contractions, making the labor wedge more cyclical (Arellano et al. 2019). Policy measures aimed at improving credit access, enhancing financial inclusion, and ensuring countercyclical credit policies can help mitigate these distortions and reduce the labour wedge.

5 Findings

We focus on the role played by the wedges in the evolution from 1960 to 2019 of the log of world GDP per capita (μ) and the following statistics of the cross-country distribution of the log of GDP per capita: the interquartile range (IQR), the standard deviation (σ), and the Theil index (T). We examine the extent to which each wedge-alone component contributed the evolution of these variables. The wedge-alone components together with the corresponding observed statistic (μ, IQR, σ, and T) are displayed in Figures 2-6.

For each wedge-alone component and each statistic, we calculate the ϕ-statistic defined by Brinca et al. (2016) to intend to capture how closely a particular component tracks the underlying statistic. The ϕ-statistic for the wedge-alone component of statistic $z \in \{\mu, \sigma, \text{IQR}, \text{T}\}$ due to wedge π_i is

$$\phi_{z,\pi_i} = \frac{1/\sum_t (z_t - z_{\pi_i,t})^2}{\sum_i \left(1/\sum_t (z_t - z_{\pi_i,t})^2\right)}$$

where $z_{\pi_i} \in \{\mu_{\pi_i}, \sigma_{\pi_i}, \text{IQR}_{\pi_i}, \text{T}_{\pi_i}\}$ is the wedge-alone component of statistic z due to the wedge π_i, with $i \in y, l, x, g, n$. The ϕ-statistic has the desirable features that it lies in $[0, 1]$ and sums to 1 across the four wedges; and when a particular wedge-alone component tracks a statistic perfectly, its value is 1. The values of the ϕ-statistic are displayed in Table 2.

Table 2
ϕ-STATISTICS.

	μ	σ	IQR	T
π_y	0.878	0.345	0.441	0.381
π_h	0.022	0.117	0.169	0.143
π_x	0.027	0.254	0.140	0.217
π_g	0.038	0.151	0.145	0.131
π_n	0.036	0.134	0.105	0.129

Growth. Figure 2 shows the log of detrended world GDP per capita and its components. From 1960 to 2019, the evolution of world GDP per capita experiences two major waves. The first runs from 1960 to 1994 and the second from 1995 to 2019. The first wave was longer and peaked in 1973, while the second peaked in 2011. The peaks of both waves are marked by two milestones: the oil crisis (1973-1978) and the Great Recession (2008-2012). Both the oil crisis (1973) and the Great Recession (2008) appear to have contributed significantly to the slowdown in global economic growth. In both cases, there seems to have been an immediate and direct impact and a somewhat later one. After the second oil crisis (1978), the world entered a prolonged period of low growth, which appears to have been exacerbated by the Iraq war (1990). Growth slowed again after the debt crises in some European countries (2011-2012), triggered by the Great Recession.

Throughout the period, the evolution of the log of world income per capita was almost exclusively driven by the wedge-alone component due to the efficiency wedge (see Figure 2). In particular, the slowdown in growth following both the oil and debt crises was exclusively driven by this wedge. The high value (0.88, see Table 2) of the

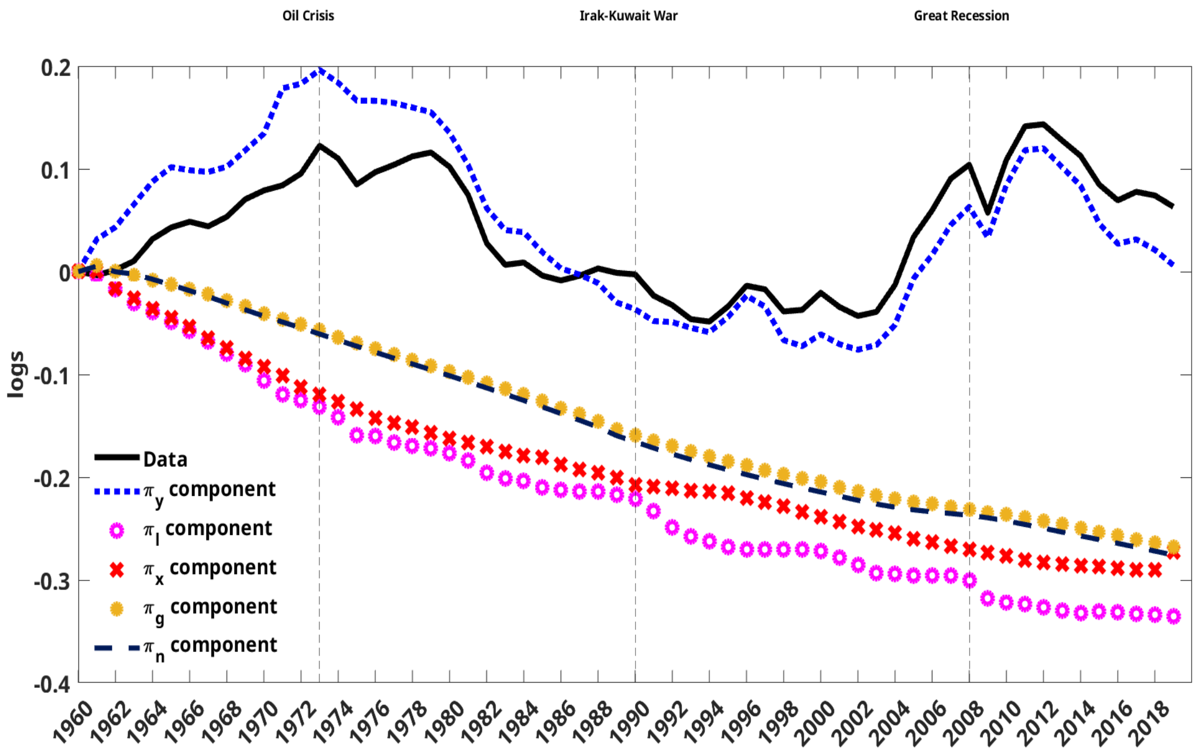


Figure 2: World GDP per capita and its components (logs).

Note: Data in Figure 2 is log of $\mu_t = \sum_{j=1}^{NC_t} N_{jt} y_{jt}/N_t$, where NC_t is the sample number of countries, N_{jt} is population of country j in period t, $N_t = \sum_{j=1}^{NC_t} N_{jt}$ is total sample population in period t, and y_{jt} is detrended GDP per capita of country j in period t. The π_{it} component of μ_t is $\sum_{j=1}^{NC_t} N_{jt} y_{jt}^{\pi_i}/N$ where $y_{jt}^{\pi_i}$ is the component of y_{jt} associated with the wedge π_i with $i \in \{y, l, x, g, n\}$. The online appendix presents for each country the wedges and the respective components of output, labour and investment.

ϕ statistic for the wedge-alone component of the log of world income per capita due to the efficiency wedge indicates the crucial importance of this wedge in explaining the evolution of world income per capita. The remaining wedge-alone components of the log of world income per capita contributed to a slight reduction in the pace of growth of world income per capita (see Figure 2). In particular, the wedge-alone components due to the labour and investment wedges slowed down world growth between 1960 and the mid-1970s.

Our results suggest that the first major wave of growth may have been driven by the fruits of the Second Industrial Revolution and the new international order that emerged after the Second World War. The benefits of these two processes were reflected in the improvement of TFP in some countries, which drove world growth during this period.[7] However, this growth pattern seems to have run out of steam around the

[7]The Second Industrial Revolution (c.1870–1914) was a period of rapid advancements in steel production, electricity, and chemical industries. Innovations such as the internal combustion engine,

mid-1970s. From the mid-1980s onwards, world growth began to slowly recover and a second major wave of growth was generated, probably driven by the advent of economic globalisation and the diffusion of information technologies. These processes allowed TFP to regain its momentum, which in turn drove world economic growth. However, global economic growth began to slow in the wake of the Great Recession and the European debt crisis.

Our results also suggest that the oil shocks and the Great Recession affected global economic growth through a deterioration in the evolution of TFP. No significant effects on other wedges and components are observed in our simulations, although this might be expected. For example, the crises could have worsened financial conditions, which could have been reflected in the investment wedge and its component. This does not seem to have been the case and is somewhat intriguing.

Dispersion. Figure 3 displays the standard deviation of the cross-country distribution of the log of detrended GDP per capita and its components. Although with a brief interruption in the first half of the eighties, the cross-country distribution of the log of detrended income per capita underwent an increase of its standard deviation (which is called σ-divergence in the growth literature) from 1960 to 2000, then it underwent a decrease of the standard deviation (which is called σ-convergence), but it reversed at the end of the period (see Figure 3). From mid-eighties to mid-nineties, σ-divergence was particularly intense, but also σ-convergence was very intense from 2000 to 2015. After the Second Oil Crisis (1978)and the Great Recession (2008), σ-convergence accelerated. Thus, both crises seem to have affected high-income countries more than low-income countries.

The wedge-alone component of the standard deviation due to the efficiency wedge drove the increase in the standard deviation from the mid-eighties to the mid-nineties, and, thereafter, largely drove its decline to 2016 as well as its subsequent increase (see Figure 3). The σ-convergence observed after the oil crisis and the Great Recession was exclusively driven by the efficiency wedge. This suggests that the negative impact of both crises was mainly reflected in total factor productivity (TFP), as the components of the other wedges showed no obvious signs of change after both crises. Furthermore, the analysis suggests that the TFP of high-income countries generally fell more than that of low-income countries, leading to an intensification of the σ-convergence across countries.

telecommunication (telephone and radio), and mass production techniques transformed economies and societies.

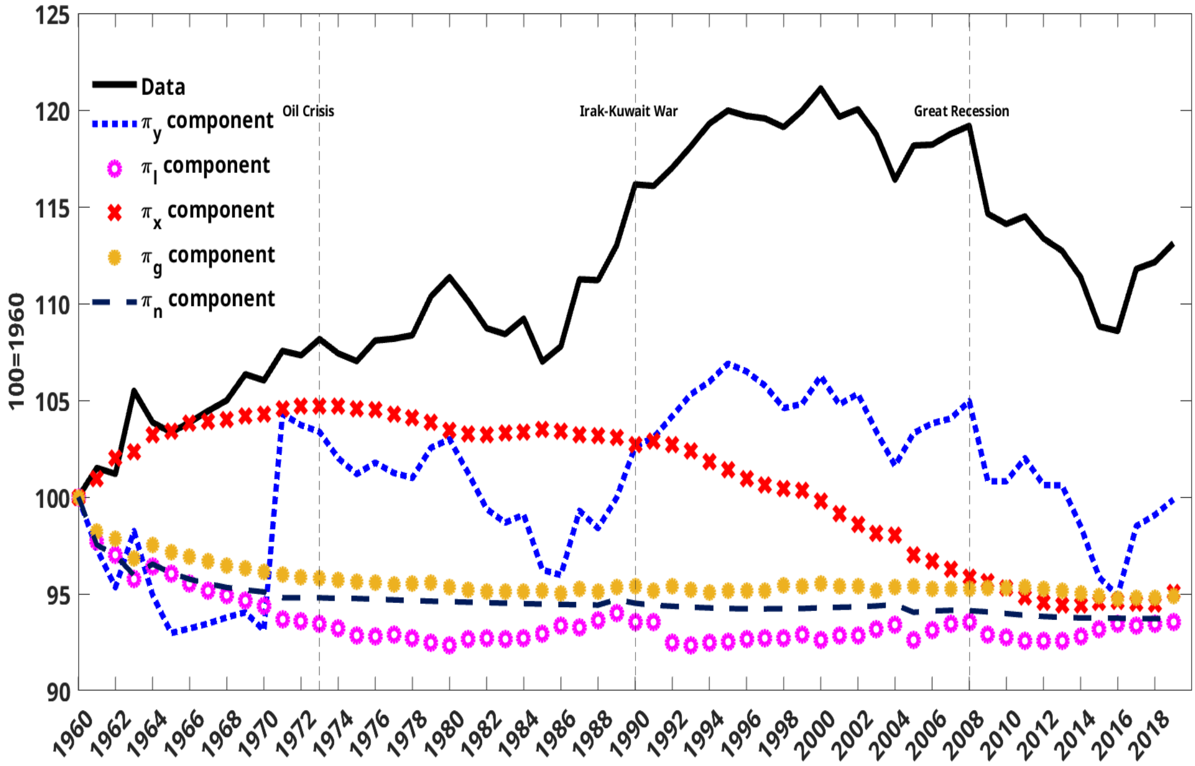


Figure 3: The standard deviation of cross-country distribution of the log of GDP per capita and its components.

Note: The variance of cross-country distribution of the log of GDP per capita is $\sigma_t^2 = \frac{1}{NC_t}\sum_{j=1}^{NC_t}(\log y_{j,t} - \overline{\mu}_t)^2$ (Data in Figure 3 is σ_t) and $\overline{\mu}_t = \sum_{j=1}^{NC_t}\log y_{j,t}$. Where NC_t is the sample number of countries, and y_{jt} is detrended GDP per capita of country j in period t. The π_{it} component of σ_t^2 is $\frac{1}{NC_t}\sum_{j=1}^{NC_t}(\log y_{j,t}^{\pi_i} - \overline{\mu}_t^{\pi_i})^2$ where $y_{jt}^{\pi_i}$ (resp. $\overline{\mu}_t^{\pi_i}$) is the component of y_{jt} (resp. $\overline{\mu}_t$) associated with the wedge π_i with $i \in \{y, l, x, g, n\}$. The online appendix presents for each country the wedges and the respective components of output, labour and investment.

The investment wedge played a significant role in the increase of the standard deviation during the sixties and in its decline from early 1990s to the early 2010s. This suggests that during the first wave of growth, investment restrictions and distortions made it difficult for many low-income countries to ride the wave of technological progress and growth. However, globalisation at the end of the last century and the spread of information technologies helped to ease restrictions on investment –financial and otherwise– in low-income countries, facilitating σ convergence across countries.

Although the evolution of the investment wedge contributed to global σ convergence, the dispersion of per capita income across countries increased until the beginning of this century, driven by the efficiency wedge component. This was probably because developed countries were the first to embrace advances in information technology and

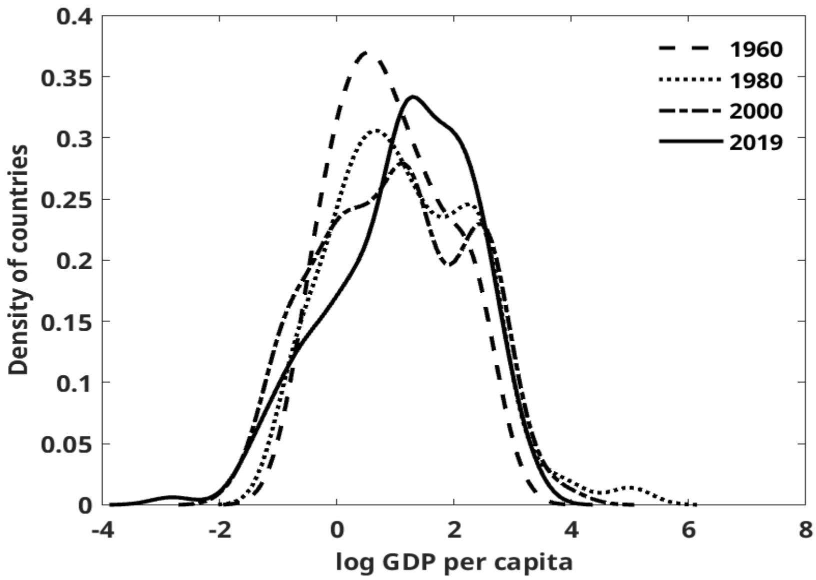


Figure 4: The cross-country distribution of the log of GDP per capita.
Note: Appendix B explains the estimation of the distributions.

to benefit from globalisation, widening the gap between their TFP and that of developing countries. However, since the late 1990s, technological change and globalisation have also been used by poor countries to improve their TFP, which has facilitated the reduction of dispersion.

The important role played by the efficiency and investment wedges in the evolution of the standard deviation is reflected in the relatively high value of its ϕ-statistics: 0.334 and 0.285, respectively (see Table 2). The wedge-alone components due to the population, labour and resource wedges contributed to reducing the standard deviation from 1960 to the mid-seventies, then they remained roughly stable (see Figure 3).

Polarisation. From 1960 to 2000, the cross-country distribution of the log of detrended GDP per capita underwent a process of polarisation, but, since 2000 this trend has reversed (see Figure 4). The the interquartile range (IQR) of the cross-country distribution of the log of detrended GDP per capita and its components are displayed in Figure 5. Polarisation and its reversal are reflected in the interquartile range. In particular, the interquartile range underwent a strong increase from 1960 to the beginning of the 21st century and then a strong decrease that reversed slightly from 2014.

The wedge-alone component due to the efficiency wedge mostly drove both the strong increase in polarisation (measured by the IQR) from mid-sixties to 2000 and the rapid decline thereafter (see Figure 5) until 2014. From 1960 to mid-sixties, the wedge-alone component due to the efficiency wedge led to reducing polarisation, but the wedge-alone components due to the investment and resource wedges led to increasing it. During the nineties, the wedge-alone component due to the investment wedge contributed to reducing polarisation.

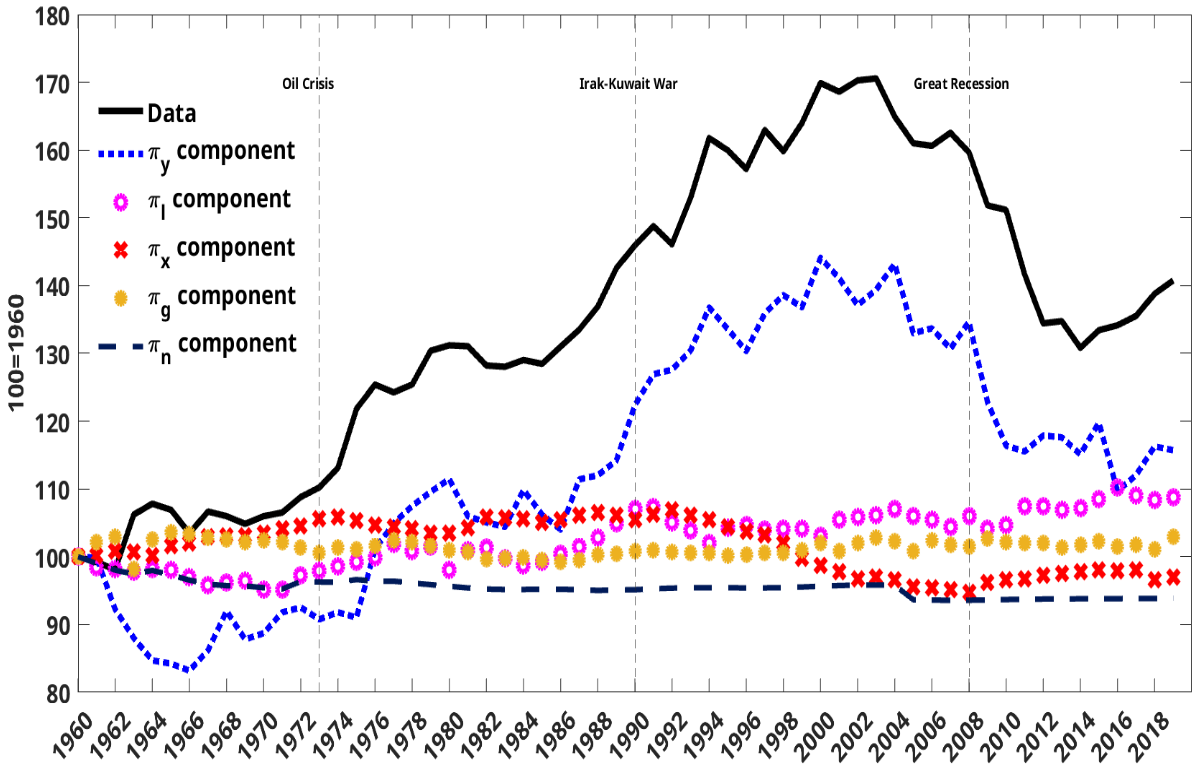


Figure 5: The interquartil range and its components.

Note: Data in Figure 5 is the IQR_t. That is, the difference between the 75$^{\text{th}}$ and 25$^{\text{th}}$ percentiles of the distribution of $\log y_{j,t}$ where y_{jt} is detrended GDP per capita of country j in period t. The π_{it} component of IQR_t is the difference between the 75$^{\text{th}}$ and 25$^{\text{th}}$ percentiles of the distribution of $\log y^{\pi_i}_{j,t}$ where $y^{\pi_i}_{jt}$ is the component of y_{jt} associated with the wedge π_i with $i \in \{y, l, x, g, n\}$. The online appendix presents for each country the wedges and the respective components of output, labour and investment.

This suggests that the globalisation that the world experienced from the mid-1980s onwards, as well as the spread of information technology, initially favoured the richest countries over the poorest. This was probably because the poorest countries were initially left out of the process, neither adopting the new technologies nor participating in global investment and trade flows. This meant that the richest countries increased their advantage in terms of TFP. However, globalisation and technological change soon facilitated investment in these countries and this meant that from the early 1990s the investment wedge component contributed to reducing polarisation. Finally, the benefits of globalisation and technological change reached the poorest countries and, from the end of the last century, polarisation declined, driven by the relative improvement in TFP in the poorest countries.

In short, the evolution of IQR shows a clear big wave between the mid-1980s and the second decade of this century, which fits very well with the dynamics that usually give rise to major economic transformations. First, a group of pioneers jumps on the bandwagon of such transformations, often the richest, and the others are left behind, usually the poorest, and thus inequality and polarisation increase, but eventually the latter also take advantage of the new opportunities and both inequality and polarisation are reduced. Our analysis suggests that the poorest first took advantage of the relaxation of investment restrictions, and only later took advantage of the new technological opportunities.

The wedge-alone components of all wedges excepting the efficiency wedge played a minor role in accounting for the evolution of the IQR, as indicated by the low values of the ϕ-statistics of all wedge-alone components except for the wedge-alone component due to the efficiency wedge (0.441, see Table 2).

Inequality. The previous analysis of polarisation and σ-convergence does not consider that the population size of the countries differs, and it may generate a false picture of the evolution of inequality in the world income distribution. Therefore, we have constructed the Theil Index of the population-weighted cross-country distribution of the log of detrended GDP per capita.

Figure 6 displays the Theil index of the cross-country distribution of the log of detrended GDP per capita and its components. From 1960 to 2000, inequality in the cross-country world income distribution slightly increased, then decreased rapidly until 2012, and then continued to decrease, but at a much slower rate (see Figure 6).

The increase in inequality was driven by the wedge-alone component due to the investment wedge until the beginning of the eighties and thereafter it was driven by the components due to the population, resource and labour wedges until 2000. Starting in 2000, there was a sharp decrease in inequality driven mainly by the wedge-alone component due to the efficiency wedge, although since the mid-eighties the wedge-alone component due to the investment wedge contributed to slightly reducing inequality (see Figure 6). From the early eighties, the wedge-alone components due to resource, labour and population wedges contributed to increase inequality. In the last years of the period analysed, the wedge-alone component due to the labour wedge particularly slowed down the rate of decline in inequality, although, from 1960 to the early eighties, it had contributed to reduce inequality (see Figure 6).

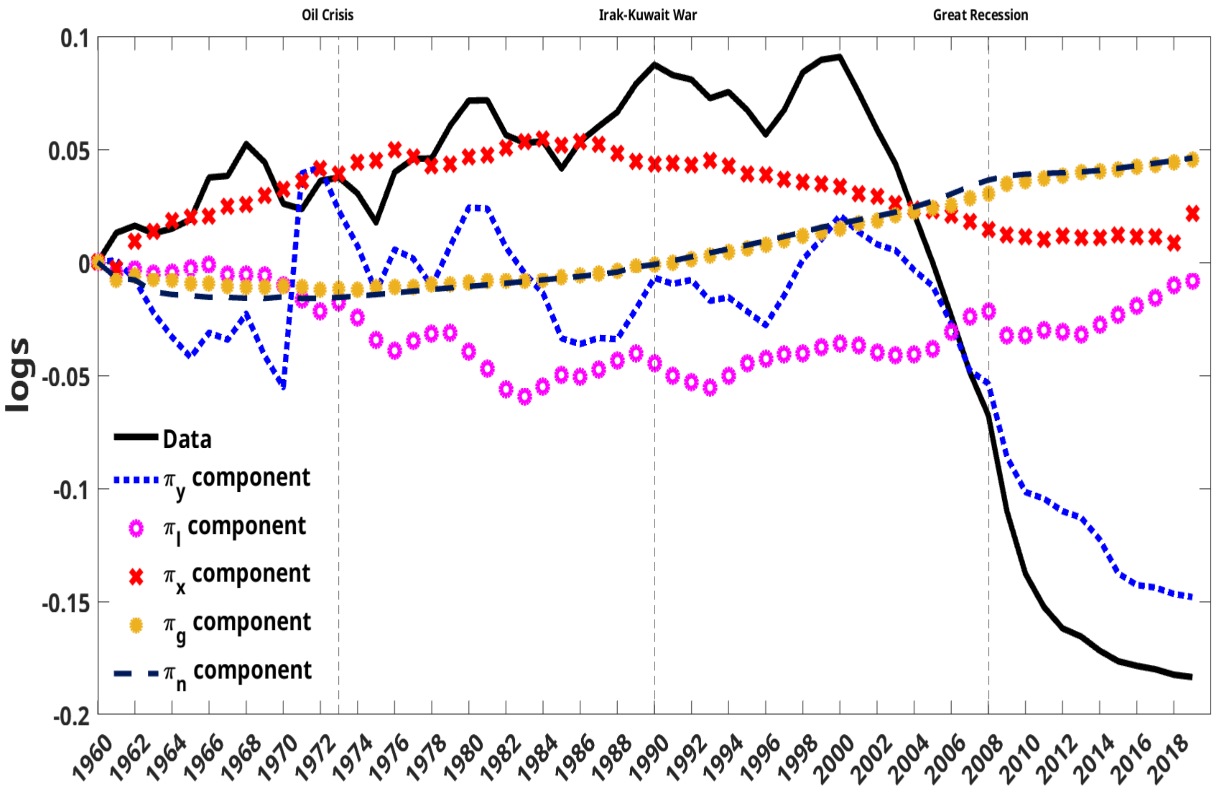


Figure 6: The Theil index of weighted by population cross-country distribution of the GDP per capita (logs).

Note: Data in Figure 6 is the log of Theil index. That is, $\mathrm{T}_t = \sum_{j=1}^{NC_t} \frac{N_{jt}}{N_t} \frac{y_{j,t}}{\mu_t} \log \frac{y_{j,t}}{\mu_t}$. Where $\mu_t = \sum_{j=1}^{NC_t} N_{jt} y_{jt} / N_t$, NC_t is the sample number of countries, N_{jt} is population of country j in period t, $N_t = \sum_{j=1}^{NC_t} N_{jt}$ is total sample population in period t, y_{jt} is detrended GDP per capita of country j in period t. The π_{it} component of T_t is $\sum_{j=1}^{NC_t} \frac{N_{jt}}{N_t} \frac{y_{j,t}^{\pi_i}}{\mu_t^{\pi_i}} \log \frac{y_{j,t}^{\pi_i}}{\mu_t^{\pi_i}}$ where $y_{jt}^{\pi_i}$ (resp. $\mu_t^{\pi_i}$) is the component of y_{jt} (resp. μ_t) associated with the wedge π_i with $i \in \{y, l, x, g, n\}$. The online appendix presents for each country the wedges and the respective components of output, labour and investment.

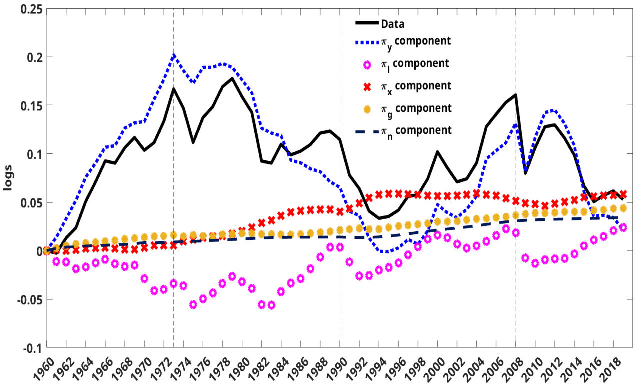
The evolution of the investment wedge component in Figure 6 suggests that from the 1960s to the early 1980s, investment restrictions and distortions slowed growth in poor countries, contributing to rising global inequality. The early 1980s saw the expansion of globalisation and the rise of information technology. From the early 1980s, however, globalisation and technological change eased these restrictions and reduced investment distortions in low-income countries, contributing to a reduction in global inequality. However, the major reduction in global inequality, driven by the efficiency wedge, did not begin until the beginning of this century, suggesting that many developing countries (especially China and India) have been able to fully exploit the potential of globalisation and technological change since then. The contribution of the labour wedge component to the decline in inequality until the early 1980s can probably be explained by the fact that during this period developed countries increased the regulation of their labour markets, but since then some of these developed countries have started to make their labour markets more flexible, while in some developing countries these markets have tended to become somewhat more rigid.

Groups of countries according to income/growth levels. We divide the sample of countries into four quartiles: low-income, lower-middle-income, upper-middle-income and high-income countries. We run a regression between the initial log of GDP per capita relative to the United States and the average annual growth rate of GDP per capita for each country over the time it remains in the sample. We then divide each of the above quartiles into two parts (see Figure 8): high-growth countries (those above the regression line) and low-growth countries (those below the line).The results of our simulations of the logarithm of GDP per capita and its components for each group of income per capita and growth are shown in Figure 7.

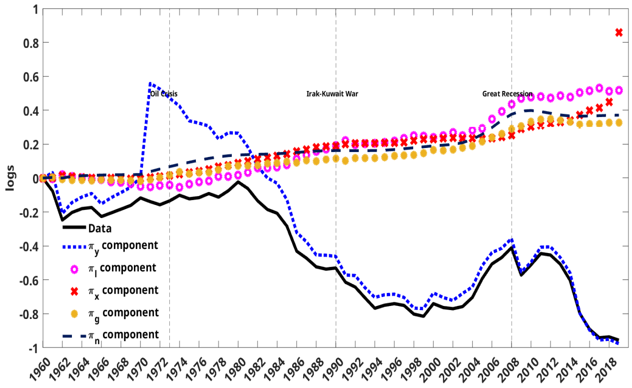
The main conclusion of our analysis is that the efficiency wedge component has driven GDP per capita growth across all quartiles in both high and low growth countries (see Figure 7). However, the analysis also provides some relevant lessons.

Focusing on high-income, low-growth countries and low-income, low-growth countries, we see that in both groups the evolution of GDP per capita is mainly driven by the efficiency wedge component. The components of the other wedges played a minor role (see Figure 7, panels (b) and (h)). Thus, according to our result, the driving force of both economic miracles and failures is TFP. The study of miracles and failures then needs to focus on the economic, technological and institutional factors that strengthened or weakened TFP growth. Factors affecting other wedges seem to be of secondary importance.

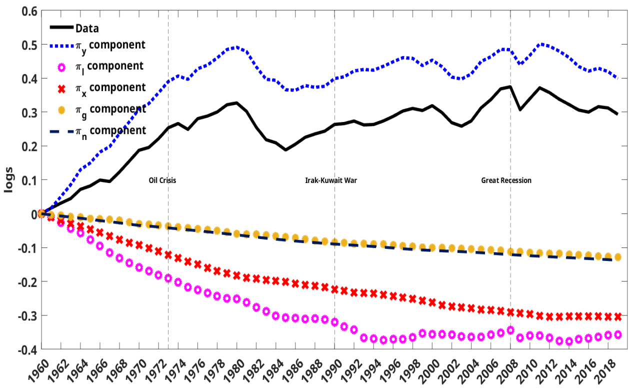
The investment and labour wedges have made a negative contribution to growth of GDP per capita in middle-income countries, especially in those that have exhibited high growth (see Figure 7 , panels (c) and (e)). This suggests that successful middle-income countries have tightened labour and investment regulations. This is often the case in countries embarking on the path of economic development as they seek to reconcile economic growth with other objectives such as equity in the distribution of income or the protection of workers or the environment.



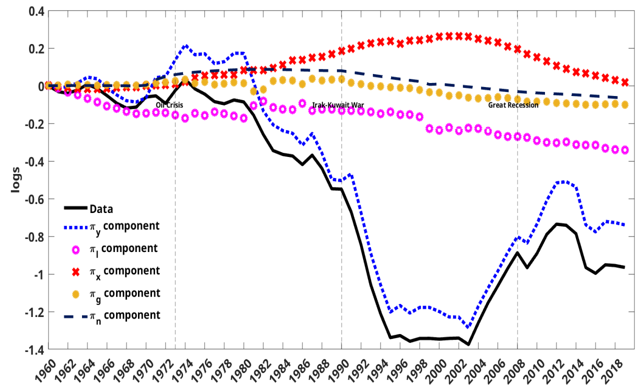
(a) High Income-High Growth Countries.



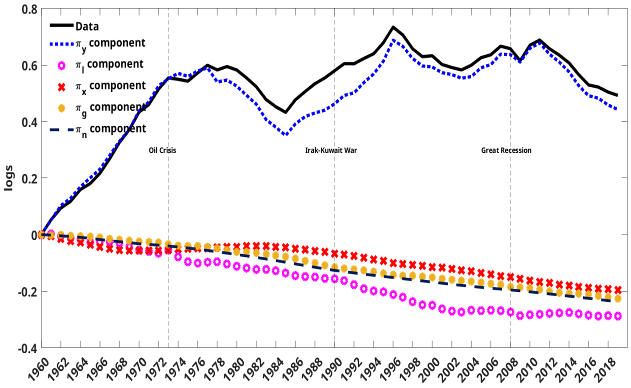
(b) High Income-Low Growth Countries.



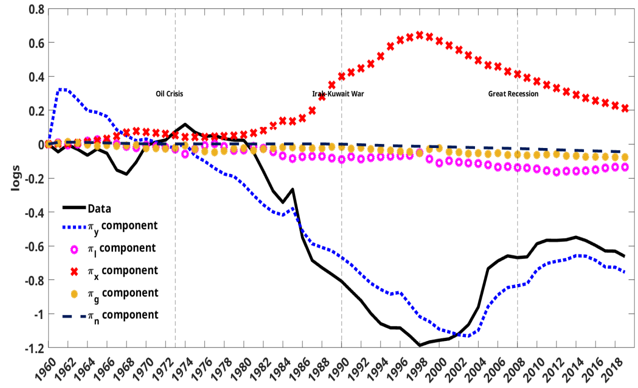
(c) Upper Middle Income-High Growth Countries.



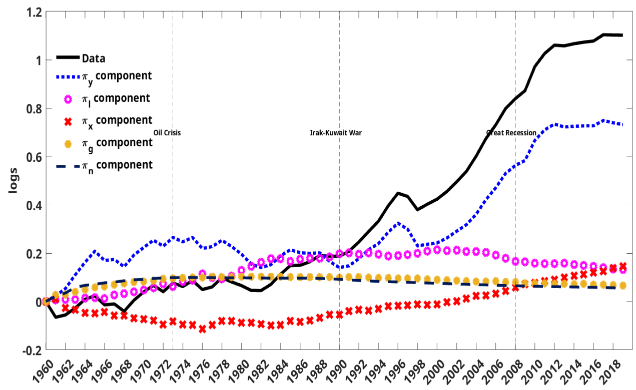
(d) Upper Middle Income-Low Growth Countries.



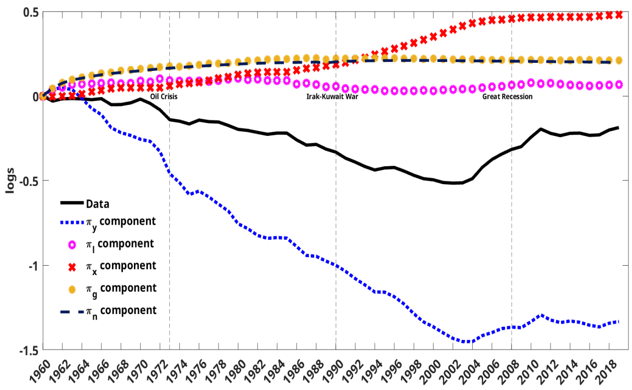
(e) Lower Middle Income-High Growth Countries.



(f) Lower Middle Income-Low Growth Countries.



(g) Low Income-High Growth Countries.



(h) Low Income-Low Growth Countries.

Figure 7: World GDP per capita and its components (logs). Groups of countries.

However, the investment wedge contributed significantly to growth of GDP per cápita in low-income countries, especially after the early 1990s (Figure 7). This suggests that low-income countries (even those with low growth) have taken advantage of globalisation and technological change to access better investment opportunities, and explains why, especially since the early 1990s, the investment wedge has contributed significantly to reducing the dispersion, polarisation and inequality in the distribution of GDPper capita across countries, as we have noted above.

The cluster analysis clearly illustrates why cross-country income inequality declined from the late 20th century onward. Panel (g) of Figure 3) demonstrates that low-income countries, particularly those with high growth but also, to a lesser extent, those with low growth, experienced substantial productivity gains driven by the efficiency wedge. In higher-income groups, TFP gains are also evident but less pronounced, especially in middle-income, high-growth countries.

Global events Three global events shook the global economy over the period analysed: the oil crisis (1973), the Iraq War (1990), and the Great Recession (2008). All three events negatively had a negative impact on global economic growth, with the growth rate of global output per capita declining in the years immediately afterwards. Our analysis reveals that the efficiency wedge was the driving force behind the slowdown following all three events (see Figure 2)).[8] At the same time, the standard deviation of the cross-country distribution of the log of GDP per capita and the Theil index also declined. In other words, these three events could have significantly reduced the dispersion and inequality in the distribution of global income across countries. Once again, the efficiency wedge was largely responsible for the reduction in dispersion and inequality (see Figure 4)).

Our analysis by country group clearly explains why a reduction in dispersion and inequality occurred alongside a reduction in growth. Per capita output growth strongly slowed after all three events in high-income countries, particularly in those that had also exhibited high growth (see Figure 3), panels (a) and (b)). The labour wedge exacerbated the growth slowdown in high-income high-growth countries (see Figure 3), panel (a)). The impact of the Great Recession was felt in upper middle income countries (see Figure 3), panels (c) and (d)). It was also the efficiency wedge that drove the slowdown in this group. In upper middle income and low growth countries, as in high-income countries, the 2012 debt crisis that followed the Great Recession

[8]Recent studies, such as Xiao et al. (2024), highlight the long-memory properties of TFP, suggesting that technological shocks during these events might have persistent effects on economic dynamics.

(2008) also had a large negative impact on economic growth. Low-growth, upper-middle-income countries experienced the greatest slowdown in their growth in the years immediately following the Iraq War (1990). The negative impact of the Great Recession was also felt on growth in lower middle income countries, although to a lesser extent than in higher-income countries. The oil shock (1973) and the Iraq War do not appear to have had, on average, a significant impact on this group of countries (see Figure 3), panels (e) and (f)). As can be seen in the panels (g) and (h) of Figure 3), these events had, on average, null impact on per capita output growth low-income country groups, regardless of whether their growth during the analysed period was high or low.

Summary. Our main findings can be summarized as follows:

1. Throughout the entire period, the evolution of world income per capita was almost exclusively driven by the contribution of the efficiency wedge, and, if we exclude the first half of the sixties, the same can be said of the evolution of the polarisation of the cross-country distribution of income per capita. All wedges, with the exception of the efficiency wedge, contributed to slightly reducing the pace of growth in world income per capita.

2. The investment wedge played a significant and primary role in accounting for the increase in the cross-country dispersion of income per capita from 1960 to the mid-seventies, but the rapid σ-divergence from the mid-eighties to the mid-nineties as well as its subsequent strong decline was mostly driven by the efficiency wedge, even if the investment wedge also played a significant, but secondary, role.

3. The sharp decline in inequality in the cross-country distribution of income per capita since the beginning of the 21^{st} century was largely driven by the contribution of the efficiency wedge. However, its slight increase between 1960 and the mid-1980s was mainly driven by the investment wedge and, from the mid-1980s to 2000 by the labour, resource and population wedges.

4. The growth of per capita income and its dispersion across countries is mainly driven by the efficiency wedge, regardless of the level of income or growth of a country and, in particular, in high-income, low-growth countries and low-income, low-growth countries. The investment and labour wedges have made a negative contribution to growth of GDP per capita in middle-income countries, especially

in those that have exhibited high growth. However, the investment wedge contributed significantly to growth of GDP per cápita in low-income countries, especially after the early 1990s.

5. World economic growth slowed in the years immediately following the oil crisis (1973), the Iraq War (1990), and the Great Recession (2008), while the dispersion and inequality in the distribution of per capita income across countries also decreased. This was due to a higher reduction in per capita output growth in high-income countries, which was mainly driven by the efficiency wedge.

In our view, these observations can be explained as follows. Between 1960 and 2019, the world experienced two periods of high growth. The first from 1960 until the oil crises (1973-1978) and the second from the late 1990s until the debt crisis (2011-2012). In both periods, global economic growth was driven by the efficiency wedge and then by technological and institutional processes that fostered technology adoption, R&D and innovation and human capital accumulation, as well as international trade, global investment flows and resource reallocation. .

In the first period, TFP growth reflected the benefits of the second industrial revolution and the new international order that emerged after the Second World War. However, these benefits were mostly concentrated in rich countries, leading to an increase in dispersion, polarisation and inequality. In many middle-income countries, obstacles to productive investment made matters worse.

In the second period, TFP growth reflected the benefits of two processes that gained particular momentum from the mid-1980s onwards: globalisation and new information technologies. Especially from the end of the last century, the benefits of these processes reached many populous emerging economies, even though globalisation and new technologies had already made investment conditions more flexible in many low and middle income countries. All this led to a reduction in dispersion, polarisation and inequality from the beginning of this century.[9]

6 Conclusion

This paper applies a stochastic dynamic general equilibrium framework with wedge decomposition to analyse global growth and income distribution dynamics between 1960 and 2019. Our findings show that TFP, captured through the efficiency wedge,

[9] Lang and Tavares (2024) find that globalization has promoted a dual trend of income convergence across countries and income divergence within countries.

has been the primary driver of global per capita income growth across all country groups, irrespective of income level or growth performance. This means, among other things, that both growth miracles and disasters have been driven by forces expressed in TFP growth. Thus, growth and development theorists have been right to focus their research on understanding the determinants of total factor productivity. The contribution of the investment and labour wedges varies significantly across contexts. In high-growth middle-income countries, these wedges tended to constrain growth, likely reflecting regulatory rigidities. Conversely, in low-income economies, the investment wedge contributed positively to growth —particularly from the early 1990s onward— likely due to improved investment conditions and access to global capital flows.

Over the period studied, income dispersion, inequality and polarization initially increased, driven by the investment and efficiency wedges. The investment wedge played a more important role until the early 1970s, while the efficiency wedge raised his importance from the mid-1980s to the mid-1990s. However, since the early 2000s, these trends reversed, largely due to TFP gains in emerging economies. These findings highlight the central role of TFP in shaping both global growth and cross-country inequality, and suggest that policies aimed at fostering innovation, strengthening institutions, and enabling technological diffusion are key to achieving sustained and inclusive development.

The evolution of global GDP per capita and its dispersion across countries is consistent with the existence of two major growth waves. The first lasted until the mid-1970s. The oil crises brought it to an abrupt end. This wave of growth could have been guided by the applications of the second industrial revolution and the opening up of international trade promoted by the new international order that emerged after the Second World War. However, with a few exceptions, the fruits of these advances were confined to the developed world, while the developing world remained relatively marginalised. As a result, the dispersion, polarisation and inequality in the distribution of per capita income between countries increased. With the advent of information technologies and economic globalisation, things changed. Although initially developed countries again took the lead and dispersion, polarisation and inequality increased, over time the benefits of technological change and globalisation were increasingly shared by many developing countries and dispersion, polarisation and inequality were reduced.

Beyond the specific findings, this analysis raises at least three relevant questions for the theory of economic growth and development. First, what underlying forces explain the two distinct waves of global per capita income growth observed between 1960 and 2019? Our results suggest that these waves are closely linked to economic forces expressed in the efficiency wedge, but further research is needed to understand the mechanisms behind those shifts. Second, why did the first wave of growth in the 1960s coincide with rising cross-country income dispersion, polarization and inequality —largely influenced by the investment wedge— while the second wave in the 2000s was associated with declining dispersion, polarization and inequality, driven by the efficiency and investment wedges? Third, what accounts for the role reversal of the efficiency wedge —from a driver of inequality in the late 20th century to a contributor to convergence in the early 21st? A plausible explanatory hypothesis for these questions lies in differences across countries in innovation, adoption, and technological diffusion during different phases of globalization, but this remains an open and important area for future research.

Appendix A Data

Data are provided by Penn World Tables 10.0 (PWT10). Population is variable *Population* (**pop**), N = **pop** . Output per capita is *Output-side real GDP at chained PPPs* (**rgdpo**) divided by **pop**, y = **rgdpo/pop**. We compute the consumption share dividing *Real consumption of households and government at current PPPs* (**ccon**) by *Output-side real GDP at current PPPs* (**cgdpo**), c/y = **ccon/cgdpo**. We compute investment at current PPPs by substracting **ccon** from *Real domestic absorption (real consumption plus investment) at current PPPs* (**cda**). The investment share is computed dividing **cda-ccon** by **cgdpo**, x/y = **(cda-ccon)/cgdpo**. Consumption and investment per capita, c and x, are obtained multiplying the consumption and investment shares by ouput per capita, y. We normalize output, consumption and investment dividing by the geometric mean of detrended world output per capita between $t_0 = 1960$ and $t_0 + T = 2019$. This means that : $\sum_{t=t_0}^{t=t_0+T} \log y_{w,t} \left(1+\gamma\right)^{t_0-t} = 0$ where $\widehat{y}_{w,t}$ is world output per capita at time t. Hours worked per capita are computed multiplying the *Number of persons engaged in production*(**emp**) by *Average annual hours worked by persons engaged* (**avh**) and dividing by *population* (**pop**): h =**emp*avh/pop**.

There is a paucity of data on employment for some countries in the PWT10.0 dataset. To address this deficit, a regression between employment (**emp**) as variable dependent and population (**pop**) and real GDP per capita (**rgdpo**) as independent variables (all variables in logs) is run for each country with an incomplete series. The regression is used to forecast the missing values, thereby filling in the series. In the case of Sint Maarten (Dutch part), where there is no employment data, the same regression is run using data from other Caribbean islands, and the forecasts are used to construct a series for Sint Maarten (Dutch part).

Despite the presence of countries with incomplete series of employment data, these nations represent a relatively small fraction of the world population. A more pressing issue is the lack of hours worked data for many countries. To address this, for each country with incomplete series of hours worked a regression was conducted, with **avh** as the dependent variable, and **rgdpo**, **pop**, **emp**, x/y (all variables in logs), and time as the independent variables. Forecasting was used to complete the series. For countries without any hours worked data, we use the avalaible data of all countries to conduct a regression with **avh** again as the dependent variable, and the same independent variables as before, plus dummies for OCDE countries, European Union countries, Anglo-Saxon countries (United Kingdom, United States, Canada, Australia and New Zealand), East Asian, Other Asian Countries, Soviet Block Ex-Countries, and South and Central America countries (including Mexico). For each country without data on hours worked, the forecasting of the regression for the available data of the country on the independent variables was used to build the series of hours worked by person engaged in production.

A lack of data on the number of hours worked per worker, and the subsequent need to estimate these figures for many countries can introduce unwanted biases into our results. However, employment and population data are available for most countries. Hours worked per capita are calculated by multiplying the number of hours worked per worker by the employment rate (i.e. the employment-to-population ratio). Most changes in hours worked per capita are due to changes in the employment rate. Changes in hours worked per worker have little influence. Therefore, even if our estimates of the number of hours worked per worker were not very precise, the resulting error will typically have little influence on the relevant variable: hours worked per capita. Furthermore, we conducted all our simulations using the employment rate as a measure of labour effort rather than hours worked per capita, and the results we obtained are very similar to those presented in the paper.

After 1960, the large changes in sample size in the 1970s and 1990s produce significant effects on the distribution statistics. Therefore, we have corrected the statistics in order to eliminate the level effects caused by such changes. For example, take U to be a distribution statistic computed using the full sample and take W to be the same statistic computed removing from the sample the countries incorporated at $T_0 = 1970$. So, we construct a new statistic

$$X_t = \begin{cases} U_t \frac{U_{T_0}}{W_{T_0}} & t < T_0 \\ U_t & t \geq T_0 \end{cases}$$

Now, consider that Y is again the same statistic, but computed by removing from the sample the countries incorporated at $T_1 = 1990$. So, we construct a new statistic

$$Z_t = \begin{cases} X_t \frac{X_{T_0}}{Y_{T_0}} & t < T_1 \\ X_t & t \geq T_1 \end{cases}$$

Appendix B Cross-Country Distributions and Inequality Measure

We approximate the cross-country's annual income distribution using a nonparametric kernel density function. This procedure does not impose specific functional forms on cross-country distributions. One key parameter that needs to be specified is the bandwidth of the kernel. We adopt the Gaussian kernel and select bandwidth by following Silverman's (1986) rule of thumb; the bandwidth is set to be $0.9 \times \hat{\sigma} \times n^{-1/5}$, where $\hat{\sigma}$ is the standard deviation of the sample and $n = 183$ is the number of observations for each year. Obviously, each year has a different $\hat{\sigma}$ so, if we use this formula for the bandwidth, we would have to assume a different bandwidth for each year. Instead, we prefer to use the same bandwidth for all periods. One reason is that, with a constant bandwidth it is very easy to visualize whether the variance of the distribution has increased or decreased over time. Given a bandwidth, the density function will have the regular hump (normal) shape when the variance of the distribution is relatively small. As the variance increases, the kernel density function starts displaying peaks and valleys. We settle on the simple (nonpopulation-weighted) mean value for $\hat{\sigma}$ of detrended which is $\hat{\sigma} = 1.1208$. The implied bandwidth used is, therefore, 0.3559. We evaluate the density function at 100 different points so that each cross-country's distribution is decomposed into 100 centiles.

As inequality statistic we have chosen the Theil index:

$$\mathrm{T}_t = \sum_{j=1}^{NC_t} \frac{N_{jt}}{N_t} \frac{y_{j,t}}{\mu_t} \log \frac{y_{j,t}}{\mu_t}$$

where $\mu_t = \sum_{j=1}^{NC_t} N_{jt} y_{jt} / N_t$, NC_t is the sample number of countries, N_{jt} is population of country j in period t, $N_t = \sum_{j=1}^{NC_t} N_{jt}$ is total sample population in period t, y_{jt} is detrended GDP per capita of country j in period t.

The Theil index is based on the concept of entropy from information theory and has the characteristic of being more sensitive to changes in the extremes of the distribution, which allows us to better capture differences when the highest or lowest values vary significantly. This is the main difference with the Gini index which is characterised by being more sensitive to differences in the mean values than at the extremes. This sensitivity is especially useful in international contexts, where there is a large dispersion of values. Thus the Theil index can better capture the impact of countries with very high or very low income per capita on overall inequality.

Appendix C Groups of countries according to income/growth levels

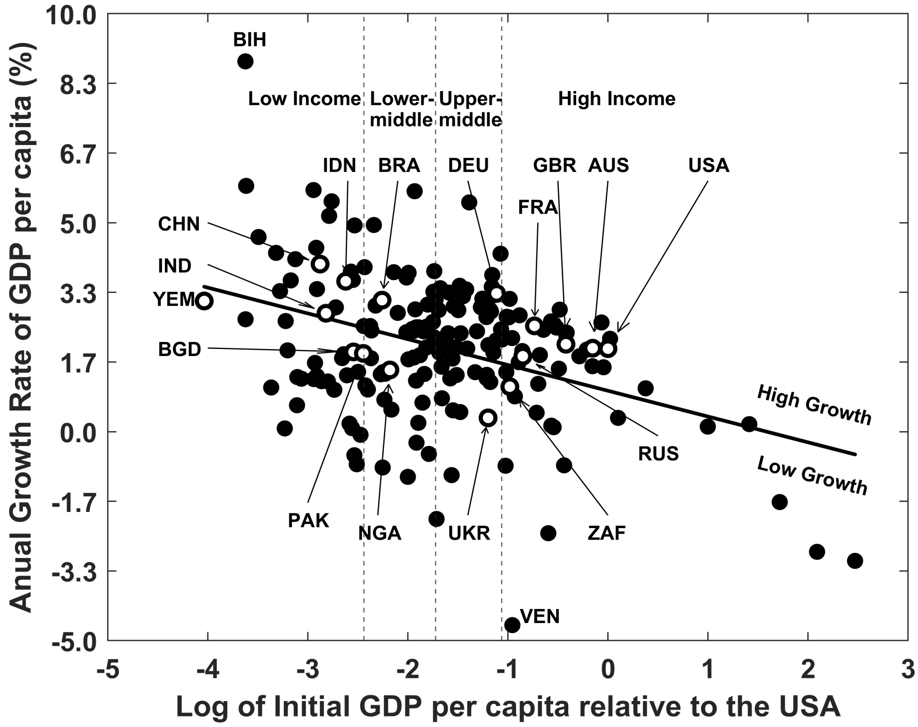


Figure 8: Country groups by income and growth.

Note: The solid line is the regression line between the average annual growth rate of GDP per working-age population and the logarithm of each country's initial GDP per working-age population relative to that of the USA. The vertical dashed lines indicate the 0.25, 0.5 and 0.75 quantiles of the log of initial GDP per capita relative to the USA distribution. CHN is China, IND is India, YEM is Yemen, BGD is Bangladesh, BIH is Bosnia and Herzegovina, IDN is Indonesia,PAK is Pakistan,BRA is Brazil, NGA is Nigeria, DEU is Germany, UKR is Ukraine, FRA is France, GBR is United Kingdom, AUS is Australia, USA is United States, ZAF is South Africa, RUS is Russian Federation, and VEN is Venezuela. Table A.1 in the online appendix shows which group each country belongs to.

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