Productivity and its Determinants: Innovation, Education, Efficiency, Infrastructure, and Institutions

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Abstract

Based on an extensive literature review, we identify the five main determinants of economic productivity as innovation, education, market efficiency, physical infrastructure, and institutional infrastructure (institutions). We construct indexes representing each main determinant as a linear combination of representative indicators, and assess the relative contribution of the indexes to the variation of productivity across 65 countries for the period 1985–2011. We quantify the relationship between the productivity growth and an overall determinant index. The results show that the variation of productivity is the most sensitive to physical infrastructure, followed by education, market efficiency, innovation, and institutional infrastructure. The overall determinant index has a positive relationship with the productivity growth.

Keywords: Productivity, Innovation, Education, Efficiency, Infrastructure, Institutions, Growth

JEL: D24, O33, I25, G14, H54, O43, O47

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1. Introduction

With the same amount of inputs, including physical capital and labor, some countries, sectors, and firms produce more and others less. This difference depends on how efficient they are in allocating and using resources to achieve high output. According to classical economic theory, productivity is defined as the residual of output that is not explained by the direct contribution of input resources. This residual is commonly referred to as total factor productivity (TFP) (Solow 1956).

In the 1950s, Solow and Swan developed a growth model in which changes in physical capital, labor, and TFP determine a growth rate (Solow 1956; Swan 1956). A main drawback of this model is that TFP that determines a long-term growth rate is assumed to be exogenous: that is, given outside the model. In mid-1980s, theoretical economists attempted to resolve the main drawback with this assumption. For example, Romer (1987, 1990) incorporated technological advances through research and development efforts into the growth model as a driver of long-run growth. Lucas (1988) argued in a model that the accumulation of human capital through education is a key factor for long-run growth. Rebelo (1991) included human capital under aggregate capital in a model that suggests that continuous investment in human capital leads to long-term growth. Barro (1990) incorporated tax-financed government goods into a growth model, and suggested that public infrastructure could affect capital accumulation and growth in the long run. In all these cases, the suggested mechanisms to increase productivity are ways of explaining (or endogenizing) economic growth in the long run without resorting to exogenous productivity changes.

As massive micro-level data became available in the 1990s, researchers began conducting empirical studies using data at the industry and firm levels. This trend has confirmed the growth models developed in mid-1980s and onward and has led to new findings that could not be attained using country-level data.
For example, some authors showed that reallocation of inputs into innovating and growing firms explains more than 50 percent of aggregate productivity in developed countries (Jorgenson, Ho, and Stiroh 2005, 2008; Lentz and Mortensen 2008). Bloom, Draca, and Van Reenen (2016) showed that Chinese import competition through a trade agreement increased productivity in European markets, as less productive firms exited the markets and competitive firms innovated. Some studies examine how regulations affect firms’ productivity. Bridgman, Qi, and Schmitz (2009) showed that regulations in the U.S sugar market served as a disincentive to farmers and refiners from making their production more efficient. Petrin and Sivadasan (2011) found that raising firing costs reduced allocative efficiency in markets in Chile and decreased productivity.

Given the numerous studies on growth and productivity published in the past few decades, we want to take stock of its main conceptual conclusions and synthesize its quantitative implications. Based on an extensive literature review, TFP determinants are categorized into five components (Kim, Loayza, and Meza-Cuadra Balcazar 2016):

1. **Innovation**: Creating new technologies leads to the development of high value-added activities and improves the performance of existing economic activities. Historically, a small number of countries have created new technologies, while many other countries have adopted the new technologies through adaptation, trade, and foreign direct investment (Coe, Helpman, and Hoffmaister 1997; de Mello 1999).

2. **Education**: Advancing knowledge and skills, with strong basic foundation and sufficient specialization, is necessary for adopting, attaining, and spreading new and better technologies, production processes, and outputs (Benhabib and Spiegel 1994; Erosa, Koreshkova, and Restuccia 2010).
3. **Market efficiency**: Timely and effective allocation of human and physical capital enhances overall productivity, as inefficient firms exit markets, efficient firms grow, and new firms emerge (Hsieh and Klenow 2009). The nature and quality of regulations are often related to efficiency. Rigid regulations reduce flexibility in resource allocation in markets and decrease productivity (Nicoletti and Scarpetta 2003).

4. **Physical infrastructure**: Transport, paved roads, telecommunication, stable electricity supply, access to improved water and sanitation, and other tangible infrastructure provide timely and cost-effective access to markets, and good physical environments for overall economic activities (Straub 2008; Galiani, Gertler, and Schargrodsky 2005).

5. **Institutional infrastructure**: High-quality institutions provide friendly environments and policies that lead to economic development. Governance and economic institutions are important components of institutions and their quality is generally associated with productivity (Hall and Jones 1999; Easterly and Levine 2003; Acemoglu, Johnson, and Robinson 2004; Rodrik, Subramanian, and Trebbi 2004).

The objectives of the paper are identifying the main determinants of productivity, proposing proxies to measure them, and assessing their relative importance as drivers of TFP growth at the country level. To achieve these objectives, we first conduct an extensive literature review on productivity that focuses not only on concepts and theories but also on empirical studies. Then, we propose and conduct a straightforward way of measuring TFP for each country for the past three decades, from 1985 to 2011. Third, we construct indexes representing the main determinants of TFP by the five categories described above. And, finally, we measure both the relative contribution of each determinant category to the variation of TFP and their overall effect on TFP growth, results of which are also used to build a TFP
module in the extended Long-Term Growth Model software, a growth prediction tool developed by the World Bank (Sinha 2017).

2. Literature review

To identify the main drivers of TFP, we conduct a literature review by focusing on papers published from 1990 to 2015, starting with the reviews conducted by Isaksson (2007) and Syverson (2011). Key search terms are “total factor productivity,” “economic growth,” and “determinants.” We filter papers based on abstracts and main texts by choosing ones that focus on developing as well as developed countries and present a quantitative relationship between productivity and its determinants of interest. We select papers that examine time-variant determinants that a country can improve either through market forces or by public policy decision and implementation (Appendix A for the list of the papers). Based on the literature review, determinants of productivity are categorized into five components: innovation, education, market efficiency, physical infrastructure, and institutional infrastructure.

Innovation

We classify papers on innovation into those related to creation of new technology and to adoption of new technology.

Creation of new technology

A limited number of countries have created new technologies based on sufficient investment in research and development (R&D) from the public and private sectors and an advanced level of human capacity and capital intensity (Furman and Hayes 2004; Griffith, Redding, and Reenen 2004). Many studies show that creating new technologies is positively associated with TFP, using investment in R&D and the number of patents and scientific and technological journal publications as indicators for new technologies (Nadiri 1993; Chen and Dahlman 2004; Guellec and van Pottelsberghe de la Potterie 2004;
Abdih and Joutz 2006). An important role of new technology is well described in studies on information technology (IT) in 1990s. For example, Jorgenson, Ho, and Stiroh (2008) and Oliner, Sichel, and Stiroh (2008) show that IT played a central role in accelerating productivity in the United States (US) from 1995 to 2000 after the lackluster pace of productivity growth in the 1970s and 1980s. The comparison of Europe and the US highlights the critical role of new technologies. Van Ark, O’Mahony, and Timmer (2008) show that the productivity slowdown in Europe during the 1990s and 2000s is attributable to the slower emergence of knowledge economy, the lower contribution of IT to growth, and the smaller share of technology-producing industries as compared to the US.

*Adoption of new technology*

Most countries adopt technologies rather than create new ones. Technological adoption from frontier countries can occur through foreign direct investment (FDI), trade, and knowledge diffusion. Studies show that to enable FDI and trade to contribute to economic growth, host countries need to be prepared with an advanced level of human capacity to learn new technologies, and have well-developed financial markets to benefit from the inflows of foreign capital and increased imports and exports (Borensztein, De Gregorio, and Lee 1998; Alfaro, Kalemli-Ozcan, and Sayek 2009; Chang, Kaltani, and Loayza 2009).

Studies on the relationship between FDI and productivity yield mixed conclusions, possibly because a positive effect depends on having favorable business market conditions. Some studies suggest that FDI is significantly associated with productivity improvement because foreign ownership leads to more productive restructuring in investment outlays and employment, enhances integration into the global economy, and fosters innovation activities (Arnold and Javorcik 2009; Fernandes and Paunov 2012; Newman et al. 2015). However, other studies argue that FDI has negative impacts—such as foreign firms gaining markets and market share and crowding out domestic firms—and thus leads to a decrease
in the productivity of domestic firms (Aitken and Harrison 1999; de Mello 1999; Elu and Price 2010; Xu and Sheng 2012; Girma, Greenaway, and Wakelin 2013).

Many studies show a positive relationship between trade openness and productivity. Various studies show that globalization from the 1960s to 2000s led to faster growth in developing countries through a remarkable increase in trade and a large decline in tariffs (Coe, Helpman, and Hoffmaister 1997; Miller and Upadhyay 2000; Dollar and Kraay 2004; Maiti 2013). Meanwhile, studies for developed countries yield mixed conclusions. For example, Coe and Helpman (1995) suggest that technical spillover through trade is associated with a productivity increase more for countries that are not in the Group of Seven (G7) (wealthy, industrialized) countries than for G7 countries (US, Japan, Germany, France, Italy, United Kingdom, and Canada). Mendi (2007) shows that technology trade has a positive relationship with productivity for member countries of the Organisation of Economic Cooperation and Development (OECD), except for G7 countries.

**Education**

Studies indicate a positive relationship between education and productivity for developing and developed countries. Some studies show that the number of schooling years or the completion rate of secondary and tertiary education is important in explaining the improvement of TFP for many countries (Benhabib and Spiegel 1994; Griffith, Redding, and Reenen 2004; Benhabib and Spiegel 2005; Bronzini and Piselli 2009; Erosa, Koreshkova, and Restuccia 2010). Miller and Upadhyay (2000) show that education attainment has a positive relationship with TFP in general; however, for low-income countries, the effect of education on TFP is negative until trade openness is sufficiently large. This implies that investment in education in low-income countries without market liberalization could lead to underutilization of human capital. Barro (2001) shows in a study of around 100 countries that the quality of education for male students is significantly related to economic growth—but not for female students.
One explanation of this result is that female workers are less incorporated in markets than male workers, implying that many countries could increase productivity if they successfully include female workers in labor markets.

**Market Efficiency**

Various studies indicate that market efficiency is associated with the variation in productivity across countries and firms. Chanda and Dalgaard (2008) show that 85 percent of the variation of TFP among around 40 countries in mid-1980s is explained by the variation in market efficiency. Jerzmanowski (2007) shows that inefficiency in the allocation of human and physical capital is the main explanation for a 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 US, productivity in manufacturing sectors could have been 1.3 times higher for China and 1.6 times higher for India in 2005. Some studies examine a relationship between regulations and productivity. Haltiwanger, Scarpetta, and Schweiger (2008) and Bartelsman, Gautier, and De Wind (2016) show that employment protection regulations preclude efficient labor allocation because they curb job flows or discourage firms from adopting risky but highly productive technologies, and in turn reduce productivity. Some studies for developed countries for the 1980s to 2000s show that strict market regulations, or the lack of reforms for promoting private corporate governance and competition, caused industries that use or produce IT to have meager productivity levels in several European countries, and deterred firms from catching up to the international technology frontier (Nicoletti and Scarpetta 2003; J. Arnold, Nicoletti, and Scarpetta 2008).

**Physical infrastructure**

Physical infrastructure—such as telecommunication, paved roads, electricity supply, and water and sanitation systems—is positively associated with productivity and economic growth. Calderón and
Servén (2010, 2012, 2014) argue in their studies that infrastructure has positive effects on growth and distributive equity; however, weak regulatory frameworks and poorly designed privatization agreements preclude efficiency and quality gains. Canning and Pedroni (2008) show that infrastructure is generally associated with long-run economic growth; however, there is substantial variation across more than 40 countries. 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 US over the 1950s–1980s. Straub (2008) shows in a study for 140 countries over 1989–2007 that 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.

**Institutional infrastructure**

Studies for many countries show that the quality of governance—represented by political stability, the rule of law, bureaucratic quality, the absence of corruption, and the like—is positively related to TFP and economic growth (Barro 1991; Chanda and Dalgaard 2008). Some studies show that good governance works as a channel for geographical endowments, such as temperate locations and good growing environments for grains, to contribute to economic growth (Easterly and Levine 2003; Rodrik, Subramanian, and Trebbi 2004). Ghali (1999) shows that government size can be positively associated with growth via the increase of well-executed government investment. On the contrary, Dar and AmirKhalkhali (2002) show that government size could be negatively associated due to policy-induced distortions such as burdensome taxation, crowding-out effects for new capital, and the lack of market forces to foster the efficient use of resources. Acemoglu, Johnson, and Robinson (2004) show that the quality of economic institutions, more than geography and culture, contributes to growth, with evidence
from the division of Korea into two parts and the colonization of countries by European powers starting in the fifteenth century.

3. Methods

Based on an extensive literature review, we first identify the most relevant and available empirical indicators for each broad category of TFP determinants. Second, we construct a set of indexes grouping together these indicators by category. Third, we estimate TFP and TFP growth rates at the country level. And fourth, we analyze the relationship between the proposed indexes of TFP determinants and the estimated TFP.

Country and time horizon

We conduct the analysis across 65 developing and developed countries for the period 1985–2011 (table B.1 for the country list). We exclude countries which have population lower than 2 million. Also, countries that heavily depend on natural resources for gross domestic product (GDP) are excluded because the contribution of natural resources to output could result in a large overestimation of TFP.¹

Total factor productivity

To calculate TFP for each country, we use a Cobb-Douglas production function, which is often considered to provide a reasonable and tractable description of production at the macroeconomic level. Equation 1 shows that total production \( Y \) is a function of TFP and input resources, including physical capital \( K \) and human capital \( L \). Following Hevia and Loayza (2012), we assume that \( L \) is a function of productivity per worker with \( E_t \) years of schooling \((e^{\theta E_t})\) and the number of workers \( N_t \). A capital

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¹ Heavy dependence is defined as a reliance on natural resources for more than 36 percent of GDP on average over the period 2006—2015, which is 95th – 100th percentile among 207 countries (World Bank 2017n). The identified countries are Libya (56%), Kuwait (52%), Congo, Rep. (47%), Iraq (45%), Saudi Arabia (44%), Liberia (43%), Mauritania (42%), Oman (39%), Angola (39%), and Papua New Guinea (39%).
share ($\alpha$) and a labor share ($1 - \alpha$), which are the proportion of total income paid to rent capital and pay wages, represent the responsiveness of total production to a change of physical and human capital, respectively. For example, if the capital share is 0.3, a 1 percent increase in physical capital stock leads to 0.3 percent increase in total production.

$$Y_{c,t} = TFP_{c,t} K_{c,t}^{1-\alpha_{c,t}} L_{c,t}^{\alpha_{c,t}},$$

where $L_{c,t} = e^{\theta_E} c_{t} N_{c,t}$

$Y$: total GDP (2010 US$)
$TFP$: total factor productivity, $TFP > 0$
$K$: physical capital stock
$L$: human capital stock
$e^{\theta_E}$: productivity per worker with $E$ years of schooling
$N$: number of employed population
$\alpha$: share of total income paid as wages, $0 < \alpha < 1$
$c$: country
$t$: year

We use data from the Penn World Table database for real GDP, physical capital stock, productivity of education per worker, the number of employed population, and capital and labor shares (Feenstra, Inklaar, and Timmer 2015). For missing capital and labor shares, we use data from the Global Trade Analysis Project database (Aguirar, Narayanan, and McDougall 2016).

**Main determinant indexes**

We construct indexes that represent each of the five determinants: innovation, education, market efficiency, physical infrastructure, and institutional infrastructure. First, we select indicators that can represent current situations and environments of each determinant. Second, we impute missing values of the selected indicators. Third, we construct an index as a linear combination of relevant indicators using a factor analysis approach.
Innovation. To construct an index for innovation (Innov), we choose public and private expenditure on research and development (R&D)(% of GDP) as an indicator of environments for creating new technology (World Bank 2017j). As indicators of the outcome of R&D, we choose the number of patent applications by residents and nonresidents and the number of scientific and technological journal articles (World Bank 2017h, 2017i, 2017l).

Education. To construct an index for education (Educ), we choose government expenditure on education (% of GDP) as an indicator of public investment in foundational human capital (World Bank 2017d). We choose the secondary enrollment rate (% of relevant population) as an indicator of the completion of primary education (World Bank 2017k); a standardized international test score (a single average of scores in math, science, and reading on the Programme for International Student Assessment, PISA) as an indicator of secondary education (OECD 2016a, 2016c, 2016b); and the tertiary completion rate (% of population aged 25 and above) as an indicator of tertiary education (Barro and Lee 2017).

Market Efficiency. To construct an index for market efficiency (Effi), we select the World Bank Doing Business scores as indicators of output market efficiency, which measure regulatory environments in terms of ease for firms to run their business, including such measures as the number of procedures and days required to start a business, trade across borders, and get electricity installed in the workplace or obtain credit (World Bank 2017a). As an indicator of financial market efficiency, we select the International Monetary Fund (IMF) Financial Development Index, 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 choose minimum wage (% of value added per worker), severance pay for redundancy dismissal (weeks of salary), and the share of women in wage employment in the nonagricultural sector (World Bank 2017f, 2017m).
Physical infrastructure. For a physical infrastructure index (Infra), we select fixed telephone and mobile subscriptions (per 100 persons) (World Bank 2017b, 2017g); the length of paved roads (km per 100 persons) (International Road Federation 2017b, 2017a); electricity production (kw per 100 persons) (OECD/IEA 2017); and access to an improved water source (% of population) and access to improved sanitation facilities (% of population) (WHO/UNICEF 2017b, 2017a).

Institutional infrastructure. An institutional infrastructure index (Inst) is assumed to consist of two components: governance and macroeconomic environment. To construct a governance index, we select the World Bank Worldwide Governance Indicators, which include voice and accountability (citizens’ participation in selecting their government, freedom of expression, and the like); 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 violence); 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). For the macroeconomic environment, we select three indicators: government budget balance (% of GDP) (IMF 2017a); gross domestic savings (% of GDP) (World Bank 2017e); and the distance of the inflation rate from an assumed stable range of 0.5–2.9 percent (IMF 2017b).

We impute missing values of the selected indicators with different methods depending on the number of available data and the characteristics of indicators. For a country that has data for more than 10 years out of 27 years (1985–2011) 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 by
income group\textsuperscript{2} except for minimum wage, severance pay, and institutional infrastructure. For minimum wage and severance pay, we apply the oldest available data (2014) to the period 1985–2011, because available data (2014–2017) are insufficient to evaluate a time trend and their values are difficult to impute based on the income group. For institutional infrastructure, we do not impute because of the difficulty to impute with the income level. For example, correlations of the income level with the government budget balance and the inflation-distance indicator are lower than 5 percent.

Lastly, we build a determinant index as a linear combination of selected indicators using a factor analysis approach. The factor analysis quantifies common variation in multiple variables as a single index (or a small set of indexes) (Mulaik 2009). For example, to measure innovation which is unobservable, we select R&D expenditure, the number of patent applications, and the number of scientific and technological journal articles, assuming the common features of these indicators explain the level of innovation in a country. The factor analysis enables to quantify common variation in the three indicators as a single index.

\textit{Overall determinant index}

We combine the five determinant indexes into an overall determinant index using a principal component analysis approach. The principal component analysis constructs an index as a linear combination of multiple variables by explaining as much of total variation in the variables as possible (Jolliffe 2002). Unlike the five determinant indexes contain the common features in their indicators as described above, an overall determinant index needs to represent the distinct feature of each determinant index. The

\textsuperscript{2} Classified based on GDP per capita, 2011 (constant 2010 US$) (World Bank 2017c). Low: <$1,000, low-middle: $1,000–$4,000, upper-middle: $4,000–$12,500, high: \( \geq \$12,500 \)
principal component analysis enables to capture as much of the distinct variation of each determinant index as possible in a single index.

The relative contribution of the main determinants to total factor productivity

To measure the relative contribution of the five main determinants to TFP, we decompose the variation of TFP to that explained by each determinant across countries over the period 1985–2011. We apply a dominance analysis approach to a model which has a TFP as an additive function of the five determinant indexes (equation 2). The dominance analysis decomposes the variance of a dependent variable into that explained by each regressor incorporating covariance among regressors. In specific, it conducts the variance decomposition for all possible subset models—from a model with a single determinant index to a model with an interaction term of all five determinant indexes—and calculates the contribution of each determinant index to the variance of TFP across the subset models (Azen and Budescu 2003). We conduct the dominance analysis without and with country or year fixed-effects and compare results.

\[
TFP_{c,t} = \beta_1 \text{Innov}_{c,t} + \beta_2 \text{Educ}_{c,t} + \beta_3 \text{Eff}_{c,t} + \beta_4 \text{Infra}_{c,t} + \beta_5 \text{Inst}_{c,t} + \epsilon_{c,t}. \tag{2}
\]

\(\epsilon_{c,t}: \text{regression residual, assumed to be independently and identically distributed}\)

The relationship between the overall determinant index and total factor productivity

To quantify the relationship between the overall determinant index and TFP, we build a model in which TFP is a function of a lagged TFP and a lagged overall determinant index (equation 3). We use the lagged index to take into account the likely endogeneity referring to Barro (2003) and assume the effect of the index is realized after five years based on the finding by Giavazzi and Tabellini (2005) that reforms affect economic growth after at least four years. The estimated variances are cluster-robust, treating countries as clusters.
\[\ln(TFP_{c,t}) = \beta_0 + \beta_1 \ln(TFP_{c,t-5}) + \beta_2 \text{Index}_{c,t-5} + \delta_t + \epsilon_{c,t}. \] (3)

\[\delta_t: \text{time fixed effect}\]

This model is equivalent to a model in which the annual growth rate of TFP is a function of a lagged TFP and a lagged overall determinant index (equation 4).

\[\frac{\ln(TFP_{c,t}) - \ln(TFP_{c,t-5})}{5} = \frac{\beta_0 + (\beta_1 - 1) \ln(TFP_{c,t-5}) + \beta_2 \text{Index}_{c,t-5} + \beta_3 I(t) + \epsilon_{c,t}}{5}. \] (4)

4. Findings

**Total factor productivity by income group**

As shown in figure 1, the median relative TFP (with US TFP =1) of the high-income group is at least five times higher than the low- and middle-income groups throughout the period 1985–2011. The median TFP of the high-income group decreases during 1985–2001 and increases afterward. The median TFP of the upper-middle income group is at least 1.5 times those of the lower-middle and low-income groups from late 1980s to mid-1990s, and decreases to the median level of the lower-middle income group afterward. The median TFPs of the lower-middle and low-income groups do not change much throughout the entire period.
Figure 1. Relative Total Factor Productivity (US=1) by Income Group, Median, 1985–2011

Main determinant indexes

In the innovation index, the indicators have similar weights (equation 5). The factor analysis shows that a correlation of the innovation index is 0.95 with R&D expenditure (R&D), 0.78 with the number of patents (patent), and 0.89 with the number of journal articles (article) in the sample across countries over the period 1985–2011.

\[
Innov_{c,t} = 0.414 \times z(R&D_{c,t}) + 0.341 \times z(patent_{c,t}) + 0.386 \times z(article_{c,t}),
\]

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

In the education index, the performance-related indicators have similar weights and the education-expenditure indicator has a lower weight (equation 6). The factor analysis indicates that a correlation of
the education index is 0.57 with education expenditure ($eduexp$), 0.87 with secondary enrollment rates ($secondary$), 0.84 with PISA scores ($pisa$), and 0.78 with tertiary completion rates ($tertiary$). This suggests that education expenditure has a low correlation with the three performance indicators.

$$Edu_{c,t} = 0.236 * z(eduexp_{c,t}) + 0.363 * z(secondary_{c,t}) + 0.350 * z(pisa_{c,t}) + 0.324 * z(tertiary_{c,t}).$$

In the market-efficiency index, the indicators are combined with similar weights (equation 7). The factor analysis shows that a correlation of the efficiency index is 0.89 with Doing Business scores ($business$), 0.88 with the IMF Financial Development Index ($financial$), and -0.76 with the labor market index ($labor$) across countries over 1985–2011. The labor market index consists of the indicators with similar weights, and its correlation is 0.76 with minimum wage, 0.86 with severance pay, and -0.65 with the share of women in wage employment.

$$Eff_{i,c,t} = 0.415 * z(business_{c,t}) + 0.408 * z(financial_{c,t}) - 0.355 * z(labor_{c,t}),$$

where $labor_{c,t} = 0.438 * z(minwage_{c,t}) + 0.495 * z(severance_{c,t}) - 0.371 * z(women_{c,t})$

In the infrastructure index, all indicators except the mobile subscription have similar weights (equation 8). The factor analysis shows that the infrastructure index has a correlation of 0.92 with telephone subscription ($tele$), 0.50 with mobile subscription ($mobile$), 0.78 with paved road ($road$), 0.80 with electricity production ($elec$), 0.82 with access to improved water source ($water$), and 0.87 with access to improved sanitation facilities ($sanit$).

$$Infra_{c,t} = 0.243 * z(tele_{c,t}) + 0.133 * z(mobile_{c,t}) + 0.205 * z(road_{c,t}) + 0.211 * z(elec_{c,t}) + 0.218 * z(water_{c,t}) + 0.231 * z(sanit_{c,t}).$$
In the institution index, the sub-indexes of governance \((gov)\) and macroeconomic-environment \((macro)\) are combined with the same weight (equation 9), because the institutional index has a very similar correlation of around 0.79 with the sub-indexes across countries over 1985–2011.

\[
Inst_{c,t} = 0.634 * z(gov_{c,t}) + 0.634 * z(macro_{c,t}).
\] (9)

The governance sub-index consists of the six indicators with similar weights (equation 10). A correlation of the governance index is 0.91 with voice and accountability \((va)\), 0.96 with the control of corruption \((cc)\), 0.97 with government effectiveness \((ge)\), 0.84 with political stability \((ps)\), 0.94 with regulatory quality \((rq)\), and 0.97 with the rule of law \((rl)\).

\[
gov_{c,t} = 0.175 * z(va_{c,t}) + 0.184 * z(cc_{c,t}) + 0.185 * z(ge_{c,t}) + 0.161 * z(ps_{c,t}) + 0.179 * z(rq_{c,t})
+ 0.185 * z(rl_{c,t}).
\] (10)

In the macroeconomic-environment sub-index, government budget balance and gross domestic savings have similar positive weights and the inflation-distance indicator has a negative weight, implying the macroeconomic environment is considered stable when the first two indicators increase and the latter indicator decreases (equation 11). The factor analysis shows that the index has a correlation of 0.83 with government budget balance, 0.84 with gross domestic savings, and -0.14 with the distance of inflation rates from the stable range; and it suggests that an inflation rate has a low correlation with other two indicators.

\[
macro_{c,t} = 0.585 * z(balance_{c,t}) + 0.592 * z(savings_{c,t}) - 0.102 * z(inflation_{c,t}).
\] (11)

**Overall determinant index**

An overall determinant index is constructed as a linear combination of the main determinant indexes with similar weights using principal component analysis (equation 12).
\[
\text{Index}_{c,t} = 0.444 \times z(\text{Innov}_{c,t}) + 0.466 \times z(\text{Edu}_{c,t}) + 0.469 \times z(\text{Effi}_{c,t}) + 0.463 \times z(\text{Infra}_{c,t}) + 0.390 \times z(\text{Inst}_{c,t}).
\]

(12)

The overall determinant index represents the main determinants with a correlation of 0.89 with the innovation index, 0.94 with the education index, 0.94 with the market-efficiency index, 0.93 with the physical infrastructure index, and 0.79 with the institutional infrastructure index.

**Comparison of determinants of total factor productivity by income and regional group**

We categorize high-income countries that have been members of OECD more than 40 years into the OECD group and classify other countries by region. For the average main and overall determinant indexes over 1985–2011, the OECD group has the highest values (figure 2). Among non-OECD countries, the average overall index is the highest for East Asia & Pacific (0.55), followed by Middle East & North Africa (0.37) and Europe & Central Asia (0.21). Specifically, the average innovation and education indexes are the highest for Middle East & North Africa (0.28 and 0.30, respectively), followed by East Asia & Pacific (0.28 and 0.26) and Europe & Central Asia (-0.16 and 0.24); the market-efficiency index is the highest for Europe & Central Asia (0.46), followed by East Asia & Pacific (0.35) and Middle East & North Africa (0.04); the infrastructure index is the highest for Middle East & North Africa (0.57), followed by Europe & Central Asia (0.45) and East Asia & Pacific (0.13); and the institution index is highest for East Asia & Pacific (0.21), followed by Middle East & North Africa (-0.08) and Europe & Central Asia (-0.24). Appendix C shows the average values of all indicators by group.
Figure 2. The Main and Overall Determinant Indexes by Income and Region, Average over 1985-2011

Correlation between total factor productivity and the main and overall determinant indexes

The average relative TFP (US=1) measure over 1985–2011 per country has a moderate correlation with the average determinant indexes (figure 3): 0.59 with the innovation index, 0.64 with the education index, 0.64 with the efficiency index, 0.65 with the physical infrastructure index, 0.44 with the institutional infrastructure index, and 0.65 with the overall determinant index.
The relative contribution of the main determinants to total factor productivity

The dominance analysis shows that the variation of TFP across countries for the last three decades is explained the most by the physical infrastructure index, followed by the education index and the market efficiency index at a similar level, the innovation index, and the institutional infrastructure index. The results are similar with and without country or year fixed-effects (table 1).

Table 1. Relative Contribution of the Main Determinant Indexes to the Variation of Total Factor Productivity Level

<table>
<thead>
<tr>
<th></th>
<th>Variance of TFP level explained by each index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without country/year fixed-effect</td>
</tr>
<tr>
<td>Innovation</td>
<td>16%</td>
</tr>
<tr>
<td>Education</td>
<td>23%</td>
</tr>
<tr>
<td>Market Efficiency</td>
<td>22%</td>
</tr>
<tr>
<td>Physical infrastructure</td>
<td>30%</td>
</tr>
</tbody>
</table>
The relationship between the overall determinant index and total factor productivity

Table 2 shows the result of the linear regression for equation 3 in which TFP is a function of a lagged TFP and a lagged overall determinant index. The coefficient of the lagged overall determinant index ($\text{Index}_{ct-5}$) is significantly positive, indicating that an increase in the overall determinant index is associated with an increase in the growth rate of TFP over the next five years (see equation 4). For example, an increase of $\text{Index}_{ct-5}$ by 1 is associated with an increase of annual TFP growth by 0.4%. The coefficient of a lagged TFP [$\ln(TFP_{ct-5})$] is lower than the unit (< 1), indicating that the growth rate of TFP converges toward a steady-state level after the effect of the overall determinant index reaches a peak during the period of 5–10 years. These results are robust when we use different time lags of 1 year and 3 years.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistics</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.151</td>
<td>0.085</td>
<td>1.78</td>
<td>0.080</td>
</tr>
<tr>
<td>$\ln(TFP_{ct-5})$</td>
<td>0.957</td>
<td>0.015</td>
<td>65.43</td>
<td>0.000</td>
</tr>
<tr>
<td>$\text{Index}_{ct-5}$</td>
<td>0.020</td>
<td>0.009</td>
<td>2.13</td>
<td>0.037</td>
</tr>
<tr>
<td>Year 1996</td>
<td>-0.065</td>
<td>0.059</td>
<td>-1.10</td>
<td>0.276</td>
</tr>
<tr>
<td>Year 2001</td>
<td>-0.009</td>
<td>0.057</td>
<td>-0.15</td>
<td>0.878</td>
</tr>
<tr>
<td>Year 2006</td>
<td>-0.129</td>
<td>0.053</td>
<td>-2.42</td>
<td>0.018</td>
</tr>
<tr>
<td>Year 2011</td>
<td>0.045</td>
<td>0.056</td>
<td>0.79</td>
<td>0.430</td>
</tr>
</tbody>
</table>

Appendix D shows the predicted growth rate of TFP for a scenario in which non-OECD countries increase the overall determinant index to the average level of OECD countries.
5. Conclusion

Based on a literature review, we select innovation, education, market efficiency, physical infrastructure, and institutional infrastructure as the five main categories of determinants of TFP. 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 main determinant indexes into an overall index through a similar procedure. Using dominance analysis for variance decomposition, we find that the variation of TFP during 1985–2011 is most sensitive to the variation in physical infrastructure, followed by education or market efficiency, innovation, and institutional infrastructure. The regression analysis shows that an increase in the overall determinant index is significantly associated with an increase in the growth rate of TFP.

This study has some limitations that need to be considered when interpreting the results. When selecting the main determinants of TFP, we exclude geographical conditions because they are impossible or very difficult to change through policy. Some authors argue that the impact of geographical conditions on growth is offset by that of institutional infrastructure. Others argue that geographical conditions still matter for growth: for instance, by affecting health (through the spread of infectious diseases) and by facilitating trade through proximity to core economies (after controlling for institutions) (Easterly and Levine 2003; Gallup, Sachs, and Mellinger 1999; Sachs 2003).

The study’s focus on global patterns may pose another limitation. The relative contribution of the determinant indexes to the variation of TFP 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.
There is a limitation to consider when the regression model is used to predict a TFP growth rate depending on the change of determinant indicators. The overall determinant index is a linear combination of the main determinant indexes, in turn that of the indicators, without interaction terms among them. This means that the potential spillover effect of a change in an indicator is not incorporated. For example, the improvement in governance potentially leads to the enhancement in market efficiency through effective market regulations. In the model, however, such an external effect is not incorporated.

Taking the results at face value, however, this study renders several policy implications. For the indicators of physical infrastructure, the most strongly associated determinant with the variation of TFP, a large gap exists among income and regional groups. For example, the average electricity supply per capita over 1985–2011 for developing countries in East Asia & Pacific and Latin America & Caribbean is 34 and 25 percent, respectively, of that for OECD countries (Appendix C). The average access to improved sanitation (% of population) for South Asia and Sub-Saharan Africa is 63 and 40 percent of that for OECD countries. These gaps imply that, for developing countries, enhancing physical infrastructure has a potential to increase productivity, considering that good-quality physical infrastructure is a foundation for most if not all economic activities.

Education is the second (or third) most strongly associated determinant with the variation of TFP. The gap between the OECD and non-OECD countries in terms of the indicators (Appendix C) suggests there is a possibility to increase productivity through the improvement in education systems. Government expenditure on education is not necessarily correlated with school enrollment rates, completion rates, and test scores as shown by the results. These findings imply that developing countries have an opportunity to increase productivity through efficient budget spending and effective policy implementation with complementary efforts from schools, societies, and governments in the long term.
Market efficiency is the third (or second) most strongly associated determinant with the variation of TFP. The gap of the index in comparison to the OECD group is the biggest for South Asia, followed by Sub-Saharan Africa and Latin America & Caribbean (Appendix C). Improving market efficiency in practice would require streamlining and modernizing the regulatory environment. The difficulties of reform implementation, nevertheless, remain a challenge if interest groups (in the bureaucracy and the private sector) can mobilize resources and even popular protests to oppose the reforms.

Innovation is the fourth strongly associated with the variation of TFP. The average R&D expenditure in developing countries over the last three decades is below 60 percent of that of the OECD group, the average number of patents is below 20 percent of that of the OECD group except East Asia & Pacific and Middle East & North Africa, and the average number of scientific and technological articles for all developing countries is below 40 percent of that of the OECD group (Appendix C). Creating new technology requires intensive investment and an advanced level of human capital; however, a return on investment could be significant as shown by high-income countries in technology frontier (Oliner, Sichel, and Stiroh 2008). For countries that may appear to be caught in a middle-income trap (Larson, Loayza, and Woolcock 2016), to invest in R&D and enact and implement policies to improve the environments for creating and adopting new technologies has a potential to increase productivity and lead to economic growth.

Institutional infrastructure is the least associated with the variation of TFP. This implies that especially changing the quality of governance might require the most time among the main determinants. In practice, enhancing the institutional infrastructure requires political, societal, and economic efforts over the long term. Although it may take a long time, good institutional infrastructure would ultimately provide a stable and friendly environment that leads to economic prosperity (North 1990).
Appendix A. Literature review

1. Innovation

Technology creation (13 studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Country/countries and years</th>
<th>Results</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nadiri (1993)</td>
<td>4 industrial countries, 1970–90</td>
<td>The results suggest a positive and strong relationship between research and development (R&amp;D) expenditures and growth of output or total factor productivity (TFP).</td>
<td>+</td>
</tr>
<tr>
<td>Coe and Helpman (1995)</td>
<td>22 industrial countries, 1971–90</td>
<td>International R&amp;D spillovers have beneficial effects on domestic productivity. The elasticity of TFP with respect to foreign R&amp;D expenditure is 0.02–0.08 for G7 countries and 0.04–0.26 for other small OECD countries.</td>
<td>+</td>
</tr>
<tr>
<td>Chen and Dahlman (2004)</td>
<td>92 countries, 1960–2000</td>
<td>The number of patents and journal publications is statistically significant in terms of real GDP growth via their effects on the TFP growth rate.</td>
<td>+</td>
</tr>
<tr>
<td>Furman and Hayes (2004)</td>
<td>29 countries, 1978–99</td>
<td>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.</td>
<td>+/-</td>
</tr>
<tr>
<td>Griffith, Redding, and Reenen (2004)</td>
<td>12 OECD countries, 1974–90</td>
<td>R&amp;D is statistically and economically important in both technological catch up and innovation. Human capital also plays a major role in productivity growth.</td>
<td>+</td>
</tr>
<tr>
<td>Guellec and van Pottelsberghe de la Potterie (2004)</td>
<td>16 OECD countries, 1980–98</td>
<td>R&amp;D performed by the business sector, the public sector, and foreign firms is a significant determinant of long-term productivity growth.</td>
<td>+</td>
</tr>
<tr>
<td>Ulku and Subramanian (2004)</td>
<td>30 OECD countries, 1981–97</td>
<td>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&amp;D stock on innovation is significant only in the OECD countries with large markets.</td>
<td>+/-</td>
</tr>
<tr>
<td>Jorgenson, Ho, and Stiroh (2005)</td>
<td>US, 1990s and 2000s</td>
<td>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.</td>
<td>+</td>
</tr>
<tr>
<td>Abdih and Joutz (2006)</td>
<td>US, 1948–97</td>
<td>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.</td>
<td>+</td>
</tr>
</tbody>
</table>
van Ark, O’Mahony, and Timmer (2008) | US, 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 US. 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). +

Technology transfer

a. Channel: Foreign direct investment (FDI) (10 studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Country/countries and years</th>
<th>Results</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borensztein, De Gregorio, and Lee (1998)</td>
<td>70+ countries, 1970–89</td>
<td>FDI contributes to economic growth only when a host economy has sufficient capability to absorb advanced technologies.</td>
<td>+/-</td>
</tr>
<tr>
<td>Aitken and Harrison (1999)</td>
<td>Venezuela, 4,000+ firms, 1976–89</td>
<td>The increase in foreign equity participation is correlated with productivity increases in small plants. The increase in foreign ownership negatively affects the productivity of domestically owned firms in the same industry. No evidence is found to support technology spillovers from foreign firms to domestically owned firms.</td>
<td>+/-</td>
</tr>
<tr>
<td>de Mello (1999)</td>
<td>16 OECD and 17 non-OECD, 1970–90</td>
<td>FDI has a positive relationship with TFP growth in OECD countries, but a negative relationship in non-OECD countries.</td>
<td>+/-</td>
</tr>
<tr>
<td>Alfaro, Kaleml-Ozcan, and Sayek (2009)</td>
<td>60+ countries, 1975–95</td>
<td>Countries with well-developed financial markets gain significantly from FDI via TFP improvements.</td>
<td>+/-</td>
</tr>
<tr>
<td>Arnold and Javorcik (2009)</td>
<td>Indonesia, firms from national census of manufacturing, 1983–99</td>
<td>Foreign ownership leads to significant productivity improvements in the acquired plants. The rise in productivity is a result of restructuring, as acquired plants increase investment outlays, employment, and wages. Foreign ownership also appears to enhance the integration of plants into the global economy through increased exports and imports. Productivity improvements and evidence of restructuring are also found in the context of foreign privatizations.</td>
<td>+</td>
</tr>
<tr>
<td>Elu and Price (2010)</td>
<td>Ghana, Kenya, Nigeria, South Africa, and Tanzania, 1991–2004</td>
<td>Across firms and countries, there is no relationship between productivity-enhancing foreign direct investment and trade with China. Increasing trade openness with China has no effect on the growth rate of TFP.</td>
<td>-</td>
</tr>
<tr>
<td>Fernandes and Paunov (2012)</td>
<td>Chile, 4,913 manufacturing firms, 1992–2004</td>
<td>FDI inflows in producer service sectors has positive on and explains 7% of the observed increase in TFP among manufacturing firms in Chile. This suggests that service FDI fosters innovation activities in manufacturing firms and offers opportunities for laggard firms to catch up with industry leaders.</td>
<td>+</td>
</tr>
</tbody>
</table>
FDI has a significant positive impact on productivity of domestic firms that purchase high-quality intermediate goods with lower input prices, or equipment from firms receiving FDI in the upstream industry. Negative horizontal effects are found after controlling for firm-level market share. The expected positive knowledge spillovers of FDI firms in the same industry to domestic firms are counterbalanced by competition effects from FDI firms. Firms do not benefit uniformly from FDI.

Foreign FDI does not have any wage or productivity spillovers to domestic firms, whether in levels or growth, on average.

Commonly used measures of spillovers do not capture all the productivity gains associated with direct linkages between foreign-owned and domestic firms along the supply chain. This includes productivity gains through forward linkages for domestic firms that receive inputs from foreign-owned firms.

**b. Channel: Trade (11 studies)**

<table>
<thead>
<tr>
<th>Study</th>
<th>Country/countries and years</th>
<th>Results</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coe, Helpman, and Hoffmaister (1997)</td>
<td>77 developing countries, 1971–90</td>
<td>Based on data for 77 developing countries, R&amp;D spillovers via trade with 22 industrial countries are substantial.</td>
<td>+</td>
</tr>
<tr>
<td>Miller and Upadhyay (2000)</td>
<td>83 countries, 1960–89</td>
<td>Higher openness benefits TFP. Outward-oriented countries experience higher TFP, over and above the positive effect of openness.</td>
<td>+</td>
</tr>
<tr>
<td>Alcalá and Ciccone (2004)</td>
<td>138 countries, 1985</td>
<td>Trade has a positive relationship with total factor productivity.</td>
<td>+</td>
</tr>
<tr>
<td>Dollar and Kraay (2004)</td>
<td>~100 developing and developed countries, 1960s–90s</td>
<td>Large increases in trade and significant declines in tariffs lead to faster growth and poverty reduction in poor countries.</td>
<td>+</td>
</tr>
<tr>
<td>Chang, Kaltani, and Loayza (2009)</td>
<td>82 countries, 1960–2000</td>
<td>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.</td>
<td>+</td>
</tr>
<tr>
<td>Mendi (2007)</td>
<td>16 OECD countries, 1971–95</td>
<td>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.</td>
<td>+/-</td>
</tr>
<tr>
<td>Kim, Lim, and Park (2009)</td>
<td>Korea, 1980–2003</td>
<td>Imports have a significant positive effect on TFP growth, but exports do not. The positive impact of imports stems not only</td>
<td>+/-</td>
</tr>
</tbody>
</table>
from competitive pressures arising from the imports of consumer goods but also from technological transfers embodied in imports of capital goods and from developed countries.

Ferreira and Trejos (2011) | 12 developing countries, 1985 | Changes in the terms of trade cause a change of productivity. That effect has an average elasticity of 0.73. | +

Maiti (2013) | India, 1998–2005 | Trade reform significantly raises mark-up and wage rent in the sector competing with exports and reduces wage rent in the sector that competes with imports. Trade openness has a significant effect on productivity growth when the market imperfections due to the trade reform are controlled. | +

Bloom, Draca, and Van Reenen (2016) | 12 European countries, 1996–2007 | Competition with Chinese imports led to increased technical change within firms and reallocated employment between firms toward more technologically advanced firms. These within and between effects were about equal in magnitude, and appear to account for 15% of European technology upgrading over 2000–07. | +

2. Education (9 studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Country/countries and years</th>
<th>Results</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benhabib and Spiegel (1994)</td>
<td>78 countries, 1965–85</td>
<td>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.</td>
<td>+</td>
</tr>
<tr>
<td>Miller and Upadhyay (2000)</td>
<td>83 countries, 1960–89</td>
<td>Human capital generally contributes positively to TFP. In poor countries, human capital interacts with openness to achieve a positive effect, on balance.</td>
<td>+/-</td>
</tr>
<tr>
<td>Barro (2001)</td>
<td>100 countries, 1965–95</td>
<td>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.</td>
<td>+/-</td>
</tr>
<tr>
<td>Benhabib and Spiegel (2005)</td>
<td>27 countries, 1960–95</td>
<td>Elasticity of TFP with respect to years of schooling is positive and statistically significant (0.008–0.018).</td>
<td>+</td>
</tr>
<tr>
<td>Bronzini and Piselli (2009)</td>
<td>Italy, 1985–2001</td>
<td>Elasticity of TFP with respect to years of schooling is positive and statistically significant (0.379).</td>
<td>+</td>
</tr>
<tr>
<td>Coe, Helpman, and Hoffmaister (2009)</td>
<td>24 countries, 1971–2004</td>
<td>Elasticity of TFP with respect to years of schooling is positive and statistically significant (0.513 – 0.756).</td>
<td>+</td>
</tr>
<tr>
<td>Wei and Hao (2011)</td>
<td>China, 1985–2004</td>
<td>School enrollment has significant and positive effects on the TFP growth of Chinese provinces. When education quality (as...</td>
<td>+</td>
</tr>
</tbody>
</table>
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. Efficiency (13 studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Country/countries and years</th>
<th>Results</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fagerberg (2000)</td>
<td>39 countries, 1973–90</td>
<td>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.</td>
<td>+/-</td>
</tr>
<tr>
<td>Foster, Haltiwanger, and Krizan (2001)</td>
<td>US, 1977–87</td>
<td>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. For the selected service industries considered, the contribution of net entry (more-productive entering establishments displacing less-productive exiting establishments) is dominant. The contribution of net entry to aggregate productivity growth is disproportionate. It increases in the horizon over which the changes are measured because longer horizon yields greater differentials from selection and learning effects. The contribution of reallocation to aggregate productivity growth varies over time (e.g. is cyclically sensitive) and across industries. It is somewhat sensitive to subtle differences in measurement and decomposition methodologies.</td>
<td>+</td>
</tr>
<tr>
<td>Nicoletti and Scarpetta (2003)</td>
<td>18 OECD countries, 1984–98</td>
<td>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.</td>
<td>+</td>
</tr>
<tr>
<td>Peneder (2003)</td>
<td>28 OECD countries, 1990–98</td>
<td>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.</td>
<td>+/-</td>
</tr>
</tbody>
</table>
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 technologies. The world technology frontier appears to be shifting out faster at input combinations close to that of the R&D leader.

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.

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.

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.

Government’s enforcement on domestic and import sales quotas significantly distorted sugar production at each factory and the location of the industry.

When capital and labor are hypothetically reallocated to equalize marginal products to the extent observed in the US, manufacturing TFP gains are estimated at 30%–50% in China and 40%–60% in India.

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.

Countries which have extensive employment protection legislation (EPL) benefit less from the arrival of new risky technologies than countries with limited EPL. The model is consistent with the slowdown in productivity in the European Union relative to the US since the mid-1990s.

4. Physical infrastructure (11 studies)

<table>
<thead>
<tr>
<th>Authors</th>
<th>Country/countries and years</th>
<th>Results</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aschauer (1989)</td>
<td>US, 1949–85</td>
<td>There is a large return to public investment.</td>
<td>+</td>
</tr>
<tr>
<td>Munnell (1992)</td>
<td>Not applicable</td>
<td>On balance, public investment has a positive effect on private investment, output, and employment growth.</td>
<td>+</td>
</tr>
</tbody>
</table>
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 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.

Improved water services are associated with significant reductions in deaths from infectious and parasitic diseases.

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.

The estimates illustrate the potential contribution of infrastructure development to growth and equity across Africa.

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.

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.

Recent theoretical and empirical literature finds positive effects of infrastructure development on income growth and, more tentatively, on distributive equity.

<table>
<thead>
<tr>
<th>Study</th>
<th>Country/countries and years</th>
<th>Results</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hulten (1996)</td>
<td>4 East Asian and 17 African countries, 1970–90</td>
<td>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.</td>
<td>+</td>
</tr>
<tr>
<td>Pritchett (1996)</td>
<td>~100 countries, thought experiment</td>
<td>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.</td>
<td>+/-</td>
</tr>
<tr>
<td>Galiani, Gertler, and Schargrodsky (2005)</td>
<td>Argentina, 1990s</td>
<td>Improved water services are associated with significant reductions in deaths from infectious and parasitic diseases.</td>
<td>+</td>
</tr>
<tr>
<td>Canning and Pedroni (2008)</td>
<td>&gt;40 countries, 1950–92</td>
<td>While infrastructure does tend to cause long-run economic growth, there is substantial variation across countries.</td>
<td>+</td>
</tr>
<tr>
<td>Straub (2008)</td>
<td>140 countries, 1989–2007</td>
<td>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.</td>
<td>+/-</td>
</tr>
<tr>
<td>Loayza and Odawara (2010)</td>
<td>Egypt, Arab Rep., 1971–2005</td>
<td>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.</td>
<td>+</td>
</tr>
<tr>
<td>Calderón and Servén (2012)</td>
<td>Latin America, 1981–2005</td>
<td>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.</td>
<td>+</td>
</tr>
<tr>
<td>(Calderón and Servén 2014)</td>
<td>Not applicable</td>
<td>Recent theoretical and empirical literature finds positive effects of infrastructure development on income growth and, more tentatively, on distributive equity.</td>
<td>+</td>
</tr>
</tbody>
</table>

5. Institutional infrastructure (10 studies)
<table>
<thead>
<tr>
<th>Author(s) and Year</th>
<th>Methodology/Study Description</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Przeworski and Limongi (1993)</td>
<td>Review of previous studies</td>
<td>Political institutions do matter for growth, but thinking in terms of regimes, democracy, autocracy, or bureaucracy does not seem to capture the relevant differences.</td>
</tr>
<tr>
<td>Sachs (2003)</td>
<td>60+ countries, 1995</td>
<td>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.</td>
</tr>
<tr>
<td>Hall and Jones (1999)</td>
<td>100+ countries, 1986–95</td>
<td>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.</td>
</tr>
<tr>
<td>Ghali (1999)</td>
<td>10 OECD countries, 1970–94</td>
<td>A big government size causes economic growth with some disparities, through the increase of government spending, investment, or international trade.</td>
</tr>
<tr>
<td>Dar and AmirKhalkhali (2002)</td>
<td>19 OECD, 1971–99</td>
<td>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 technologies, and the lack of market forces that could foster efficient use of resources.</td>
</tr>
<tr>
<td>Easterly and Levine (2003)</td>
<td>64+ countries, 1995</td>
<td>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.</td>
</tr>
<tr>
<td>Acemoglu, Johnson, and Robinson (2004)</td>
<td>Korea, colonized countries by European powers</td>
<td>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.</td>
</tr>
<tr>
<td>Rodrik, Subramanian, and Trebbi (2004)</td>
<td>79+ countries, 1995</td>
<td>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.</td>
</tr>
<tr>
<td>Chanda and Dalgaard (2008)</td>
<td>40+ countries, 1985</td>
<td>The study compiles a Government Anti-Diversionary Policy index (GADP), an average of five indexes capturing the quality of government: rule of law, bureaucratic quality, risk of expropriation by the government, government repudiation of contracts, and corruption. The GADP is strongly related to total factor productivity. Introducing geographical variables reduces the impact of GADP considerably. The coefficient of GADP falls in value by approximately half. Geographical explanations seem to be at least as important as institutional explanations.</td>
</tr>
</tbody>
</table>
Appendix B. Countries in the Sample

The sample covers 65 countries. We classify high-income countries that have been members of OECD for more than 40 years as the OECD group and others by region. The country list is as follows.

**OECD (20):** Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom, United States

**East Asia & Pacific (10):** Cambodia, China, Indonesia, Korea, Rep., Malaysia, Mongolia, Philippines, Singapore, Thailand, Vietnam

**Europe & Central Asia (6):** Albania, Bulgaria, Hungary, Poland, Romania, Turkey

**Latin America & Caribbean (14):** Argentina, Brazil, Chile, Colombia, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Panama, Paraguay, Peru, Uruguay

**Middle East & North Africa (5):** Egypt, Arab Rep., Iran, Islamic Rep., Israel, Jordan, Qatar

**South Asia (3):** India, Pakistan, Sri Lanka

**Sub-Saharan Africa (7):** Botswana, Cameroon, Namibia, South Africa, Sudan, Tanzania, Zimbabwe
### Appendix C. Comparison of average determinant indexes and indicators over 1985–2011

Table C.1. The Main and Overall Determinant Indexes and Indicators by Income and Regional Group, Average over 1985–2011

<table>
<thead>
<tr>
<th>A. Overall determinant index</th>
<th>OECD</th>
<th>East Asia &amp; Pacific</th>
<th>Europe &amp; Central Asia</th>
<th>Latin America &amp; Caribbean</th>
<th>Middle East &amp; North Africa</th>
<th>South Asia</th>
<th>Sub-Saharan Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.78</td>
<td>0.55</td>
<td>0.21</td>
<td>-0.72</td>
<td>0.36</td>
<td>-1.81</td>
<td>-1.31</td>
<td></td>
</tr>
</tbody>
</table>

**B. Main determinant index and its indicators**

#### 1. Innovation index
- Research and development expenditure (% of GDP): 2.13
- Patents per 100 people: 0.11
- Journal articles per 100 people: 0.15

#### 2. Education index
- Government expenditure on education, total (% of GDP): 5.59
- Gross enrolment ratio, secondary, both sexes (%): 109.91
- PISA, average of math, science, and reading: 503.97
- Percentage of population age 25+ with tertiary schooling: 18.98

#### 3. Market efficiency index
- Doing business scores: 77.33
- Financial development index: 0.76
- Labor market index: -0.86
- Ratio of minimum wage to value added per worker: 0.27
- Severance pay for redundancy dismissal (weeks of salary): 4.54
- Share of women in wage employment in the nonagricultural sector: 47.92

#### 4. Infrastructure index
- Fixed telephone subscriptions (per 100 people): 45.20
- Mobile cellular subscriptions (per 100 people): 117.07
- Electricity production (kWh per 100 people): 974858.80
- Paved roads (km per 100 people): 1.15
- Improved sanitation facilities (% of population with access): 98.78
- Improved water source (% of population with access): 99.81

#### 5. Institution index
- Governance index: 1.10
<table>
<thead>
<tr>
<th></th>
<th>OECD</th>
<th>East Asia &amp; Pacific</th>
<th>Europe &amp; Central Asia</th>
<th>Latin America &amp; Caribbean</th>
<th>Middle East &amp; North Africa</th>
<th>South Asia</th>
<th>Sub-Saharan Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice and Accountability</td>
<td>1.33</td>
<td>-0.42</td>
<td>0.43</td>
<td>0.17</td>
<td>-0.76</td>
<td>-0.34</td>
<td>-0.45</td>
</tr>
<tr>
<td>Control of corruption</td>
<td>1.59</td>
<td>-0.21</td>
<td>-0.03</td>
<td>-0.18</td>
<td>0.06</td>
<td>-0.67</td>
<td>-0.43</td>
</tr>
<tr>
<td>Government Effectiveness</td>
<td>1.52</td>
<td>0.29</td>
<td>0.21</td>
<td>-0.11</td>
<td>0.24</td>
<td>-0.31</td>
<td>-0.47</td>
</tr>
<tr>
<td>Political Stability and Absence of Violence/Terrorism</td>
<td>0.85</td>
<td>-0.18</td>
<td>0.16</td>
<td>-0.27</td>
<td>-0.68</td>
<td>-1.60</td>
<td>-0.32</td>
</tr>
<tr>
<td>Regulatory Quality</td>
<td>1.43</td>
<td>0.15</td>
<td>0.63</td>
<td>0.12</td>
<td>0.06</td>
<td>-0.36</td>
<td>-0.49</td>
</tr>
<tr>
<td>Rule of Law</td>
<td>1.53</td>
<td>-0.03</td>
<td>0.17</td>
<td>-0.40</td>
<td>0.15</td>
<td>-0.36</td>
<td>-0.52</td>
</tr>
<tr>
<td>b. Macroeconomic environment index</td>
<td>-0.22</td>
<td>0.78</td>
<td>-0.29</td>
<td>-0.09</td>
<td>0.42</td>
<td>-0.66</td>
<td>-0.42</td>
</tr>
<tr>
<td>Government budget balance (Percent of GDP)</td>
<td>-4.53</td>
<td>-0.36</td>
<td>-3.43</td>
<td>-1.49</td>
<td>-2.32</td>
<td>-7.27</td>
<td>-2.56</td>
</tr>
<tr>
<td>Gross domestic savings (% of GDP)</td>
<td>23.12</td>
<td>32.87</td>
<td>19.26</td>
<td>18.73</td>
<td>30.37</td>
<td>20.77</td>
<td>14.91</td>
</tr>
<tr>
<td>Distance of inflation rate from a stable range</td>
<td>0.38</td>
<td>3.63</td>
<td>1.78</td>
<td>3.02</td>
<td>5.34</td>
<td>6.26</td>
<td>5.60</td>
</tr>
</tbody>
</table>

Note 1. OECD countries in the figure are high-income countries that have been members of OECD more than 40 years. Other countries are grouped by region.

Note 2. Average values are calculated after imputing missing values of indicators.
Appendix D. Scenario analysis to assess the effects of the determinant index on the growth rate of total factor productivity

With a scenario that developing countries increase their overall determinant index to the average level of OECD countries over the period 2012–32, we predict the change in the growth rate of TFP for the developing countries by region. The average overall determinant index in 2011 is 2.78 for the OECD group, 0.55 for East Asia & Pacific, 0.21 for Europe & Central Asia, -0.72 for Latin America & Caribbean, 0.36 for Middle east & North Africa, -1.81 for South Asia, and -1.31 for Sub-Saharan Africa. Using the regression model in table 2, we predict the change in the growth rate of TFP per country, and calculate the average change across countries by region. The result in figure C.1 shows that, if the developing countries increase the overall determinant index to the average of OECD countries over 2012–32, the change in the growth rate of TFP is expected to increase to 1.7% for South Asia, 1.5% for Sub-Saharan Africa, 1.3% for Latin America & Caribbean, 1.0% for Europe & Central Asia, 0.9% for Middle East & North Africa, and 0.8% for East Asia & Pacific over 2012–42, and decrease afterward.

Figure C.1. The Predicted Change in Total Factor Productivity Growth for Developing Countries with the Determinant Index Change to the Level of OECD Countries

<table>
<thead>
<tr>
<th>Year</th>
<th>Change in TFP growth rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>0.006</td>
</tr>
<tr>
<td>2017</td>
<td>0.012</td>
</tr>
<tr>
<td>2022</td>
<td>0.015</td>
</tr>
<tr>
<td>2027</td>
<td>0.018</td>
</tr>
<tr>
<td>2032</td>
<td>0.015</td>
</tr>
<tr>
<td>2037</td>
<td>0.012</td>
</tr>
<tr>
<td>2042</td>
<td>0.009</td>
</tr>
<tr>
<td>2047</td>
<td>0.006</td>
</tr>
<tr>
<td>2052</td>
<td>0.003</td>
</tr>
<tr>
<td>2057</td>
<td>0.006</td>
</tr>
<tr>
<td>2062</td>
<td>0.009</td>
</tr>
<tr>
<td>2067</td>
<td>0.012</td>
</tr>
<tr>
<td>2072</td>
<td>0.015</td>
</tr>
<tr>
<td>2077</td>
<td>0.018</td>
</tr>
</tbody>
</table>

Source: Authors' calculation
References


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

———. 2017n. “Total Natural Resources Rents (% of GDP).” World Development Indicators.