CHAPTER 3

Benchmarking Competitiveness in the Fourth Industrial Revolution: Introducing the Global Competitiveness Index 4.0

This chapter presents the new Global Competitiveness Index 4.0 methodology. Building on the original idea of Professor Klaus Schwab and the guidance of Professor Xavier Sala-i-Martin of Columbia University, the GCI 4.0 is the culmination of a rigorous process initiated in 2015 involving extensive review of the empirical literature and numerous workshops and consultations. Dozens of experts and practitioners from academia, international organizations, NGOs, think tanks, central banks and governments provided input and feedback on conceptual and technical aspects to incorporate the newest theories and indicators into the index.[1]

The need to update the competitiveness index was made clear by the combination of the ongoing effects of the 2008's Great Recession and the gathering pace of the Fourth Industrial Revolution (4IR). The Great Recession has taught us that financial crises can have long-lasting effects on productivity. Prolonged periods of under-investment caused by a financial meltdown can lower the long-run growth trajectory, setting the economic system on to a less prosperous path, even after the financial sector eventually rebounds.[2] At the same time, the advent of the 4IR is producing, among other effects, an acceleration of the innovation cycle and causing business models to become obsolete at a faster rate. This process of constant creative destruction generates opportunities for new entrants and reduces the barriers to transfer technology or innovate, but also requires managing frequent industry disruptions. To respond to these challenges prosperous economies need to put in place appropriate mechanisms to reduce the risk of new financial crises and to govern the socio-economic effects of innovation. In other words, successful economies in the 4IR era need to:

- Be **resilient,** building buffers and economic mechanisms to prevent financial crises or mass unemployment and to respond to external shocks.
- Be **agile,** embracing change rather than resisting it. Companies, public policy-makers and workers should be able to quickly adapt how they operate and to take advantage of the opportunities to produce goods or provide services in new ways.
- Build an **innovation ecosystem** where innovation is incentivized at all levels and all stakeholders contribute to create the best conditions for new ideas to emerge, to be financed and commercialized as new products and services.
- Adopt a **human-centric** approach to economic development. This means recognizing that human capital is essential for generating prosperity and that any policy that adversely affects human factors' potential will reduce economic growth in the long run. As a consequence, policy-making will

Box 1: Navigating the GCI 4.0 in light of the Fourth Industrial Revolution's (4IR) key concepts

The development of the GCI 4.0 has been guided by the emergence of new fundamental changes in the functioning of national economies with the advent of the Fourth Industrial Revolution (4IR). These concepts span across multiple factors captured by the GCI (see Figure 1). While organizing the index methodology across 12 pillars provides a clear structure for the computation of the index, and for actionable policy indications, it is also informative to look at the 12 pillars through the lens of the four meta-concepts described in this chapter: resilience, agility, innovative ecosystems and a human-centric approach. Looking at the GCI from this perspective enables interpreting the pillars as 4IR-readiness measures.

The concept of **resilience** is reflected in the Financial system pillar (pillar 9), which includes measures to minimize the risk of a financial meltdown and resources to adjust to external shocks. By the same token, the Macroeconomic stability pillar (pillar 4) captures the extent to which a country's public sector can provide appropriate counter-cyclical measures and invest in projects that the private sector cannot finance. Similarly, the Skills pillar (pillar 6) captures workers' capacity to learn and adapt to changing circumstances.

The concept of **agility** is present in the Domestic market competition and Entrepreneurial culture sub-pillars of the index[1] because they imply greater capacity for "creative destruction", allowing innovative companies to emerge against incumbents and rewarding a risk-taking attitude. In addition, the concept is present in the Public-sector performance sub-pillar: low levels of bureaucracy make it easier for businesses to re-organize and re-invent themselves when legal formalities are not taxing. Labour market flexibility (another sub-pillar) implies agility through easier re-allocation of talent across sectors and firms.

The **innovation ecosystem** encompasses all pillars. Although business dynamism and innovation cabability are the factors impacting innovation more directly, these need to be complemented by high levels of human capital (health, education and skills); optimal allocation of skills (labour market functioning); and availability of venture capital and ad-hoc financial products (financial system development). A strong innovation ecosystem also presumes sound infrastructure, ICT readiness and institutions that allow ideas to flow and protect property rights, and a large market size that incentivizes the generation of new ideas.

The **human-centric** approach to development is embodied by the Health (pillar 5) and Skills (pillar 6) pillars, which together account for one-sixth of the total GCI score and take a broad approach to human capital: health is thought of as a state of complete physical, mental and social well-being, not merely the absence of disease or disabilities;[2] education measures the skills humans need to thrive in the 4IR. The Labour market pillar (pillar 8) includes measures of talent reward and respect of workers' rights, while the Innovation capability pillar (pillar 12) includes measures that capture human collaboration, interaction and creativity.

Notes

1 See the detailed structure in Appendix A.

2 This definition is based on the preamble to the World Health Organization's Constitution. See WHO, 1946.

have to ensure that the speed of change and the introduction of new technologies ultimately translate into better living conditions.

Box 1 shows how to interpret the GCI 4.0 in light of these concepts.

THE GCI 4.0 FRAMEWORK

The review process not only updated concepts and statistics, but also offered an opportunity to reflect on the scope of the GCI. The GCI 4.0 is focused on the institutions, policies and other factors that drive productivity.[3] For, as explored in Chapter 1, productivity ultimately determines long-term economic growth, and, although there can be trade-offs between economic prosperity and environmental or social goals, raising productivity is a necessary pre-condition towards greater human development.

The Global Competitiveness Index 4.0 evaluates the factors that collectively determine the level of a country's productivity—the most important driver of long-term improvements in living standards.[4]

The factors are organized into 12 pillars, and for presentation purposes they are grouped into four categories (Enabling environment, Human capital, Markets and Innovation ecosystem), as shown in Figure 1. While maintaining its predecessor's objective, the GCI 4.0 has re-considered what determines productivity and its measurement: Of the 98 indicators, 34 have been retained from the previous methodology while the other 64 indicators are new. Appendix C presents the detailed structure of the index and the definition of each variable. The new methodology captures all the factors identified by the literature and by experts as important for productivity in the era of the 4IR.

Figure 1: The Global Competitiveness Index 4.0 2018

Enabling Environment

Pillar 1
Institutions

Pillar 2
Infrastructure

Pillar 3
ICT adoption

Pillar 4
Macroeconomic stability

Markets

Pillar 7
Product market

Pillar 8
Labour market

Pillar 9
Financial system

Pillar 10
Market size

Human Capital

Pillar 5
Health

Pillar 6
Skills

Innovation Ecosystem

Pillar 11
Business dynamism

Pillar 12
Innovation capability

Pillar 1: Institutions

What does it capture? Security, property rights, social capital, checks and balances, transparency and ethics, public-sector performance and corporate governance.

Why does it matter? By establishing constraints, both legal (laws and enforcement mechanisms) and informal (norms of behaviors), institutions determine the context in which individuals organize themselves and their economic activity. Institutions impact productivity, mainly through providing incentives and reducing uncertainties.[5]

Pillar 2: Infrastructure

What does it capture? The quality and extension of transport infrastructure (road, rail, water and air) and utility infrastructure.

Why does it matter? Better-connected geographic areas have generally been more prosperous. Well-developed infrastructure lowers transportation and transaction costs, and facilitates the movement of goods and people and the transfer of information within a country and across borders. It also ensures access to power and water—both necessary conditions for modern economic activity.

Pillar 3: ICT adoption

What does it capture? The degree of diffusion of specific information and communication technologies (ICTs).

Why does it matter? ICTs reduce transaction costs and speed up information and idea exchange, improving efficiency and sparking innovation. As ICTs are general purpose technologies increasingly embedded in the structure of the economy, they are becoming as necessary as power and transport infrastructure for all economies.

Pillar 4: Macroeconomic stability

What does it capture? The level of inflation and the sustainability of fiscal policy (see Box 2 for further explanation).

Why does it matter? Moderate and predictable inflation and sustainable public budgets reduce uncertainties, set returns expectations for investments and increase business confidence—all of which boost productivity. Also, in an increasingly interconnected world where capital can move quickly, loss of confidence in macroeconomic stability can trigger capital flight, with destabilizing economic effects.

Box 2: Debt dynamics in the Macroeconomic stability pillar[1]

The Macroeconomic stability pillar (pillar 4) aims to measure the main factors impacting countries' competitiveness via the investment decision channel. It is based on two indicators: Inflation (4.01) and Debt dynamics (4.02). The importance of inflation for economic stability is well grounded in literature and policy—inflation is an explicit target of monetary authorities who aim at keeping it within a certain range (the target of European Central Bank, US Federal Reserve, Bank of Japan and Bank of England is 2%). Debt dynamics aims to approximate the sustainability of public finance. Its computation is relatively complex and requires adopting goalposts that are not fully established in the literature. This box explains its conceptual idea and its implementation in the context of the GCI.

Over the past three decades, economists have been debating whether high public debt matters for economic development. There is consensus that countries cannot sustain unlimited amounts of debt—it would clearly be unsustainable if, for instance, interest payments were to exceed GDP—but there is no consensus on the level of debt at which countries' economies begins to suffer. Some economists believe that negative effects on long-term growth kick in when debt reaches around 100% of GDP.[2] Others have found no causal relationship between debt and economic growth,[3] making it hard to define a particular level of debt at which a country's growth would start to decline.

The lack of consensus around the level beyond which public debt becomes too large suggests the need for taking into account other factors. The new indicator draws on the debt dynamic literature[4] and assesses a country's debt change based on four elements:

- Debt-to-GDP levels, to control for the initial level of debt (Source: IMF's *World Economic Outlook*)
- Projected change in debt, to control for how much the debt of a country is growing (Source: IMF's *World Economic Outlook*)
- Country credit ratings, to capture qualitative and confidence aspects (Sources: Fitch, S&P, Moody's)[5]
- A country's development status, based on whether the IMF categorizes it as either "Advanced" or "Emerging/Developing"

Each country is assigned into a bracket, based on its credit rating, debt level and development status. The Debt dynamics indicator is computed by applying different normalization thresholds according to the bracket to which a country is assigned. Table 2.1 below summarizes the details of the methodology. Within each bracket, the exact score depends on the absolute change in debt level. If there is no change or debt is decreasing, the score is the upper-bound value. If the increase is of 20 percentage points or more, the score is the lower-bound value. Between the extreme values, the score is obtained by interpolation:

$$\text{score} = \text{upper} - (\text{upper} - \text{lower}) \times \frac{\text{debt change}}{20}$$

For example, consider a developing country whose rating is defined as "speculative", the debt-to-GDP ratio is below 50% and the debt change is 20. Based on the methodology detailed in Table 2.1, this country will receive a score of 50. Had the same developing country registered a debt change of 10 its score would have been 55.

This methodology has the merit of incorporating all relevant information in one indicator. However, we acknowledge some limitations that depend on lack of data[6] and definition of thresholds. In particular, because of lack of sufficient data availability, this indicator does not take into account the size and liquidity of public assets. Everything else being equal, the debt of countries with larger and more liquid public assets, should be more sustainable.[7] Although this information is partially reflected in credit ratings, using "net debt" (gross debt minus public assets) would be beneficial. Also, the debt dynamics indicator should consider

Table 2.1: Cases for computing Debt dynamics (indicator 4.02) score

Case	Lower and upper bounds used to normalize debt change
Credit rating "Default"	0 < Score < 30
Credit rating "n/a"—High debt	30 < Score < 40
Credit rating "n/a"—Low debt	40 < Score < 50
Credit rating "Speculative"—Developing country—High debt (>60%)	30 < Score < 40
Credit rating "Speculative"—Developing country—Low debt (< 60%)	40 < Score < 50
Credit rating "Speculative"—Advanced country—High debt (>110%)	40 < Score < 50
Credit rating "Speculative"—Advanced country—Low debt (<110%)	50 < Score < 60
Credit rating "Investment 2"—High debt (>110%)	60 < Score < 70
Credit rating "Investment 2"—Low debt (<110%)	70 < Score < 80
Credit rating "Investment 1"—High debt (>110%)	80 < Score < 90
Credit rating "Investment 1"—Low debt (<110%)	90 < Score < 100
Credit rating "Investment 1"—Very low debt (<60%)	100

(Continued)

Box 2: Debt dynamics in the Macroeconomic stability pillar[1] *(cont'd.)*

the proportion of the debt denominated in foreign currency—which raises the risk of an exchange rate depreciation increasing the country's interest's bill, a particular concern for many developing countries[8] –and the proportion of the debt owed to foreigners, which is riskier because governments cannot tax non-citizens.[9] With respect to the definition of thresholds, the empirical evidence on the impact of different levels of debt on its sustainability is inconclusive. As a consequence we base our definition on the statistical distribution of the current cross-country distribution of debt-to-GDP ratio. Given the large confidence intervals in determining thresholds, we have been conservative in calibration, with most countries attaining a score of 30 or higher. As new data and new empirical evidence become available, the methodology will be revised accordingly.

Despite these limitations this indicator provides a practical way to assess a country's fiscal situation more accurately than just its current debt-to-GDP ratio, or a combination of public debt level and budget balance.

Notes

1 We would like to thank Ugo Panizza, Professor, International Economics, Pictet Chair in Finance and Development, Graduate Institute of International and Development Studies, Geneva, for his comments and suggestions.

2 See, among others, Reinhart and Rogoff, 2010; Kumar and Woo, 2010; Cecchetti, Mohanty and Zampolli, 2011.

3 See, for example, Panizza and Presbitero, 2012, or Égert, 2015.

4 For a formal definition refer to Escolano 2010.

5 The general credit rating for each country is computed as the average of Fitch, Standards and Poor's (S&P) and Moody's credit ratings. A country's rating is considered "investment grade 1" for S&P's grades AAA to A, Moody's grades Aaa to A1, and Fitch's grades AAA to A. A country's rating is considered "investment grade 2" for S&P's grades A- to BBB-, Moody's grades A- to Baa1, and Fitch's grades A- to BBB+. A country's rating is considered "speculative" for S&P's grades BB+ to CCC+, Moody's grades Ba3 to Caa2, and Fitch's grades BBB- to B-. A country credit rating is considered "default" for S&P's grade SD, Moody's grades Caa1 and C, and Fitch's grades CC and RD.

6 IMF, *World Economic Outlook* provides information on net debt for 84 countries, and World Bank's *Quarterly Public Sector Debt* database provides information on public debt in foreign currency for 41 economies.

7 Notably, the government of Singapore issues bonds that are entirely invested in other assets. Singapore's bonds are issued to develop the domestic debt market rather than to finance the budget deficit.

8 Eichengreen, Hausmann and Panizza, 2002.

9 Gros, Daniel, 2011.

Pillar 5: Health

What does it capture? Health-adjusted life expectancy (HALE)—the average number of years a newborn can expect to live in good health.

Why does it matter? Healthier individuals have more physical and mental capabilities, are more productive and creative, and tend to invest more in education as life expectancy increases. Healthier children develop into adults with stronger cognitive abilities.

Pillar 6: Skills

What does it capture? The general level of skills of the workforce and the quantity and quality of education. While the concept of educational quality is constantly evolving, important quality factors today include: developing digital literacy, interpersonal skills, and the ability to think critically and creatively.

Why does it matter? Education embeds skills and competencies in the labour force. Highly-educated populations are more productive because they possess greater collective ability to perform tasks and transfer knowledge quickly, and create new knowledge and applications.

Pillar 7: Product market

What does it capture? The extent to which a country provides an even playing field for companies to participate in its markets. It is measured in terms of extent of market power, openness to foreign firms and the degree of market distortions.[6]

Why does it matter? Competition supports productivity gains by incentivizing companies to innovate; update their products, services and organization; and supply the best possible products at the fairest price.

Pillar 8: Labour market

What does it capture? It encompasses "flexibility", namely, the extent to which human resources can be re-organized and "talent management", namely, the extent to which human resources are leveraged.

Why does it matter? Well-functioning labour markets foster productivity by matching workers with the most suitable jobs for their skillset and developing talent to reach their full potential. By combining flexibility with protection of workers' basic rights, well-functioning labour markets allow countries to be more resilient to shocks and re-allocate production to emerging segments; incentivize workers to take risks; attract and retain talent; and motivate workers.

Pillar 9: Financial system

What does it capture? The depth, namely the availability of credit, equity, debt, insurance and other financial products, and the stability, namely, the mitigation of excessive risk-taking and opportunistic behavior of the financial system.

Why does it matter? A developed financial sector fosters productivity in mainly three ways: pooling savings into productive investments; improving the allocation of capital to the most promising investments through monitoring borrowers, reducing information asymmetries; and providing an efficient payment system. At the same time, appropriate regulation of financial institutions is needed to avoid financial crises that may cause long-lasting negative effects on investments and productivity.

Pillar 10: Market size

What does it capture? The size of the domestic and foreign markets to which a country's firms have access. It is proxied by the sum of the value of consumption, investment and exports.

Why does it matter? Larger markets lift productivity through economies of scale: the unit cost of production tends to decrease with the amount of output produced. Large markets also incentivize innovation. As ideas are non-rival, more potential users means greater potential returns on a new idea. Moreover, large markets create positive externalities as accumulation of human capital and transmission of knowledge increase the returns to scale embedded in the creation of technology or knowledge.

Pillar 11: Business dynamism

What does it capture? The private sector's capacity to generate and adopt new technologies and new ways to organize work, through a culture that embraces change, risk, new business models, and administrative rules that allow firms to enter and exit the market easily.

Why does it matter? An agile and dynamic private sector increases productivity by taking business risks, testing new ideas and creating innovative products and services. In an environment characterized by frequent disruption and redefinition of businesses and sectors, successful economic systems are resilient to technological shocks and are able to constantly re-invent themselves.

Pillar 12: Innovation capability

What does it capture? The quantity and quality of formal research and development; the extent to which a country's environment encourages collaboration, connectivity, creativity, diversity and confrontation across different visions and angles; and the capacity to turn ideas into new goods and services.

Why does it matter? Countries that can generate greater knowledge accumulation and that offer better collaborative or interdisciplinary opportunities tend to have more capacity to generate innovative ideas and new business models, which are widely considered the engines of economic growth.

COMPUTATION OF THE GCI 4.0

Of the 98 indicators composing the GCI 4.0 methodology, 44 are sourced from the Forum's Executive Opinion Survey (see Appendix C), and 54 are based on statistics provided by reliable external sources suppliers. The indicators were selected based on four principles. First, they need to adequately capture the concept identified by the review. Second, external statistics have to come from trusted organizations that collect data according to high-quality standards. Third, it must be expected that the data will be updated periodically in the future. Fourth, data must have extensive geographical coverage and be available for at least 75% of the economies covered by the GCI.

As well as redefining concepts and measures, the GCI 4.0 review updated the computation methodology, including how indicators are aggregated, scores are normalized and missing data is treated.

Aggregation and weights

The GCI 4.0 computation is based on successive aggregations of normalized scores from indicators (the most disaggregated level) all the way up to the overall GCI score. Pillar and GCI scores are expressed on a 0 to 100 scale and are interpreted as "progress scores", indicating how close a country is to the ideal state.

The overall GCI score is the simple average of the 12 pillars, so each pillar's implicit weight is 8.3% (1/12). The four components presented in Figure 1 (Enabling Environment, Human Capital, Markets and Innovation Ecosystem) are used only for presentation purposes and do not enter into the calculation. The "stage of development"[7] weighting scheme from previous versions of the GCI is no longer used. Instead, the same aggregation methodology is now applied to all countries. The rationale is that as the 4IR proceeds, all competitiveness factors will have a similar bearing on countries' competitiveness, regardless of their income levels. Automation will possibly reduce the feasibility of developing a country relying on low labour costs in manufacturing. Rodrik (2015), for example, showed that growth in many developing countries is led by services, while newly industrializing countries start to de-industrialize much earlier than has been the case for Western countries. At the same time, ICTs are reducing information barriers and enabling rapid transfer of ideas, technologies and intangible products across

Box 3: Is the GCI 4.0 a valid measure of productivity? A formal statistical test

We define competitiveness as the set of institutions, policies and factors that determine a country's level of productivity. If the GCI 4.0 is a good measure of competitiveness, then it should be strongly correlated with productivity levels. This analysis provides evidence that it is indeed the case.

If we knew the level of productivity for each country, the test would be simple: we would regress the GCI 4.0 on that measure of productivity and verify that its coefficient is positive and statistically significant. Lacking good measures of productivity levels, economists revert to use productivity growth. Following Solow (1957) they define total factor productivity (TFP) as the portion of GDP growth not explained by inputs of labour and capital, and compute TFP as the difference between GDP growth, the growth rate of capital (times the capital share), and the growth rate of human capital (times the human capital share). However, as we are interested in productivity *level* rather than in productivity *growth* we cannot follow this approach.

Hall and Jones (1999) tried to measure the level of productivity in a large cross-section of countries by subtracting the level of capital and the level of human capital from the level of GDP. That is, assume that the production function takes a Cobb-Douglas form: $Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{1-\alpha}$ where Y_{it} is GDP for country i at time t, K_{it} is the capital stock for country i at time t, L_{it} is the level of human capital for country i at time t, and α is the capital share (so $1 - \alpha$ is the labour share). Then we can take logarithms of both sides and get $\ln(Y_{it}) = \ln(A_{it}) + \alpha\ln(K_{it}) + (1 - \alpha)\ln(L_{it})$. We could find a measure of $\ln(A_{it})$ by subtracting $\alpha\ln(K_{it}) + (1 - \alpha)\ln(L_{it})$ from both sides to get $\ln(A_{it}) = \ln(Y_{it}) - \alpha\ln(K_{it}) + (1 - \alpha)\ln(L_{it})$.

However, data limitations prevent us from using this methodology. We have good data on GDP, so the first term can be easily estimated for many countries, but we would also need good measures of each economy's aggregate capital stock and aggregate human capital. This is an almost impossible task, especially because we would need to measure not only the quantity of capital (both physical and human) but also its quality. Some studies have attempted to estimate these measures for a small sample of countries, but the estimates depend on a number of unrealistic assumptions and are not reliable.

The economic growth literature offers a simple alternative that requires only data on GDP: the conditional convergence regression developed by Mankiw, Romer and Weil (1992) and Barro and Sala-i-Martin (1992, 2004). The level of productivity determines the rate of return of an economy, and hence its growth rate; in other words, most growth theories—including the neo-classical growth theories of Solow-Swan or Ramsey-Cass-Koopmans—predict that the productivity level not only determines the *level of income* (as shown in the production function displayed above) but also its *growth rate*.[1]

Proceeding in three steps, then, we can derive a statistical theory that will tell us exactly what needs to be tested. First, we start from the fundamental equation of the Solow-Swan theory of growth.[2] According to this theory, the growth of capital stock per person (k) is a function of the saving rate (s), GDP per capita (y), population growth (n) and capital depreciation (δ). Using the Solow -Swan formulation, and recalling that $y = f(k)$, this is:

$$\dot{k}_{it} = s_i\, f\,(A_{it}k_{it}) - (n_i + \delta_i) \tag{1}$$

Second, taking a log-linear transformation of equation (1), and using Taylor approximation,[3] we can find that economic growth (GDP growth) is a negative function of the initial level of per capita income (GDP) of a country and its steady-state[4] level of income per capita. This is:

$$\gamma_{it,t+T} = \beta_0 - \beta_1\ln(y_{it}) + \beta_2\ln(y_{i^*}) + \epsilon_{it} \tag{2}$$

where $\gamma_{it,t+T}$ is the average annual growth rate of GDP per person for country i between times t and $t+T$, y_{it} is the per capita GDP for country i at time t and $y_i{}^*$ is the steady-state level of per capita GDP for country i and ϵ_{it} is an error term. Equation (2) is a conditional convergence regression. It posits that the growth rate of capital per person is a function of the difference between the initial level of income (that is, everything else being equal, poor countries should grow faster, a phenomenon known as the "convergence effect") and the steady-state level of income (that is, holding everything else constant, countries that grow towards a higher target should be growing faster).

Third, we identify a proxy for the steady-state level of income per capita (y^*). This depends on the theory of growth. Using a Solow-Swan model with a Cobb-Douglas production function (see note 1), constant savings rate s, a constant rate of population growth n and a constant depreciation rate δ, the steady state capital stock is given by $k_i{}^* = \left[s_i \frac{A_i}{\delta+n_i}\right]^{1/(1-\alpha)}$.

Consequently the steady state level of GDP per capita is $y_i{}^* = A_i{}^{1/(1-\alpha)} \left[\frac{s_i}{\delta+n_i}\right]^{\alpha/(1-\alpha)}$.

Taking logs, we obtain:

$$\ln(y_i{}^*) = \frac{1}{1-\alpha}\ln(A_i) + \frac{\alpha}{1-\alpha}\ln\left(\frac{s_i}{\delta+n_i}\right) \tag{3}$$

Hence, plugging (3) into (2) and replacing A with GCI we have:

$$\gamma_{it,t+T} = \beta_0 - \beta_1\ln(y_{it}) + \tilde{\beta}_2\ln(A_i) + \tilde{\beta}_2\frac{\alpha}{1-\alpha}\ln\left(\frac{s_i}{\delta+n_i}\right) + \epsilon_{it} \tag{4}$$

(Continued)

Box 3: Is the GCI 4.0 a valid measure of productivity? A formal statistical test *(cont'd.)*

Where: $\tilde{\beta} = \beta_2 \times \frac{1}{1-\alpha}$

Equation (4) says that the growth rate of GDP per capita is a (negative) function of the initial level of per capita GDP and a positive function of the level of productivity. It is also a positive function of the savings rate and a negative function of the depreciation rate and the rate of population growth. Ignoring any of these terms would bias our estimates if the ignored terms are correlated with the right hand side variables. However, the consumption literature shows that the savings rate is uncorrelated with income. The population growth rate is slightly negatively related to income (population growth is the sum of fertility minus mortality, or births minus deaths, and net migration; rich countries have lower fertility but also lower mortality, or larger life expectancy, and larger migration rates). Hence we believe that omitting $\beta_2 \frac{\alpha}{1-\alpha} \ln(\frac{s_i}{\delta + n_i})$ and putting it in the error term should not bias our estimates of β_1 and $\tilde{\beta}_2$, and estimate the equation:

$$\gamma_{it,t+T} = \beta_0 - \beta_1 \ln(y_{it}) + \tilde{\beta}_2 \ln(A_i) + w_{it} \qquad (5)$$

Equation 5 says that the growth rate of GDP per capita between time *t* and time *t+T* is a negative function of the initial level of GDP per capita and a positive function of productivity. Notice that to estimate this growth equation we need to hold constant both $\ln(y_{it})$ and $\ln(A_i)$. If we omit $\ln(A_i)$ and this term turns out to be correlated with $\ln(y_{it})$, then our estimates of β_1 will be biased towards zero. Similarly, if we regress growth on $\ln(A_i)$, ignoring $\ln(y_{it})$, we will also tend to find that β_2 is biased towards zero. The correct equation is, therefore, a bivariate regression where both $\ln(A_i)$ and $\ln(y_{it})$ are held constant.

If, as we claim, the GCI estimate for country *i* is a good proxy for A_i, when we substitute the GCI for A_i in equation (5), we get:

$$\gamma_{it,t+T} = \beta_0 - \beta_1 \ln(y_{it}) + \tilde{\beta}_2 \ln(GCI_i) + w_{it} \qquad (6)$$

Hence, if the GCI is a good proxy for the level of productivity, then when we regress the growth rate of GDP per capita between *t* and *t+T* on the level of GDP per capita at time *t* and the GCI, we should get a negative coefficient on the initial level of GDP and a positive one on the GCI.

We apply this test for the period 1998 to 2018[5] by running the following regression:

$$\frac{\Delta \log (GDPpc)_{i,1998-2018}}{20} = \beta_0 - \beta_1 \, logGDPpc_{i,1998} + \tilde{\beta}_2 \, logGCI_{i,2018} + \mu_{i,} \qquad (7)$$

Where $\frac{\Delta \log (GDPpc)_{i,1998-2018}}{20}$ is the annual growth rate in each country *i*[6] computed as the difference in log GDP per capita (PPP terms) between 1988 and 2018, logGCI is the log in the index score for the year 2018, and logGDPpc is GDP per capita in PPP terms in 1988.

If we are correct, we should find $\tilde{\beta}_2$ to be positive and β_1 to be negative.

Table 3.1 reports the results of the estimation of equation (7) with the ordinary least squares. We find that the coefficient on the log of GCI is 0.0969 with a standard error of .015 and a t-statistic of 6.42, while the coefficient on the log of the initial (i.e. 1988) level of income is –0.37 with a standard error of 0.002 and the t-statistic is –9.04. Both achieve a significance level of 99%. This validates our hypothesis: the GCI is indeed highly correlated to productivity.

Table 3.1: GCI and productivity test result

Dependent variable	Annual GDP growth between 1998 and 2018
Log (GCI 4.0, 2018)	0.0969*** (0.015)
Log (GDP per capital, 1998)	–0.0186*** (0.002)
Constant	–0.205*** (0.046)
Observations	137
R-squared	0.489

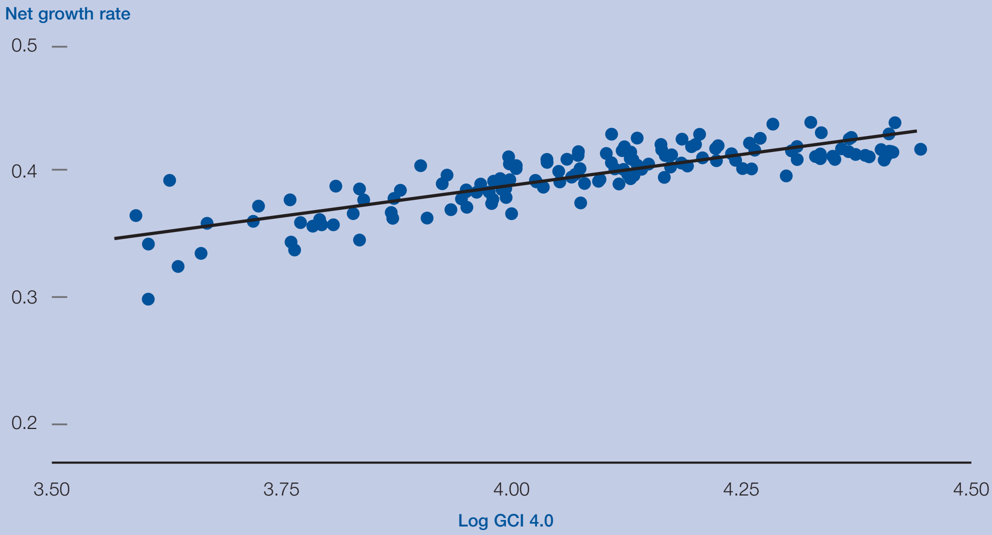
Note: Cross-section OLS (Ordinary Least Square) regression estimated with robust standards of error. Observations correspond to the countries covered by the GCI. In addition, *** denotes p-value < 0.01. Standards of error are in parentheses.

(Continued)

Box 3: Is the GCI 4.0 a valid measure of productivity? A formal statistical test *(cont'd.)*

To visualize these results in a graph, we can plot the partial correlation between the net growth[7] and the GCI, which is the growth rate netted out of the convergence factor. Figure 3.1 shows that there is a strong correlation between the GCI and the net growth rate, providing a visual demonstration of the statistical test provided above.

Figure 3.1. Correlation between GCI 4.0 and net growth rate



Note: Adjusted $R^2 = 0.70$.

Notes

1 In both Solow-Swan and Ramsey growth models the growth rate depends on A. In fact, with Cobb-Douglass production function, $y = Ak^{\alpha}$, and $\dot{y} = (1 - \alpha)g + \alpha\dot{k}$ where g is the growth rate of A, α is the capital share and is $\dot{k}_{it} = sA_{it}k_{it}^{\alpha} - (n + \delta)$.

2 We could also use the Ramsey-Cass-Koopmans theory as a guide. As shown by Barro and Sala-i-Martin (1992) and Barro and Sala-i-Martin (2004) Chapter 2 and Chapter 12, the end result is identical although the derivation is a bit more complicated.

3 For a derivation refer to Barro and Sala-I-Martin, 1992; and Barro-Sala-i-Martin, *Economic Growth*, second edition, MIT Press, 2004, p. 57.

4 The steady state is a situation in which the growth of capital per unit of effect labor is $0(\dot{k})$ and exogenous variables grow at a constant rate. The steady-state level of per capita GDP is, in a way, the target towards which the economy is going.

5 For 2017 and 2018 data we use IMF estimates.

6 *i* corresponds to 137 country observations available for the GCI 2018; GDP per capita data is obtained from *IMF Word Economic Outlook 2018*, April edition.

7 Technically the net growth rate is computed as: $net\ growth = \frac{\Delta \log (GDPpc)_{i,1998-2018}}{20} - \beta_1 logGDPpc_{i,1998} + \hat{\beta}$, where $\hat{\beta}$ is the estimated parameter obtained from regression (5).

the globe, opening new opportunities for developing economies. Drawing from these learnings the GCI 4.0 is less prescriptive about the path to prosperity, rewarding countries that leapfrog, and penalizing those that neglect any aspect of competitiveness, regardless of their stage of development.

Normalization of scores

The normalization of all 98 individual indicators in the GCI 4.0 is based on a min-max approach. Each indicator's value is converted into a unit-less "progress score" ranging from 0 to 100. These normalized scores are then combined to produce pillar and index scores. Formally, we have:

$$score_{i,c} = \underbrace{\left(\frac{value_{i,c} - wp_i}{frontier_i - wp_i}\right)}_{\alpha} \times 100,$$

where $value_{i,c}$ is the raw value of country *c* for indicator *i*; wp_i (worst performance) is the value at, or below which the score is 0; and $frontier_i$ is the value corresponding to the ideal value at or above which the score is 100. Depending on the indicator, this may be a policy target or aspiration, the maximum possible value, or a number derived from statistical analysis of the distribution (90th or 95th percentile). If a value is below the worst performance, its score is 0; if a value is above the frontier value, its score is capped at 100.

In the case of indicators where a higher value corresponds to a worse outcome (e.g. Terrorism incidence to power losses), the normalized score becomes $100 - \alpha$, so 100 always corresponds to the ideal outcome.

The "progress score" shows the level attained by a country in any given year with respect to the frontier set in the 2018 edition, and it informs on how a country moves towards or away from the frontier over time. Table 2 in Appendix C reports the wp_i and $frontier_i$ scores.

Imputation

In the GCI 4.0 methodology, the missing data points are imputed.[8] Approximate estimates are preferred to missing values because, in arithmetic means, the number of indicators included implicitly defines the weight of each indicator. Consequently, imputation avoids assigning greater weight to available indicators in a category that contains missing values. It is also hoped that this approach will encourage the production of reliable statistics.

The imputation method for each indicator is based either on econometric models or on the performance of peer countries.[9] Imputation estimates based on regression methods correspond to the predicted value of a cross-country ordinary least-squared regression using an indicator-specific set of regressors. These are selected based on their correlation with the non-missing values of the dependent variable. Peer country imputation consists of using the average score of a peer group to fill in missing values of countries in that group for a specific indicator. Imputed values are used for the purpose of the computation but are not ranked and not reported in the ranking tables. Imputed values and description of the imputation method for each indicator are provided in Table 1 of Appendix C.

As a result of these conceptual, statistical and methodological updates, the GCI 4.0 is an improved measure of countries' productivity levels. Statistical evidence of the soundness of the GCI as a productivity measure is provided in Box 3.

NOTES

1 See World Economic Forum, 2017, pages 359–360.

2 This idea incorporated the concept of hysteresis (see for instance Dixit, 1992).

3 This definition can be considered an extension of Hall and Jones's idea of social infrastructure: "Our hypothesis is that differences in capital accumulation, productivity, and therefore output per worker are fundamentally related to differences in social infrastructure across countries. By social infrastructure we mean the institutions and government policies that determine the economic environment within which individuals accumulate skills, and firms accumulate capital and produce output".

4 Economic literature recognizes productivity (total factor productivity) as the main factor explaining income differences across countries and growth perspectives. See Mankiw, Romer and Weil, 1992; Hall and Jones, 1999; Barro, 1996; and OECD, 2016.

5 For a detailed and comprehensive literature review of the empirical literature underpinning the selection of indicators for the GCI 4.0, refer to World Economic Forum, 2015.

6 We focus on the distortionary effect of taxes on productivity rather than their redistribution effect.

7 The previous GCI methodology applied different weights to different factors to countries according to income per capita and mineral exports. For more details refer to *Global Competitiveness Report, 2017–2018*, pp. 320–322.

8 Missing values in the "Railroad density" and "Liner shipping connectivity index" indicators are not imputed when a country has strategically decided not to develop a railroad network or is land-locked, respectively.

9 Peer groups of countries are defined in terms of the combination of their region and income level. The income levels are low income, upper-middle income, lower-middle income, and high income, and are based on World Bank's classification. Regions are: South Asia, Europe, Middle East & North Africa, Sub-Saharan Africa, Latin America & Caribbean, Eurasia, East Asia & the Pacific, and North America, and are based on the IMF's classification.

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