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Productivity Growth

Patterns and Determinants across the World

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Abstract

This is the background paper for the productivity extension of the World Bank's Long-Term Growth Model (LTGM). Based on an extensive literature review, the paper identifies the main determinants of economic productivity as innovation, education, market efficiency, infrastructure, and institutions. Based on underlying proxies, the paper constructs indexes representing each of the main categories of productivity determinants and, combining them through principal component analysis, obtains an overall determinant index. This is done for every year in the three decades spanning 1985–2015 and for more than 100 countries. In parallel, the paper presents a measure of total factor productivity (TFP), largely obtained from the Penn World Table, and assesses the pattern of productivity growth across regions and income groups over the same sample. The paper then examines the relationship between the measures of TFP and its determinants. The variance of productivity growth is decomposed into the share explained by each of its main determinants, and the relationship between productivity growth and the overall determinant index is identified. The variance decomposition results show that the highest contributor among the determinants to the variance in TFP growth is market efficiency for Organisation for Economic Co-operation and Development countries and education for developing countries in the most recent decade. The regression results indicate that, controlling for country- and time-specific effects, TFP growth has a positive and significant relationship with the proposed TFP determinant index and a negative relationship with initial TFP. This relationship is then used to provide a set of simulations on the potential path of TFP growth if certain improvements on TFP determinants are achieved. The paper presents and discusses some of these simulations for groups of countries by geographic region and income level. An accompanying Excel-based toolkit, linked to the LTGM, provides a larger set of simulations and scenario analysis at the country level for the next few decades.

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"It is not by augmenting the capital of the country, but by rendering a greater part of that capital active and productive than would otherwise be so, that the most judicious operations of banking can increase the industry of the country." Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations* (page 131).

1. Introduction

With the same amount of inputs –including labor, human and physical capital, and materials—some countries, sectors, and firms produce more and others less. This difference depends on how productive they are in allocating and using resources in the production process. One of the most important lessons in economics is that productivity improvement is key to sustained economic growth. (See, among others, Hall and Jones 1999, Easterly and Levine 2001, and Caselli 2005.)

Productivity was a main concern of the fathers of modern economics, Adam Smith and David Ricardo, in the eighteenth century, as they considered the advantages of specialization and trade as the basis for the wealth of nations. In the first half of the twentieth century, as advanced economies started to recover from the Great Depression, Hicks (1939) and Schumpeter (1942) emphasized the importance of productivity improvements, linking them to enterprise renewal and "creative destruction." When economists turned their attention to developing countries, they described productivity growth as crucial in the search for sustained growth and development. For Lewis (1954), Kuznets (1957), and Chenery (1960), economic development required a structural transformation that shifted resources from less to more productive sectors of the economy. More recently, since the productivity slowdown in developed countries in the 1970s, the lackluster growth of developing countries in the 1980s, and the collapse of the communist regimes in Eastern Europe and East Asia in the early 1990s, interest in understanding the sources of growth and productivity has grown exponentially (see Woo, Parker, and Sachs 1997; Ben-David and Papell 1998; Easterly 2001; Jorgenson, Ho, and Stiroh 2008).

Placing the study of productivity in the context of economic growth research may bring about important insights. In the 1950s, Solow and Swan developed a growth model in which changes in physical capital, labor, and total factor productivity (TFP) determine the economy's growth rate (Solow 1956; Swan 1956). It has proven to be a

workhorse of growth theory and applications for over 50 years. A drawback of this model, however, is that the path of TFP is assumed to be exogenous. At least since the mid-1980s, theoretical economists have addressed this shortcoming. For example, Romer (1987, 1990), Grossman and Helpman (1991), and Aghion, Philippe, and Howitt (1992) incorporated technological advance through research and development (R&D) as a driver of long-run growth. Lucas (1988) argued that the accumulation of human capital through education creates a positive externality that drives productivity, which in turn explains long-run growth. Rebelo (1991) included both human and physical capital in a composite measure that faces no decreasing returns, suggesting that continuous investment can lead to long-term growth. Barro (1990) and Barro and Sala-I-Martin (1992) incorporated tax-financed public goods and assumed that they complement private capital, so that concurrent investment in both public and private capital could lead to growth in the long run. Engerman and Sokoloff (2000) and Acemoglu, Johnson, and Robinson (2001, 2004) deepen the notion of public goods to argue that the role of political and economic institutions is fundamental to economic growth. It can be said that in all these cases, the proposed mechanisms driving productivity are ways of explaining economic growth in the long run without resorting to exogenous changes.

The interest in understanding the microeconomic foundations of aggregate behavior has also led to important insights on productivity. Hopenhayn (1992), Hopenhayn and Rogerson (1993), Caballero and Hammour (1996), and Davis, Haltiwanger, and Schuh (1996) pioneered research on the role of firm dynamics driving productivity and, consequently, economic growth. The conclusion from this extensive body of research is that resource reallocation (including firm entry and exit, innovation and renewal, and structural transformation) explains a substantial share of productivity improvement in the economy. Resource reallocation requires, however, a costly adjustment: the adoption of new technologies, the assimilation of production inputs by expanding firms, and the shedding of labor and capital by declining firms. Differences in the ease of resource reallocation can then explain why some countries are more productive than others. These differences can be related to the level of development of the country (e.g., lack of human capital and functioning justice system; see Caballero and Hammour 1998 and Daron Acemoglu and Zilibotti 2001) and to the quality of government's regulations and interventions (e.g.,

excessive labor regulations, subsidies to inefficient sectors, and barriers of firm entry and exit; see Parente and Prescott 2000). Although more refined in the mechanisms, the microfoundations literature points to the same conclusions as the aggregate literature highlighted above, regarding the roles of innovation, education, regulatory environment, and public goods and institutions in driving productivity.

The surge in theoretical research on economic growth and productivity has been paralleled by an enormous empirical literature. A selected review is offered in the second section of the paper. In brief, this empirical research attempted to, first, test the validity of recent growth theories in contrast to (or in conjunction with) the neoclassical growth theory, and, second, determine the quantitative importance of various proposed drivers of growth. The first wave of empirical studies on new growth research focused on aggregate, cross-country data. In academic circles, this line of work is best exemplified by Barro's (1991) seminal study. In the World Bank and other policy-oriented organizations, empirical studies such as Easterly and Levine (1997, 2001), Loayza, Fajnzylber, and Calderón (2005), and Loayza and Servén (2010) offered a guide for understanding economic growth and its determinants, including policies and institutions. As micro-level data became more widely available in the 1990s, a second wave of empirical research used data at the industry and firm levels to study firm renewal, resource redistribution, and structural transformation. This led to insights and findings that could not have been obtained using country-level data, as shown in Foster, Haltiwanger, and Krizan (2001), Restuccia and Rogerson (2008), and Hsieh and Klenow (2009).

Considering numerous studies on economic growth and productivity published in the past few decades, in this paper we take stock of the main conceptual conclusions surrounding productivity growth and synthesize the quantitative implications through original data collection and analysis. Apart from its independent contribution, this paper serves as background for an extension of the World Bank Long-Term Growth Model (Loayza and Pennings 2018). This extension quantifies how changes in TFP growth are driven by changes in its underlying determinants, and, in turn, how changes in TFP growth lead to different paths for economic growth.

The drivers of productivity growth can be grouped into five components (Kim, Loayza, and Meza-cuadra 2016): *innovation*, to create and adopt new technologies; *education*, to spread these new technologies throughout the economy and to develop the capacity of the workforce to assimilate them; *market efficiency*, to promote the effective and flexible allocation of resources across sectors and firms; *infrastructure* (in transport, telecommunication, energy, and water and sanitation), to support and facilitate the economic activity of households, businesses, and markets; and *institutions* (in the regulatory, justice, policy, and political systems), to provide social and economic stability, to defend property rights, and to safeguard basic civil rights. These five components are interrelated and can clearly influence one another.

In this paper we identify the main determinants of productivity growth, propose proxies to measure them, assess the pattern of TFP growth across regions and over time, and quantify the relationship between the TFP determinants proxies and TFP growth. For this purpose, we first conduct an extensive literature review on productivity that considers not only concepts and theories but also empirical studies. Then, we estimate TFP and construct indexes representing each of the five main determinants of TFP for a large group of countries in the past three decades (from 1985 to 2014). Finally, we measure the relative contribution of each of the main determinants to the variance of TFP growth, and we estimate their overall effect on TFP growth. As mentioned above, these results are used to build a TFP module for the extended Long-Term Growth Model (LGTM).

In the rest of the paper, section 2 presents a review of the literature; this is important because it not only frames the context of the paper but also helps to identify and categorize the drivers of TFP growth. Section 3 describes the methodology, including the selection of countries and variables, the estimation of TFP, the construction of indexes to measure each TFP determinant category, and the variance decomposition and regression analysis. Section 4 presents and discusses the main results, from descriptive statistics to regression analysis. Section 5 uses the main results to generate simulations on the path of TFP growth if certain reforms are accomplished. Section 6 concludes.

2. Literature review

To identify and categorize the main determinants of TFP, we conduct a literature review spanning papers published from 1990 to 2016. We start with the reviews conducted by Isaksson (2007) and Syverson (2011) and expand the search further by using the key terms “total factor productivity,” “economic growth,” and “determinants.” We filter papers based on abstracts and main texts, choosing those that present a quantitative relationship between productivity and its potential determinants, using evidence from developing and developed countries. We select papers that examine time-variant determinants that a country can improve either through market forces or by public policy decision and implementation. (See Appendix A for the full list of the papers.) Based on the literature review, the main determinants of productivity are categorized into five components: innovation, education, market efficiency, infrastructure, and institutions (Kim, Loayza, and Meza-Cuadra 2016).

Innovation

Innovation, as the generation and adoption of new technologies, leads to the development of higher value-added activities, products, and processes and improves the performance of existing ones. Historically, a small number of countries have created new technologies based on investment in research and development (R&D) by the public and private sectors and an advanced level of human capacity and physical capital (Furman and Hayes 2004; Griffith, Redding, and Reenen 2004). Other countries have then adapted and adopted technological changes, with varying time lags and degrees of intensity (Comin, Hobijn, and Rovito 2008).

Using indicators such as investment in R&D, the number of patents, and the number of scientific and technological journal publications, many studies show that the creation or adoption of a new technology is positively associated with TFP growth (see, for example, Nadiri 1993; Chen and Dahlman 2004; Guellec and van Pottelsberghe de la Potterie 2004). For instance, Jorgenson, Ho, and Stiroh (2008) and Oliner, Sichel, and Stiroh (2008) show that Information and Communication Technologies (ICT) played a central role in accelerating productivity in the United States (U.S.) from the mid-1990s to the 2000s after the lackluster pace of productivity growth in the 1970s and 1980s. The comparison of Europe and the U.S. highlights the critical role of new

technologies in expanding productivity. Van Ark, O'Mahony, and Timmer (2008) show that the productivity slowdown in Europe during the 1990s and 2000s is attributable to the lower contribution of ICT to growth, the smaller share of technology-producing industries, and slower advances in technology and innovation as compared to the U.S. Not only the development of new technologies but also the adoption of existing ones play a substantial role in enhancing productivity and income growth. Comin and Hobijn (2010) and Comin and Mestieri (2018), using data on the diffusion of more than 15 technologies across a large number of countries over the last two centuries, show that varying patterns of the adoption and diffusion of technologies since 1820 account for at least 25 percent of the income divergence across countries and 75 percent of the income difference between rich and poor countries.

Education

Education, as the knowledge and skills of the population, is essential to generate new technologies, as well as to disseminate, adapt, and implement them throughout the economy. Education allows workers not only to produce more and better, but also to expand and disseminate the technological frontier. For education to contribute to productivity, it must consist of strong basic foundations and sufficient specialization, rich in both quantity and quality, and spread throughout the population (Barro 2001; Hanushek and Woessmann 2015).

Studies suggest that indicators such as the number of schooling years and the completion rate of secondary and tertiary education of the population are associated with output growth through both TFP improvements and the direct contribution of human capital (Benhabib and Spiegel 1994; Griffith, Redding, and Reenen 2004; Bronzini and Piselli 2009; Erosa, Koreshkova, and Restuccia 2010). Having a sufficiently high level of education increases productivity growth in developing countries by enabling them to adopt new technologies from frontier countries. Benhabib and Spiegel (2005), for example, show that a country's average years of schooling (as a proxy for education) has a positive impact on TFP growth through technology catch-up. Miller and Upadhyay (2000) show that education (also using the years of schooling as a proxy) can affect how developing countries adopt new technologies through trade, with a positive impact on TFP. Barro (2001) shows in a study of around 100 countries that the quantity and quality of education, using the years of schooling and student test scores as respective

proxies, are significantly related to economic growth. Wei and Hao (2011) show that education quality, using government expenditure on education and teacher-student ratio as proxies, is significantly associated with TFP growth in China.

Market Efficiency

Market efficiency, defined as the efficient allocation of resources (e.g., labor, capital, and materials) across firms and sectors, enhances TFP by inducing unproductive firms to exit the market, facilitating productive firms to grow, and allowing new firms to emerge (Foster, Haltiwanger, and Krizan 2001; Hsieh and Klenow 2009; Parente and Prescott 2000; Restuccia and Rogerson 2017). Market efficiency has several components, including the proper functioning of output markets, financial systems, and labor markets.

A number of studies find that market efficiency is associated with variation in productivity across firms, sectors, and countries. Jerzmanowski (2007) shows that inefficiency in the allocation of human and physical capital is the main explanation for low income level among around 80 countries from 1960 to 1995. Hsieh and Klenow (2009) estimate that, if capital and labor had been allocated at the relatively efficient level of the U.S., productivity in manufacturing sectors could have been 1.3 times higher for China and 1.6 times higher for India in 2005. Melitz (2003) shows that exposure to trade induces more productive firms to enter the export market and the least productive firms to exit, leading to an increase in aggregate industry productivity growth. The quality of the regulatory framework matters significantly for the ease of resource reallocation, including firm dynamics and structural transformation (Djankov et al. 2002; Loayza and Servén 2010). Drawing the link between shortcomings in technological adoption and burdensome regulations, Bergoeing, Loayza, and Piguillem (2016) argue that regulatory barriers of firm entry and exit account for 26 to 60 percent of the income gap between the United States and 107 developing countries and that not just removing these barriers but removing them jointly is critical. Nicoletti and Scarpetta (2003) and Arnold, Nicoletti, and Scarpetta (2008) show that burdensome market regulations, as well as and the lack of reforms for promoting private corporate governance and competition, caused industries that use or produce ICT to have meager productivity levels in several European countries and deterred firms from catching up to the international technological frontier.

Regarding financial systems, Rajan and Zingales (1998) show that financial development facilitates economic growth by reducing the costs of external finance to firms for a large number of countries in the 1980s. Beck, Levine, and Loayza (2000) argue that financial development affects economic growth mainly through its positive effect on TFP. Buera, Kaboski, and Shin (2011) show that financial frictions distort the allocation of capital and entrepreneurial talent across production units, adversely affecting TFP and sectoral relative productivity. With respect to labor markets, studies show that regulations that provide flexibility in the allocation of labor enhance productivity. Haltiwanger, Scarpetta, and Schweiger (2008) and Bartelsman, Gautier, and De Wind (2016) show that employment protection regulations preclude efficient labor reallocation because they curb job flows or discourage firms from adopting risky but highly productive technologies. Barro (2001) shows that the education of female students has an insignificant impact on economic growth unlike that of male students, suggesting that labor market reforms to incorporate female workers has a potential to increase TFP.

Infrastructure

Public infrastructure –in transport, telecommunication, energy, and water and sanitation – can provide timely and cost-effective access to input and output markets, workplaces, and knowledge and information sources, thus supporting all possible economic activities (Straub 2008; Galiani, Gertler, and Schargrodsky 2005). An appropriate infrastructure network –in terms of quantity, quality, and diversity – can complement private capital and labor, increasing their returns and impact on economic growth. In this way, expanding public infrastructure becomes a source of TFP growth.

The evidence that appropriate public infrastructure has a positive impact on productivity and economic growth is convincing. Hulten (1996) shows that 25 percent of the growth difference between East Asia and Africa over 1970−90 is explained by the efficient use of infrastructure. Aschauer (1989) argues that public capital stock, especially core infrastructure such as highways, airports, sewers, and water systems, was critical in determining productivity in the U.S. over 1950s–1980s. Straub (2008) shows in a study of 140 countries over 1989–2007 that the infrastructure stock has a positive external impact on growth, for example, by allowing firms to invest in more productive machineries, decreasing workers' commuting times, and promoting health and education. Considering

also a panel of countries over time, Calderón and Servén (2010, 2012, 2014) argue persuasively that infrastructure can have positive effects on both growth and distributive equity. These beneficial effects, however, require a framework that regulates, organizes, and coordinates the governments and companies that build public infrastructure and provide its services. Moreover, as highlighted by Pritchett (1996) and Devadas and Pennings (2018), the amount of infrastructure spending is not necessarily an indication of effective infrastructure investment. The quality of spending matters, and this seems to be highly related to the strength of public institutions (World Bank 2003, 2017r).

Institutions

Public Institutions – in the regulatory, justice, policy, and political systems – can promote social and economic stability, provide a safe living and working environment, defend property rights, and safeguard basic civil rights. The environment and policies that public institutions provide have a large, fundamental impact on economic development (North 1990; Acemoglu, Johnson, and Robinson 2004). The evidence that good governance (reflected in political stability, the rule of law, the protection of property rights, bureaucratic quality, transparency and accountability, and the absence of corruption) has a positive effect on productivity and economic growth is large, comprehensive, and convincing.

Barro (1991) shows in a study of around 100 countries for 1960–85 that economic growth is positively related to political stability and inversely to government-induced market distortions. Using ethnolinguistic fractionalization as an instrumental variable for measures of government corruption, Mauro (1995) finds that corruption has a statistically significant and economically large negative effect on economic growth. Knack and Keefer (1995) find that property rights, proxied by contract enforceability and risk of expropriation, has a substantial impact on economic growth, even after accounting for capital accumulation. Rodrik, Subramanian, and Trebbi (2004) show that the quality of institutions, measured by a composite indicator of the protection of property rights and the rule of law, has a positive impact on income levels across a large sample of countries. Chanda and Dalgaard (2008) find that the quality of institutions (proxied by a composite index of the rule of law, bureaucratic quality, corruption, the risk of expropriation, and the government repudiation of contracts) is positively related to

productivity. Easterly and Levine (2003) show that institutions is a channel for geographical endowments to have an impact on economic development. They also show that when institutional quality is controlled for, macroeconomic policies do not account for development, implying good governance leads to conducive macroeconomic environments.

The five categories of TFP determinants presented above span a comprehensive array of factors driving productivity. They are also the channels through which other potential variables affect TFP. Some of them are time-invariant, such as historical origins and geographic conditions. Their effect is captured by our proposed determinants. For example, Rodrik, Subramanian, and Trebbi (2004) show that geography has an impact on incomes by influencing the quality of institutions. Other potential variables account for slow-moving processes, such as social mobility and income inequality. Their effect on TFP growth, however, can be explained by education, market efficiency, and governance. Consider, as illustration, the following papers. Cingano (2014) shows that income inequality has a negative impact on economic growth by impeding skill development among individuals with poorer parental education background. Dabla-Norris and others (2015) show that low-income households and small firms face difficulties in accessing financial services, which decreases economic growth. Hoeller, Joumard, and Koske (2014) argue that the lack of policies that provide more inclusive access to education, financial services, and labor markets leads to income inequality, and eventually lower economic growth.

3. Methods

First, we present the sample of countries and years included in the analysis. Second, we report how TFP growth at the country level is estimated. Third, we construct a set of indexes representing each of the main productivity determinants; we then obtain an overall index by grouping the indexes together. Fourth, we analyze the relationship between TFP growth and the proposed indexes of TFP determinants.

3.1 Sample

We conduct the statistical analysis using a sample of 98 developing and developed countries for the period 1985–2014. They are selected from the larger sample of countries featured in the Penn World Table (PWT) 9.0 and the World Bank World Development Indicators (WDI) databases. We exclude countries that do not have a minimal set of historical data for statistical analysis, countries that depend heavily on oil production (because the contribution of oil to output could result in a large overestimation of TFP growth),[1] and small countries, defined as those with population less than 2 million (in 2016) (World Bank 2017m).

For the descriptive analysis of TFP growth across regions and decades (in section 4.1), we add 16 countries for which data on the share of labor in income is missing in PWT 9.0 but available from the Global Trade Analysis Project (GTAP) 9.0 (Aguiar, Narayanan, and McDougall 2016). For the descriptive analysis of TFP determinants (in section 4.2), we additionally include 22 countries, which, though not having information to obtain TFP estimates, do have data for the proposed determinant indicators. For growth projections in the Long-Term Growth Model (LTGM), we add back small countries, heavily oil dependent countries, and those for which we can complete missing data from other sources and additional assumptions; thus, the TFP extension of the LTGM can be applied to about 190 countries for growth projections.

We classify high-income countries that have been members of OECD for more than 40 years as the OECD group. The rest of countries are classified by region and income. We use the average of GDP per capita (World Bank 2017e) over 1985–2014 to break the sample into income quintiles. Table B.1 shows the country list by region and income quintile groups, indicating their inclusion in the samples by type of analysis (descriptive and statistical), data source (PWT, GTAP, and WDI), and other characteristics (oil rent and population).

[1] Heavy dependence is defined as reliance on oil production for more than 32 percent of GDP on average during 2006-15, which is 90th – 100th percentile among 98 countries with positive oil rents (World Bank 2017j); Angola (45%), Congo, Rep. (46%), Equatorial Guinea (42%), Gabon (32%), Iraq (52%), Kuwait (47%), Libya (54%), Oman (37%), Saudi Arabia (44%), and South Sudan (45%).

3.2 Construction of total factor productivity

Total factor productivity is commonly measured as a residual, that is, the portion of GDP that remains after accounting for the direct contributions of capital and labor inputs in total GDP (Barro and Sala-i-Martin 2004). The aggregate capital stock is usually computed through the perpetual-inventory method, as the accumulation of gross physical investment (from a given initial capital stock), discounting the depreciation of existing stocks. Labor input can be calculated as the number of employed people, adjusted for human capital. The capital share is the fraction of total GDP used to pay for capital, and the labor share is the fraction of total GDP used to pay for labor. The shares of each factor of production are often assumed to be constant over time.

For the level of (relative) TFP, we use the estimate provided in Penn World Table (PWT) 9.0, labeled *rtfpna* (Feenstra, Inklaar, and Timmer 2015). This series is obtained by setting the TFP level of 2011 equal to 1, and then computing the remaining TFP levels backwards and forwards by applying the TFP growth rates. The TFP growth rates are obtained implicitly through the following equations:

$$\frac{RTFP_{jt}^{NA}}{RTFP_{jt-1}^{NA}} = \frac{RGDP_{jt}^{NA}}{RGDP_{jt-1}^{NA}} \ /Q_{jt,t-1},$$

where, $Q_{jt,t-1} = \frac{1}{2}(LABSH_{jt} + LABSH_{jt-1})(\frac{EMP_{jt}}{EMP_{jt-1}}\frac{HC_{jt}}{HC_{jt-1}}) + \left[1 - \frac{1}{2}\left(LABSH_{jt} + LABSH_{jt-1}\right)\right]\left(\frac{RK_{jt}^{NA}}{RK_{jt-1}^{NA}}\right)$. (1)

$RTFP^{NA}: TFP\ level, computed\ with\ RGDP^{NA}, RK^{NA}, EMP, HC, and\ LABSH$

$RGDP^{NA}: Real\ GDP\ at\ constant\ national\ prices$

$RK^{NA}: Capital\ stock\ at\ constant\ national\ prices$

$EMP: The\ number\ of\ people\ employed$

HC: *Human capital based on the average years of schooling from Barro and Lee (2013) and an assumed rate for primary, secondary, and tertiary education from Caselli (2005)*

$LABSH: The\ share\ of\ labor\ income\ of\ employees\ and\ self-employed\ workers\ in\ GDP$

$j: country$, and $t: year$

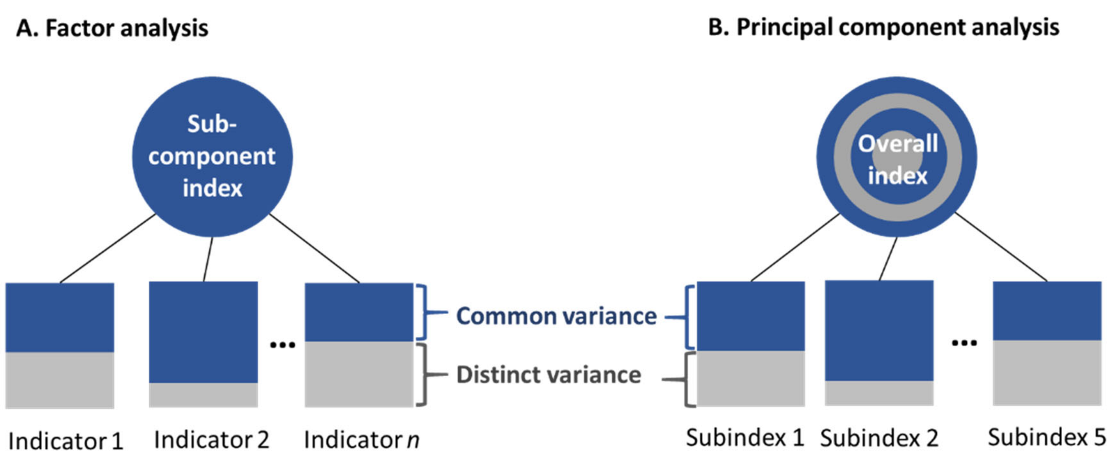
For our analysis, we calculate annual TFP growth rates by differencing the log-transformed TFP levels of year *t* and *t-1*, $ln(rtfpna_t) - ln(rtfpna_{t-1})$.

As a robustness check, we calculate TFP using mainly data from the World Development Indicators database (instead of PWT). In Appendix E, we compare the results (on descriptive statistics and econometric analysis) using this alternative TFP measure.

3.3 Construction of main determinant indexes

We construct subcomponent indexes that represent each of the five determinants ─innovation, education, market efficiency, infrastructure, and institutions─ and an overall index representing the five determinants all together. First, to construct a subcomponent index, we select relevant indicators and combine them using factor analysis, which captures as much of *common* variance in the indicators as possible in a single index (figure 1A) (Mulaik 2009).

Figure 1. Comparison of factor analysis and principal component analysis



Source: SAS 2017. The authors revised the original diagrams.

Then, to construct an overall determinant index, we combine the five subcomponent indexes using principal component analysis (PCA), which captures as much of *total* variance in the five subcomponent indexes as

possible in a single index (figure 1B) (Jolliffe 2002).[2] We use PCA for the overall determinant index because it is intended to represent the different features of each of the subcomponent indexes. This is unlike each subcomponent index, which is supposed to represent the common feature of its indicators.[3]

For each category of TFP determinants, we select indicators based on whether they measure an important characteristic, have been used in the literature, and have data available across countries and over time. In a few cases where most but not all information is available, we impute missing values based on income groups or trends, as explained at the end of this subsection.

Innovation. To construct a subcomponent index for innovation (*Innov*), we choose the following indicators: Public and private expenditure on R&D as a percentage of GDP as an indicator of the effort to create new technologies (World Bank 2017o); and the number of patent applications by residents and nonresidents and the number of scientific and technical journal articles as indicators of the outcome of R&D activities (World Bank 2017k, 2017l, 2017p).

Education. To construct a subcomponent index for education (*Educ*), we choose the following indicators: Government expenditure on education as percentage of GDP as an indicator of public investment in foundational human capital (World Bank 2017f); the shares of population aged 25 and over with completed secondary education and with completed tertiary education (Barro and Lee 2013) as indicators of educational attainment among workers; and a standardized international test score – a single average of scores in math, science, and

[2] We select a factor, or a principal component in the case of PCA, with an eigenvalue higher than 1. In our analysis, there is only one factor for each subcomponent index and one principal component for the overall index with an eigenvalue higher than 1.

[3] In order for the variables to enter factor/principal component analysis, they must have a sufficiently high degree of commonality. We run the Kaiser-Meyer-Olkin test to examine whether the indicators have enough common variance. A test value below the critical value of 0.5 means that an indicator or a group of indicators are unacceptable. For factor analysis, the test results show that the selection of indicators as a group is acceptable with a value of 0.60 for innovation, 0.69 for education, 0.63 for market efficiency, 0.83 for infrastructure, and 0.92 for institutions. The test results for individual indicators in each category are also above the critical value. For principal component analysis, used to construct the overall index, the test result is 0.88 for the group of the subcomponent indexes, and also above the critical value for each subcomponent index.

reading on the Programme for International Student Assessment (PISA) – as an indicator of educational quality (OECD 2016a, 2016b, 2016c).

Market Efficiency. To construct a subcomponent index for market efficiency (*Effi*), we classify markets into output, financial, and labor markets. We select the World Bank Doing Business scores as an indicator of output market efficiency, which measure the regulatory environment in terms of ease for firms to start a business, trade across borders, register property, get credit, and the like (World Bank 2017a). We choose the International Monetary Fund (IMF) Financial Development Index as an indicator of financial market efficiency, which measures the level of financial development by including the size and liquidity of financial markets, ease for individuals and firms to access financial services, and the ability of financial institutions to provide services at low costs with sustainable revenues (Svirydzenka 2016). As indicators of labor market efficiency, we construct an composite index, using factor analysis, consisting of minimum wage (% of value added per worker), severance pay for redundancy dismissals (weeks of salary), and the share of women in wage employment in the nonagricultural sector from World Bank databases (World Bank 2017h, 2017q).

Infrastructure. For a subcomponent index for infrastructure (*Infra*), we select fixed-telephone and mobile subscriptions (per 100 people) (World Bank 2017c, 2017i); the length of paved roads (km per 100 people) (International Road Federation 2017a, 2017b); electricity production (kw per 100 people) (OECD/IEA 2017); and access to an improved water source and improved sanitation facilities (% of population) (WHO/UNICEF 2017b, 2017a).

Institutions. To construct a subcomponent index for institutions (*Inst*), we select the World Bank Worldwide Governance Indicators. These include measures of voice and accountability (citizens' participation in selecting their government and freedom of expression); control of corruption (the extent to which public power is exercised for personal gain); government effectiveness (the quality of public services and policy formulation and implementation); political stability (the absence of politically motivated conflict); regulatory quality (the ability of

government to formulate and implement regulations that promote private sector development); and the rule of law (the extent to which citizens have confidence in and abide by laws) (Kaufmann and Kraay 2017).

When necessary, we impute missing values of the selected indicators to balance sample sizes across countries and maximize the number of countries in the sample. We use different methods depending on the number of available data and the characteristics of the indicators. For a country that has data for more than 10 out of 30 years (1985−2014) for an indicator, we project a linear trend over years to impute missing values. For a country that has data for less than 10 years, we replace missing values with a median value corresponding to the country's income and regional group. We apply a different method for PISA scores because available data are less than for 10 years for all countries. Considering a statistically significant correlation of 0.66 (p-value<0.01) between PISA scores and log-transformed GDP per capita lagged by five years, we regress PISA scores on the lagged log-transformed GDP per capita, controlling for time-effects in a cross-country, time-series pooled data set.[4] Then, we replace missing PISA scores with a median score by the country's income and regional group using scores predicted by the regression model. For minimum wage and severance pay, we apply the oldest available data (2014) to the period before 2014, because available data (2014−2017) are insufficient to evaluate a time trend and their values are difficult to impute based on the country's income and regional group.

3.4 Relationship between the main determinants of TFP and TFP growth

The relative contribution of the main determinants to the variance of total factor productivity growth

To help assess the relative contribution of the five main determinants to TFP growth, we decompose the variance of the TFP growth rate (over t-5 to t) to that explained by each subcomponent index (at t-5), controlling for an initial TFP level (at t-5) and time-effects for 98 countries. A review of measures of relative importance based on variance decomposition by Grömping (2007) suggests that the "dominance analysis" approach (Budescu 1993; Azen and Budescu 2003) is a reasonable method, mainly to deal with the presence of covariance across individual

[4] $PISA_{c,t} = \beta_0 + \beta_1 \ln(GDP\ per\ capita)_{c,t-5} + \delta_t, c: country\ (1, \ldots, 76), t: year\ (2003/06/09/12/15);\ \beta_0 = 187.1^*, \beta_1 = 28.7^{***}$ (***: p-value<0.01), $R^2 = 0.444$

determinants. This approach calculates the contribution of a subcomponent index as the increase in the explained variance when the subcomponent index is added to each subset of other subcomponent indexes. For instance, the contribution of the innovation index ($innov_{c,t}$) is computed by averaging[5] the increase in the explained variance of TFP growth rate when $innov_{c,t}$ is added to each of the 16 additive subsets of other four subcomponent indexes ($\{.\}, \{educ_{c,t}\}, \ldots, \{inst_{c,t}\}, \{educ_{c,t}, effi_{c,t}\}, \ldots \{infra_{c,t}, inst_{c,t}\}, \{educ_{c,t}, effi_{c,t}, infra_{c,t}\}, \ldots,$

$\{educ_{c,t}, infra_{c,t}, inst_{c,t}\}, \ \{educ_{c,t}, effi_{c,t}, infra_{c,t}, inst_{c,t}\}$.)

The relationship between the overall determinant index and total factor productivity growth

To quantify the relationship between the overall determinant index and TFP growth, we build a regression model in which TFP growth rate is a function of a time-lagged overall determinant index and a time-lagged TFP level with country- and time-effects (equation 2). We rescale the overall index to be from 1, representing the lowest performance, to 100, the best across countries over the last three decades. For this purpose, we use the following linear transformation, $(original\ index\ for\ country\ c\ and\ time\ t - lowest\ index)/(highest\ index - lowest\ index) * (100 - 1) + 1$. According to preliminary analysis, the relationship between the index and TFP growth declines as the index increases; to allow for this non-linearity, we log-transform the rescaled index. We apply a time lag of five years to reduce the likelihood of endogeneity as reverse causation. This also allows us to smooth the TFP growth series, considering that, at shorter frequencies, it may be driven by business-cycle fluctuations (see Beck, Levine, and Loayza 2000; and Giavazzi and Tabellini 2005).

We run different regressions for comparison and robustness check: without country-effects and with random country-effects, and with different time lags of three and seven years. We use (White-Huber) robust standard errors. After fitting the models to the sample, we incorporate the results into the Long-Term Growth Model (Loayza and Pennings 2018) in order to run country and region simulations on the potential path of TFP growth.

[5] Two-step average: First, the additional contributions are averaged within a group of the same size of the subset, then the results from the first step are averaged across groups with different sizes of the subset.

$$Annualized\ TFP\ growth_{c,(t,t-5)} = \beta_0 + \beta_1 ln(Index_{c,t-5}) + \beta_2 ln(rtfpna)_{c,t-5} + \theta_c + \delta_t + \varepsilon_{c,t}. \quad (2)$$

$Annualized\ TFP\ growth_{c,(t,t-5)}$: annualized TFP growth over t-5 and t

$Index_{c,t-5}$: overall determinant index, rescaled 1 to 100

$rtfpna_{c,t-5}: TFP\ level\ (2011 = 1)$

θ_c: country effect

δ_t: time effect

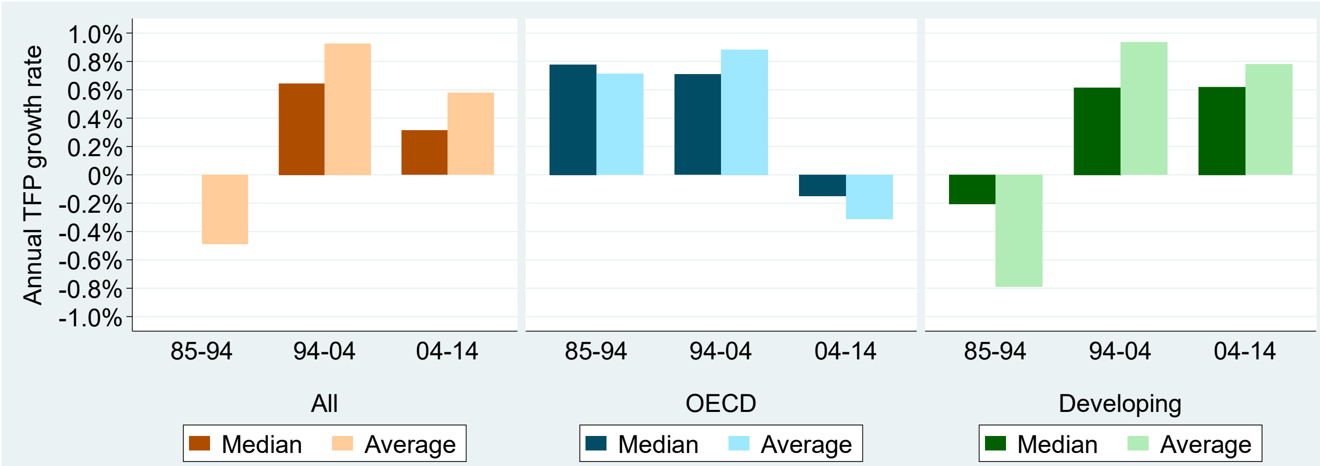
$\varepsilon_{c,t}$: residuals

4. Results

4.1 Total factor productivity

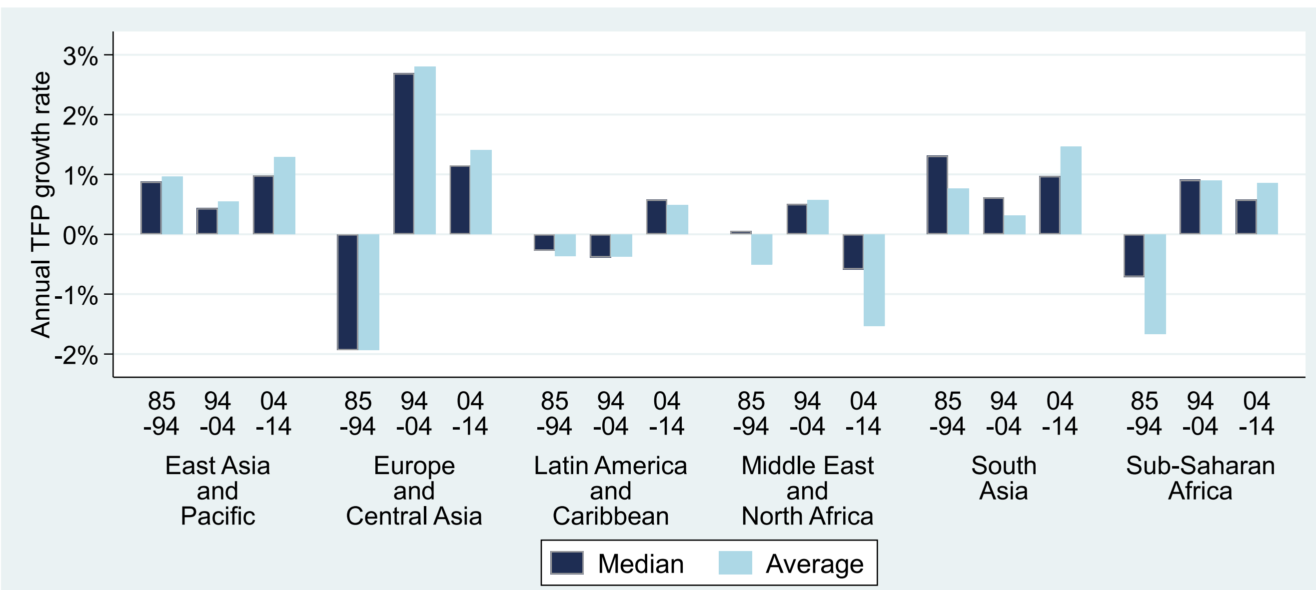
Figure 2 shows that for 21 OECD countries, the median and (simple) average annual TFP growth rates are positive during 1985–2004 and decrease below zero for 2005–14; whereas for 93 developing countries, they are negative during 1985–94 and increase above zero for 1995–2014. Figure 3 shows median and (simple) average annual TFP growth rates for developing countries by region. For East Asia and Pacific, TFP growth rates are positive for the last three decades between 0.4 percent and 1.3 percent. For Europe and Central Asia, TFP growth rates are negative for 1985–94, increase in the next decade to above 2 percent, and decrease to around 1.2 percent for the last decade. For Latin America and Caribbean, TFP growth rates increase from around -0.4 percent during 1985–2004 to around 0.5 percent for 2005–14. For Middle East and North Africa, TFP growth rates increase from near zero or negative in 1985–94 to around 0.5 percent in the next decade and decrease to below -0.5 percent in the last decade. For South Asia, TFP growth rates are positive for the last three decades, ranging between 0.3 percent and 1.5 percent. For Sub-Saharan Africa, TFP growth rates increase from around -1 in 1985–1994 to +1 in the two decades spanning 1994–2014. Figure 4 shows regional average TFP growth rates weighted by total GDP (World Bank 2017d), the trend of which is similar to that of the unweighted average TFP growth rates in figure 3.

Figure 2. Annual TFP growth rate for all, OECD, and developing countries, median and simple average by decade



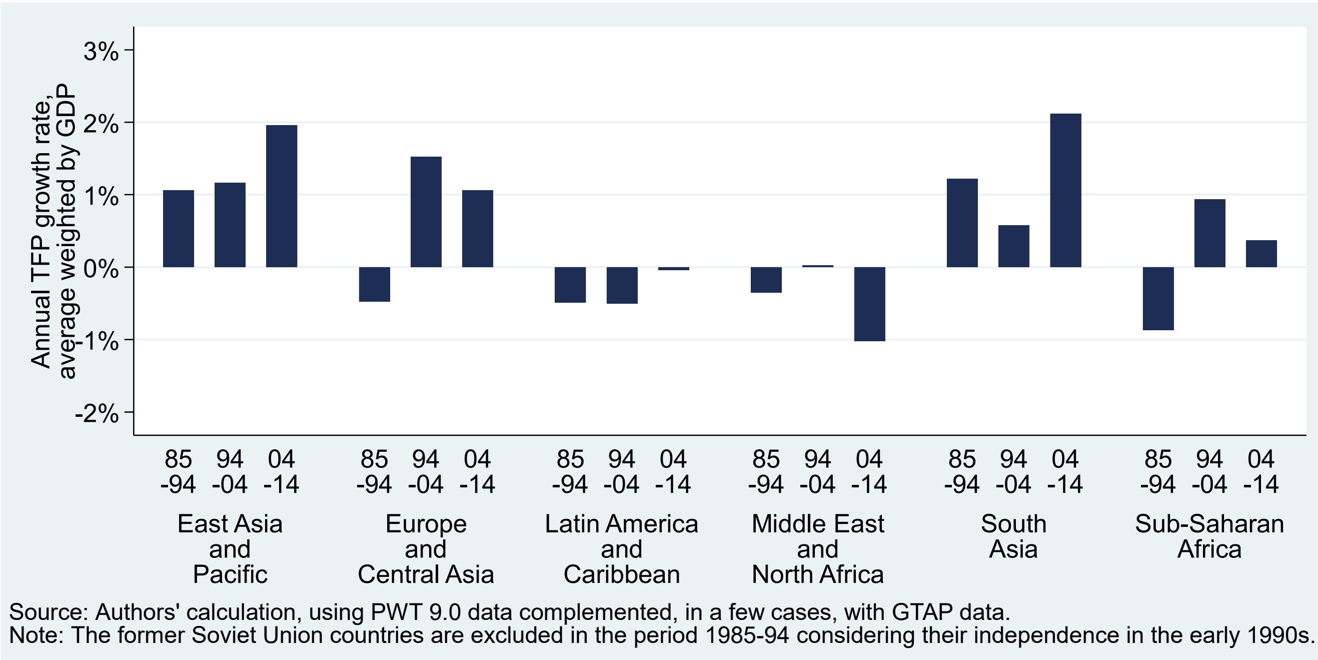
Source: Authors' calculation, using PWT 9.0 data complemented, in a few cases, with GTAP data.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years; the former Soviet Union countries are excluded in the period 1985-94 considering their independence in the early 1990s.

Figure 3. Annual TFP growth rate for developing countries, median and simple average by region and decade



Source: Authors' calculation, using PWT 9.0 data complemented, in a few cases, with GTAP data.
Note: The former Soviet Union countries are excluded in the period 1985-94 considering their independence in the early 1990s.

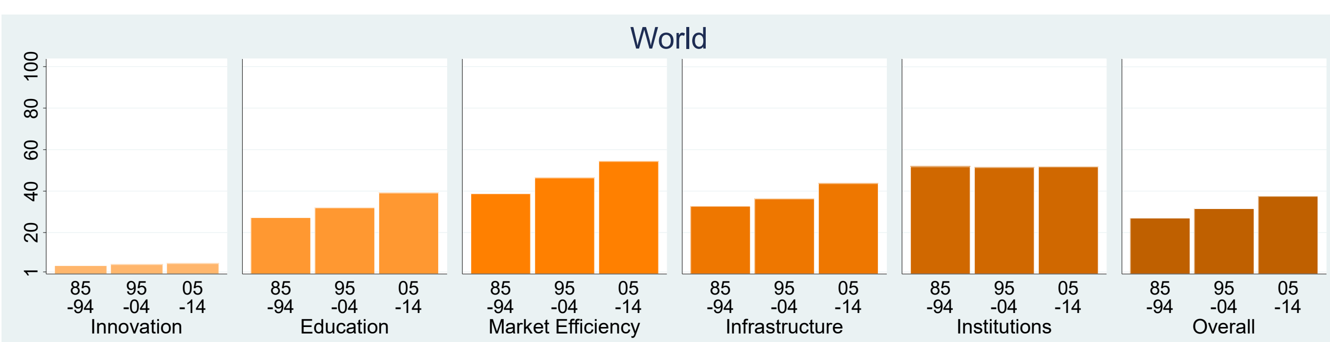
Figure 4. Annual TFP growth rate for developing countries, average weighted by real GDP by region and decade

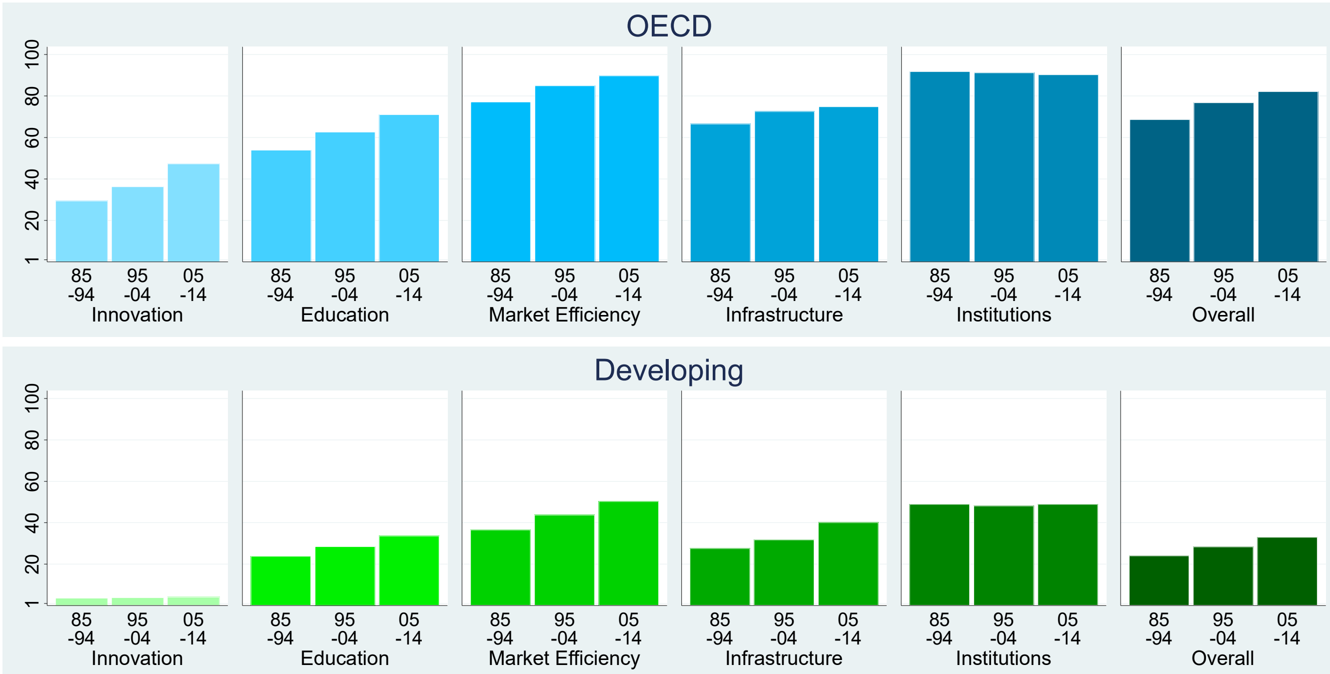


4.2 Main determinant indexes

Figure 5 shows the median of the subcomponent indexes representing the main categories of TFP determinants, as well as the median of the overall index, for all, 21 OECD, and 115 developing countries by decade. All the median indexes are lower for the developing countries as compared to the OECD countries. A noticeable difference is that the innovation index stays at the lowest level for the developing countries, whereas it increases in the OECD group over time. For both groups, the subcomponent indexes of education, market efficiency, and infrastructure increase over decades, whereas that of institutions stays at the same level.

Figure 5. Median of subcomponent and overall determinant indexes for all, OECD, and developing countries by decade





Source: Authors' calculation.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years; the indexes are rescaled to range from 1, the lowest performance, to 100, the best among all countries over the three decades.

For the innovation subcomponent index, the indicators carry similar weights (equation 3). Factor analysis shows that the subcomponent index accounts for 76 percent of the total variance of the indicators, accounting for 90 percent of the variance of R&D expenditure (*R&D*), 61 percent of that of the number of patents (*patent*), and 79 percent of that of the number of journal articles (*article*).

$$Innov_{c,t} = 0.41 * z(R\&D_{c,t}) + 0.34 * z(patent_{c,t}) + 0.39 * z(article_{c,t}) \,, \qquad (3)$$

where $z(X)$ *is standardized* $X, \frac{\text{X}-\text{mean}(X)}{standard\ deviation\ (X)}$.

For the education subcomponent index, the performance-related indicators have similar weights and the education-expenditure indicator has a lower weight (equation 4). Factor analysis indicates that the subcomponent index accounts for 55 percent of the total variance in the indicators, accounting for 20 percent of the variance of education expenditure (*eduexp*), 63 percent of that of secondary attainment (*secondary*), 75 percent of that of tertiary attainment, and 63 percent of that of PISA scores (*pisa*). The lower weight and the smaller contribution of

the education expenditure indicator to the common variance shows that this indicator has a low correlation with the outcome indicators.

$$Edu_{c,t} = 0.20 * z(eduexp_{c,t}) + 0.36 * z(secondary_{c,t}) + 0.39 * z(pisa_{c,t}) + 0.36 * z(tertiary_{c,t}). \quad (4)$$

For the market-efficiency subcomponent index, the indicators are combined with similar weights (in absolute terms) (equation 5). Factor analysis shows that the subcomponent index accounts for 69 percent of the total variance in the three indicators, accounting for 79 percent of the variance of Doing Business scores (*business*), 78 percent of that of Financial Development Index (*financial*), and 49 percent of the labor index (*labor*). In turn, factor analysis shows that the labor index accounts for 48 percent of the total variance of the minimum wage (*minwage*), 53 percent of that of the severance pay (*severance*), and 52 percent of that of the share of women employed in the nonagricultural sector (*women*).

$$Effi_{c,t} = 0.43 * z(business_{c,t}) + 0.43 * z(financial_{c,t}) - 0.34 * z(labor_{c,t}), \quad (5)$$

$$where\ labor_{c,t} = 0.45 * z(minwage_{c,t}) + 0.47 * z(severance_{c,t}) - 0.47 * z(women_{c,t})$$

For the infrastructure subcomponent index, all indicators except for mobile subscription have similar weights (equation 6). Factor analysis shows that the subcomponent index accounts for 65 percent of the total variance in its indicators, accounting for 78 percent of the variance of the number of telephone subscription (*tele*), 28 percent of that of mobile subscription (*mobile*), 64 percent of that of paved road (*road*), 67 percent of that of electricity production (*elec*), 70 percent of that of access to improved water source (*water*), and 76 percent of that of access to improved sanitation facilities (*sanit*).

$$Infra_{c,t} = 0.23 * z(tele_{c,t}) + 0.14 * z(mobile_{c,t}) + 0.21 * z(road_{c,t}) + 0.21 * z\ (elec\_(c,t)) + 0.22 * z(water_{c,t}) + 0.23 * z(sanit_{c,t}). \quad (6)$$

The institutions subcomponent index consists of the six indicators with similar weights (equation 7). The subcomponent index accounts for 87 percent of the total variance in its indicators, accounting for 83 percent of

the variance of voice and accountability (*va*), 90 percent of that of the control of corruption (*cc*), 93 percent of that of government effectiveness (*ge*), 71 percent of that of political stability (*ps*), 89 percent of that of regulatory quality (*rq*), and 94 percent of that of the rule of law (*rl*).

$$Inst_{c,t} = 0.18 * z(va_{c,t}) + 0.19 * z(cc_{c,t}) + 0.19 * z(ge_{c,t}) + 0.16 * z(ps_{c,t}) + 0.18 * z(rq_{c,t}) + 0.19 * z(rl_{c,t}). \quad (7)$$

The overall determinant index is a linear combination of the (standardized) five subcomponent indexes with similar weights (equation 8). The overall index, obtained through principal component analysis, represents the innovation index with a correlation of 0.88; the education index, 0.90; the market-efficiency index, 0.94; the infrastructure index, 0.94; and the institutions index, 0.87.

$$Index_{c,t} = 0.43 * z(Innov_{c,t}) + 0.44 * z(Edu_{c,t}) + 0.46 * z(Effi_{c,t}) + 0.47 * z(Infra_{c,t}) + 0.43 * z(Inst_{c,t}). \quad (8)$$

Appendix C shows the average values of the individual indicators, as well as the subcomponent and overall indexes, over 1985–2014 by income and regional group.

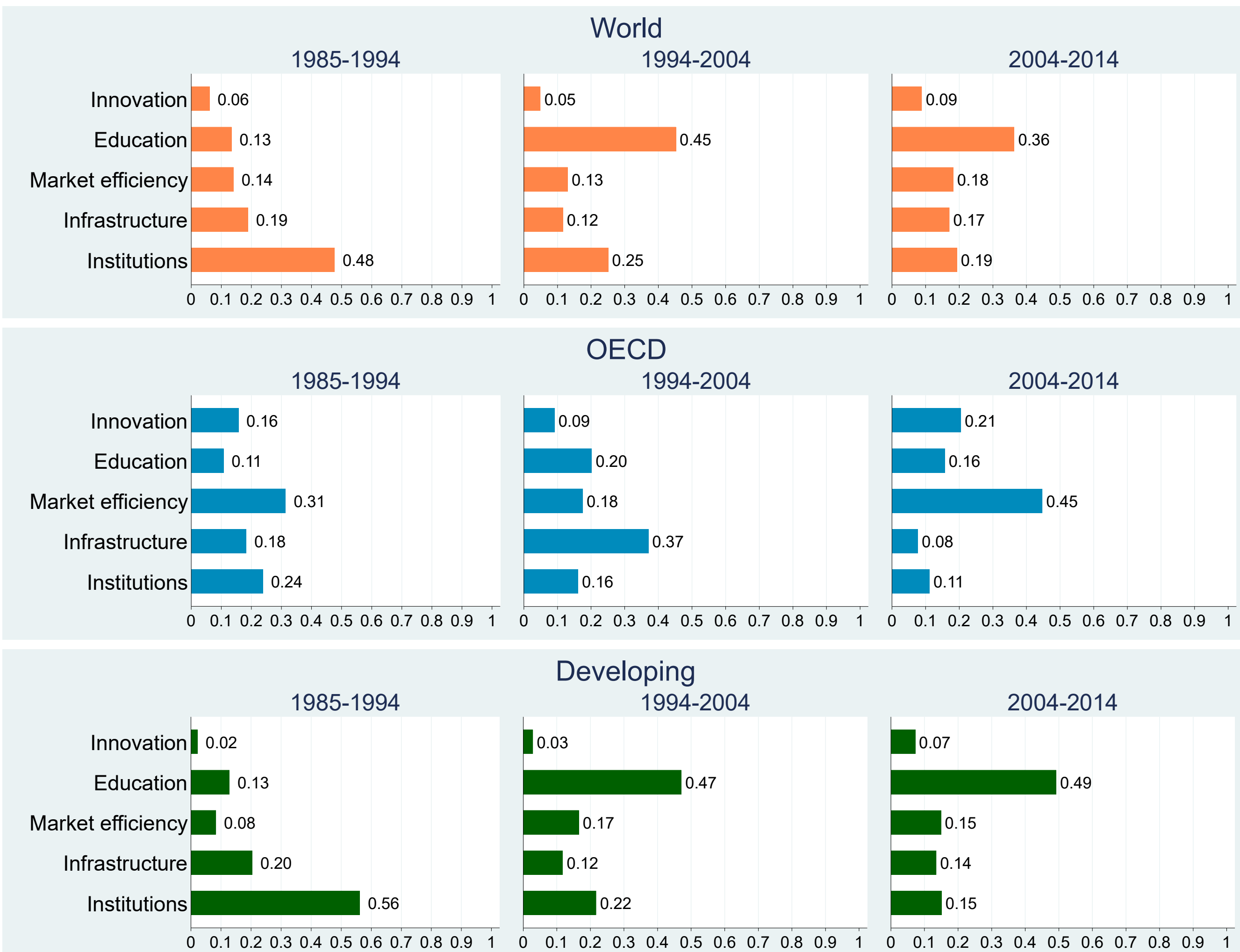
4.3 Relationship between the main determinants of TFP and TFP growth

The relative contribution of the main determinants to the variance of total factor productivity growth

Figure 6 shows the decomposition of the total explained variance of the TFP growth rate corresponding to each of the main TFP determinants by decade for all, OECD, and developing countries (controlling for the five-year-lagged TFP level and time-effects). For the OECD countries, a notable trend is that the contribution of the market-efficiency index increases and accounts for 45 percent of the explained variance of TFP growth in the last decade; whereas that of infrastructure decreases and explains the least. For developing countries, in 1985-94 the TFP determinant with the highest explanatory power of TFP growth variance is institutions; however, its contribution decreases afterward. The contribution of education increases over the two decades and accounts for almost 50 percent of the explained variance of TFP growth in the last decade.

The variance decomposition analysis helps understand what drives the differences across countries regarding TFP growth. It does not, however, indicate what the most important or relevant drivers of TFP growth are for specific countries. For this, we would need to know the country-specific gaps in each determinant of TFP. We turn to this issue in section 6, on simulations and scenario analysis. Before, however, we need to obtain a reasonable estimate of the effect of the overall index on TFP growth, which we attempt next.

Figure 6. Variance decomposition of TFP growth rate corresponding to the determinant subcomponent indexes by decade for all, OECD, and developing countries, controlling for initial TFP and time effects



Source: Authors' calculation.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years.

The relationship between the overall determinant index and total factor productivity growth

Table 1 shows the regression results for equation 2 in which the TFP growth rate is a function of the lagged overall determinant index and the lagged TFP level, along with country- and time-effects. We do not attempt a regression with the five subcomponent indexes as individual regressors because they are very highly correlated, and their estimated marginal effects would be contaminated by multicollinearity.

As Table 1 shows, the lagged overall index and the lagged TFP level are statistically significant in all regressions, with no, random, and fixed country-specific effects, respectively. Based on the Hausman test, which suggests bias estimation if correlated country-specific effects are not considered, we choose to focus on the regression with fixed (correlated, not random) country-specific effects.

Table 1. Linear regression results

Dependent variable:	$Annualized\ TFP\ growth_{c,(t-5,t)}$		
Number of observations:	477		
Number of groups (countries):	98		
	Country effects:		
	None	Random	Fixed
Regressors (below):	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
$ln(Index_{c,t-5})$	0.004 (0.0011) ***	0.004 (0.0011) ***	0.050 (0.0183) ***
$ln(TFP\ level)_{c,t-5}$	-0.082 (0.0052) ***	-0.082 (0.0052) ***	-0.099 (0.0151) ***
Year 1999	-0.001 (0.0036)	-0.001 (0.0036)	-0.006 (0.0034)
Year 2004	0.012 (0.0031) ***	0.012 (0.0031) ***	0.004 (0.0034)
Year 2009	0.010 (0.0030) ***	0.010 (0.0030) ***	-0.001 (0.0045)
Year 2014	0.010 (0.0034) ***	0.010 (0.0034) ***	-0.004 (0.0063)
(Reference year: 1993)			
Constant	-0.021 (0.0055) **	-0.021 (0.0055) ***	-0.180 (0.0636) ***
R^2:			
Within	Not applicable	0.2784	0.3048
Between	Not applicable	0.8573	0.2749
Overall	0.4022	0.4022	0.1586
SE = Standard error; *: significant at 10%; **: significant at 5%; ***: significant at 1% level Note: Hausman test rejects the null hypothesis (Ho: coefficients are consistent under both random and fixed effects) with Chi-square 22.90 and p-value less than 0.01. The R^2 in the case of the fixed-effects estimator does not consider the explanatory contribution of the country-specific constants (which is why its overall value is lower than in the other cases). In the regression with no country effects, we use clustered robust (White-Huber) variance estimation, treating countries as clusters.			

In the fixed effects model, an increase of the lagged overall determinant index by 1 percent is associated with an increase of the annual TFP growth rate by 0.05 percent, after controlling for the lagged TFP level and country and time effects. Suggesting convergence, an increase of lagged TFP by 1 percent is associated with a decrease of annual TFP growth rate by 0.10 percent, holding other variables constant. This implies that countries with a higher level of TFP need to increase the determinant index more than those with a lower level of TFP to achieve the same amount of increase in TFP growth. These results are robust in terms of signs and significance when we use different lags of three and seven years (see appendix D). They are also robust when we use the WDI-based data in the construction of TFP levels and growth rates (see appendix E).

5. Simulations and Scenario Analysis

For illustration purposes, in this section we simulate the change in TFP growth rate for 78 low- and middle-income developing countries (that is, countries with GDP per capita in 2014 lower than $12,056, constant USD 2010). We present the simulation results in averages by region or income group. More generally, the Long-Term Growth Model (LTGM) toolkit can be used to generate country-specific projections for TFP growth for a much larger set of countries. This allows of the LTGM users to replace the assumption of an exogeneous path for TFP growth by one that is based on improvements in innovation, education, market efficiency, infrastructure, and institutions, feeding into the overall determinant index.

We provide four scenarios below. They present different ways and extents of improving the TFP determinant index, to regional or world benchmarks (or leaders). We use the fixed-effect regression results to relate changes in TFP growth to changes in the overall determinant index. The corresponding increase in TFP growth depends directly on the speed of progress in the country's TFP determinants and inversely on the extent of previous TFP improvement. Thus, countries with a larger gap on their TFP determinant index with respect to the benchmark could experience a larger increase in TFP growth if they made reforms to approach the leader. In turn, countries with a high increase in TFP growth would slow down their subsequent growth in TFP. The positive impact of improvements in the TFP determinant index and the negative impact of previous TFP growth create an interesting, nonlinear path of projected TFP growth: In most cases, TFP growth follows a convex path that

increases at a decreasing rate, reaches a maximum, and then decreases or stabilizes. Since in the simulations the reforms to improve TFP determinants do not occur immediately but gradually over time (in two scenarios, to imitate the actual trajectory of benchmark countries in the last three decades), the projected TFP growth has an additional source of convexity, as the growth rate of the TFP determinant index tends to decline over time.

Scenario I: Improving to the highest TFP determinant index in the region

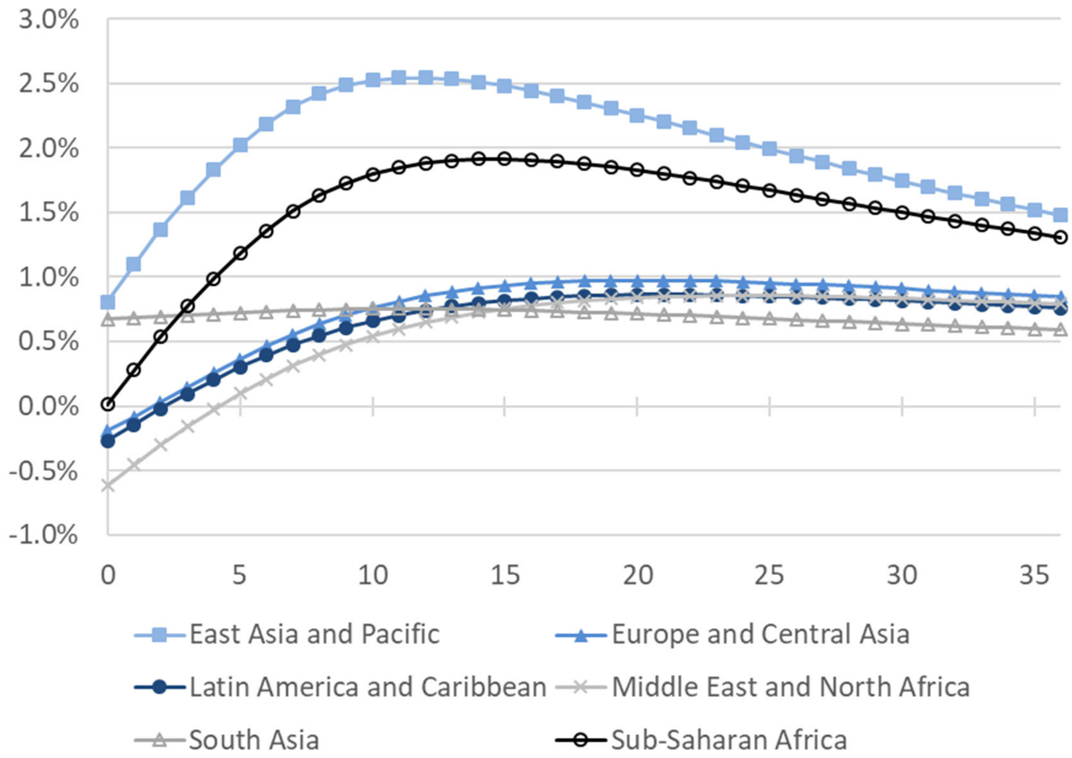
Scenario I assumes that a country improves its overall determinant index to the highest index among all developing (non-OECD) countries in its region. We assume a country's overall determinant index increases at constant increments from the initial value (in 2014) to the current index of its benchmark country, shown in table 2, over 15 years and keeps increasing with the same slope afterward.

Table 2. Benchmark countries with the highest overall determinant index as of 2014 by region

Region	**Country with the highest index as of 2014**
East Asia and Pacific	Korea
Europe and Central Asia	Czech Republic
Latin America and Caribbean	Chile
Middle East and North Africa	United Arab Emirates
South Asia	India
Sub-Saharan Africa	South Africa

Figure 7 shows the average TFP growth rate under scenario I. For East Asia and Pacific, starting from the highest historical average TFP growth rate over 1985─2014 among all regions, the average TFP growth rate is expected to increase to 2.5 percent over the next 12 years and then gradually decrease. For Sub-Saharan Africa, the average TFP growth is expected to increase to 1.9 percent over the next 15 years, which is the sharpest increase from the corresponding historical TFP growth rate among all regions. For Europe and Central Asia, Latin America and Caribbean, and Middle East and North Africa, the simulated average TFP growth rates are similar in that they increase to almost 1 percent in the next 23 years and decrease gradually. For South Asia, the average TFP growth rate stays in the range from 0.6 to 0.8 percent. Using regional benchmarks limits the possibility of progress in TFP growth because the regional leaders may not be very advanced themselves. Such is the case of India for South Asia.

Figure 7. Simulated average TFP growth rate by region with the scenario that a country increases its overall determinant index to the highest index among developing countries in its region over 15 years



<u>*Scenario II: Following the trajectory of the most improving TFP overall index in the region*</u>

Scenario II assumes that a country replicates the trajectory, in terms of annual change, in the last three decades of the TFP overall determinant index corresponding to the regional benchmark country. The regional benchmark under scenario II is the country whose overall determinant index increases the most over 1985–2014 among all developing (non-OECD) countries in a given region (see table 3).

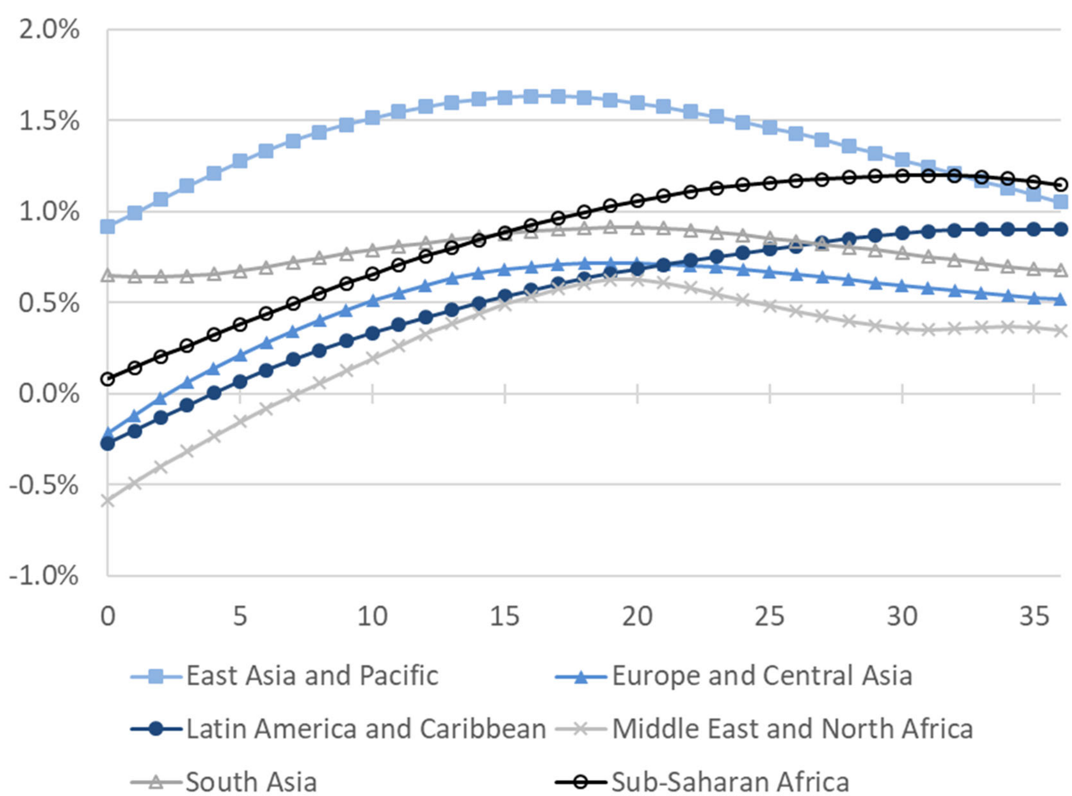
Table 3. Benchmark countries with the most increase in the overall determinant index during 1985-2014 by region

Region	**Country with the most increase in the overall index during 1985-2014**
East Asia and Pacific	Korea
Europe and Central Asia	Czech Republic
Latin America and Caribbean	Colombia
Middle East and North Africa	United Arab Emirates
South Asia	India
Sub-Saharan Africa	Rwanda

We apply the annual change in the index of the benchmark country over 1985—2014 to that of all countries in the same region, starting from the initial index (2014) for the next 30 years and the average change over 2005—2014 for subsequent years.

Figure 8 shows the predicted average TFP growth rate under scenario II. For East Asia and Pacific, starting from the highest historical average TFP growth rate over 1985—2014, the average TFP growth rate is expected to increase to 1.7 percent over the next 15 years and then decrease. For Latin America and Caribbean and Sub-Saharan Africa, the simulated average TFP growth rate increases for more than 30 years to 0.9 and 1.2 percent, respectively. For Europe and Central Asia and Middle East and North Africa, the average TFP growth rate is expected to increase to 0.7 and 0.6 percent, respectively, over the next 20 years and decrease gradually. For South Asia, the simulated TFP growth rate stays in the range from 0.6 to 0.9 percent.

Figure 8. Simulated average TFP growth rate by region with the scenario that a country replicates the annual index change that its benchmark country has had in the last three decades



Scenario III: Improving to the highest TFP determinant index among all developing countries

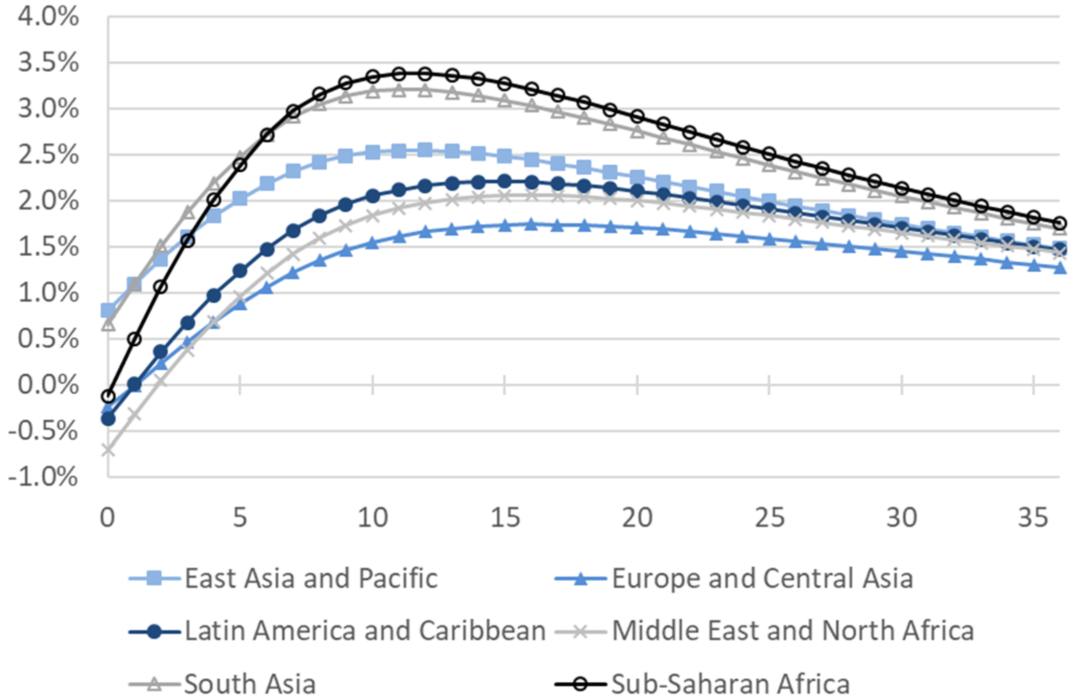
Scenario III assumes that a developing country increases its overall determinant index to the highest index among all developing (non-OECD) countries as of 2014, which is that of the Republic of Korea. We assume a country's overall determinant index increases linearly from the value in 2014 to the index of Korea over 15 years and keeps increasing with the same slope afterward.

Figure 9a shows that Sub-Saharan Africa, which has the largest gap with respect to the benchmark and has a relatively low TFP growth rate, is expected to have the highest increase from its historical average over 1985–2014 (initial value in the graph) and reach the highest average TFP growth rate of 3.4 percent in 11 years and then gradually decline. South Asia is expected to increase its TFP growth rate to 3.2 percent in 11 years and then decrease, similarly to Sub-Saharan Africa. East Asia and Pacific, with the highest historical average, is expected to increase its average TFP growth rate to 2.5 percent in 11 years; this is smallest gain from the historical average among all regions, reflecting its already high TFP growth in the past. Latin America and Caribbean and Middle East and North Africa, with negative historical average TFP growth, are expected to increase the average TFP growth rate to 2.2 and 2.1 percent, respectively, in 15 years. For Europe and Central Asia, with a negative historical growth, the average TFP growth rate increases to 1.7 percent in 16 years and then decreases.

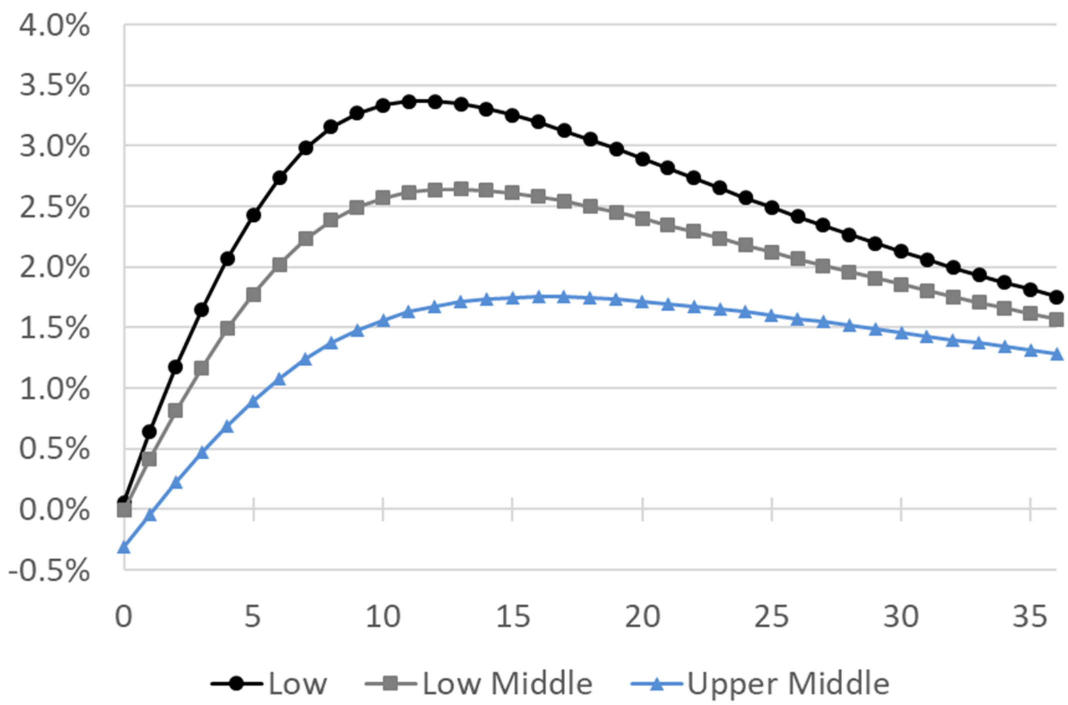
Grouping countries by income level reveals interesting patterns. Figure 9b shows that the low-income group is expected to increase its average TFP growth rate the most to 3.3 percent in 11 years, the low-middle income group to 2.6 percent in 12 years, and the upper-middle income group to 1.8 percent in 16 years. In all cases, TFP growth gradually declines after reaching a peak, approaching around 1.5 percent in 35 years. These results confirm the notion obtained from the regional results: a country, region, or group with a larger gap in the TFP determinant index with respect to the benchmark has more to gain and can experience a substantial increase in TFP growth if they conduct the corresponding reforms. For those with already high TFP growth and for those whose TFP growth rises sufficiently, subsequent TFP growth will tend to taper down.

Figure 9. Simulated average TFP growth rate by region and income group with the scenario that a country increases its overall determinant index to the highest index among developing countries over 15 years

9a. Average TFP growth rate by region



9b. Average TFP growth rate by income level[a]



[a] Low: average GDP per capita over 1985-2014 (constant 2010 USD) ≤ $995; Low middle: $995-$3,895; Upper middle: $3,895-$12,055.

Scenario IV: Following the trajectory of the most improving TFP overall index among all developing countries

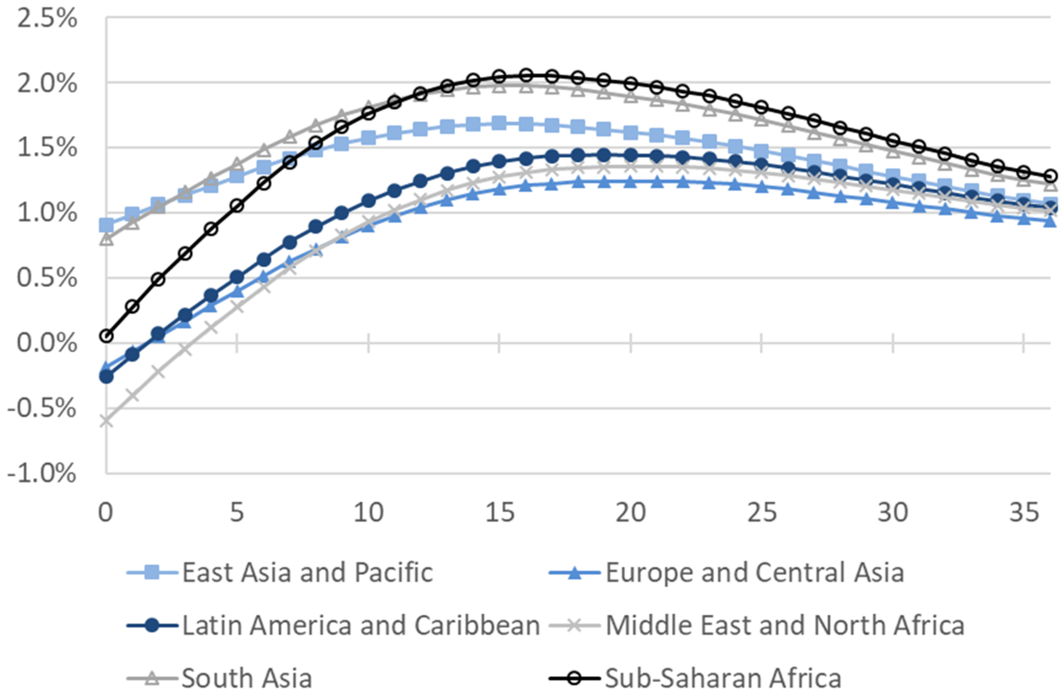
Scenario IV assumes that a country replicates a trajectory, in terms of annual change, of the world benchmark country. This is the country that has increased its overall determinant index the most over 1985─2014 among all developing (non-OECD) countries, which is Korea. We apply the annual change in the index of Korea over 1985─2014 to that of a country, starting from the initial index (2014) for the next 30 years and the average change over 2005─2014 for subsequent years.

Figure 10a shows that Sub-Saharan Africa, with the largest gap with respect to the benchmark and a relatively low TFP growth rate, has the highest increase from its historical average over 1985─2014 (initial value in the graph) and reaches the highest average TFP growth rate of 2.1 percent in 16 years. South Asia is expected to increase its TFP growth rate to 2.0 percent in 16 years and decrease afterwards. East Asia and Pacific, with the highest historical average TFP growth, has the smallest projected increase in TFP growth, to 1.7 percent in 15 years. Latin America and Caribbean, Middle East and North Africa, and Europe and Central Asia, with negative historical average TFP growth, are expected to increase their TFP growth rates to 1.2 to 1.4 percent in 19─20 years.

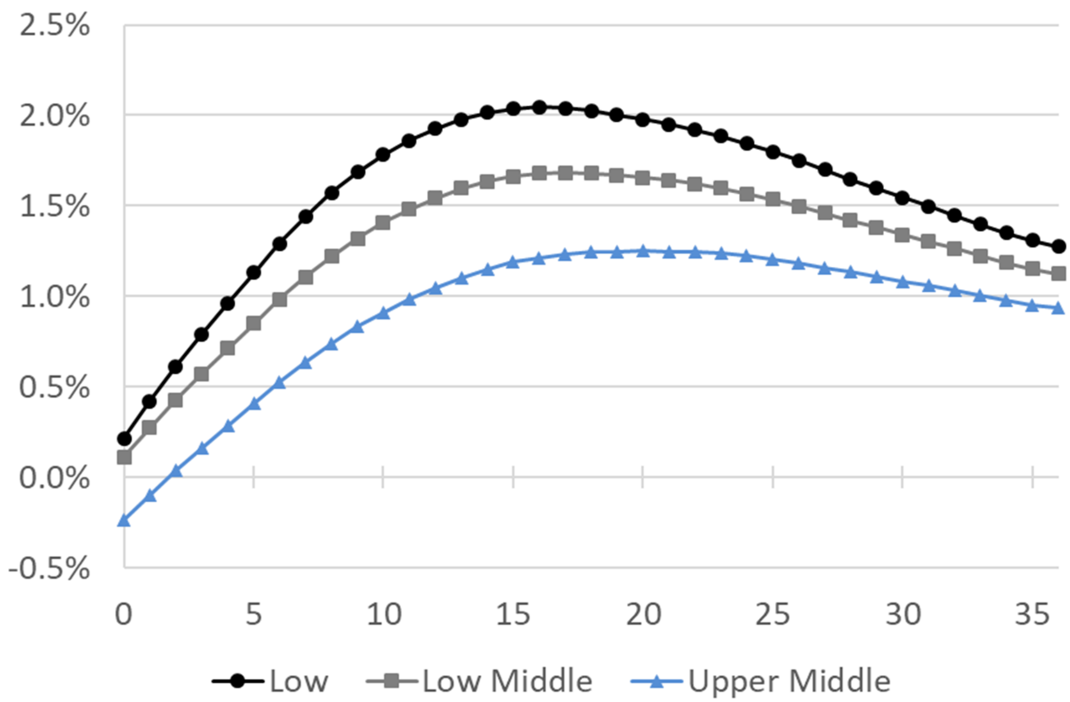
Figure 10b presents the results for income groups. It shows that the low-income group is expected to increase its average TFP growth rate the most to 2.0 percent in 16 years, the low-middle income group to 1.7 percent in 17 years, and the upper-middle income group to 1.2 percent in 20 years. The results in figure 10 confirm the insight that countries, regions, or groups with a larger gap with respect to the benchmark, such as Sub-Saharan Africa, have more to gain in terms of future TFP growth, and those with higher TFP growth, for example, East Asia and Pacific, have a slower subsequent TFP growth.

Figure 10. Simulated average TFP growth rate by region and income group with the scenario that a country replicates the trajectory of the overall index of Korea, which increases the index the most among all developing countries in the last three decades

10a. Average TFP growth rate by region



10b. Average TFP growth rate by income level[a]



[a] Low: average GDP per capita over 1985-2014 (constant 2010 USD) ≤ $995; Low middle: $995-$3,895; Upper middle: $3,895-$12,055.

6. Conclusion

This is the background paper for the TFP extension of the World Bank's Long-Term Growth Model (LTGM). It proposes a way to project the future path of TFP growth for most developing countries around the world if they were to follow a program of reforms that would approach them to regional and global leaders. The paper is accompanied by an Excel-based toolkit, which can be used for scenario analysis on TFP and corresponding income growth (available at the LTGM's website: https://www.worldbank.org/LTGM).

Based on a comprehensive literature review, we select innovation, education, market efficiency, infrastructure, and institutions as the five main categories of TFP determinants. For each of these categories, we construct an index as a linear combination of representative indicators (or proxies) by factor analysis, that is, by accounting for as much of the common variance in the indicators as possible. We then combine the five subcomponent indexes into an overall index by the principal component analysis, which accounts for as much of the total variance in the subcomponent indexes as possible.

Using dominance analysis, the variance decomposition of the TFP growth rate into the main subcomponent indexes shows that for OECD countries, market efficiency contributes the most to the variance of TFP growth and infrastructure, the least for the recent decade; and for developing countries, the contribution of education increases continuously and is the largest among the determinants in the recent decade. Although the variance decomposition of TFP into its determinants is not necessarily a guide for policy reform, it illustrates how the observed variation in TFP growth can be explained differentially over time and across development levels. This suggests patterns that countries can use to assess their own progress in the various determinants of productivity.

On its part, regression analysis shows that an increase in the overall determinant index is significantly associated with an increase in the TFP growth rate, controlling for the initial TFP level and country- and time-effects. Countries that have a larger room for improvement in the determinants of TFP and make a stronger effort of reform would experience a larger increase in TFP growth, which is expected to rise over time and then taper down. The slowdown of TFP growth in the long run is explained by the increasing difficulty of expanding TFP

when its level is higher (given the estimated negative regression coefficient on past TFP) and the deceleration (in proportional terms) in the TFP determinant index itself.

Though significant and reasonable by historical standards, the increase in TFP growth is projected to be between 2.5-3 percentage points in the best cases of substantial reform, not enough by itself to support overly ambitious economic growth targets. Alongside productivity improvements, savings, investment, labor participation, and human capital formation should continue to figure prominently in countries' growth and development agendas.

This study has some limitations that should be considered when interpreting the results. One limitation is that the TFP determinants could be endogenous in relation to TFP growth. To mitigate this risk, we use lagged observations of the TFP determinant index in the variance decomposition and regression analyses. This may be a more straightforward and less biased approach than using instrumental variables that could be questionable (see Young 2017). Another limitation is that we do not include all possible determinants of productivity, either as broad categories or specific indicators. For instance, we do not directly include geographic conditions, workforce demographics, income and wealth inequality, or firm-specific entrepreneurship, and managerial ability (Feyrer 2007; Mastromarco and Zago 2012; Kremer, Rao, and Schilbach 2019). We attenuate the potential problem by including country-specific effects, a reasonable strategy to control for productivity determinants that are persistent over time. Also, we include a number of indicators that represent not only their limited definition but also proxy for a wider array of variables not represented in our measurements. A third limitation deals with the well-known drawbacks of measuring productivity as a residual. In a sense, the Solow residual is a "measure of our ignorance" (Abramovitz 1956), capturing not only productivity proper but also a variety of factors, from excess capacity and natural resources to heterogeneous and intangible capital (Hulten 2001; and Corrado, Hulten, and Sichel 2009). Nevertheless, we believe that focusing on average growth rates of TFP over several years (rather than on TFP levels or high-frequency TFP growth) is conducive to reducing mismeasurement and allowing the possibility of explaining TFP growth (Jorgenson and Griliches 1967). A fourth limitation is that the study focuses on global patterns, not taking sufficiently into account country heterogeneity. The relative contribution of the determinant indexes to the variance of TFP growth and the impact of the overall determinant index on TFP growth could be

different for each country and region, generally depending on the level of economic development and the nature of their political and social environment. Despite these limitations, we expect that this paper and accompanying toolkit can be a starting point – an international benchmark – for researchers and policy makers in their analysis of productivity and growth for particular countries.[6]

[6] See, for instance, Céspedes, Loayza, and Ramírez, forthcoming.

References

Abdih, Yasser, and Frederick Joutz. 2006. "Relating the Knowledge Production Function to Total Factor Productivity: An Endogenous Growth Puzzle." WP/05/74. IMF Working Paper.

Abramovitz, M. 1956. "Resource and Output Trends in the United States since 1870." *American Economic Review* 46: 5-23.

Acemoglu, Daron, Simon Johnson, and James Robinson. 2004. "Institutions as the Fundamental Cause of Long-Run Growth." 10481. NBER Working Paper.

Acemoglu, Daron, Simon Johnson, and James A. Robinson. 2001. "The Colonial Origins of Comparative Development: An Empirical Investigation." *American Economic Review* 91 (5): 1369–1401. https://doi.org/10.1257/aer.91.5.1369.

Aghion, Philippe, and Howitt. 1992. "A Model of Growth through Creative Destruction." *Econometrica* 60 (2): 323–51. https://doi.org/10.2307/2951599.

Aguiar, Angel, Badri Narayanan, and Robert McDougall. 2016. "An Overview of the GTAP 9 Data Base." *Journal of Global Economic Analysis* 1 (1): 181–208. https://doi.org/10.21642/JGEA.010103AF.

Alfaro, Laura, Areendam Chanda, Sebnem Kalemli-Ozcan, and Selin Sayek. 2004. "FDI and Economic Growth: The Role of Local Financial Markets." *Journal of International Economics* 64 (1): 89–112. https://doi.org/10.1016/S0022-1996(03)00081-3.

Alfaro, Laura, Sebnem Kalemli-Ozcan, and Selin Sayek. 2009. "FDI, Productivity and Financial Development." *World Economy* 32 (1): 111–35. https://doi.org/10.1111/j.1467-9701.2009.01159.x.

Ark, Bart van, Mary O'Mahony, and Marcel P Timmer. 2008. "The Productivity Gap between Europe and the United States: Trends and Causes." *Journal of Economic Perspectives* 22 (1): 25–44. https://doi.org/10.1257/jep.22.1.25.

Arnold, Jens, Giuseppe Nicoletti, and Stefano Scarpetta. 2008. "Regulation, Allocative Efficiency and Productivity in OECD Countries." 616. OECD Economics Department Working Papers. https://doi.org/10.1787/241447806226.

Aschauer, David Alan. 1989. "Is Public Expenditure Productive?" *Journal of Monetary Economics* 23 (2): 177–200. https://doi.org/10.1016/0304-3932(89)90047-0.

Azen, Razia, and David V Budescu. 2003. "The Dominance Analysis Approach for Comparing Predictors in Multiple Regression." *Psychological Methods* 8 (2): 129–48. https://doi.org/10.1037/1082-989X.8.2.129.

Barro, Robert J., and Jong Wha Lee. 2013. "A New Data Set of Educational Attainment in the World, 1950-2010." *Journal of Development Economics* 104: 184–98. https://doi.org/10.1016/j.jdeveco.2012.10.001.

Barro, Robert J., and Xavier Sala-I-Martin. 1992. "Public Finance in Models of Economic Growth." *The Review of Economic Studies* 59 (4): 645. https://doi.org/10.2307/2297991.

Barro, Robert J., and Xavier I. Sala-i-Martin. 2004. "Capter 10. Growth Accounting." In *Economic Growth*, 2nd ed. Cambridge, Massachusetts: The MIT Press.

Barro, Robert J. 1990. "Government Spending in a Simple Model of Endogeneous Growth." *Journal of Political Economy* 98 (5): S103–25. https://doi.org/10.1086/261726.

———. 1991. "Economic Growth in a Cross-Section of Countries." *The Quarterly Journal of Economics* 106 (2): 407–43. https://doi.org/10.2307/2937943.

———. 2001. "Human Capital and Growth." *The American Economic Review* 91 (2): 12–17. https://doi.org/10.2307/2677725.

Bartelsman, Eric J., Pieter A. Gautier, and Joris De Wind. 2016. "Employment Protection, Technology Choice, and Worker Allocation." *International Economic Review* 57 (3): 787–826. https://doi.org/10.1111/iere.12176.

Beck, Thorsten, Ross Levine, and Norman Loayza. 2000. "Finance and the Sources of Growth." *Journal of Financial Economics* 58 (1–2): 261–300. https://doi.org/10.1016/S0304-405X(00)00072-6.

Ben-David, Dan, and David H. Papell. 1998. "Slowdowns and Meltdowns: Postwar Growth Evidence from 74 Countries." *Review of Economics and Statistics* 80 (4): 561–71. https://doi.org/10.1162/003465398557834.

Benhabib, J., and Mark M. Spiegel. 2005. "Chapter 13 Human Capital and Technology Diffusion." *Handbook of Economic Growth*. https://doi.org/10.1016/S1574-0684(05)01013-0.

Benhabib, J, and M Spiegel. 1994. "The Role of Human Capital in Economic Development. Evidence from Aggregate Cross-Country Data." *Journal of Monetary Economics* 144: 117–43. https://doi.org/10.1016/0304-3932(94)90047-7.

Benhabib, Jess, and M.M. Spiegel. 1994. "The Role of Human Capital in Economic Development Evidence from Aggregate Cross-Country Data." *Journal of Monetary Economics* 34 (2): 143–173. https://doi.org/http://dx.doi.org/10.1016/0304-3932(94)90047-7.

Benhabib, Jess, and Mark M Spiegel. 2005. "Human Capital and Technology Diffusion." In *Handbook of Economic Growth*, 1:936–65. https://doi.org/10.1016/S1574-0684(05)01013-0.

Bergoeing, Raphael, Norman V. Loayza, and Facundo Piguillem. 2016. "The Whole Is Greater than the Sum of Its Parts: Complementary Reforms to Address Microeconomic Distortions." *World Bank Economic Review* 30 (2): 268–305. https://doi.org/10.1093/wber/lhv052.

Borensztein, E., J. De Gregorio, and J-W. Lee. 1998. "How Does Foreign Direct Investment Affect Economic Growth?" *Journal of International Economics* 45 (1): 115–35. https://doi.org/10.1016/S0022-1996(97)00033-0.

Bridgman, Benjamin, Shi Qi, and James A. Schmitz. 2009. "The Economic Performance of Cartels: Evidence from the New Deal U.S. Sugar Manufacturing Cartel, 1934–74." 437. Federal Reserve Bank of Minneapolis Staff Report.

Bronzini, Raffaello, and Paolo Piselli. 2009. "Determinants of Long-Run Regional Productivity with Geographical Spillovers: The Role of R&D, Human Capital and Public Infrastructure." *Regional Science and Urban Economics* 39 (2): 187–99. https://doi.org/10.1016/j.regsciurbeco.2008.07.002.

Budescu, David V. 1993. "Dominance Analysis: A New Approach to the Problem of Relative Importance of Predictors in Multiple Regression." *Psychological Bulletin*. https://doi.org/10.1037/0033-2909.114.3.542.

Buera, Francisco J, Joseph P Kaboski, and Yongseok Shin. 2011. "American Economic Association Finance and Development: A Tale of Two Sectors." *Source: The American Economic Review* 101 (5): 1964–2002. https://doi.org/10.1257/aer.

Caballero, and Hammour. 1998. "Jobless Growth: Appropriability, Factor Substitution, and Unemployment." *Carnegie-Rochester Conference Series on Public Policy* 48: 95–99. https://doi.org/http://dx.doi.org/10.1016/S0167-2231(98)00016-5.

Caballero, R. J., and M. L. Hammour. 1996. "On the Timing and Efficiency of Creative Destruction." *The Quarterly Journal of Economics* 111 (3): 805–52. https://doi.org/10.2307/2946673.

Calderón, César, and Luis Servén. 2010. "Infrastructure and Economic Development in Sub-Saharan Africa." *Journal of African Economies* 19 (Supplement 1): i13–87. https://doi.org/10.1093/jae/ejp022.

———. 2012. *Infrastructure in Latin America*. *The Oxford Handbook of Latin American Economics*. https://doi.org/10.1093/oxfordhb/9780199571048.013.0026.

———. 2014. "Infrastructure, Growth, and Inequality: An Overview." 7034. World Bank Policy Research Working Paper. https://doi.org/10.1596/1813-9450-7034.

Canning, David, and Peter Pedroni. 2008. "Infrastructure, Long-Run Economic Growth and Causality Tests for Cointegrated Panels." *Manchester School* 76 (5): 504–27. https://doi.org/10.1111/j.1467-9957.2008.01073.x.

Caselli, Francesco. 2005. "Chapter 9 Accounting for Cross-Country Income Differences." *Handbook of Economic Growth*. https://doi.org/10.1016/S1574-0684(05)01009-9.

Centre for Economic Performance. 2017. "World Management Survey." 2017.

Céspedes, N., N. Loayza, and N. Ramírez. *Economic Growth in Peru: Causes and Consequences* [in Spanish]. Lima: Fondo Editorial de la Universidad del Pacífico (forthcoming).

Chanda, Areendam, and Carl Johan Dalgaard. 2008. "Dual Economies and International Total Factor Productivity Differences: Channelling the Impact from Institutions, Trade, and Geography." *Economica* 75 (300): 629–61. https://doi.org/10.1111/j.1468-0335.2007.00673.x.

Chang, Roberto, Linda Kaltani, and Norman V. Loayza. 2009. "Openness Can Be Good for Growth: The Role of Policy Complementarities." *Journal of Development Economics* 90 (1): 33–49. https://doi.org/10.1016/j.jdeveco.2008.06.011.

Chen, Derek H C, and Carl J Dahlman. 2004. "Knowledge and Development A Cross-Section Approach." 3366. World Bank Policy Research Working Paper.

Chenery, Hollis B. 1960. "Patterns of Industrial Growth." *The American Economic Review* 50 (4): 624–54. https://doi.org/10.1257/jep.6.3.79.

Cingano, Federico. 2014. "Trends in Income Inequality and Its Impact on Economic Growth." *OECD Social, Employment, and Migration Working Papers*, no. 163: 0_1,5-59. https://doi.org/http://dx.doi.org/10.1787/5jxrjncwxv6j-en.

Cirera, Xavier, and William F. Maloney. 2017. *The Innovation Paradox : Developing-Country Capabilities and*

the Unrealized Promise of Technological Catch-Up. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/28341.

Coe, David T., Elhanan Helpman, and Alexander W. Hoffmaister. 2009. "International R&D Spillovers and Institutions." *European Economic Review* 53 (7): 723–41. https://doi.org/10.1016/j.euroecorev.2009.02.005.

Coe, David T, and Elhanan Helpman. 1995. "International R&D Spillovers." *European Economic Review* 39 (5): 859–87. https://doi.org/10.1016/0014-2921(94)00100-E.

Coe, David Theodore, Elhanan Helpman, and Alexander W. Hoffmaister. 1997. "North-South R&D Spillovers." *Economic Journal* 107 (440): 134–49. https://doi.org/10.1111/1468-0297.00146.

Comin, Diego, and Bart Hobijn. 2010. "An Exploration of Technology Diffusion." *American Economic Review* 100 (5): 2031–59. https://doi.org/10.1257/aer.100.5.2031.

Comin, Diego, Bart Hobijn, and Emilie Rovito. 2008. "Technology Usage Lags." *Journal of Economic Growth* 13 (4): 237–56. https://doi.org/10.1007/s10887-008-9035-5.

Comin, Diego, and Martí Mestieri. 2018. "If Technology Has Arrived Everywhere, Why Has Income Diverged?" *American Economic Journal: Macroeconomics* 10 (3): 137–78. https://doi.org/10.1257/mac.20150175.

Corrado, C., C. Hulten, and D. Sichel. "Intangible Capital and U.S. Economic Growth." *The Review of Income and Wealth* 55(3): 661-685.

Dabla-norris, Era, and Kalpana Kochhar. 2015. "Causes and Consequences of Income Inequality : A Global Perspective." *IMF Staff Discussion Note*. https://doi.org/DOI:

Dar, Atul A., and Sal AmirKhalkhali. 2002. "Government Size, Factor Accumulation, and Economic Growth: Evidence from OECD Countries." *Journal of Policy Modeling* 24 (7–8): 679–92. https://doi.org/10.1016/S0161-8938(02)00163-1.

Daron Acemoglu, And, and Fabrizio Zilibotti. 2001. "Productivity Differences." *Quarterly Journal of Economics* 116 (2): 563–606. https://doi.org/10.1162/00335530151144104.

Davis, Steven J., John Haltiwanger, and Scott Schuh. 1996. "Small Business and Job Creation: Dissecting the Myth and Reassessing the Facts." *Small Business Economics* 8 (4): 297–315. https://doi.org/10.1007/BF00393278.

Devadas, Sharmila, and Steven Michael Pennings. 2018. "Assessing the Effect of Public Capital on Growth: An Extension of the World Bank Long-Term Growth Model." World Bank Policy Research Working Paper, No. 8604.

Djankov, Simeon, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer. 2002. "The Regulation of Entry." *The Quarterly Journal of Economics* 117 (1): 1–37.

Dollar, David, and Aart Kraay. 2004. "Trade, Growth, and Poverty." *The Economic Journal* 114 (493): F22–49. https://doi.org/10.1111/j.0013-0133.2004.00186.x.

Easterly, William. 2001. "The Middle Class Consensus and Economic Development." *Journal of Economic Growth* 6 (4): 317–35. https://doi.org/10.1023/A:1012786330095.

Easterly, William, and Ross Levine. 1997. "Africa's Growth Tragedy." *The Quarterly Journal of Economics* 112

(4): 1203–50. https://doi.org/10.1002/ps.3780.

———. 2003. "Tropics, Germs, and Crops: How Endowments Influence Economic Development." *Journal of Monetary Economics*. https://doi.org/10.1016/S0304-3932(02)00200-3.

Easterly, William, and Ross E. Levine. 2001. "It's Not Factor Accumulation: Stylized Facts and Growth Models." *The World Bank Economic Review* 15 (2): 177–219. https://doi.org/10.2139/ssrn.269108.

Engerman, S, and Kenneth L. Sokoloff. 2000. "Institutions, Factor Endowments, and Paths of Development in the New World." *Journal of Economic Perspectives* 14 (3): 217–32. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Institutions+,+Factor+Endowments+,+and+Paths+of+Development+in+the+New+World#1.

Erosa, Andrés, Tatyana Koreshkova, and Diego Restuccia. 2010. "How Important Is Human Capital? A Quantitative Theory Assessment of World Income Inequality." *Review of Economic Studies* 77 (4): 1421–49. https://doi.org/10.1111/j.1467-937X.2010.00610.x.

Fagerberg, Jan. 2000. "Technological Progress, Structural Change and Productivity Growth: A Comparative Study." *Structural Change and Economic Dynamics* 11 (4): 393–411. https://doi.org/10.1016/S0954-349X(00)00025-4.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. "The next Generation of the Penn World Table." *American Economic Review* 105 (10): 3150–82. https://doi.org/10.1257/aer.20130954.

Feyrer, James. 2007. "Demographics and Productivity." *The Review of Economics and Statistics* 89 (1): 100-109.

Foster, L., Haltiwanger, J. C., & Krizan, C. J. 2001. "Aggregate Productivity Growth. Lessons from Microeconomic Evidence." In *New Developments in Productivity Analysis*, pp 303-372. University of Chicago Press.

Furman, Jeffrey L., and Richard Hayes. 2004. "Catching up or Standing Still? National Innovative Productivity among 'follower' Countries, 1978-1999." *Research Policy* 33 (9): 1329–54. https://doi.org/10.1016/j.respol.2004.09.006.

Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. "Water for Life: The Impact of the Privatization of Water Services on Child Mortality." *Journal of Political Economy* 113 (1): 83–120. https://doi.org/10.1086/426041.

Ghali, Khalifa H. 1999. "Government Size and Economic Growth: Evidence from a Multivariate Cointegration Analysis." *Applied Economics* 31 (8): 975–87. https://doi.org/10.1080/000368499323698.

Giavazzi, Francesco, and Guido Tabellini. 2005. "Economic and Political Liberalizations." *Journal of Monetary Economics* 52 (7): 1297–1330. https://doi.org/10.1016/j.jmoneco.2005.05.002.

Griffith, Rachel, Stephen Redding, and John Van Reenen. 2004. "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries." *The Review of Economics and Statistics* 86 (4): 883–95. https://doi.org/10.1162/0034653043125194.

Grömping, Ulrike. 2007. "Estimators of Relative Importance in Linear Regression Based on Variance Decomposition." *American Statistician* 61 (2): 139–47. https://doi.org/10.1198/000313007X188252.

Grossman, Gene M., and Elhanan Helpman. 1991. "Quality Ladders in the Theory of Growth." *The Review of Economic Studies* 58 (1): 43. https://doi.org/10.2307/2298044.

Guellec, Dominique, and B. van Pottelsberghe de la Potterie. 2004. "From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter?" *Oxford Bulletin of Economics and Statistics* 66 (3): 353–78. https://doi.org/10.1111/j.1468-0084.2004.00083.x.

Hall, Robert E, and Charles I Jones. 1999. "Why Do Some Countries Produce so Much More Outper per Worker than Others?" *Quarterly Journal of Economics* 114 (1): 83–116. https://doi.org/10.1162/003355399555954.

Haltiwanger, John, Stefano Scarpetta, and Helena Schweiger. 2008. "Assessing Job Flows across Countries: The Role of Industry, Firm Size and Regulations." 13920. NBER Working Paper. https://doi.org/10.1017/CBO9781107415324.004.

Hanushek, Eric A., and Ludger Woessmann. 2015. *The Knowledge Capital of Nations: Education and the Economics of Growth*. The MIT Press.

Hicks, John. 1939. *Value and Capital*. Edited by John Hicks. Oxford, United Kingdom: Clarendon Press.

Hoeller, Peter, Isabelle Joumard, and Isabell Koske. 2014. "Reducing Income Inequality While Boosting Economic Growth: Can It Be Done? Evidence from OECD Countries." *The Singapore Economic Review* 59 (01): 1450001. https://doi.org/10.1142/S0217590814500015.

Hopenhayn, Hugo. 1992. "Entry, Exit, and Firm Dynamics in Long Run Equilibrium." *Econometrica* 60 (5): 1127–50.

Hopenhayn, Hugo, and Richard Rogerson. 1993. "Job Turnover and Policy Evaluation: A General Equilibrium Analysis." *Journal of Political Economy* 101 (5): 915–38. https://doi.org/10.1086/261909.

Hsieh, Chang-Tai, and Peter J. Klenow. 2009. "Misallocation and Manufacturing TFP in China and India." *Quarterly Journal of Economics* 124 (4): 1403–48. https://doi.org/10.1162/qjec.2009.124.4.1403.

Hulten, Charles R. 2001. "Total Factor Productivity: A Short Biography." In *New Developments in Productivity Analysis*, edited by Charles R. Hulten, Edwin R. Dean, and Michael J. Harper. https://doi.org/10.1080/09535310701571828.

Hulten, Charles R. 1996. "Infrastructure Capital and Economic Growth How Well You Use It May Be More Important Than How Much You Have." 5847. NBER Research Working Paper. https://doi.org/10.3386/w5847.

International Road Federation. 2017a. "Roads, Paved (% of Total Roads)." International Road Federation. 2017.

———. 2017b. "Roads, Total Network (Km)." International Road Federation. 2017.

Isaksson, A. 2007. "Determinants of Total Factor Productivity: A Literature Review." *Research and Statistics Branch, UNIDO*. http://www.rrojasdatabank.info/87573_determinants_of_total_factor_productivity.pdf.

Jerzmanowski, Michał. 2007. "Total Factor Productivity Differences: Appropriate Technology vs. Efficiency." *European Economic Review* 51 (8): 2080–2110. https://doi.org/10.1016/j.euroecorev.2006.12.005.

Jolliffe, I . T. 2002. *Principal Component Analysis*. *Springer Series in Statistics*. https://doi.org/10.1007/b98835.

Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh. 2005. *Productivity, Volume 3: Information Technology and the American Growth Resurgence*. *The MIT Press*. Vol. 3. http://ideas.repec.org/b/mtp/titles/0262101114.html.

———. 2008. "A Retrospective Look at the US Productivity Growth Resurgence." *Journal of Economic Perspectives* 22 (1): 3–24. https://doi.org/10.1257/jep.22.1.3.

Jorgenson, D., and Z. Griliches. 1967. "The Explanation of Productivity Change." *Review of Economic Studies* 34: 349-83.

Kaufmann, Daniel, and Aart Kraay. 2017. "Worldwide Governance Indicators." World Bank. 2017. www.govindicators.org, accessed on 31 May 2017.

Kim, Young Eun, Norman Loayza, and Claudia Meza-Cuadra. 2016. "Productivity as the Key to Economic Growth and Development." *World Bank Research Policy Brief*, no. 3. http://documents.worldbank.org/curated/en/314741472533203058/Productivity-as-the-key-to-economic-growth-and-development.

Knack, Stephen, and Philip Keefer. 1995. "Institutions and Economic Performance: Cross-country Tests Using Alternative Institutional Measures." *Economics & Politics* 7 (3): 207–27. https://doi.org/10.1111/j.1468-0343.1995.tb00111.x.

Kremer, Michael, Gautam Rao, and Frank Schilbach. 2019. "Behavioral Development Economics." In *Handbook of Behavioral Economics - Foundations and Applications 2*, edited by B. Douglas Bernheim, Stefano DellaVigna, and David Laibson, 1st ed., 345–458. https://doi.org/10.1016/bs.hesbe.2018.12.002.

Kuznets, Simon. 1957. "Quantitative Aspects of the Economic Growth of Nations: II. Industrial Distribution of National Product and Labor Force." *Economic Development and Cultural Change* 5 (S4): 1–111. https://doi.org/10.1086/449740.

Larson, Gregory Michael, Norman V. Loayza, and Michael Woolcock. 2016. "The Middle-Income Trap : Myth or Reality?" *World Bank Research & Policy Briefs*, no. 1. http://documents.worldbank.org/curated/en/965511468194956837/The-middle-income-trap-myth-or-reality.

Lentz, Rasmus, and Dale T. Mortensen. 2008. "An Empirical Model of Growth through Product Innovation." *Econometrica* 76 (6): 1317–73. https://doi.org/10.3982/ECTA5997.

Lewis, Arthur W. 1954. "Economic Development with Unlimited Supplies of Labour." *The Manchester School* 22 (2): 139–91. https://doi.org/10.1073/pnas.1006652108.

Loayza, Norman V.; Pennings, Steven. 2018. "The Long Term Growth Model." World Bank: Washington D.C. 2018. http://www.worldbank.org/LTGM.

Loayza, Norman V., and Rei Odawara. 2010. "Infrastructure and Economic Growth in Egypt." World Bank Policy Research Working Paper. https://doi.org/10.1177/097493060900100105.

Loayza, Norman V, Pablo Fajnzylber, and César Calderón. 2005. *Economic Growth in Latin America and the Caribbean : Stylized Facts, Explanations, and Forecasts*. Washington, DC: World Bank.

Loayza, Norman V, and Luis Servén. 2010. "Business Regulation and Economic Performance." World Bank Publications, No. 2554.

Lucas, Robert E. 1988. “On the Mechanics of Economic Development.” *Journal of Monetary Economics* 22 (1): 3–42. https://doi.org/10.1016/0304-3932(88)90168-7.

Mastromarco, Camilla, and Angelo Zago. 2012. “On modeling the determinants of TFP growth.” *Structural Change and Economic Dynamics* 23 (4): 373-382.

Mauro, P. 1995. “Corruption and Growth.” *The Quarterly Journal of Economics* 110 (3): 681–712. https://doi.org/10.2307/2946696.

Mello, L.R. de. 1999. “Foreign Direct Investment-Led Growth: Evidence from Time Series and Panel Data.” *Oxford Economic Papers* 51: 133–51. https://doi.org/10.1093/oep/51.1.133.

Mendi, Pedro. 2007. “Trade in Disembodied Technology and Total Factor Productivity in OECD Countries.” *Research Policy* 36 (1): 121–33. https://doi.org/10.1016/j.respol.2006.09.028.

Melitz, Marc J. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity." *Econometrica* 71 (6): 1695-1725.

Miller, Stephen M., and Mukti P. Upadhyay. 2000. “The Effects of Openness, Trade Orientation, and Human Capital on Total Factor Productivity.” *Journal of Development Economics* 63 (2): 399–423. https://doi.org/10.1016/S0304-3878(00)00112-7.

Mulaik, Stanley A. 2009. *Foundations of Factor Analysis*. 2nd editio. Boca Raton: Taylor & Francis Group, LLC.

Munnell, Alicia H. 1992. “Policy Watch: Infrastructure Investment and Economic Growth.” *Journal of Economic Perspectives* 6 (4): 189–98. https://doi.org/10.1257/jep.6.4.189.

Nadiri, M. Ishaq. 1993. “Innovations and Technological Spillovers.” 4423. NBER Working Paper. https://doi.org/10.3386/w4423.

Nicoletti, Giuseppe, and Stefano Scarpetta. 2003. “Regulation, Productivity and Growth: OECD Evidence.” *Economic Policy* 18 (36): 9–72. https://doi.org/10.1111/1468-0327.00102.

North, Douglas C. 1990. *Institutions, Institutional Change and Economic Performance*. *Cambridge University Press*. https://doi.org/10.1017/CBO9780511606892.012.

North, Douglass C. 1990. “Institutions, Institutional Change, and Economic Performance.” *Cambridge University Press* 5 (1): 1–153. https://doi.org/10.2307/2234910.

OECD/IEA. 2017. “Electricity Production (KWh).” OECD/IEA. 2017.

OECD. 2016a. “PISA: Mean Performance on the Mathematics Scale.” 2016.

———. 2016b. “PISA: Mean Performance on the Reading Scale.” 2016.

———. 2016c. “PISA: Mean Performance on the Science Scale.”

Oliner, Stephen D., Daniel E. Sichel, and Kevin J. Stiroh. 2008. “Explaining a Productive Decade.” *Journal of Policy Modeling* 30 (4): 633–73. https://doi.org/10.1016/j.jpolmod.2008.04.007.

Parente, Stephen L., and Edward C Prescott. 2000. *Barriers to Riches*. The MIT Press.

Peneder, Michael. 2003. “Industrial Structure and Aggregate Growth.” *Structural Change and Economic Dynamics* 14 (4): 427–48. https://doi.org/10.1016/S0954-349X(02)00052-8.

Petrin, Amil, and Jagadeesh Sivadasan. 2011. “Estimating Lost Output from Allocative Inefficiency, with an Application to Chile and Firing Costs.” *Review of Economics and Statistics* 95 (1): 286–301. https://doi.org/10.1162/REST_a_00238.

Pritchett, L. 1996. “Mind Your P’s and Q’s: The Cost of Public Investment Is Not the Value of Public Capital.” World Bank Policy Research Working Paper. https://doi.org/10.1596/1813-9450-1660.

Przeworski, Adam, and Fernando Limongi. 1993. “Political Regimes and Economic Growth.” *Journal of Economic Perspectives* 7 (3): 51–69. https://doi.org/10.1257/jep.7.3.51.

Rajan, Raghuram G., and Luigi Zingales. 1998. “Financial Dependence and Growth.” *American Economic Review* 88 (3): 559–86.

Rebelo, S. 1991. “Long-Run Policy Analysis and Long-Run Growth.” *Journal of Political Economy* 99 (3): 500–521. https://doi.org/10.1086/261764.

Restuccia, Diego, and Richard Rogerson. 2008. “Policy Distortions and Aggregate Productivity with Heterogeneous Establishments.” *Review of Economic Dynamics* 11 (4): 707–20. https://doi.org/10.1016/j.red.2008.05.002.

Restuccia, D., and R. Rogerson. 2017. “The Causes and Costs of Misallocation.” Journal of Economic Perspectives 31(3): 151–74.

Rodrik, Dani, Arvind Subramanian, and Francesco Trebbi. 2004. “Institutions Rule : The Primacy Over in Economic and Integration Geography Development.” *Journal of Economic Growth* 9 (2): 131–65.

Romer, Paul M. 1987. “Growth Based on Increasing Returns Due to Specialization.” *The American Economic Review* 77 (2): 56–62. https://doi.org/10.2307/1805429.

———. 1990. “Endogenous Technological Change.” *Journal of Political Economy* 98 (5): S71–102. https://doi.org/10.1086/261725.

Sachs, Jeffrey D. 2003. “Institutions Don’t Rule: Direct Effects of Geography on per Capita Income.” 9490. NBER Working Paper.

SAS Institute Inc. 2017. “Principal Components or Factor Analysis?” 2017. https://community.jmp.com/t5/JMP-Blog/Principal-components-or-factor-analysis/bc-p/50703#M3325, accessed on 15 March 2018.

Schumpeter, Joseph. 1942. *Capitalism, Socialism and Democracy*. New York: Harper & Row.

Solow, R. M. 1956. “A Contribution to the Theory of Economic Growth.” *The Quarterly Journal of Economics* 70 (1): 65–94. https://doi.org/10.2307/1884513.

Straub, Stéphane. 2008. “Infrastructure and Growth in Developing Countries : Recent Advances and Research Challenges.” 4460. World Bank Policy Research Working Paper. https://doi.org/10.1596/1813-9450-4460.

Svirydzenka, Katsiaryna. 2016. “Introducing a New Broad-Based Index of Financial Development.” 16/5. IMF Working Paper.

Swan, T. 1956. "Economic Growth and Capital Accumulation." *Economic Record* 32 (2): 334–61. https://doi.org/10.1111/j.1475-4932.1956.tb00434.x.

Syverson, Chad. 2011. "What Determines Productivity?" *Journal of Economic Literature* 49 (2): 326–65. https://doi.org/10.1257/jel.49.2.326.

Ulku, Hulya, and Arvind Subramanian. 2004. "R&D, Innovation, and Economic Growth: An Empirical Analysis." 04/185. IMF Working Paper. https://doi.org/10.5089/9781451859447.001.

Wei, Zheng, and Rui Hao. 2011. "The Role of Human Capital in China's Total Factor Productivity Growth: A Cross-Province Analysis." *The Developing Economies* 49 (1): 1–35. https://doi.org/10.1111/j.1746-1049.2010.00120.x.

WHO/UNICEF. 2017a. "Improved Sanitation Facilities (% of Population with Access)." 2017.

———. 2017b. "Improved Water Source (% of Population with Access)." 2017.

Woo, Wing Thye, Stephen Parker, and Jeffrey Sachs. 1997. *Economies in Transition: Comparing Asia and Europe*. The MIT Press.

World Bank. 2003. *World Development Report 2004 : Making Services Work for Poor People*. World Bank. https://openknowledge.worldbank.org/handle/10986/5986.

World Bank. 2017a. *Doing Business 2017: Equal Opportunity for All*. Washington, DC: World Bank Group. https://doi.org/10.1596/978-1-4648-0948-4.

———. 2017b. "Employment to Population Ratio, 15+, Total (%) (Modeled ILO Estimate)." World Development Indicators. 2017.

———. 2017c. "Fixed Telephone Subscriptions (per 100 People)." World Development Indicators. 2017.

———. 2017d. "GDP (Constant 2010 US$)." World Development Indicators. 2017.

———. 2017e. "GDP per Capita (Constant 2010 US$)." World Development Indicators. 2017.

———. 2017f. "Government Expenditure on Education, Total." World Development Indicators. 2017.

———. 2017g. "Gross Capital Formation (Constant 2010 US$)." World Development Indicators. 2017.

———. 2017h. "Labor Market Regulation Indicators." Doing Business Database. 2017.

———. 2017i. "Mobile Cellular Subscriptions (per 100 People)." World Development Indicators. 2017.

———. 2017j. "Oil Rents (% of GDP)." World Development Indicators. 2017.

———. 2017k. "Patent Applications, Nonresidents." World Development Indicators. 2017.

———. 2017l. "Patent Applications, Residents." World Development Indicators. 2017.

———. 2017m. "Population, Total." World Development Indicators. 2017.

———. 2017n. "Population Ages 0-14 (% of Total)." World Development Indicators. 2017.

———. 2017o. “Research and Development Expenditure (% of GDP).” World Development Indicators. 2017.

———. 2017p. “Scientific and Technical Journal Articles.” World Development Indicators. 2017.

———. 2017q. “Share of Women in Wage Employment in the Nonagricultural Sector (% of Total Nonagricultural Employment).” World Development Indicators. 2017.

———. 2017r. *World Development Report 2017: Governance and the Law*. World Bank. http://www.worldbank.org/en/publication/wdr2017.

Young, Alwyn. 2017. “Consistency without Inference: Instrumental Variables in Practical Application.” London School of Economics Working Paper. http://personal.lse.ac.uk/YoungA/ConsistencyWithoutInference.pdf.

Appendix A. Literature review

1. Innovation (12 studies)

Study	Country and year	Results	Relationship
Nadiri (1993)	4 industrial countries, 1970–90	The results suggest a positive and strong relationship between research and development (R&D) expenditures and growth of output or total factor productivity (TFP).	+
Coe and Helpman (1995)	22 industrial countries, 1971–90	International R&D spillovers have beneficial effects on domestic productivity. The elasticity of TFP with respect to foreign R&D expenditure is 0.02–0.08 for G7 countries and 0.04–0.26 for other small OECD countries.	+
Chen and Dahlman (2004)	92 countries, 1960–2000	The number of patents and journal publications is statistically significant in terms of real GDP growth via their effects on the TFP growth rate.	+
Furman and Hayes (2004)	29 countries, 1978–99	Innovation-enhancing policies and infrastructure need to be developed to achieve leadership in innovation, but these are insufficient unless coupled with ever-increasing financial and human capital investments in innovation.	+/-
Griffith, Redding, and Reenen (2004)	12 OECD countries, 1974–90	R&D is statistically and economically important in both technological catch up and innovation. Human capital also plays a major role in productivity growth.	+
Guellec and van Pottelsberghe de la Potterie (2004)	16 OECD countries, 1980–98	R&D performed by the business sector, the public sector, and foreign firms is a significant determinant of long-term productivity growth.	+
Ulku and Subramanian (2004)	30 OECD countries, 1981–97	The results suggest a positive relationship between per capita GDP and innovation in both OECD and non-OECD countries. However, the effect of the R&D stock on innovation is significant only in the OECD countries with large markets.	+/-
Jorgenson, Ho, and Stiroh (2005)	United States, 1990s and 2000s	Industries that produce or use information technology (IT) account for only 30% of U.S. GDP but contributed to half of the acceleration in economic growth in the 1990s and 2000s.	+
Abdih and Joutz (2006)	United States, 1948–97	Long-run elasticity of TFP with respect to the stock of patents is positive, but small. These results seem to suggest that while research workers benefit greatly from “standing on the shoulders” of prior researchers, the knowledge that they produce seems to have complex and slowly diffusing impacts on TFP.	+
Jorgenson, Ho, and Stiroh (2008)	United States 1960–2006	Information technology was critical to the dramatic acceleration of U.S. labor productivity growth in the mid-1990s.	+
Oliner, Sichel, and Stiroh (2008)	United States, 1990s–2000s.	Authors confirm the central role for IT in the productivity revival during 1995–2000 and show that IT played a significant, though smaller, role after 2000.	+
van Ark, O’Mahony, and Timmer (2008)	United States, Europe, 1980s–2000s	The slow-down in productivity in Europe can be attributed to the slower emergence of the knowledge economy in Europe compared to the United States. Explanations include lower growth contributions from investment in information and communication technology in Europe, the relatively small share of technology-producing industries in Europe, and	+

		slower multifactor productivity growth (a proxy for advances in technology and innovation).	

2. Education (9 studies)

Study	Country and year	Results	Relationship
Benhabib and Spiegel (1994)	78 countries, 1965–85	Human capital is not significant in explaining per capita growth rates. However, the growth rate of TFP depends on a nation's human capital stock level.	+
Miller and Upadhyay (2000)	83 countries, 1960–89	Human capital generally contributes positively to TFP. In poor countries, human capital interacts with openness to achieve a positive effect, on balance.	+/-
Barro (2001)	100 countries, 1965–95	Growth is significantly related to the years of schooling at the secondary and higher levels for males and students' test scores (a proxy for the quality of education). The insignificant relation between growth and years of schooling for females implies that women are not well utilized in the labor markets of many countries.	+/-
Griffith, Redding, and Reenen (2004)	12 OECD countries, 1974–90	Human capital (percentage of higher school attained in the total population) affects the rate of convergence of TFP growth.	+
Benhabib and Spiegel (2005)	27 countries, 1960–95	Results support that human capital plays a positive role in the determination of total factor productivity growth rates through its influence on the rate of technology catch-up.	+
Bronzini and Piselli (2009)	Italy, 1985–2001	Elasticity of TFP with respect to years of schooling is positive and statistically significant (0.379).	+
Coe, Helpman, and Hoffmaister (2009)	24 countries, 1971–2004	Authors find evidence that countries where the ease of doing business and the quality of tertiary education systems are relatively high tend to benefit more from their own R&D efforts, from international R&D spillovers, and from human capital formation.	+
Erosa, Koreshkova, and Restuccia (2010)	United States, 1990–95	Human capital accumulation strongly amplifies TFP differences across countries.	+
Wei and Hao (2011)	China, 1985–2004	School enrollment has significant and positive effects on the TFP growth of Chinese provinces. When education quality (as measured by the teacher-student ratio and government expenditure on education) is incorporated, TFP growth appears to be significantly enhanced by quality improvements in primary education at the national level. TFP growth is significantly associated with secondary education in the eastern region; with primary and university education in the central region; and with primary education in the western region.	+

3. Market Efficiency (21 studies)

Study	Country and year	Results	Relationship
Coe, Helpman, and Hoffmaister (1997)	77 developing countries, 1971–90	Based on data for 77 developing countries, R&D spillovers via trade with 22 industrial countries are substantial.	+
Borensztein, De Gregorio, and Lee (1998)	70+ countries, 1970–89	FDI contributes to economic growth only when a host economy has sufficient capability to absorb advanced technology.	+/-
de Mello (1999)	16 OECD and 17 non-OECD, 1970–90	FDI has a positive relationship with TFP growth in OECD countries, but a negative relationship in non-OECD countries.	+/-
Fagerberg (2000)	39 countries, 1973–90	While structural change on average has not been conducive to productivity growth, countries that have managed to increase their presence in the technologically most progressive industry (electronics) have experienced higher productivity growth than other countries.	+/-
Foster, Haltiwanger, and Krizan (2001)	United States, 1977–87	The contribution of reallocation of outputs and inputs from less productive to more productive establishments plays a significant role in accounting for aggregate productivity growth.	+
Nicoletti and Scarpetta (2003)	18 OECD countries, 1984–98	Productivity growth is boosted by reforms that promote private corporate governance and competition. In manufacturing, the productivity gains from liberalization are greater the further a given country is from the technology leader. Strict product market regulations – and lack of regulatory reforms – appear to underlie the meagre productivity performance in industries where Europe has accumulated a technology gap.	+
Peneder (2003)	28 OECD countries, 1990–98	Structural change generates positive as well as negative contributions to aggregate productivity growth. Because many of these effects net out, structural change on average appears to have only a weak impact. Given that certain industries systematically achieve higher rates of productivity growth and expansion of output than others, structural change in favor of specific industries might still be conducive to aggregate growth.	+/-
Alfaro, Chanda, Kalemli-Ozcan, and Sayek (2004)	49+ countries, 1975-95	FDI alone plays an ambiguous role in contributing to economic growth. However, countries with well-developed financial markets gain significantly from FDI.	+
Dollar and Kraay (2004)	~100 developing and developed countries, 1960s–90s	Large increases in trade and significant declines in tariffs lead to faster growth and poverty reduction in poor countries.	+
Jerzmanowski (2007)	79 developing and developed countries, 1960–95	Inefficiency appears to be the main explanation for low incomes throughout the world; it explains 43% of output variation in 1995, and its importance has increased over time. Countries with an inadequate mix of inputs are unable to access the most productive technology. The world technology frontier appears to be shifting out faster at input combinations close to that of the R&D leader.	+

Mendi (2007)	16 OECD countries, 1971–95	Within OECD countries that are not in the G7, technology imports increase the host country's TFP. The effect is stronger in the initial years of the sampling period. There is no evidence on this positive effect of technology trade on productivity among G7 countries.	+/-
Arnold, Nicoletti, and Scarpetta (2008)	OECD countries, 1985−2004	Tight regulation of services has slowed down growth in sectors that use IT by hindering the allocation of resources toward the most dynamic and efficient firms. Regulations especially hurt firms that are catching up to the technology frontier and that are close to international best practice.	+
Chanda and Dalgaard (2008)	40+ countries, 1985	A development accounting analysis suggests that as much as 85% of the international variation in aggregate TFP can be attributed to variation in relative efficiency across sectors.	+
Haltiwanger, Scarpetta, and Schweiger (2008)	16 industrial and emerging economies, 1990s	Hiring and firing costs tend to curb job flows, particularly in those industries and firm size classes that require more frequent labor adjustment.	+
Lentz and Mortensen (2008)	Denmark, 4900 firms, 1992–97	The estimated model implies that more productive firms in each cohort grow faster and consequently crowd out less productive firms in steady state. This selection effect accounts for 53% of aggregate growth in the estimated version of the model.	+
Alfaro, Kalemli-Ozcan, and Sayek (2009)	60+ countries, 1975–95	Countries with well-developed financial markets gain significantly from FDI via TFP improvements.	+/-
Bridgman, Qi, and Schmitz (2009)	United States, sugar manufacturing firms, 1934–74	Government's enforcement on domestic and import sales quotas significantly distorted sugar production at each factory and the location of the industry.	+
Chang, Kaltani, and Loayza (2009)	82 countries, 1960–2000	The growth effects of openness may be significantly improved if certain complementary reforms are undertaken in the areas of investment in education, financial depth, inflation stabilization, public infrastructure, governance, labor market flexibility, ease of firm entry, and ease of firm exit.	+
Hsieh and Klenow (2009)	China (1998–2005) and India (1987–95) vs. United States (1977–97)	When capital and labor are hypothetically reallocated to equalize marginal products to the extent observed in the United States, manufacturing TFP gains are expected to be substantial in China and India.	+
Petrin and Sivadasan (2011)	Chile, manufacturing firms, 1982–94	Comparing blue- and white-color labor in terms of the marginal product and cost of an input suggests that the increase in severance pay is associated with the decrease in allocative efficiency.	+
Bartelsman, Gautier, and De Wind (2016)	European countries, United States, 1980s–2000s	Countries which have extensive employment protection legislation (EPL) benefit less from the arrival of new risky technology than countries with limited EPL. The model is consistent with the slowdown in productivity in the European Union relative to the United States since the mid-1990s.	+

4. Infrastructure (11 studies)

Authors	Country and year	Results	Relationship
Aschauer (1989)	United States, 1949–85	There is a large return to public investment.	+
Munnell (1992)	Not applicable	On balance, public investment has a positive effect on private investment, output, and employment growth.	+
Hulten (1996)	4 East Asian and 17 African countries, 1970–90	25% of the growth difference between East Asia and Africa is due to inefficient use of infrastructure. This result may partly proxy for TFP differences.	+
Pritchett (1996)	~100 countries, thought experiment	Pritchett presents theory and calculations to show that part of the explanation of slow growth in many poor countries is not that governments did not spend on investments, but that these investments did not create productive capital. A variety of calculations suggest that in a typical developing country, less than 50 cents of capital were created for each public dollar invested.	+/-
Galiani, Gertler, and Schargrodsky (2005)	Argentina, 1990s	Improved water services are associated with significant reductions in deaths from infectious and parasitic diseases.	+
Canning and Pedroni (2008)	>40 countries, 1950–92	While infrastructure does tend to cause long-run economic growth, there is substantial variation across countries.	+
Straub (2008)	140 countries, 1989–2007	Good infrastructure allows firms to have more productive investments in machinery, reduces time wasted commuting, promotes better health and education, and so on. The analysis obtains positive effects of infrastructure on growth when it uses physical indicators of infrastructure. However, the effects are not clear when infrastructure investment flows are used as proxies for infrastructure.	+/-
Calderón and Servén (2010)	>100 countries, 1960–2005	The estimates illustrate the potential contribution of infrastructure development to growth and equity across Africa.	+
Loayza and Odawara (2010)	Egypt, Arab Rep., 1971–2005	An increase in infrastructure expenditures from 5 to 6 percent of gross domestic product would raise the annual per capita growth rate of GDP by about 0.5 percentage points in a decade's time and 1 percentage point by the third decade.	+
Calderón and Servén (2012)	Latin America, 1981–2005	Poor infrastructure is a key obstacle to economic development. The experience of Latin America shows that there is no question that private participation did deliver some efficiency and quality gains. But they were held back by weak regulatory and supervisory frameworks, and poorly designed concession and privatization agreements, which led to ubiquitous renegotiations and ended up costing governments enormous sums.	+
(Calderón and Servén 2014)	Not applicable	Recent theoretical and empirical literature finds positive effects of infrastructure development on income growth and, more tentatively, on distributive equity.	+

5. Institutions (10 studies)

Study	Country and year	Results	Relationship
Barro (1991)	98 countries, 1960–85	Growth is inversely related to the share of government consumption in GDP, but insignificantly related to the share of public investment. Growth rates are positively related to measures of political stability and inversely related to a proxy for market distortions.	+/-
Przeworski and Limongi (1993)	Review of previous studies	Political institutions do matter for growth, but thinking in terms of regimes, democracy, autocracy, or bureaucracy does not seem to capture the relevant differences.	+/-
Sachs (2003)	60+ countries, 1995	The transmission of malaria, which is strongly affected by ecological conditions, directly affects the level of per capita income after controlling for the quality of institutions.	+/-
Hall and Jones (1999)	100+ countries, 1986–95	Output is driven by differences in institutions and government policies, which the authors call "social infrastructure." The authors treat social infrastructure as endogenous, determined historically by location and other factors captured in part by language.	+
Ghali (1999)	10 OECD countries, 1970–94	A big government size causes economic growth with some disparities, through the increase of government spending, investment, or international trade.	+/-
Dar and AmirKhalkhali (2002)	19 OECD, 1971–99	Total factor productivity on average is weaker in countries where government size is larger due to policy-induced distortions such as burdensome taxation, crowding-out effects for new capital that embodies new technology, and the lack of market forces that could foster efficient use of resources.	+/-
Easterly and Levine (2003)	64+ countries, 1995	Tropics, germs, and crops affect development through institutions. No evidence is found that tropics, germs, and crops affect country incomes directly other than through institutions. Macroeconomic policies on development are not significant once the factor of institutional quality is controlled.	+
Acemoglu, Johnson, and Robinson (2004)	Korea, Rep., colonized countries by European powers	Differences in economic institutions, rather than geography or culture, cause differences in per capita incomes. Countries with more secure property rights (that is, with better economic institutions), have higher average incomes.	+
Rodrik, Subramanian, and Trebbi (2004)	79+ countries, 1995	The study estimates the respective contributions of institutions, geography, and trade in determining income levels around the world, using recently developed instrumental variables for institutions and trade. Results indicate that the quality of institutions "trumps" everything else.	+
Chanda and Dalgaard (2008)	40+ countries, 1985	The study compiles a Government Anti-Diversionary Policy index (GADP), an average of five indices capturing the quality of government: rule of law, bureaucratic quality, risk of expropriation, government repudiation of contracts, and corruption. The GADP is strongly related to total factor productivity. Introducing geographical variables reduces the impact of GADP considerably. Geographical explanations seem to be as important as institutional explanations.	+

Appendix B. Countries in the sample

Table B.1 shows countries we use in the analysis with their region and income quintile by group depending on analysis type (descriptive and statistical), data source (PWT, GTAP, and WDI), and some characteristics (oil rent and population). We calculate income quintiles for non-OECD countries using the average GDP per capita over 1985–2014 (World Bank 2017e). The OECD group includes high-income countries that have been members of the OECD for more than 40 years.

Table B.1. Countries with region and income quintile by group

1. Countries from PWT 9.0 for the statistical analysis (98)			
ID	Country	Region	Income quintile*
1	Argentina	Latin America and Caribbean	5
2	Armenia	Europe and Central Asia	3
3	Australia	OECD	Not applicable
4	Austria	OECD	Not applicable
5	Belgium	OECD	Not applicable
6	Benin	Sub-Saharan Africa	2
7	Bolivia	Latin America and Caribbean	3
8	Botswana	Sub-Saharan Africa	4
9	Brazil	Latin America and Caribbean	5
10	Bulgaria	Europe and Central Asia	4
11	Burkina Faso	Sub-Saharan Africa	1
12	Burundi	Sub-Saharan Africa	1
13	Cameroon	Sub-Saharan Africa	2
14	Canada	OECD	Not applicable
15	Central African Republic	Sub-Saharan Africa	1
16	Chile	Latin America and Caribbean	5
17	China	East Asia and Pacific	3
18	Colombia	Latin America and Caribbean	4
19	Costa Rica	Latin America and Caribbean	4
20	Côte d'Ivoire	Sub-Saharan Africa	2
21	Croatia	Europe and Central Asia	5
22	Czech Republic	Europe and Central Asia	5
23	Denmark	OECD	Not applicable
24	Dominican Republic	Latin America and Caribbean	4
25	Ecuador	Latin America and Caribbean	4
26	Egypt, Arab Rep.	Middle East and North Africa	3
27	Finland	OECD	Not applicable
28	France	OECD	Not applicable
29	Germany	OECD	Not applicable
30	Greece	OECD	Not applicable
31	Guatemala	Latin America and Caribbean	3
32	Honduras	Latin America and Caribbean	3
33	Hong Kong SAR, China	East Asia and Pacific	5
34	Hungary	Europe and Central Asia	5
35	India	South Asia	2
36	Indonesia	East Asia and Pacific	3
37	Iran, Islamic Rep.	Middle East and North Africa	4
38	Ireland	OECD	Not applicable
39	Israel	Middle East and North Africa	5
40	Italy	OECD	Not applicable
41	Jamaica	Latin America and Caribbean	4
42	Japan	OECD	Not applicable

1. Countries from PWT 9.0 for the statistical analysis (98)			
43	Jordan	Middle East and North Africa	3
44	Kazakhstan	Europe and Central Asia	4
45	Kenya	Sub-Saharan Africa	2
46	Korea, Rep.	East Asia and Pacific	5
47	Kyrgyz Republic	Europe and Central Asia	2
48	Lao PDR	East Asia and Pacific	2
49	Lesotho	Sub-Saharan Africa	2
50	Lithuania	Europe and Central Asia	5
51	Malaysia	East Asia and Pacific	5
52	Mauritania	Sub-Saharan Africa	2
53	Mexico	Latin America and Caribbean	5
54	Moldova	Europe and Central Asia	3
55	Mongolia	East Asia and Pacific	3
56	Morocco	Middle East and North Africa	3
57	Mozambique	Sub-Saharan Africa	1
58	Namibia	Sub-Saharan Africa	4
59	Netherlands	OECD	Not applicable
60	New Zealand	OECD	Not applicable
61	Nicaragua	Latin America and Caribbean	3
62	Niger	Sub-Saharan Africa	1
63	Nigeria	Sub-Saharan Africa	3
64	Norway	OECD	Not applicable
65	Panama	Latin America and Caribbean	4
66	Paraguay	Latin America and Caribbean	3
67	Peru	Latin America and Caribbean	4
68	Philippines	East Asia and Pacific	3
69	Poland	Europe and Central Asia	5
70	Portugal	OECD	Not applicable
71	Qatar	Middle East and North Africa	5
72	Romania	Europe and Central Asia	4
73	Russian Federation	Europe and Central Asia	5
74	Rwanda	Sub-Saharan Africa	1
75	Senegal	Sub-Saharan Africa	2
76	Serbia	Europe and Central Asia	4
77	Sierra Leone	Sub-Saharan Africa	1
78	Singapore	East Asia and Pacific	5
79	Slovak Republic	Europe and Central Asia	5
80	Slovenia	Europe and Central Asia	5
81	South Africa	Sub-Saharan Africa	4
82	Spain	OECD	Not applicable
83	Sri Lanka	South Asia	3
84	Sudan	Sub-Saharan Africa	2
85	Sweden	OECD	Not applicable
86	Switzerland	OECD	Not applicable
87	Tajikistan	Europe and Central Asia	2
88	Tanzania	Sub-Saharan Africa	1
89	Thailand	East Asia and Pacific	4
90	Togo	Sub-Saharan Africa	1
91	Tunisia	Middle East and North Africa	3
92	Turkey	Europe and Central Asia	5
93	Ukraine	Europe and Central Asia	3
94	United Kingdom	OECD	Not applicable
95	United States	OECD	Not applicable
96	Uruguay	Latin America and Caribbean	5
97	Venezuela, RB	Latin America and Caribbean	5
98	Zimbabwe	Sub-Saharan Africa	2

B. Additional countries using GTAP 9.0 (for labor share) for the descriptive analysis of TFP growth (16)			
ID	Country	Region	Income quintile*
1	Albania	Europe and Central Asia	3
2	Bangladesh	South Asia	1
3	Cambodia	East Asia and Pacific	1
4	Congo, Dem. Rep.	Sub-Saharan Africa	1
5	Ethiopia	Sub-Saharan Africa	1
6	Ghana	Sub-Saharan Africa	2
7	Liberia	Sub-Saharan Africa	1
8	Madagascar	Sub-Saharan Africa	1
9	Malawi	Sub-Saharan Africa	1
10	Mali	Sub-Saharan Africa	2
11	Nepal	South Asia	1
12	Pakistan	South Asia	2
13	Uganda	Sub-Saharan Africa	1
14	Vietnam	East Asia and Pacific	2
15	Yemen, Rep.	Middle East and North Africa	2
16	Zambia	Sub-Saharan Africa	2

C. Additional countries for the descriptive analysis of the determinant indexes (22)			
ID	Country	Region	Income quintile*
1	Afghanistan	South Asia	1
2	Algeria	Middle East and North Africa	4
3	Azerbaijan	Europe and Central Asia	3
4	Belarus	Europe and Central Asia	4
5	Bosnia and Herzegovina	Europe and Central Asia	4
6	Chad	Sub-Saharan Africa	2
7	Cuba	Latin America and Caribbean	4
8	El Salvador	Latin America and Caribbean	3
9	Eritrea	Sub-Saharan Africa	1
10	Gambia, The	Sub-Saharan Africa	1
11	Georgia	Europe and Central Asia	3
12	Guinea	Sub-Saharan Africa	1
13	Haiti	Latin America and Caribbean	2
14	Lebanon	Middle East and North Africa	4
15	Macedonia, FYR	Europe and Central Asia	4
16	Myanmar	East Asia and Pacific	1
17	Papua New Guinea	East Asia and Pacific	2
18	Puerto Rico	Latin America and Caribbean	5
19	Turkmenistan	Europe and Central Asia	4
20	United Arab Emirates	Middle East and North Africa	5
21	Uzbekistan	Europe and Central Asia	2
22	West Bank and Gaza	Middle East and North Africa	3

D. Additional countries to include in the LTGM toolkit: high oil rent (10)			
ID	Country	Region	Income quintile*
1	Angola	Sub-Saharan Africa	3
2	Congo, Rep.	Sub-Saharan Africa	3
3	Equatorial Guinea	Sub-Saharan Africa	5
4	Gabon	Sub-Saharan Africa	5
5	Iraq	Middle East and North Africa	4
6	Kuwait	Middle East and North Africa	5
7	Libya	Middle East and North Africa	5
8	Oman	Middle East and North Africa	5
9	Saudi Arabia	Middle East and North Africa	5
10	South Sudan	Sub-Saharan Africa	2

E. Additional countries to include in the LTGM toolkit: small population (50)			
ID	Country	Region	Income quintile*
1	American Samoa	East Asia and Pacific	5
2	Andorra	Europe and Central Asia	5
3	Antigua and Barbuda	Latin America and Caribbean	5
4	Aruba	Latin America and Caribbean	5
5	Bahamas, The	Latin America and Caribbean	5
6	Bahrain	Middle East and North Africa	5
7	Barbados	Latin America and Caribbean	5
8	Belize	Latin America and Caribbean	4
9	Bhutan	South Asia	2
10	Brunei Darussalam	East Asia and Pacific	5
11	Cabo Verde	Sub-Saharan Africa	3
12	Comoros	Sub-Saharan Africa	2
13	Cyprus	Europe and Central Asia	5
14	Djibouti	Middle East and North Africa	2
15	Dominica	Latin America and Caribbean	4
16	Estonia	Europe and Central Asia	5
17	Fiji	East Asia and Pacific	4
18	Greenland	Europe and Central Asia	5
19	Grenada	Latin America and Caribbean	4
20	Guam	East Asia and Pacific	5
21	Guinea-Bissau	Sub-Saharan Africa	1
22	Guyana	Latin America and Caribbean	3
23	Iceland	Europe and Central Asia	5
24	Kiribati	East Asia and Pacific	3
25	Latvia	Europe and Central Asia	5
26	Liechtenstein	Europe and Central Asia	5
27	Luxembourg	Europe and Central Asia	5
28	Macao SAR, China	East Asia and Pacific	5
29	Malta	Middle East and North Africa	5
30	Marshall Islands	East Asia and Pacific	3
31	Mauritius	Sub-Saharan Africa	4
32	Micronesia, Fed. Sts.	East Asia and Pacific	3
33	Monaco	Europe and Central Asia	5
34	Montenegro	Europe and Central Asia	4
35	Palau	East Asia and Pacific	5
36	Samoa	East Asia and Pacific	3
37	São Tomé and Príncipe	Sub-Saharan Africa	2
38	Seychelles	Sub-Saharan Africa	5
39	Solomon Islands	East Asia and Pacific	2
40	St. Kitts and Nevis	Latin America and Caribbean	5
41	St. Lucia	Latin America and Caribbean	4
42	St. Vincent and the Grenadines	Latin America and Caribbean	4
43	St. Suriname	Latin America and Caribbean	4

E. Additional countries to include in the LTGM toolkit: small population (50)			
44	Eswatini	Sub-Saharan Africa	3
45	Timor-Leste	East Asia and Pacific	2
46	Tonga	East Asia and Pacific	3
47	Trinidad and Tobago	Latin America and Caribbean	5
48	Tuvalu	East Asia and Pacific	3
49	Vanuatu	East Asia and Pacific	3
50	Virgin Islands (U.S.)	Latin America and Caribbean	5

F. Countries for the statistical analysis with WDI dataset in Appendix E (96)			
ID	Country	Region	Income quintile*
1	Albania	Europe and Central Asia	3
2	Argentina	Latin America and Caribbean	5
3	Australia	OECD	Not applicable
4	Austria	OECD	Not applicable
5	Bangladesh	South Asia	1
6	Belgium	OECD	Not applicable
7	Benin	Sub-Saharan Africa	2
8	Bolivia	Latin America and Caribbean	3
9	Botswana	Sub-Saharan Africa	4
10	Brazil	Latin America and Caribbean	5
11	Bulgaria	Europe and Central Asia	4
12	Burkina Faso	Sub-Saharan Africa	1
13	Burundi	Sub-Saharan Africa	1
14	Cambodia	East Asia and Pacific	1
15	Cameroon	Sub-Saharan Africa	2
16	Canada	OECD	Not applicable
17	Central African Republic	Sub-Saharan Africa	1
18	Chile	Latin America and Caribbean	5
19	China	East Asia and Pacific	3
20	Colombia	Latin America and Caribbean	4
21	Congo, Dem. Rep.	Sub-Saharan Africa	1
22	Côte d'Ivoire	Sub-Saharan Africa	2
23	Denmark	OECD	Not applicable
24	Dominican Republic	Latin America and Caribbean	4
25	Ecuador	Latin America and Caribbean	4
26	Egypt, Arab Rep.	Middle East and North Africa	3
27	El Salvador	Latin America and Caribbean	3
28	Finland	OECD	Not applicable
29	France	OECD	Not applicable
30	Germany	OECD	Not applicable
31	Ghana	Sub-Saharan Africa	2
32	Greece	OECD	Not applicable
33	Guatemala	Latin America and Caribbean	3
34	Honduras	Latin America and Caribbean	3
35	Hong Kong SAR, China	East Asia and Pacific	5
36	Hungary	Europe and Central Asia	5
37	India	South Asia	2
38	Indonesia	East Asia and Pacific	3
39	Iran, Islamic Rep.	Middle East and North Africa	4
40	Ireland	OECD	Not applicable
41	Israel	Middle East and North Africa	5
42	Italy	OECD	Not applicable
43	Jamaica	Latin America and Caribbean	4
44	Japan	OECD	Not applicable
45	Jordan	Middle East and North Africa	3
46	Kenya	Sub-Saharan Africa	2
47	Korea, Rep.	East Asia and Pacific	5

F. Countries for the statistical analysis with WDI dataset in Appendix E (96)			
48	Lao PDR	East Asia and Pacific	2
49	Liberia	Sub-Saharan Africa	1
50	Madagascar	Sub-Saharan Africa	1
51	Malawi	Sub-Saharan Africa	1
52	Malaysia	East Asia and Pacific	5
53	Mali	Sub-Saharan Africa	2
54	Mauritania	Sub-Saharan Africa	2
55	Mexico	Latin America and Caribbean	5
56	Mongolia	East Asia and Pacific	3
57	Morocco	Middle East and North Africa	3
58	Mozambique	Sub-Saharan Africa	1
59	Namibia	Sub-Saharan Africa	4
60	Nepal	South Asia	1
61	Netherlands	OECD	Not applicable
62	New Zealand	OECD	Not applicable
63	Nicaragua	Latin America and Caribbean	3
64	Niger	Sub-Saharan Africa	1
65	Nigeria	Sub-Saharan Africa	3
66	Norway	OECD	Not applicable
67	Pakistan	South Asia	2
68	Panama	Latin America and Caribbean	4
69	Paraguay	Latin America and Caribbean	3
70	Peru	Latin America and Caribbean	4
71	Philippines	East Asia and Pacific	3
72	Poland	Europe and Central Asia	5
73	Portugal	OECD	Not applicable
74	Qatar	Middle East and North Africa	5
75	Rwanda	Sub-Saharan Africa	1
76	Senegal	Sub-Saharan Africa	2
77	Sierra Leone	Sub-Saharan Africa	1
78	Singapore	East Asia and Pacific	5
79	South Africa	Sub-Saharan Africa	4
80	Spain	OECD	Not applicable
81	Sri Lanka	South Asia	3
82	Sudan	Sub-Saharan Africa	2
83	Sweden	OECD	Not applicable
84	Switzerland	OECD	Not applicable
85	Tanzania	Sub-Saharan Africa	1
86	Thailand	East Asia and Pacific	4
87	Togo	Sub-Saharan Africa	1
88	Tunisia	Middle East and North Africa	3
89	Turkey	Europe and Central Asia	5
90	Uganda	Sub-Saharan Africa	1
91	United Kingdom	OECD	Not applicable
92	United States	OECD	Not applicable
93	Uruguay	Latin America and Caribbean	5
94	Vietnam	East Asia and Pacific	2
95	Zambia	Sub-Saharan Africa	2
96	Zimbabwe	Sub-Saharan Africa	2
* 1: <$583 (constant 2010 US$), 2: $583-$1,347, 3: $1,347-$3,243, 4: $3,243-$6,837; 5: ≥$6,837			

Appendix C. Average values of the determinant indexes and their indicators over 1985–2014

Table C.1 shows the average values of the rescaled subcomponent and overall determinant indexes from 1 (the worst) to 100 (the best) and their indicators over 1985─2014. The individual indicators are shown without any transformation or standardization. Missing indicators are imputed if eligible as described in the section 3.3.

Table C.1. TFP determinant indexes and their indicators for OECD countries (21) and non-OECD countries (115), average (standard deviation), 1985−2014

	OECD	Non-OECD by region					
		East Asia and Pacific	Europe and Central Asia	Latin America and Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa
Overall determinant index	74.38 (11.66)	35.87 (21.91)	41.13 (11.85)	32.10 (9.00)	35.55 (14.52)	20.76 (6.62)	18.16 (7.79)
I. Innovation index	37.49 (16.06)	11.95 (19.73)	9.45 (7.19)	4.46 (2.80)	12.32 (15.85)	3.59 (2.00)	3.74 (1.62)
Research and development expenditure (% of GDP)	1.85 (0.85)	0.50 (0.76)	0.53 (0.40)	0.26 (0.22)	0.70 (0.88)	0.28 (0.21)	0.29 (0.14)
Number of patents (per 100 people)	0.13 (0.14)	0.08 (0.16)	0.03 (0.02)	0.01 (0.01)	0.05 (0.08)	0.00 (0.00)	0.00 (0.01)
Number of journal articles (per 100 people)	0.09 (0.05)	0.01 (0.04)	0.02 (0.03)	0.00 (0.01)	0.02 (0.03)	0.00 (0.00)	0.00 (0.00)
II. Education index	61.12 (12.88)	33.62 (22.01)	49.87 (12.10)	31.54 (10.69)	33.47 (12.48)	18.88 (8.05)	15.28 (7.82)
Government expenditure on education, total (% of GDP)	5.21 (1.15)	3.11 (1.38)	4.19 (1.24)	3.83 (1.80)	4.83 (1.93)	2.75 (0.81)	4.02 (2.54)
Percentage of population aged 25-64 with completed secondary schooling	30.10 (11.93)	16.96 (12.49)	42.78 (16.05)	16.91 (7.93)	16.61 (8.74)	12.69 (9.97)	7.42 (7.08)
Percentage of population aged 25-64 with completed tertiary schooling	14.06 (6.42)	6.90 (7.65)	10.17 (4.77)	7.10 (4.55)	7.39 (6.01)	4.20 (2.17)	1.17 (0.84)
PISA, average of math, science, and reading	503.47 (21.43)	438.37 (76.21)	427.63 (44.57)	408.83 (25.57)	405.57 (30.81)	370.94 (14.62)	368.65 (2.82)
III. Market efficiency index	82.94 (9.90)	54.04 (19.74)	52.06 (12.42)	47.12 (10.67)	45.67 (14.09)	38.55 (5.92)	34.47 (12.49)
a. World Bank Doing Business scores	72.37 (9.61)	48.02 (19.82)	45.33 (18.13)	44.14 (14.21)	43.33 (15.88)	38.45 (13.60)	31.87 (15.26)
b. IMF Financial Development Index	0.66 (0.16)	0.34 (0.24)	0.20 (0.15)	0.22 (0.11)	0.29 (0.14)	0.22 (0.09)	0.11 (0.08)
c. Labor market index	-0.92 (0.37)	0.01 (0.87)	-0.67 (0.48)	0.13 (0.54)	0.64 (0.83)	0.99 (0.46)	0.58 (1.17)
- Ratio of minimum wage to value added per worker	0.25 (0.14)	0.35 (0.26)	0.29 (0.13)	0.56 (0.39)	0.45 (0.41)	0.38 (0.33)	0.64 (0.56)
- Severance pay for redundancy dismissal (weeks of salary)	4.33 (5.81)	20.26 (15.25)	8.74 (4.59)	17.72 (7.73)	14.12 (9.70)	25.89 (13.58)	14.52 (16.67)
- Share of women in wage employment in the nonagricultural sector (% of total nonagricultural employment)	45.37 (4.39)	39.52 (5.50)	44.23 (8.35)	40.10 (5.47)	20.25 (10.64)	20.47 (7.12)	27.74 (10.74)
IV. Infrastructure index	71.55 (9.53)	33.55 (16.91)	47.64 (10.39)	36.80 (9.50)	42.24 (12.60)	24.04 (8.77)	18.94 (7.37)

	OECD	Non-OECD by region					
		East Asia and Pacific	Europe and Central Asia	Latin America and Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa
Fixed telephone subscriptions (per 100 people)	48.40 (10.77)	13.76 (18.29)	18.81 (10.67)	11.05 (8.13)	14.04 (12.30)	2.04 (3.25)	1.21 (1.99)
Mobile cellular subscriptions (per 100 people)	53.97 (49.71)	33.76 (49.96)	37.77 (49.52)	31.96 (44.52)	34.36 (45.99)	15.78 (26.73)	15.21 (28.23)
Electricity production (kWh per 100 people)	932462.60 (559809.30)	199921.20 (251765.20)	355155.10 (167625.10)	174065.30 (173809.20)	356559.90 (456594.60)	28440.79 (21837.76)	35189.09 (80191.89)
Paved roads (km per 100 people)	1.20 (0.48)	0.07 (0.07)	0.51 (0.37)	0.14 (0.15)	0.17 (0.07)	0.11 (0.13)	0.06 (0.08)
Improved sanitation facilities (% of population with access)	98.48 (2.51)	62.70 (30.08)	88.30 (10.93)	71.56 (19.84)	82.82 (17.96)	38.58 (23.20)	24.55 (15.58)
Improved water source (% of population with access)	99.60 (0.96)	74.15 (22.66)	91.02 (11.69)	85.85 (10.22)	89.76 (12.24)	71.65 (20.94)	59.81 (17.14)
V. Institutions index	89.37 (7.19)	54.84 (17.71)	51.30 (15.58)	54.15 (12.67)	52.73 (12.22)	41.83 (12.48)	43.90 (13.32)
Voice and accountability	1.39 (0.22)	-0.46 (0.85)	-0.23 (0.89)	0.03 (0.67)	-0.64 (0.53)	-0.58 (0.70)	-0.70 (0.71)
Control of corruption	1.76 (0.61)	-0.16 (1.01)	-0.47 (0.66)	-0.27 (0.72)	-0.12 (0.69)	-0.77 (0.55)	-0.59 (0.65)
Government effectiveness	1.69 (0.44)	0.02 (0.94)	-0.35 (0.74)	-0.20 (0.64)	-0.06 (0.70)	-0.67 (0.65)	-0.70 (0.63)
Political stability	1.05 (0.42)	-0.21 (0.92)	-0.25 (0.86)	-0.34 (0.66)	-0.50 (0.95)	-1.45 (0.72)	-0.71 (1.02)
Regulatory quality	1.42 (0.38)	-0.02 (1.06)	-0.22 (0.89)	0.05 (0.73)	-0.21 (0.74)	-0.72 (0.71)	-0.65 (0.66)
Rule of law	1.54 (0.35)	-0.17 (0.87)	-0.46 (0.78)	-0.46 (0.71)	-0.08 (0.67)	-0.59 (0.72)	-0.77 (0.68)

Appendix D. Regression with different time-lags for robustness check

We run regressions with different time lags of 3 and 7 years for a robustness check of the fixed-effect model. Table D.1 shows that the sign and the significance of coefficients under the models using 3- and 7-year lags are consistent with those using 5-year lags.

Table D.1. Regression with different time lags

Dependent variable:	$annualized\ TFP\ growth_{c,(t-\alpha,t)}$		
Number of observations:	869	477	379
Number of groups (countries):	98	98	98
Time lag (α):	3 years	5 years	7 years
Regressors (below):	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
$ln(Index_{c,t-\alpha})$	0.039 (0.0138) ***	0.050 (0.0183) ***	0.025 (0.0074) ***
$ln(TFP\ level)_{c,t-\alpha}$	-0.120 (0.0119) ***	-0.099 (0.0151) ***	-0.102 (0.0100) ***
Constant	-0.143 (0.0470) ***	-0.180 (0.0636) ***	-0.094 (0.0244) ***
R^2:			
Within	0.2729	0.3048	0.4535
Between	0.2669	0.2749	0.6002
Overall	0.1457	0.1586	0.3841
SE = Standard error; *: significant at 10%; **: significant at 5%; ***: significant at 1% level Note. The coefficients of time dummies are not listed.			

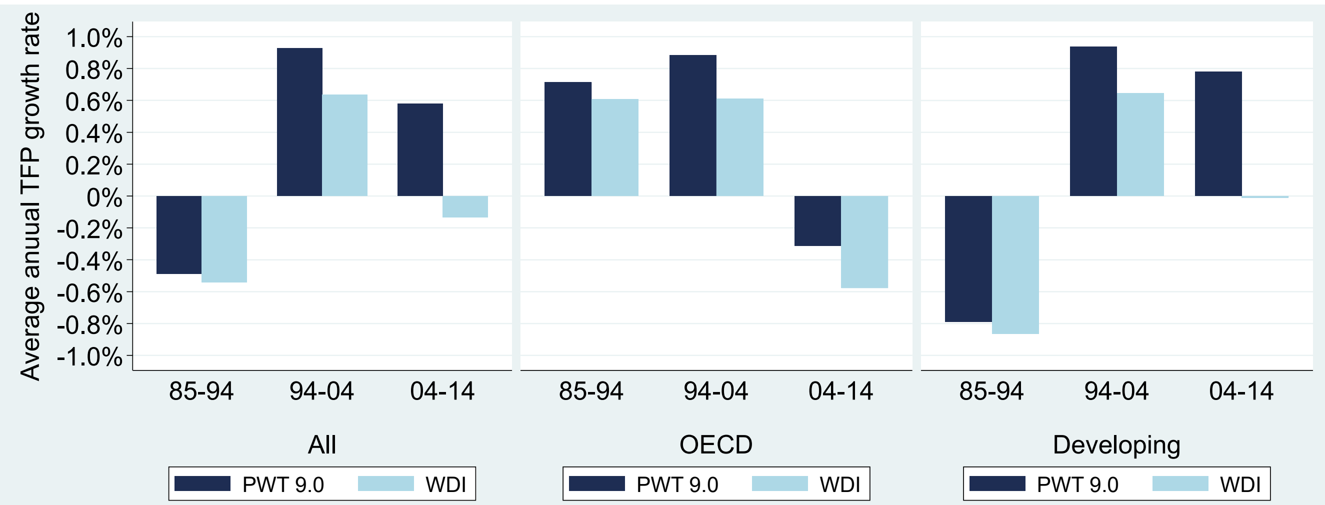
Appendix E. Robustness check using World Development Indicators for TFP calculation

As a robustness check, we obtain results using World Development Indicators (WDI) as a primary source for TFP calculations and compare them with those presented in the main text, which use PWT 9.0 as primary data. Specifically, we use WDI for real GDP, capital formation, population, and employment rate (World Bank 2017d, 2017g, 2017m, 2017n, 2017b) and the PWT 9.0 (Feenstra, Inklaar, and Timmer 2015) and GTAP 9.0 for country- and time-specific labor shares. Because the employment rate in WDI is available from 1991 and onward, we impute missing values for 1985–90 applying the annual change of the employment rate in PWT. To calculate the physical capital stock, we use the perpetual inventory method (Barro and Sala-i-Martin 2004) with a depreciation rate of 4% and an initial year of 1960 or the earliest year with available data. The list of countries included in the analysis using the WDI data set is presented in table B.1.

1) Total factor productivity

Figure E.1 shows the trend of average annual TFP growth rate over decades calculated using PWT 9.0 and WDI as primary sources.

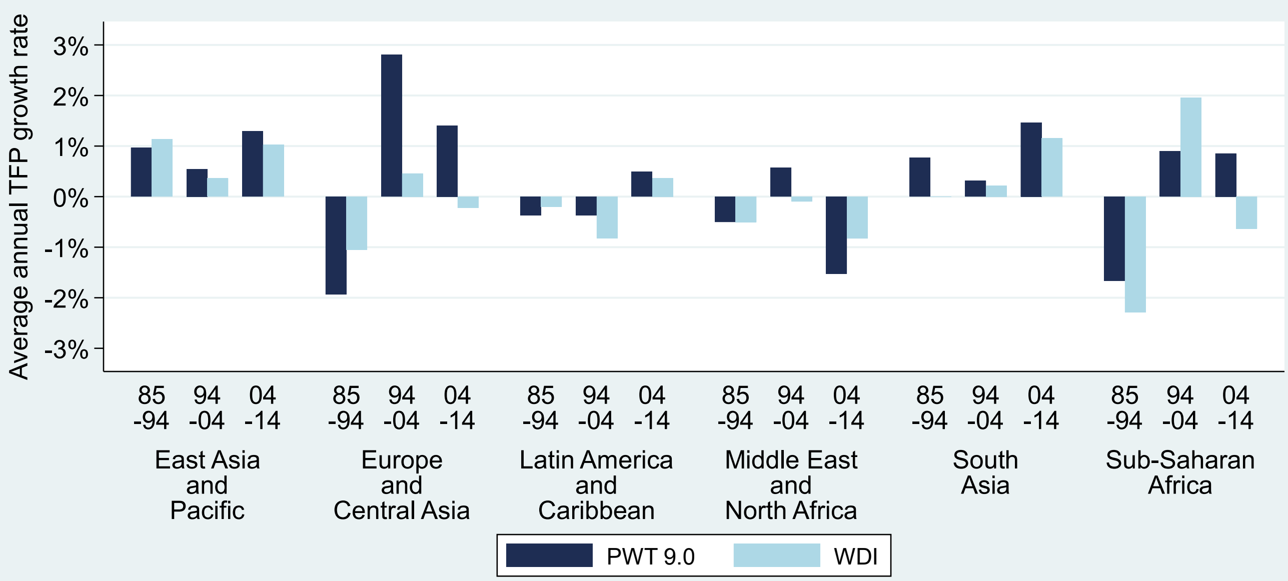
Figure E.1. Comparison of average annual TFP growth rates using PWT 9.0 and WDI for all, OECD, and developing countries



Source: Authors' calculation, using PWT 9.0, GTAP (for a few cases), and WDI data.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years.

The results from the two sources are similar in terms of signs and magnitude for the period 1985—2004 for all, OECD, and developing countries. For the period 2004—14, the average TFP growth rate calculated using WDI is much lower than that using PWT, especially for the developing countries. This is driven by the gap in the average TFP growth rate between the two sources for Europe and Central Asia and Sub-Saharan African for the recent decade as shown in figure E.2. For Europe and Central Asia, WDI has missing values for several countries unlike PWT. For Sub-Saharan Africa, some countries such as Mozambique and Zimbabwe have quite low average TFP growth rates (less than -3 percent).

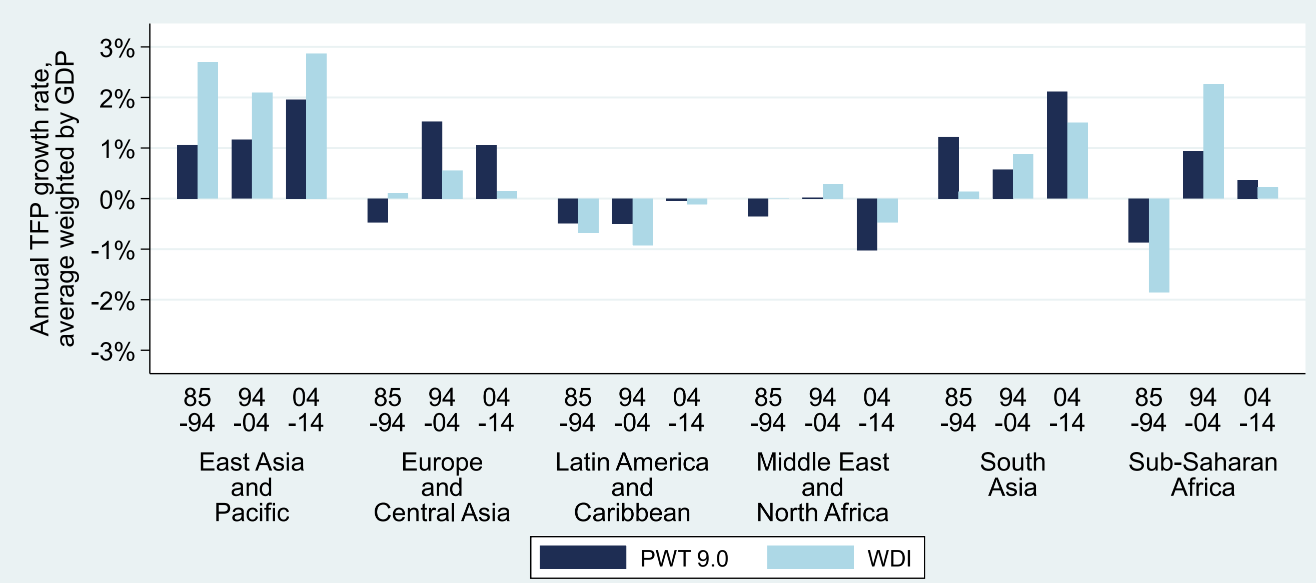
Figure E.2. Comparison of average annual TFP growth rates using PWT 9.0 and WDI for developing countries by region



Source: Authors' calculation, using PWT 9.0, GTAP (for a few cases), and WDI data.

Figure E.3 shows the comparison of average annual TFP growth rates weighted by real GDP using PWT 9.0 and WDI. The results are similar in terms of signs. However, the magnitude tends to be bigger when WDI is used as the primary source for East Asia and Pacific, Latin America and Caribbean, and Sub-Saharan Africa.

Figure E.3. Comparison of average annual TFP growth rate weighted by real GDP using PWT 9.0 and WDI for developing countries by region



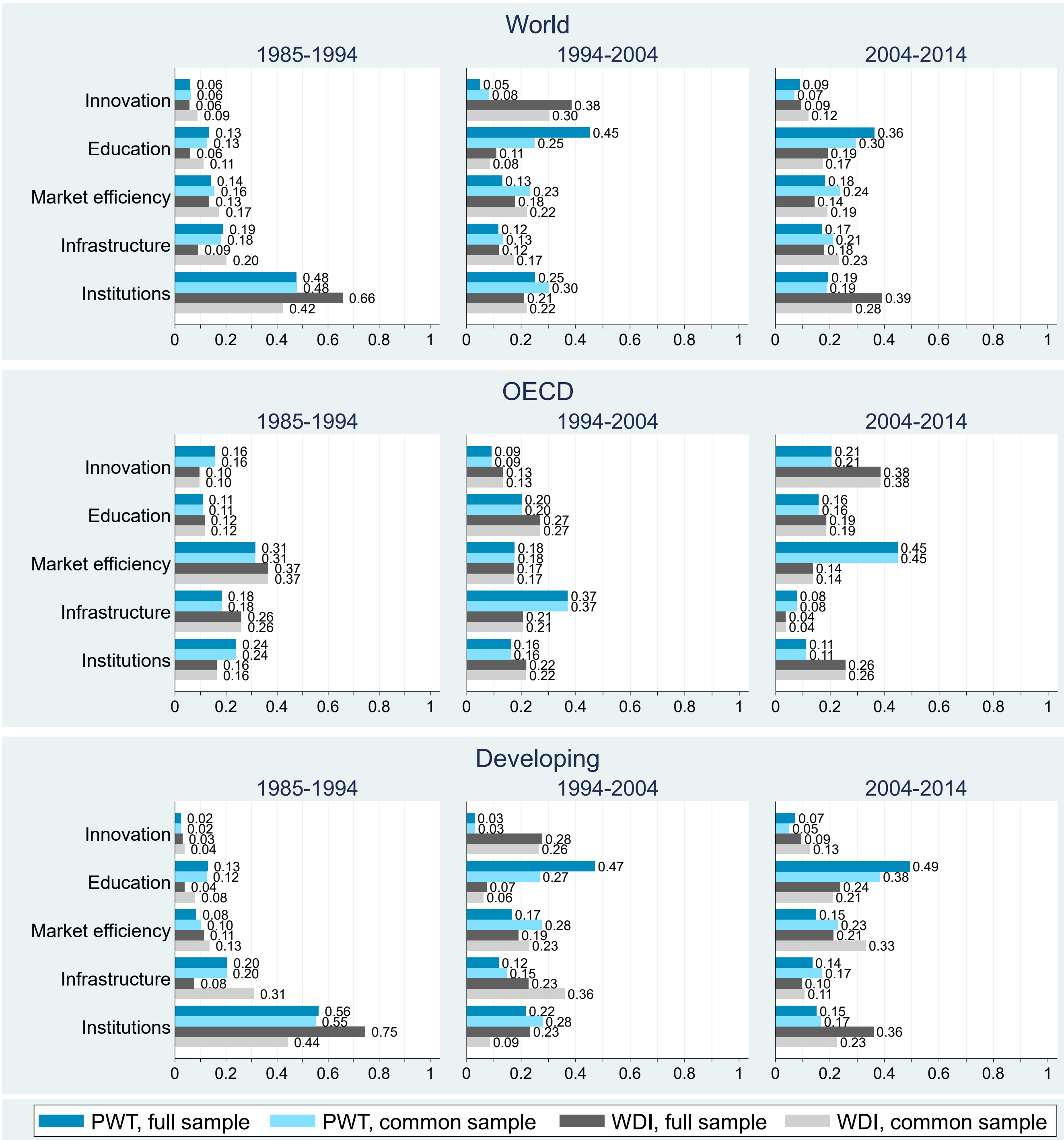
Source: Authors' calculation, using PWT 9.0, GTAP (for a few cases), and WDI data.

2) Statistical analysis

<u>*The relative contribution of the main determinants to total factor productivity*</u>

We conduct the variance decomposition of TFP growth rates using PWT 9.0 and WDI as primary sources and compare the results. The list of developing countries with available TFP growth rates is different between PWT 9.0 and WDI; therefore, we conduct the analysis for the full sample of countries for each source and for the common sample (60 developing and 21 OECD countries). Figure E.4 shows, for the OECD group, the largest contributor is market efficiency using PWT 9.0 and innovation using WDI for the recent decade, and the smallest contributor is infrastructure using the both data sources. For the developing countries, the largest contributor is institutions in the period 1985—94; however, in the period 2004—14, it varies among education, market efficiency, and institutions depending on a set of countries and data sources. The common feature among the four sets of results for the developing countries is that innovation and infrastructure have a lower contribution compared to other determinants in the last decade.

Figure E.4. Comparison of the variance decomposition of TFP growth rates into the determinant indexes using PWT 9.0 and WDI by decade for all, OECD, and developing countries, controlling for the TFP level lagged by five years and time-effects



Source: Authors' calculation.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years.

The relationship between the overall determinant index and total factor productivity

We run regressions for the same model (equation 2) using PWT 9.0 and WDI as primary sources and compare results. The list of countries with available TFP growth rates is different between PWT 9.0 and WDI; therefore, we run regressions for the full sample of countries for each source and the common sample (81 countries).

For the pooled OLS, random-effect, and fixed-effect models, shown in table E.1-E.3 respectively, the results are consistent in terms of sign and significance between PWT 9.0 and WDI for the full and the common sample of countries. These results suggest that the fixed-effect model with the five-year lag fitted to the full sample of PWT 9.0, the model we choose for simulation and the extended LTGM, is robust.

Table E.1. Comparison of the regression results using PWT 9.0 and WDI, pooled OLS

Dependent variable:	$Annualized\ TFP\ growth_{c;\, t-5,t}$			
Country effects:	None (pooled OLS)			
Primary source:	PWT 9.0		WDI	
Number of observations:	477	400	468	394
Number of groups (countries):	98	81	96	81
Country sample:	Full	Common	Full	Common
$ln(Index_{c,t-5})$	0.004 (0.0011) ***	0.004 (0.0012) ***	0.006 (0.0023) **	0.004 (0.0013) ***
$ln(TFP\ level)_{c,t-5}$	-0.082 (0.0052) ***	-0.087 (0.0076) ***	-0.089 (0.0189) ***	-0.070 (0.0063) ***
Constant	-0.021 (0.0055) **	-0.020 (0.0062) ***	-0.030 (0.0113) ***	-0.019 (0.0062) ***
R^2:	0.4022	0.3564	0.4260	0.4073
Results are expressed as coefficient (standard error). *: significant at 10%; **: significant at 5%; ***: significant at 1% level. The coefficients of time dummies are not listed.; We use country-cluster robust variance estimation.				

Table E.2. Comparison of the regression results using PWT 9.0 and WDI, random effect

Dependent variable:	$Annualized\ TFP\ growth_{c;\,t-5,t}$			
Country effects:	Random			
Primary source:	PWT 9.0		WDI	
Number of observations:	477	400	468	394
Number of groups (countries):	98	81	96	81
Country sample:	Full	Common	Full	Common
$ln(Index_{c,t-5})$	0.004 (0.0011) ***	0.004 (0.0012) ***	0.006 (0.0023) ***	0.004 (0.0013) ***
$ln(TFP\ level)_{c,t-5}$	-0.082 (0.0052) ***	-0.087 (0.0076) ***	-0.089 (0.0189) ***	-0.070 (0.0063) ***
Constant	-0.021 (0.0055) ***	-0.020 (0.0062) ***	-0.030 (0.0113) ***	-0.019 (0.0062) ***
R^2:				
Within	0.2784	0.3245	0.4003	0.2158
Between	0.8573	0.7482	0.4639	0.4779
Overall	0.4022	0.3564	0.4260	0.4073
Results are expressed as coefficient (standard error). *: significant at 10%; **: significant at 5%; ***: significant at 1% level. The coefficients of time dummies are not listed.				

Table E.3. Comparison of the regression results using PWT 9.0 and WDI, fixed effect

Dependent variable:	$Annualized\ TFP\ growth_{c;\,t-5,t}$			
Country effects:	Fixed			
Primary source:	PWT 9.0		WDI	
Number of observations:	477	400	468	394
Number of groups (countries):	98	81	96	81
Country sample:	Full	Common	Full	Common
$ln(Index_{c,t-5})$	0.050 (0.0183) ***	0.055 (0.0197) ***	0.098 (0.0268) ***	0.062 (0.0233) ***
$ln(TFP\ level)_{c,t-5}$	-0.099 (0.0151) ***	-0.124 (0.0171) ***	-0.116 (0.0351) ***	-0.071 (0.0143) ***
Constant	-0.180 (0.0636) ***	-0.198 (0.0684) ***	-0.333 (0.0894) ***	-0.219 (0.0803) ***
R^2:				
Within	0.3048	0.3660	0.5050	0.2776
Between	0.2749	0.2193	0.1499	0.1376
Overall	0.1586	0.1238	0.1371	0.1089
Results are expressed as coefficient (standard error). *: significant at 10%; **: significant at 5%; ***: significant at 1% level. The coefficients of time dummies are not listed.				