Diagnosing Human Capital as a Binding Constraint to Growth: Tests, Symptoms and Prescriptions

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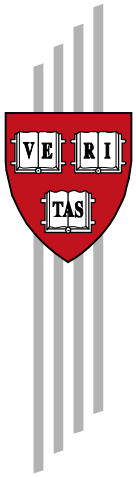

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Diagnosing Human Capital as a Binding Constraint to Growth: Tests, Symptoms and Prescriptions

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Abstract

The empirical literature on the contributions of human capital investments to economic growth shows mixed results. While evidence from OECD countries demonstrates that human capital accumulation is associated with growth accelerations, the substantial efforts of developing countries to improve access to and quality of education, as a means for skill accumulation, did not translate into higher income per capita. In this paper, we propose a framework, building on the principles of Growth Diagnostics (Hausmann, Rodrik and Velasco, 2008), to enable practitioners to determine whether human capital investments are a priority for a country's growth strategy. We then discuss and exemplify different tests to diagnose human capital in a place, drawing on the Harvard Growth Lab's experience in different development context, and discuss various policy options to address skill shortages.

Keywords

Human capital, skills, economic growth, growth diagnostics, developing countries.

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Introduction

Common wisdom along the hallways of development agencies preaches the importance of human capital for development, whereas one of the most important issues policymakers in developing countries often face is unemployment among educated youth. While evidence from OECD countries shows that human capital accumulation is associated with growth accelerations, the massive efforts to improve access and quality of schooling in developing countries have not translated, on average, into higher incomes per capita. Moreover, cross-country differences in schooling per worker and output per capita have moved in opposite directions, with the near universal expansion in schooling reducing the former whilst per capita income gaps widened.[1] How do we reconcile these seemingly contradictory positions? Is the problem that some developing countries have a relative abundance of skills, but other constraints are preventing these from being demanded and utilized? Is it that schooling is not producing skills, so that there is demand for human capital that existing schooling and training programs do not meet? Or is it instead that there is demand for human capital and relative abundance skills, but labor markets failures are preventing skilled people from being hired? In this book we argue that the answer to this puzzle depends on country-specific factors and propose a framework to assess whether improvements in a country's human capital can reasonably be expected to have an impact on economic growth.

When can we expect improvements in the provision of a factor – human capital – to be good for growth? Solow (1956) proposed modeling and studying economic output as a production function with complementary inputs: physical capital and labor, and a productivity factor that depends on the level of technological progress. Mankiw, Romer and Weil (1992) introduced an augmented model by incorporating the notion of human capital. The model assumes diminishing returns to capital – as capital accumulation increases, the incentive to save and invest in capital decreases – leading to a level of income per capita that is determined by savings rates, population growth and technological progress, all exogenous variables. Under these assumptions, growth in output per capita is exogenous: any permanent increases in the provision of a production factor will lead to temporarily positive growth rates that allow income level to shift permanently. The economic growth delivered thereby can only be transitional in nature. Within this context, investments in the stock of human capital yield a shift in income level but does not boost growth.

Escaping Solow invariance and the exogeneity of growth requires an endogenous growth engine and therefore moving away from the assumption of diminishing returns. Romer (1986) proposed a growth model of endogenous technological change, expanding the concept of factor accumulation as a determinant of growth from physical and human capital to include knowledge. The accumulation of knowledge leads to externalities – as knowledge is non-rivalrous in nature – and thereby exhibits increasing returns to scale. Hence, growth in output per capita is no longer a temporary and exogenous phenomenon but rather the product of knowledge accumulation by profit-maximizing agents and as such can increase over time. Within this context, investments in human capital may have a significant impact on long-run growth if they are related to the production, adoption and diffusion of knowledge.

A policy implication of this model is that knowledge can be transferred to developing countries as blueprints, and the only constraint to economic growth being the speed of physical and human capital accumulation. Yet, by the early 2000s, economic growth outcomes of developing countries showed income divergence in most regions except for East Asia and South Asia, mostly due to the slow or

[1] See Pritchett (2006).

lack of convergence of total factor productivity (Bosworth and Collins, 2003). Decades of standard growth accounting exercises between 1960 and 2000 show capital accumulation – physical or human – only partially explains the cross-country output gap (Hall and Jones, 1999; Bils and Klenow, 2000; Caselli, 2005) .

The Growth Diagnostics framework introduced by Hausmann, Rodrik and Velasco (2008) argues for the prioritization of growth reforms contingent on a country's economic environment. They propose a simple model in which economic growth is determined by the returns on factor accumulation, which in turn are a function of the appropriability of these returns in the place and the costs of financing factor accumulation. Within this context, the biggest bang in a specific country at a point in time can be approximated by determining the growth impact of removing distortions on the provision of the underlying production factors. The distortion with the highest estimated growth yield is called the most binding constraint and shall be prioritized within the allocation of policy attention and government resources. The range of factors that underlie the economic growth process and whose impacts shall be assessed is very broad, including finance, infrastructure, human capital, macroeconomic and microeconomic risks, and market failures.

We build on the principles of Growth Diagnostics proposed by Hausmann, Rodrik and Velasco (2008) and propose a framework to investigate and assess *whether improvements in the accumulation of human capital shall be prioritized to accelerate economic growth in a specific country*. We illustrate the application of the framework by drawing on Harvard University's Growth Lab's 15 years of experience in applying Growth Diagnostics at the national and sub-national levels worldwide. We demonstrate the deployment of four principles of differential diagnosis to test whether human capital is the most binding constraint. Practitioners will find in this book a combination of econometric tests, characteristics of the data required and proposed visualizations for their results, as well as more descriptive calculations derived from data available through various enterprise surveys, international financial institutions, or other publicly available sources. Additionally, we take stock of common policy interventions aimed at alleviating or overcoming distortions in cases where human capital is diagnosed as the most binding constraint.

The book is organized as follows. Section 1 reviews the evolution of the concept of human capital in the economic literature, contrasts definitions against recent research outputs on schooling – an avenue to acquire human capital – in developing countries and proposes a framework to assess the adequacy of human capital to support the process of economic growth in a specific country. Section 2 describes the four diagnostic principles to assess the adequacy of the human capital supply and access to it, as well as illustrates their use through examples from national and sub-national contexts. In doing so, we consider means to acquire human capital that are different from schooling. On-the-job training and experience can account for skill accumulation in ways that are not captured by schooling alone. Section 3 provides guidance on distilling the analysis results to judge whether human capital is indeed a binding constraint to growth and formulate policies that governments may adopt to overcome shortages in the supply of human capital. Conclusions, limitations, and potential avenues for further applied research work are presented in Section 4.

1. What Is Human Capital?

The term *capital* has traditionally referred to assets generated through a deliberate investment and whose operation is associated with a return. The most obvious forms of capital are physical and financial assets. The notion of human skills and knowledge as a form of capital, while alluded to by Adam Smith as early as 1776 (Smith, 1776), was formalized by pivotal contributions from Schultz, Becker and Mincer in the late 1950s and early 1960s, which gave rise to a literature that sought to define the concept, and study the return on investments in human capital.

Schultz (1961) defined human capital as the skills and knowledge that constitute an individual's productive capacity and ought to be treated as capital, since individuals in jobs apply their abilities and "provide a productive service of value to the economy". As such, human capital formation, through schooling and training, promised positive growth-promoting externalities making human capital essential for economic development (Myrdal, 1957; Schultz, 1960). Schultz also emphasized the need to understand the return on investment in human capital, and ultimately how it contributes to national income. Building on this literature (Schultz, 1960, 1961, 1963) and Lucas (1988) extended the neoclassical economic growth model to incorporate human capital as an cumulative factor contributing to economic productivity and growth, beyond manual labor and similar to physical capital. In these models, individuals' human capital affects not only their own productivity but also that of other factors.

In parallel, the contributions of Becker and Mincer provided the foundational frameworks and methods to measure the return on schooling and other human capital investments. Becker (1962) argued that some activities affect future individual well-being rather than the present, by "embedding" individuals with resources that impact their future real earnings. He proposed a theory connecting "investments in human capital" to worker earnings, which would increase with the value of investment in skill accumulation, on or out of the job. Becker and Chiswick (1966) provided empirical estimates of the return to different levels of schooling on earnings. Mincer (1958, 1974, 1984) provided empirical models to measure the effects of skills accumulation – with schooling and work experience as proxies – on income distributions.

Schooling and on-the-job training are the most common forms of human capital investment. Other investments that contribute to productivity include physical and mental healthcare, nutrition, other means of acquiring knowledge or information or non-cognitive skills (Becker, 1962). Healthcare and nutrition are critical to help build cognitive abilities and keep individuals engaged in economic activities beneficial for them and their societies. The impact of deteriorating health on human well-being and the economy has been studied (Rosen, 1988; Becker, 2007) and echoed stronger than ever in the wake of the COVID-19 pandemic. Interestingly, Schultz (1961) also discusses migration, particularly internal migration when individuals migrate from rural to urban areas to benefit from job opportunities, as a form of investment in human capital. Under this view, individuals incur a "cost of migration" to be able to employ their human capital in opportunities in the destination which, over their lifetime, will generate a larger return than they generate in the location of origin.

Before we proceed to discuss a framework to determine whether policy interventions aimed at augmenting human capital shall be the priority, at time t, to accelerate growth in a specific country, we note three points regarding human capital accumulation and economic growth.

First, despite near universal school enrollment achieved as part of the international drive to promote schooling under the second Millennium Development Goal (MDG), evidence suggests that little human capital was created to generate literacy, let alone provide children with skills and knowledge. Pritchett (2013) documents extensively the paradox that while the average years of schooling in the developing world went from 2 years in 1950 to 7 years in 2010, the poor quality of schooling worldwide hadn't led to *education* or learning. Assessments from several developing countries, such as India, Indonesia, Pakistan, Nigeria, Peru, show that learning outcomes of students in these countries lag behind those of students in OECD countries. Kaffenberger and Pritchett (2017) study the learning profiles of young adults between 18 and 37 years of age in ten developing countries to examine the association between schooling completion and learning outcomes. They find that in six out of the ten countries, half or more than half of young adults who completed primary schooling cannot read a few sentences without assistance. Moreover, according to a 2017 survey of learning outcomes of youth between 14 and 18 years old in rural communities in India carried by ASER Centre,[2] 45% of those enrolled in tertiary education were not able to tell the time ('Look Beyond Basics: Annual Status Education Report', 2017). In short, there has been a lot of schooling in the developing world but no accumulation of human capital, in any of the senses implied by the set of definitions provided above.

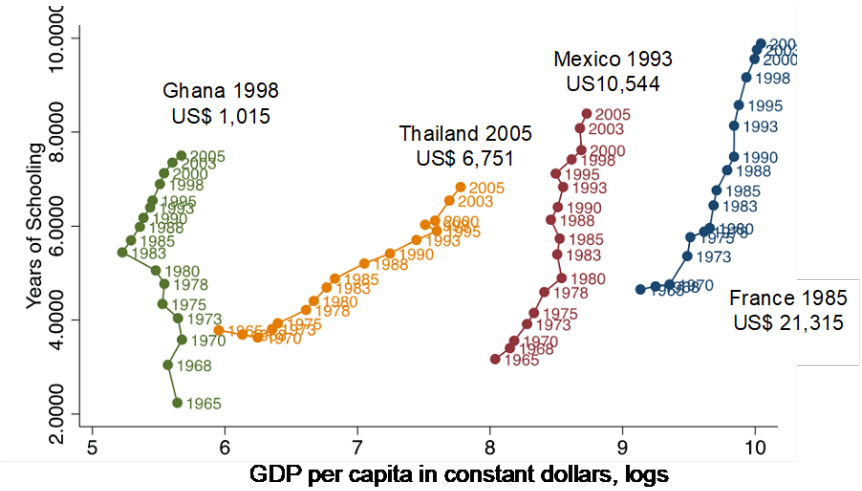
Second, it goes without saying that investing in human capital may carry numerous non-economic or non-monetary benefits. Increasingly, the international development agenda has emphasized and sought to study the impact of investments in human capital on a broad range of life outcomes (United Nations Economic Commission for Europe, 2016). For example, investing in women's schooling is expected to positively influence their own wellbeing and that of their families. Kaffenberger and Pritchett (2020) leverage cross-national data on schooling and assessed literacy to compare the association of child mortality, fertility, women's empowerment with women's literacy (that is, learning resulting from schooling) versus schooling (assuming schooling often doesn't translate into literacy). Not surprisingly, they find the associations to be larger than initially estimated when using schooling levels only – not adjusted for learning. An important implication of this study is that the life or non-monetary impact to schooling as an investment in human capital, depends on the transmission mechanism through which it generates the benefit. The study points towards learning – that is the effectiveness of the investment at generating human capital.

Third, in line with points one and two above, and also with the Growth Diagnostics framework, empirical evidence from developing countries demonstrates that the marginal return to schooling were lower than expected in many countries (Temple, 1999; Pritchett, 2006). Higher levels of schooling did not translate to higher levels of national development or human well-being. Figure 1 compares cross-country schooling levels and income per capita, across four different countries. The data shows convergence in schooling with a divergence in income. While schooling levels in Ghana, Thailand and Mexico were much lower than a more developed country like France in before 1970, these countries (and many other developing countries) witnessed an expansion in schooling after 1970. By 2005, Mexico's level of schooling was similar to France's level of schooling in year 1995. Ghana was not much further behind. Thailand showed the least progress among this group of countries – by 2005 it achieved the 1985 and 2000 level of schooling of France and Ghana respectively. Yet, comparing the countries' per capita income levels shows a massive boom in income

[2] ASER Centre is an autonomous assessment, survey, evaluation and research unit within the Pratham network.

per capita in Thailand, which comes with an improvement in the country's socio-economic indicators. Yet, Ghana's income per capita – and therefore level of development – stagnated.

Figure 1: Years of Schooling Versus Per Capita Income



Source: World Development Indicators

Human Capital as a Binding Constraint to Growth: A Framework

For the purposes of this book, we will adopt different definitions of human capital at the individual and at the country level. *The human capital of an individual refers to the physical and cognitive capabilities, acquired through schooling and training, that allows individuals to increase the productivity of their efforts. Consequently, a country's human capital is the spectrum of skills available through its working age population.* The skills spectrum enables economic activities, adoption of new technologies, and development of new products and services, which are all tightly link to the process of economic growth.

The starting point of a growth diagnostics exercise is a growth model with different distortions leading to two potential problems constraining investments: (1) low expected private returns to asset accumulation or (2) high cost of finance (Hausmann, Klinger and Wagner, 2008). Potential constraints to growth coming from human capital fall under the former: firms might be hesitant to carry out investment as the expected returns are low due to low levels of human capital. As such, the question of whether human capital is a binding constraint to growth refers to whether the skills spectrum *in the country* is adequate and accessible to firms looking to make a return on their investment.

Figure 2 lays out the framework to study the motivating question: do firms have access to adequate skills to invest and generate desired returns? Firms might not be investing either because (1) the stock of skills in the country is inadequate, or (2) they are unable to access available skills due to misallocations, or (3) the cost or risk associated with hiring needed skills is high. Constraints (1) and (2) can be characterized as problems of low social returns on investments because the needed skills are not available in the economy or are not accessible to high-growth potential sectors and firms. That is, firms expect a low return on their investment due to a shortage in needed skills. Low levels of

human capital or inadequate spectrum of skills might hinder returns either because it prevents firms from operating at the frontier of their production possibilities (forcing them to be less efficient), or because they must bid up for scarce skills and that render their returns less competitive when compared to other potential locations.

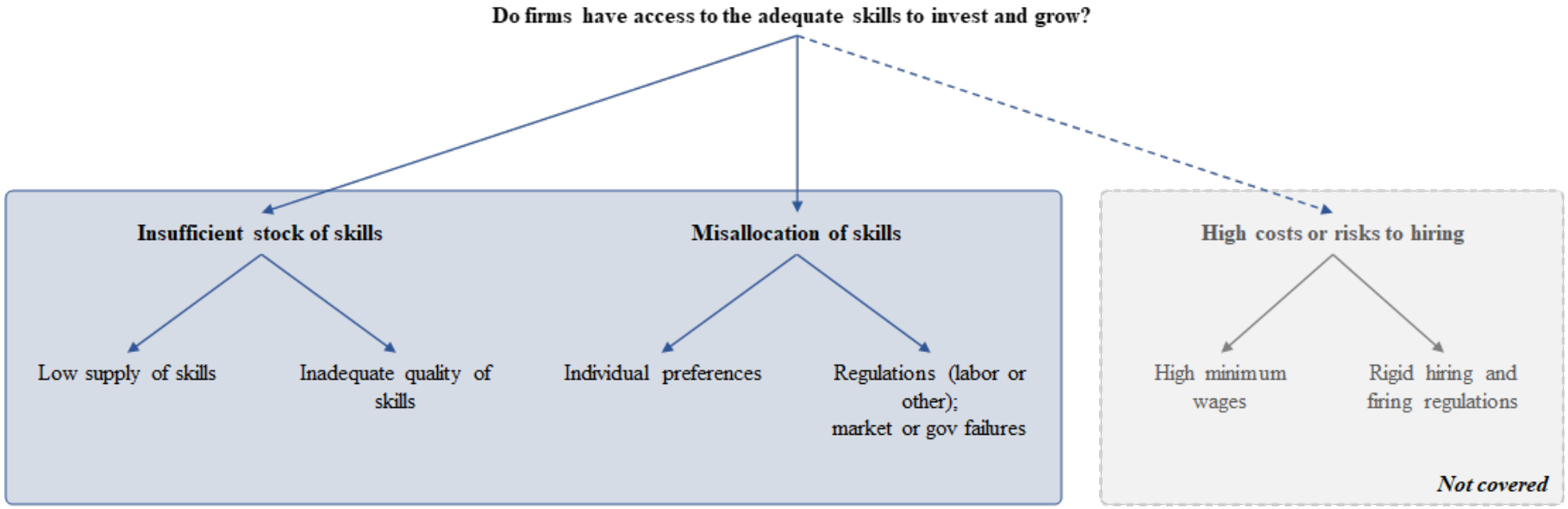
The third potential constraint (3) is a problem of appropriability, where firms' ability to privately appropriate the return to their investment is low due to macroeconomic or microeconomic risks, such as, in the case of human capital, labor market rigidities like binding minimum wage or employment regulations that reduce firms' ability to generate an acceptable return on their investment.

In this book, we focus on the problem of low social return (Constraints 1 and 2) and leave out appropriability problems (Constraint 3), as the latter requires a different set of diagnostic tools and policy strategies to resolve.

We define Constraint (1) – insufficient stock of skills – to be a shortage in the quantity or poor quality of skills supplied to meet existing demand. We define Constraint (2) – misallocation of skills – as a mismatch or limited firm access to available skills. Several country-specific institutions, rules, regulations, or norms can lead to misallocation of skills. For example, cultural norms leading women to work in traditional and culturally "acceptable" occupations or young talent queueing for public sector employment, might deprive high potential sectors from needed skills and possibly hinder human capital accumulation in the country. Other sources of misallocation include labor regulations such as professional licensing rules creating barriers to entry to certain occupations, or outright exclusion of foreign labor from certain occupations that are reserved for nationals. Market failures can also lead to the misallocation of skills across sectors or geographies: here the extensive margin of labor supply constrains investments in potential sectors, and poses as fixed cost preventing the emergence of potential sectors (Blundell, Bozio and Laroque, 2011; Michau, 2011).

Finally, it is necessary to reiterate that under the growth diagnostics framework, the question of whether human capital is the most binding constraint to growth cannot be answered in isolation. A country's skills spectrum exists along with other complementary factors that enable its deployment in economic activities. As such, the conclusion on the binding constraint must be made in relative terms, after diagnosing other complementary factors. Human capital only becomes a binding constraint to growth when it is relatively scarcer than the supply of other complementary factors and capabilities.

Figure 2: Diagnostic tree for human capital constraints



2. Testing for Human Capital as a Binding Constraint to Growth

Hausmann et al. (2008) propose four principles of differential diagnosis to establish whether a factor is a binding constraint to private investment and economic growth. Is the factor's price high, signaling higher relative scarcity? Would a relaxation in the constraint be associated with an increase in private investment and growth? Are firms that rely on the factor more intensively relatively less prevalent than those that do not? Are there firms attempting to bypass the potential constraint? (Table 1). These four signals aim to reveal whether private firms are incurring high costs or facing distortions in securing the supply of a certain production input. This section is devoted to illustrating how to deploy these diagnostic signals to test whether human capital is the binding constraint.

Table 1: The four diagnostic signals

Diagnostic signal: If human capital is a binding constraint to growth	**Description**
The shadow price of human capital should be high; there should be high-wage premiums for skilled workers.	• Actual or implied market prices (wages) of a factor – in our case human capital. • A high shadow price implies that relieving the constraint would have a large impact on private investment.
Changes in the stock of human capital should produce changes in private investment and growth	• If a production input is a binding constraint to investment or growth, relaxing the constraint should be associated to incremental investments or growth
Agents attempting to overcome or bypass skill shortages	• Agents in the economy experience the binding constraint, which is likely delaying their own growth. These agents are likely responding to the constraint through various interventions or investments
Camels and Hippos: Agents less intensive in human capital are more likely to thrive (and vice versa)	• If a factor is binding, sectors more intensively in that factor should be less prevalent or have a relatively lower contribution to exports, value added or employment than sectors that are less intensive in the factor.

Note: Authors' adaptation based on the principles of Hausmann, Klinger and Wagner (2008)

Before we jump into testing the four diagnostic signals, a natural starting point in our quest would be to examine the characteristics of the labor market against comparable countries. A thorough understanding of the demographics, employment trends, schooling, and quality of education would help in framing the results of our empirical tests within the specifics of the country's labor market.

Demographics

It is important to start the growth diagnostic exercise by framing the question of growth and human capital in the larger context of the country under study. A great point to start is portraying the trajectories of growth and human capital: evolution of birth rates, fertility rates, mortality, dependency ratios, and literacy rates. Observing the evolution of these indicators with respect to the income level, and comparing the country's position vis-à-vis its peers, can be informative regarding the relative evolution of the socioeconomic dynamics within the place of interest.

The World Bank's Human Capital Index (World Bank, 2020, *The Human Capital* Index 2020) measures the amount of human capital an individual in a given country can achieve. The index allows a benchmarking comparison of relevant health and education indicators across countries and can be a useful starting point to contextualize the human capital profile of the country of interest.

Employment

Labor market outcomes can help paint an initial picture of the relative supply and demand of skills in the economy. What are the characteristics of those who are employed versus those who are unemployed? How is the labor force distributed across sectors and occupations? These questions help in characterizing the supply of skills and are ideally answered differentiating by education level and considering specific dimensions that are relevant for the particular country (gender, age, citizenship, indigenous origins).

If human capital were a binding constraint due to limited availability of specific skills, one would expect to see the employment levels in that category of skills to be exceptionally high. By contrary, high unemployment may suggest low demand for those skills. Yet, low demand may be due to the low quality of graduates in domestic colleges, hence this signal by itself is not sufficient to dismiss the constraint. Analyzing patterns of employment among immigrant workers might be fertile source of additional evidence. For example, large concentrations of foreigners across high skill jobs coupled with low employment rates or low wages for skilled domestic workers, is a stronger indicator of the inadequacy of the local supply of skills.

If human capital were a binding constraint due to misallocation of skills across sectors, one would expect to see a sharp segmentation of the labor force, with one or more groups concentrated in few sectors, staying out of the labor force or out of specific sectors. For example, it is a common feature in some developing countries that citizens prefer public employment over private employment, either because of job security, social protection, or higher relative wages. Additionally, social norms might restrict women's participation in the labor force to a few sectors seen as "acceptable for women" (Kaasolu, Hausmann, O'Brien, & Santos, 2019). Evidence of segmentation may indicate that obstacles to the employment and further accumulation of human capital as private sectors face shortages in the availability of talent to recruit and develop.

Schooling Quantity and Quality

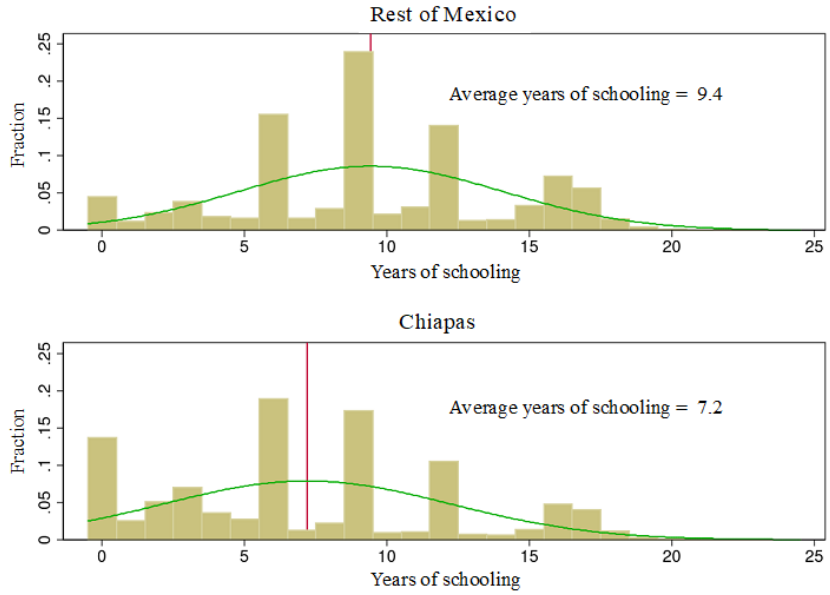
In terms of schooling, one condition for human capital to be a constraint is low supply of skills – relative to demand. The availability of skills can be proxied by a population's years of schooling and by the quality of education. Increasingly, skills measurement surveys are becoming available to assess

particular skills, such as numerical, of working populations (*Comisión Nacional de Productividad | Informe Anual 2016. La productividad en Chile: Una mirada de largo plazo*, no date).

We look at the example of Mexico's poorest state: Chiapas. It is located at the southernmost of Mexico, and is most known for the Zapatista Rebellion, an uprising carried by more than 3,000 indigenous people in the early morning of January 1st, 1994 – on the very same day the North American Free Trade Agreement became effective. Chiapas has the third largest share (27%) of individuals speaking an indigenous language among all Mexican federal entities, after neighboring states Oaxaca (34%) and Yucatan (30%).[3]

If we were to understand whether human capital is the binding constraint to growth in Chiapas, we could start off by displaying the schooling distribution of the labor force in the state vis-a-vis the rest of Mexico. According to the panels shown in Figure 3, the labor force in Chiapas is less educated than in the rest of the country by a significant margin. By 2010, the average Mexican worker had 2.2 more years of schooling than a worker in Chiapas. The breach shows up at different levels of schooling. According to the 2010 Population Census, the share of illiterate people in Chiapas that year was more than twice that in the rest of Mexico (16% vs. 6%); the share of individuals with zero schooling was also more than twice as large (13% vs. 5%); and the population of individuals that have completed secondary schooling was two thirds of the observed share in the rest of Mexico (44% vs. 64%).

Figure 3: Years of Schooling of the Labor Force: Chiapas vs. Rest of Mexico



Source: 2010 Population Census

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[3] These figures come from the 2010 Population Census.

The distribution of the years of schooling does not tell the full story. It is also important to account for the quality of education. The World Bank's Human Capital Index provides a measure of learning-adjusted years of schooling to allow for assessing schooling quality in a given country as well as a cross-country comparison of education outcomes. Also, the World Bank's Education Statistics (EdStates) compiles comprehensive data for analysis of learning outcomes, among many other indicators on education access, expenditure by country, and more (World Bank, *Education Statistics | Learning Outcomes*).

For many countries, the Program for International Student Assessment scores (PISA scores) of the Organization for Economic Cooperation and Development (OECD) are available, providing students' standardized tests scores in the following topics: reading, mathematics, science and other skills (*PISA*). For Latin American countries, UNESCO has conducted educational quality assessments called Second Regional Comparative and Explanatory Study (Valdés *et al.*, 2008) and Third Regional Comparative and Explanatory Study (Pizarro *et al.*, 2016). Additionally, country-specific standardized student assessments may be available, revealing differences at the sub-national level.

Data on educational assessments are useful to adjust for differences in the quality of schooling across countries and subnational regions but should be interpreted with care. First, there may be implicit biases stemming from the way in which the tests have been deployed, whether they cover rural and poorer communities, which may be prone to suffer from lower quality of education. Second, recent assessments only reflect the current quality of education rather than the quality of education received by the current labor force. Third, test results are endogenous to several household characteristics, such as household income or the level of schooling of the head of household.

Going back to our Chiapas example, the Ministry of Education of Mexico runs the National Evaluation of Academic Achievement in School Establishments (ENLACE),[4] a standardized test held for all public and private schools at all pre-college levels measuring Math and Spanish language proficiency. [5] ENLACE test scores can be used to factor in the analysis differences in the quality of schooling, after correcting for the impact of some household characteristics that might be endogenous to the test results. In the case of Chiapas, quality results at the municipal level can be regressed against maximum level of schooling in household (other than the student), household income, and ethnicity. We then use the residuals between the actual test scores and test scores predicted based on the observed variables as our net indicator of education quality. The result is a corrected quality indicator that nets out the correlations between quality and a group of relevant variables.[6]

The results of both the unconditional and conditional performance for all Mexican states are presented – for Spanish and Mathematics – in Figure 4. Differences between the quality of education as measured by the conditional or unconditional test indicator do not alter the existing skill spectrum of a particular place – poor results signal potential skill shortages, regardless of the origin – but they are relevant to the type of policy intervention that is needed to address the constraint. Chiapas' relative positioning in Spanish (Panel a) does not change much between the unconditional (fourth from bottom) and conditional (third from bottom). When it comes to Mathematics (Panel b) the picture is somewhat different, as the state ranks third from bottom in the unconditional figure (just above

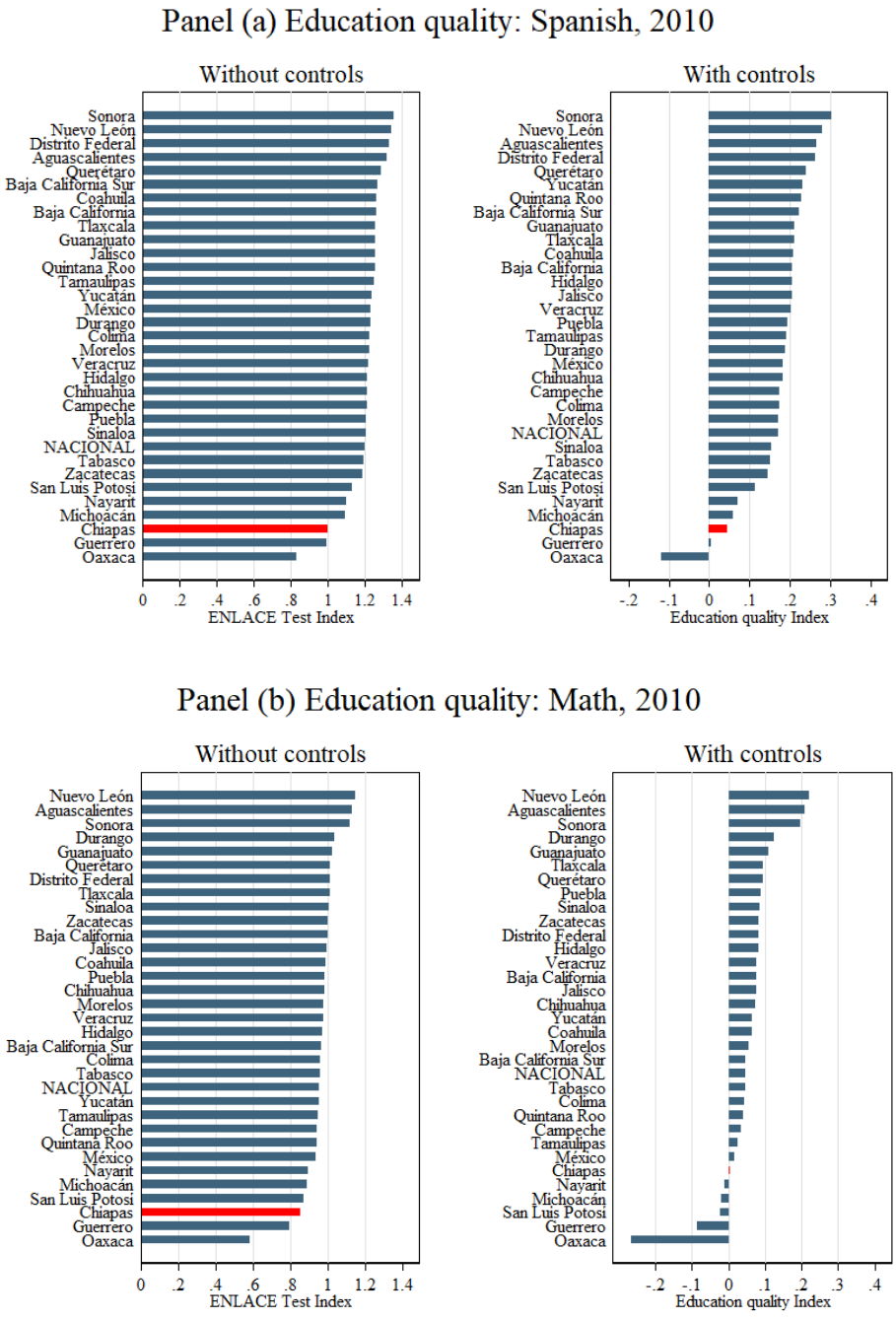
[4] ENLACE is the Spanish acronym for *Evaluación Nacional de Logros Académicos en Centros Escolares.*

[5] Levels of schooling covered by the ENLACE test: primary (the last four grades), secondary (the three grades) and media-superior (last grade).

[6] See Appendix 2 for estimating the quality of schooling.

Oaxaca and Guerrero, two Mexican states with significant indigenous population) but registers a moderate improvement when we control for relevant household characteristics (sixth from bottom).

Figure 4: ENLACE Assessment of Educational Quality by State



Source: Minister of Education (ENLACE), and Population Census (2010)

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Low levels of schooling and learning may signal potential constraints in human capital but are far from sufficient. As it turns out, these results might also be driven by low demand of skills, which in turn reduces the incentives of individuals to invest in education. The key lies in having a robust analytical framework that allow us to tell these two situations apart.

2.1 The Shadow Price of Human Capital Should Be High

If an input is relatively scarcer than others, agents should be willing to pay a premium for it. That is the premise of the first principle of differential diagnosis. The labor force contributes varying levels of skills to the transformative process of producing goods and services. Additionally, among high skilled labor, vast specializations exist at different relative prices. If one or more skills are a binding constraint to growth, the price differentials of these skills shall reflect their relative scarcity and be priced at a premium.

How can an analyst observe the skill premium? The main challenge in the deployment of this principle is the determination of the factor's price. Sometimes production factors have observable market prices, such as the real interest rate in the case of financing, or electricity tariffs in the case of the power sector. Yet, even considering these same factors there are times when market distortions – credit rationing or interest rate ceilings in the case of finance; subsidized tariffs or power outages in the case of electricity – result in observed prices that are meaningless from an economic standpoint, as they do not reflect real relative scarcities. These distortions open a wedge between observed factor prices and the real cost of sourcing these factors for businesses. In those cases, we shall resort to shadow prices, which are estimated prices for factors for which no relevant market price exists.

To assess the relative scarcity of human capital in a specific place we need to rely on shadow prices: The information required to arrive at the price businesses are willing to pay for skills is not readily available in most cases and requires some statistical processing.

Mincer Regressions

The method most widely used in economics to estimate the shadow price of skills are Mincer regressions (Mincer, 1958). The typical Mincer regression estimates the monetary returns associated to an additional year of schooling, by modeling employment earnings as a function of years of schooling and experience.

$$Log\_income_i = \alpha + \beta_1 * years\ of\ schooling_i + \beta_2 * years\ of\ experience_i + \mu_i$$

By representing the individual's income derived from work in logarithms, Mincer regressions provide an easy interpretation of the coefficient of interest β_1: percentage increase in wages associated to an additional year of schooling. The model is flexible, allowing researchers to include other variables that might have a significant influence in wages in particular contexts, such as gender, ethnic origins, or foreign workers. It also allows to measure the impact of different levels of education, by substituting years of schooling for discrete levels of completion such as primary, secondary, and tertiary education. Although Mincer regressions are mostly used to measure private returns to schooling and guide individual decisions on how much to invest in human capital, they also provide evidence on the relative scarcity of talent at different levels of schooling, experience, occupation, and other segments of the labor market.

Previous research based on Mincer regression reports that the distribution of Mincer returns tends to be centered around an average ranging between 5% to 8% per year of schooling, with fat tails ranging

from 1% to 20%. The highest returns to schooling are reported for women in sub-Saharan Africa (15%), whereas the lowest are for men in the Middle East and North Africa (at 6%). At a worldwide level, the highest returns accrue to tertiary education, followed by primary and then secondary schooling (Patrinos, 2016; Psacharopoulos and Patrinos, 2018).

Mincer regressions have their limitations, which have become more salient as rapid technological progress underscores the difference between actual skills and schooling (Heckman, Lochner and Todd, 2003). The result of a Mincer regression is an average marginal rate of return for each additional year of schooling, yet the rate of return most likely varies in a non-linear fashion as the number of years of schooling increase, and potentially decreases over the working lifecycle. Also, the model does not differentiate the quality or relevance of work experience, as the latter is usually defined as age minus years of schooling minus six (the typical school starting age). Mincer regressions only consider opportunity cost of foregone wages. They do not account for taxes or benefits – which vary significantly by level of wages – or tuition costs. Despite that, they continue to serve as a good initial estimate of the return on schooling.

Modeling Mincer regressions normally requires hourly wage data. In many cases, particularly in developing countries, population census and labor force surveys report annual or monthly wages. Estimates of the returns to schooling using monthly or annual data can potentially be a better estimate of returns, as individuals with higher levels of schooling tend to work more hours for their wage (Card, 1999).

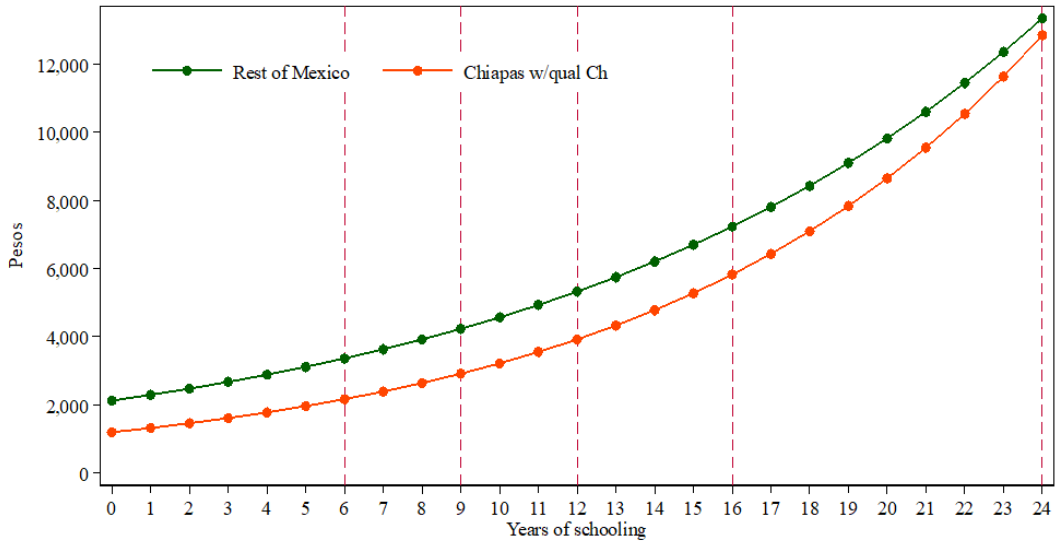
For a Mincer regression, we also need datasets at the worker level with wages, years of schooling, gender, date and place of birth. If you are interested in testing if the skills of internal (within country) or external migrants are priced at a premium or at a discount, an additional field on place of work (to contrast with place of birth) will be needed. Typically, this information can be found in population or economic censuses or labor force surveys. In most countries, these surveys include additional information that allow for controlling for observed individual characteristics (gender, ethnicity, native language), work-specific characteristics (occupation, economic sector), and place-specific characteristics (urban or rural setting, indicators of knowhow agglomeration).

Figure 5 portrays an example of the output of a Mincer regression to estimate the differential level of wages associated to different years of schooling in Mexico and the state Chiapas (Mexico's poorest state).[7] In estimating Mexico's Mincer coefficient, we can also control for place of origin, gender and indigenous language (as a proxy for ethnic origins).[8] [9] In order to estimate the average change in monthly wage associated to each year of schooling, the authors used the averages of each regressors per each particular year.

For all levels of education, the wages of Mexican workers are significantly higher than those in Chiapas. On average, Chiapas' workers make 35.8% less than workers elsewhere in Mexico with the same level of schooling, experience, gender, and ethnic origin. An alternative reading of Figure 5 is that workers in Chiapas need twelve years of schooling to earn the same wage of workers elsewhere in Mexico with an average of six years of schooling.

[7] The data comes from the 10% microdata sample of the 2010 Population Census carried out by the National Institute of Statistics and Geography of Mexico (INEGI).
[8] See the specification and complete output of the Mincer regression in Appendix 1
[9] Hausmann, Pietrobelli and Santos (2021)

Figure 5: Returns to schooling in Chiapas versus the rest of Mexico.



Source: 10% Microdata sample of 2010 Population Census, National Institute of Statistics and Geography (INEGI).

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One potential explanation behind different returns to schooling are differences in the quality of education. Based on the results reported by ENLACE and the correction for households' characteristics mentioned before, it is possible to reproduce the schedule of expected value of wages by level of education portrayed in Figure 5, by attributing to Chiapas' workers the average quality of education at each level of schooling in the rest of Mexico. The results are reported in Figure 6.

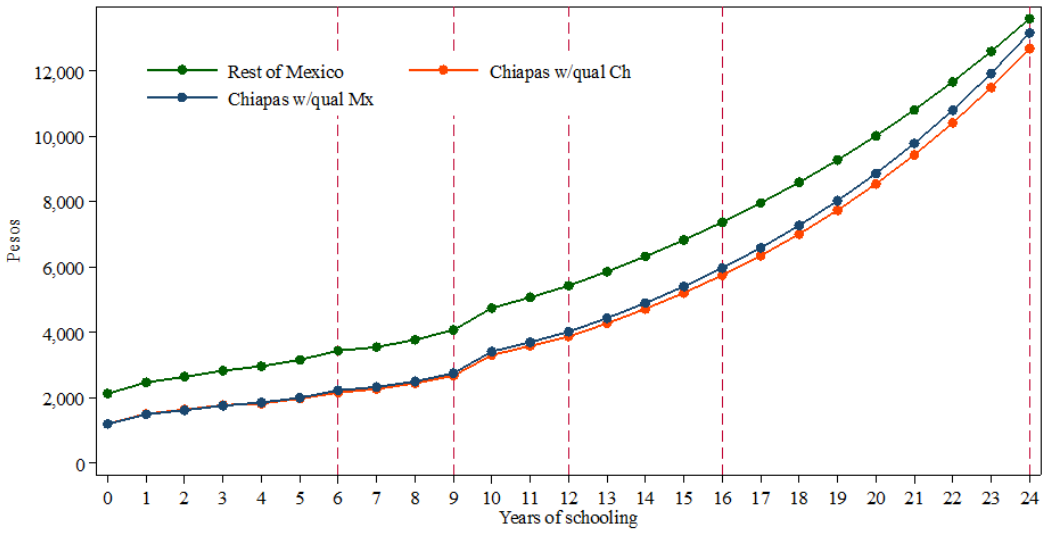
These results suggest that the difference in the quality of education between Chiapas and the rest of Mexico does not explain the large differences in wages at each level of schooling. Even after assigning to workers in Chiapas Mexico's average quality of education, the expected wage at each schooling level (the blue line in Figure 6) is still below the rest of Mexico (green) for workers with similar schooling, experience, gender, and indigenous origins.[10]

Mincer returns may provide additional insights when contrasted with unemployment figures. Low returns on tertiary schooling in the context of high unemployment of individuals with college degrees may signal excess supply of skills relative to demand. Alternatively, a high return to tertiary schooling when unemployment among college degree holders is low points towards an insufficient supply of skills in the economy. Similarly, high returns on tertiary schooling coupled with high unemployment among individuals with no college degree signals there is demand for high skills and firms' willingness to pay for them, but also points out to a potential bottleneck preventing individuals from pursuing higher levels of education. Finally, high returns to tertiary schooling when unemployment among college degree holders is high may signal problems of quality of skills available (including

[10] Appendix 2 explains the methodology behind the estimation portrayed in Figure 6. Quality differences between Chiapas and the rest of Mexico at high school level were assumed for college and above.

quality of schooling or training) or misallocation of labor. Further analysis would be required to identify earners of the wage premium.

Figure 6: Differences in the quality of schooling between Chiapas and the rest of Mexico



Source: 10% Microdata sample of 2010 Population Census, National Institute of Statistics and Geography (INEGI).

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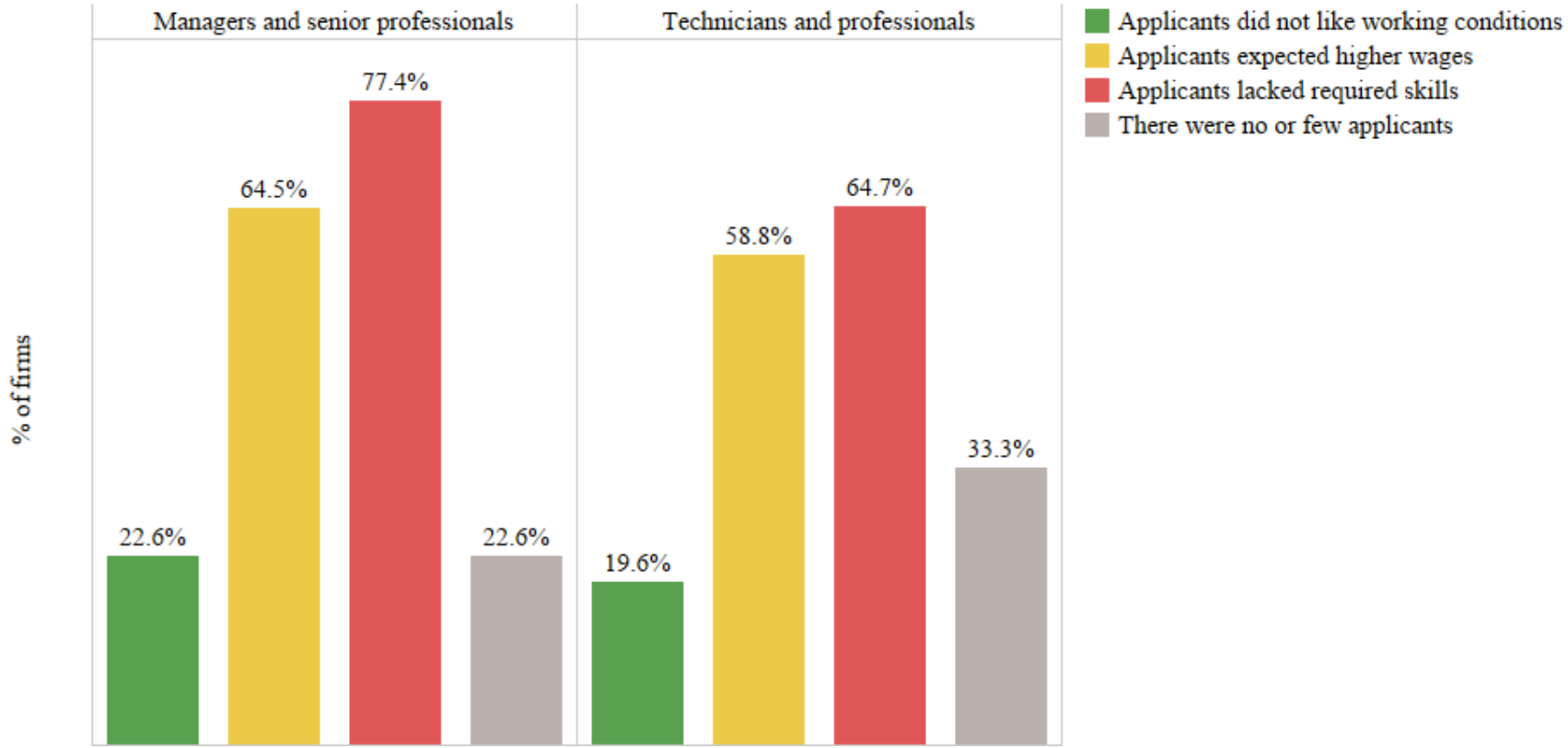
In the cases where there is not microdata available to estimate returns to schooling it is difficult to ascertain whether there is a premium on skills or not. Yet, the analyst can observe the cost of labor through a variety of sources, which coupled with direct interviews with companies across the most relevant economic sectors can provide an initial assessment on the relative scarcity of skills. For example, ILOSTAT reports the hourly cost of labor for 58 countries by economic activity.[11] Additionally, UNIDO compiles datasets on the manufacturing sector at a four-digit level in several countries, reporting sectoral output, wage bill and number of employees, among other variables.

The World Bank's Enterprise Survey may offer further insights into the scarcity of skills. We explore the experience of business establishments in Indonesia trying to hire employees across the skills spectrum, as reported by the 2015 Enterprise Survey. Figure 7 summarizes firms' responses when asked about obstacles to hiring (1) managers and senior staff, and (2) professionals and technicians. As portrayed by the red bar in both panels, 77.4% of establishments that tried to hire managers and senior professionals cited difficulty doing so due to the lack of the right skills; 64.7% for hiring high skill technicians and professionals. This provides suggestive evidence that the supply of managerial and technical skills might be inadequate in Indonesia.

[11] Unfortunately, their database does not include low-income countries.

Figure 7: Main obstacles to hiring that face Indonesian firms [12]



Source: World Bank, Indonesia Enterprise Survey (2015)

[12] Percentages do not add to 100% because respondents can choose multiple obstacles.

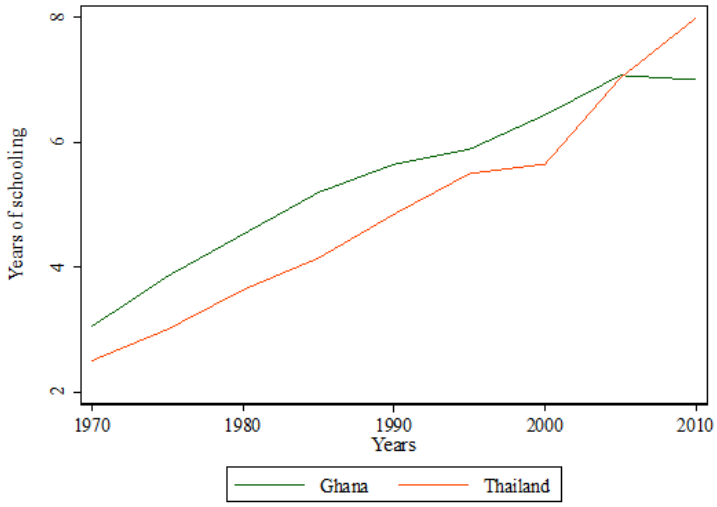
2.2 Movements in the Level of Human Capital Should Be Associated with Movements in Private Investment and Growth

If a factor is a binding constraint, improving its provision should lead to significant improvements in the objective function. More specifically, if human capital is constraining private investment, an increase in the availability of qualified labor should be accompanied by increased investments and growth (and vice versa).

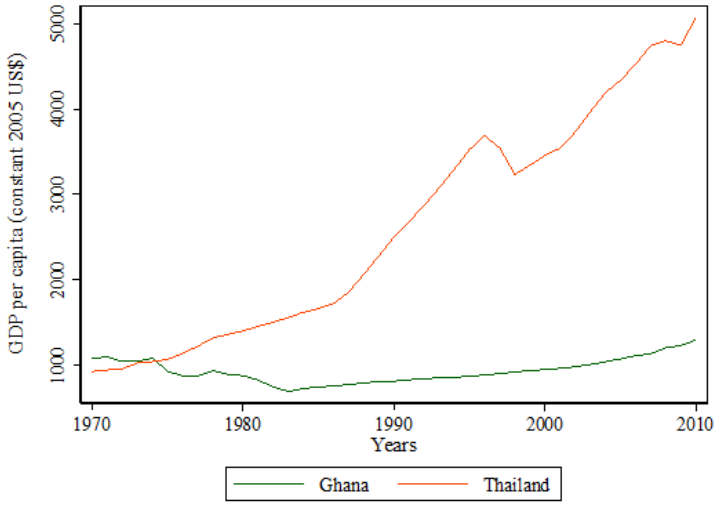
Consider the contrasting cases of Ghana and Thailand. With the international drive to promote schooling, both countries embarked on large-scale programs to increase access to education, which led to the significant progress reported in the Panel a of Figure 8. As a matter of fact, Ghana was more successful, reversing the levels observed around 1965 and duplicating the average years of schooling of its workforce by 2010.

Figure 8. Thailand and Ghana: Aggregate years of schooling

(a)



(b)



Source: Education Statistics (World Bank)

As reported in the Panel b of Figure 8, the large increase in schooling in Ghana was not accompanied by a corresponding increase in GDP per capita, which stagnated over the following decades. In this case, it is hard to argue that lack of schooling or poor human capital were the most binding constraints to growth in Ghana. On the other hand, the somewhat slower – still impressive – improvement in schooling in Thailand was accompanied by a significant growth acceleration, particularly after 1990. That provides initial indication that human capital might have been constraining economic growth in Thailand. As the constraint improved, there was an associated payoff in terms of investment and growth.

As persuasive as the panels in Figure 8 might be, they must be interpreted with care. After all, when an economy experiences a growth acceleration there are usually multiple factors changing at the same time. This is particularly relevant when testing for human capital as a constraint, as changes tend to occur with a significant lag. Policies aimed at expanding access to education manifest in higher average years of schooling or higher quality of education in the labor force one or two decades down the road.

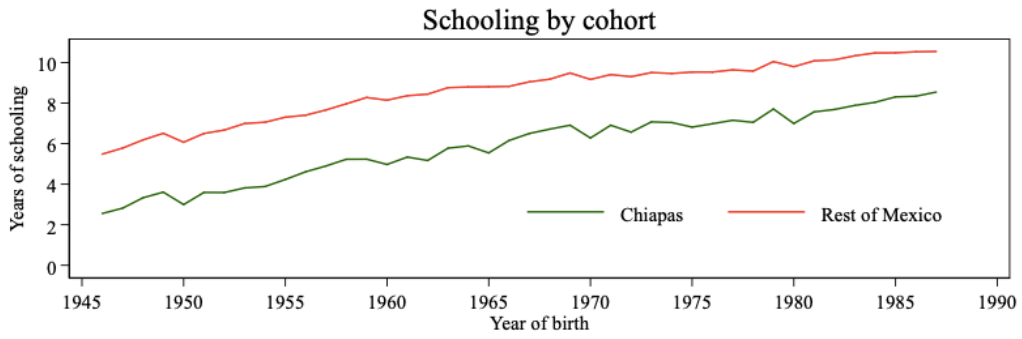
In the case of Thailand, the significant growth acceleration from 1990 onwards is associated with a massive inflow of Japanese foreign direct investment (FDI) and knowhow. At a critical time when Japanese firms were looking for countries with lower wages to build their plants, Thailand aggressively opened its economy and attracted a large number of these "flying geese" (Bernard and Ravenhill, 1995; Kojima, 2000; Kasahara, 2004). The improvement in schooling surely contributed to the readiness of the workforce, but the growth acceleration might not have occurred in the absence of the Japanese FDI boom.

Another interesting example from a sub-national context is again that of Chiapas. Over the twenty years following the Zapatista Rebellion (1994), the federal government devoted significant attention and resources to the region, in an effort to address the large income gaps and prevent further social unrest (Hausmann, Pietrobelli & Santos, 2021). One of the targets of public investment was reducing the schooling gap between Chiapas and the rest of Mexico. Figure 9 shows the schooling gap declined steadily, going from 3.2 years on average for the cohort born in 1965 to 2.2 years for those born in 1987.

And yet, the increase in schooling in Chiapas was not accompanied by a growth acceleration. In the twenty years between the Population Censuses of 1990 and 2010, the productivity gap between Chiapas' workers – as proxied by wages – and workers in the rest of Mexico widened. Figure 10 portrays the wages on the three most important sectors in the Chiapas' economy – representing on average two thirds of all economic activity throughout the period – as a share of the average of workers in the rest of Mexico. In parallel to the rapid reduction in the schooling gap, relative wages in Chiapas fell 35% in Agriculture, 20% in Wholesale and Retail, and 18% in Manufacturing. This evolution provides suggestive evidence that human capital was not the main driver behind the large income gaps observed between Chiapas and the rest of Mexico.

In addition to improvements in schooling outcomes, other interventions that can lead to changes in the availability of human capital in a country include changes to immigration policies, the adoption of national skilling or sectoral training programs, or new policies that aim to boost the employability of the workforce, such as wage subsidies. Therefore, an analysis of the impact of such interventions on sectoral- or economy-wide investment and growth can demonstrate whether "adding" skills to the economy translate to demand for these skills. This in turn informs the question posed by this signal.

Figure 9: Schooling gap between Chiapas and rest of Mexico by year of birth



Source: 2010 Population Census (INEGI)

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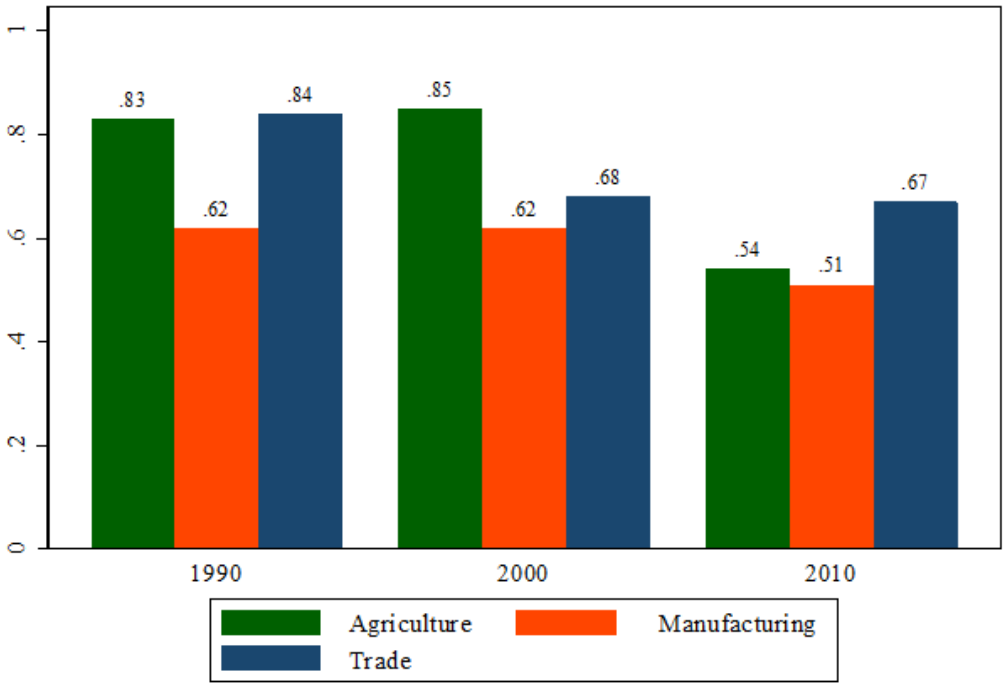
Figure 10: Relative Wages by Sector: Chiapas vs. Rest of Mexico



Source: Mexican Population Census

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2.3 Agents Attempting to Overcome or Bypass Skill Shortages

When searching for potential binding constraints, it is important to remember that private companies must be aware of the distortions holding them back and are likely working to overcome them. In the case of human capital, the efforts of agents attempting to bypass the constraint might be observed through several practices. For example, firms may be investing in resources or programs that allow them to increase access to skills; or they may be investing in training or retraining employees. How do their investments compare to country peers? Are firms attempting to hire skills outside the country? What about labor mobility between firms within the same sector? Is employee flight (between firms) prevalent among skill intensive sectors?

Enterprise Surveys: Obstacles Faced by Firms and Their Actions

It is possible to assess the extent to which skill shortages are constraining a country's growth prospects by analyzing the evolution of business practices coupled with the evolution of firms' complaints regarding production inputs. In doing so, it is useful to analyze both firms' indications of major obstacles to doing business, as well as the effort or cost or investments undertaken by firms to address the factor. Enterprise surveys are a useful source for this data.

Consider the case of Ecuador portrayed in Figure 11. The horizontal axis plots the share of firms offering formal training to their workers, whereas the vertical axis plots the share of firms that consider *Inadequately Educated Workforce* as one of the major obstacles in Ecuador. Green dots represent all countries worldwide for which the data required for both axes are available; orange dots represent a group of Ecuador's benchmark countries. Blue dots allow to assess the evolution of the relative positioning of Ecuador along these axes for available Enterprise Surveys (*Enterprise Surveys Indicators Data*).

According to Figure 11, by 2017, 74% of firms in Ecuador offered formal training to their workers. This is the third highest percentage in the world and the highest percentage among Latin American peers. Moreover, the number of firms offering formal training has increased steadily since 2006, a potential indicator that businesses are facing obstacles in finding the skills they need in the market, and therefore are forced to invest in employee training.

Is this sufficient evidence to identify human capital as a potential constraint? The relative positioning of Ecuador along the vertical axis indicates that less than 5% of the firms surveyed consider *Inadequately Educated Workforce* as a major obstacle in Ecuador. This percentage is the lowest among Latin American peers. If we use business complaints as the shadow price of a potentially inadequately trained workforce, we can conclude that there may be other more important obstacles constraining productivity and growth in Ecuador.

Now consider the case of Chile (Figure 12). Despite having a lower number of firms offering formal training (58%), by 2010 22% of the business surveyed considered *Inadequately Educated Workforce* to be their number one obstacle. This is the highest percentage among Latin American peers – twice the share of the first runner-up – suggesting businesses incur significant costs (shadow price) to secure the skills they need. As a matter of fact, together with Labor Regulations (24%), these are the two most significant hurdles identified by firms surveyed in Chile.[13]

[13] Data for at least one of these indicators is not available for Chile in the 2017 Enterprise Survey.

The analysis described above can be used to assess whether human capital is a potential constraint to firms of different types: based on size (small, medium or large), sector (manufacturing or services), origin of capital (domestic or foreign), and tradability of output (exporting or non-exporting).

Figure 11: Ecuador: Firms offering formal training versus labor force inadequacy.

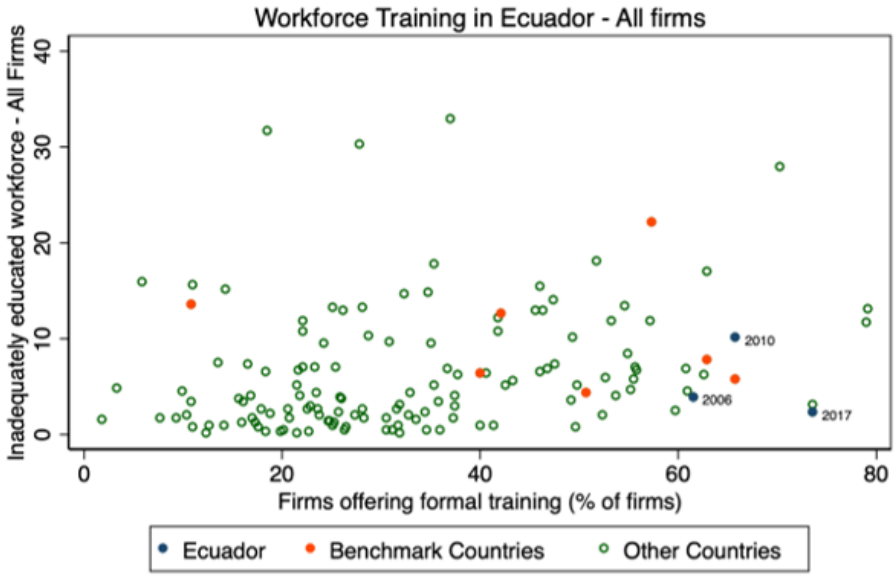


Figure 12: Chile: Firms offering formal training versus labor force inadequacy.

Migrant Wage Premia

Firms may also attempt to bypass skill shortages by importing labor – a dynamic of which Panama is a prime example. Between 2005 and 2015 Panama earned its place amongst the top-ten fastest

growing economies in the world. Contrary to the patterns observed in most developing countries, the export-led boom relied exclusively on services. Exports of transportation and logistics, business services, and travel receipts coming from the air hub at Tocumen Airport quadrupled, paving the way for Panama to double its income per capita within a decade (Hausmann, Obach and Santos, 2016).

Service sectors are skill intensive. In order to increase the supply of skills the Panama relied on two policy devices. First, in 2006 Congress passed Law 41, a bill granting companies that establish their headquarters in Panama a complete tax holiday and various regulatory benefits, including unrestricted work visas for their employees. One year later a massive industrial park –Panama Pacific– was created on the premises of a former USA military base. Within that special economic zone, firms got certain tax benefits, including an allowance to hire foreign workers beyond the 10% cap imposed by Panama's labor regulation. Ten years down the road, 117 multinational companies had established their headquarters in Panama, and 251 firms had joined Panama Pacific. These policies eased the supply of know-how required by high-skill tradable services to flourish. The ensuing growth acceleration suggest that human capital might have been the most binding constraint to investment and growth in Panama in the early 2000s, but ten years of rapid growth seem to have dried out talent once again, in particular for firms operating outside the special economic zones.

Figure 13 describes the premiums earned by foreign workers when compared with Panamanians, as estimated by a Mincer regression controlling for schooling, years of experience, gender, ethnicity, occupation (left panel) and industry (right panel).[14] According to the latest Population Census, by 2010 foreign workers earned on average a wage premium of 47% over comparable Panamanians. All premiums to foreign workers were positive and statistically significant across the spectrum of industries and occupations. Within industries, the highest wage premium for foreigners (72%) was recorded by one of the industries that led the growth acceleration: Transportation and storage. Within professions, foreign Managers earned a premium of 70% over similar Panamanians; 54% in the case of Professionals, scientists and intellectuals, and 54% for Services and sales workers. [15]

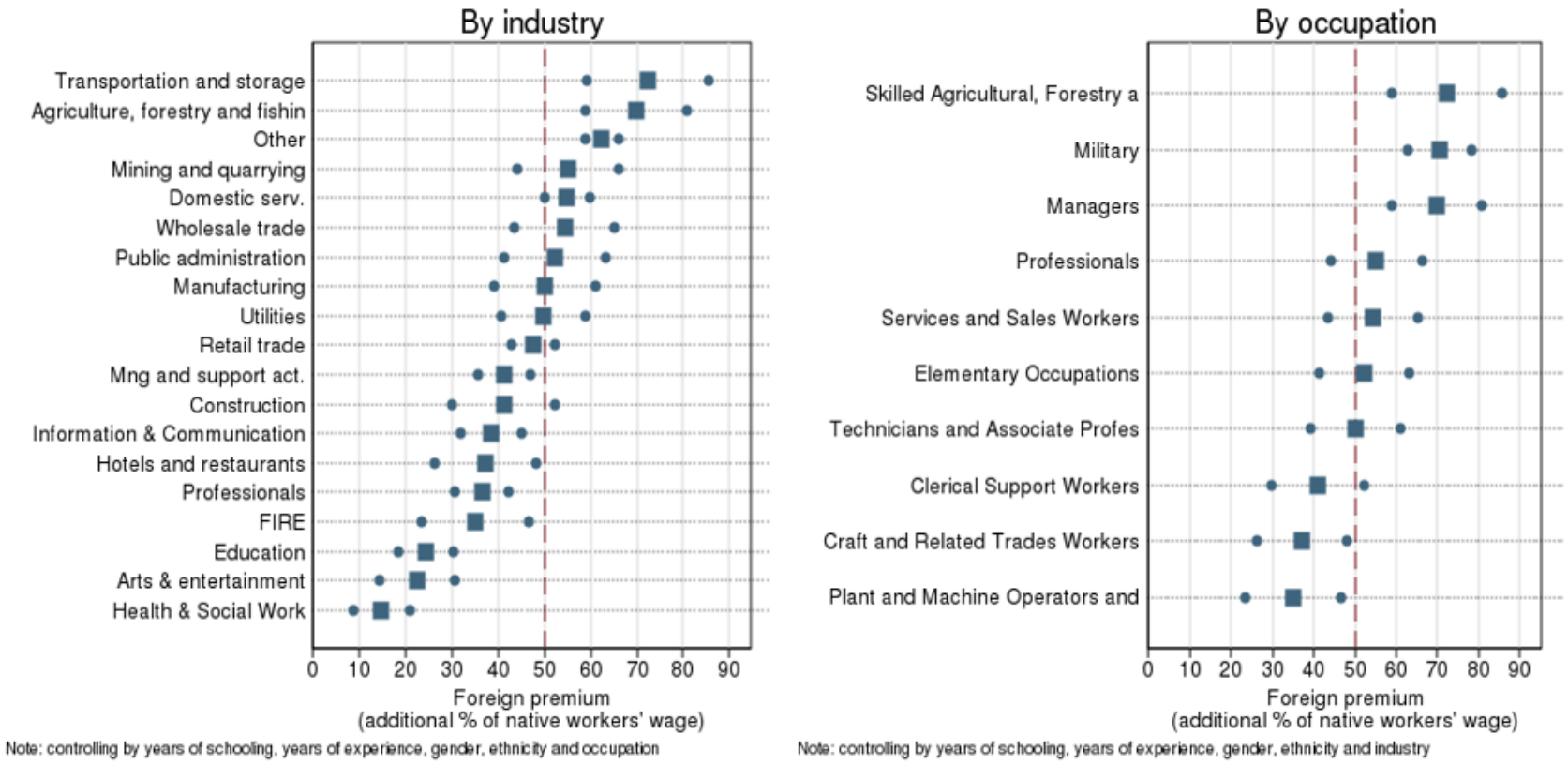
A few insights can be derived from Figure 13. First, businesses in Panama overcame skill shortages and human capital constraints by hiring foreign talent. Second, while lifting restrictions to foreign workers relaxed the constraint and enabled a rapid growth acceleration in Panama, there is significant evidence indicating that by 2010 skills brought by foreign workers were again in short supply and business were willing to pay dearly for them. Most businesses in Panama complained about the high turnover rates driven by aggressive competition for the available talent (Hausmann, Obach and Santos, 2016). That same year (2010), the share of businesses in Panama identifying the need to invest in *Retraining Workforce* came only second (to Corruption) in the World Bank Enterprise Survey.

These results suggest that foreign workers brought skills that were not available in the Panamanian economy, and therefore came to complement those supplied by domestic workers. Otherwise, it would be very hard to explain why businesses in tradable sectors would be willing to pay such high premiums for foreign talent. Yet, the case of Panama – positive and statistically significant wage premiums for foreigners across all industries and occupations – is very unique.

[14] Wage premiums are estimated by a Mincer regression controlling for education, experience, gender, ethnicity; with occupation (left panel) and industry fixed effects (right panel). Estimates and 95% confidence interval are shown. See Appendix 3 for a more detailed description of the specification used.

[15] This result holds even when comparing only people with university education (foreigners earn 31% more).

Figure 13: Panama: Foreign Wage Premium by Industry and Occupation



Source: Population Census 2010 (INEC)

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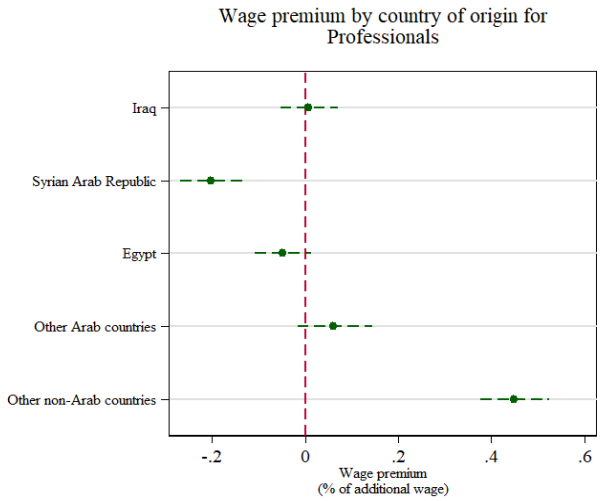
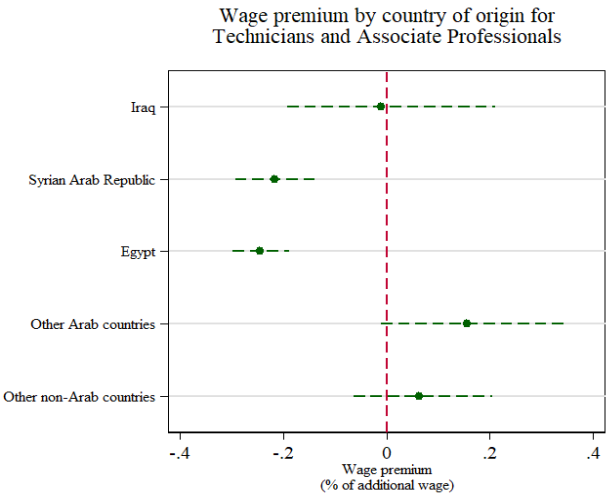
Consider now the case of Jordan, which witnessed a massive wave of refugee influx following the Syrian Civil war (2011) and Arab Spring more broadly, resulting in a population increase of 50% between 2008 and 2017. Immigrants brought a varied array of skills, which were highly segmented by the country of origin. Within that context, an analysis of wage premiums to migrants from different countries by occupation provides a more nuanced understanding on the substitutability or complementarity of foreigners and their impact on the labor supply. Figure 14 portrays an estimation of wage premiums earned by foreign Professionals (Panel a) and Technicians and Associate Professionals (Panel b) by country of origin (Hausmann *et al.*, 2019).[16]

Figure 14: Jordan: Wage premiums to foreigners, selected occupations (2016)

(a)



(b)



Source: CID calculations based on Harmonized Labor Force Surveys (HLFS 2016) (OAMDI, 2017)

[16] Wage premia are calculated through a Mincer regression that controls for education, experience, gender, and industry fixed effects. Estimate and 95% confidence interval are shown.

For Professionals (Panel a), Syrian immigrants earned significantly lower wages than their Jordanian counterparts. That feature is in stark contrast with immigrants coming from non-Arab countries, for whom the wage premiums were positive, significant and large. These results suggest that non-Arab professionals brought valuable skills that were scarce within the Jordanian labor market, and therefore businesses were willing to pay a premium for them. When it comes to Technicians and Associate Professionals (Panel b), non-Arab immigrants do not seem to earn significantly more or less than their Jordanian counterparts, but there is a large positive wage premium for Arabs coming from other countries. This pattern suggests that some immigrants provide unique know-how and skills that complements that of Jordanian workers.

Firms might attempt to overcome human capital constraints by investing large sums in retraining workers or bringing in foreign labor with the knowhow that are scarce in the domestic market. In this situation, restrictions to hire foreign workers with skills that are complementary to those of domestic workers usually results in business competing for talent and driving wage premiums upwards, which in turn might discourage further investment and affect the competitiveness of companies operating in tradable industries.[17]

2.4 Camels and Hippos: Agents Less Intensive in Human Capital are More Likely to Thrive (and vice versa)

The premise of the fourth test is that the business footprint of an economy –what is present and what is not– is informative of its most binding constraints. It relies on a metaphor first introduced by Hausmann, Klinger and Wagner (2008): What we observe in a place is indicative of what factors are in relative abundance and which ones are relatively scarcer. More specifically, the fact that the animals we tend to observe and thrive in a desert are not intensive in water (such as camels) and that others that are absent tend to be more water intensive (such as hippos), suggests that the supply of water might be a binding constraint in those places.

If a factor is binding, firms in sectors that rely on that factor more intensely are expected to be relatively less prevalent in the economy. At the same time, firms that are less intensive in the use of this factor are expected to thrive. Another way to think about this principle is that, if a factor is binding, we would expect to see firms moving away from industries or products that rely more on the factor as an input to production, towards industries or products that are less dependent on that particular factor. In the case where human capital is a binding constraint, we expect to see firms moving away from skill-intensive industries – that is, sophisticated industries that require more skills – towards capital-intensive industries.

Nunn (2007) offers a method to test if a country's exports are dependent on country-specific factors. Although this contribution was originally aimed at assessing the impacts of contract intensiveness on exports, we can use the same principles to test the marginal impact of country-specific factors on economic activity. To quantify these impacts, Nunn (2007) models a country's exports by sector as

[17] The regressions estimating these premia are imperfect. Despite controlling for observed traits, there will likely remain unobserved traits that partially explain wage premia. As such, it is crucial to complement these analyses with interviews with businesses in sectors registering the more extreme premiums.

an interaction between the country's characteristics or factors and the sector's dependency on these factors. For example, a sector that is skill-intensive in a country with an adequate skills supply will contribute relatively more to the country's exports. Alternatively, a sector that is skill-intensive in a country with a skills shortage will contribute relatively less to the country's exports.

South Africa stands in a showcase for this test. For decades, apartheid excluded and impoverished Black South Africans, restricting them to second-class education while at the same time subsidizing the use of capital. As a result, the only employment options for most Black South Africans were located far from urban centers, either in unskilled agriculture or mining (Levinsohn, 2008).

Since the transition in 1994, South Africa has replaced the old system of parliamentary sovereignty by a constitutional democracy and bestowed political rights upon Black South Africans. However, reversing the legacy of economic exclusion has proven a much harder task (Hanusch, World Bank, 2018). Twenty-five years later, the unemployment rate in South Africa reached 28% (2019), with youth unemployment at twice that rate (56%). Additionally, unemployment has been persistent and pervasive among less skilled and less experienced workers, while wage and employment growth for skilled workers have increased. This begs the question of whether human capital is a binding constraint to private investments and subsequently growth in South Africa, particularly given the historic exclusion and its legacy weighing down on the employability of its large Black majority. To answer this question, we examine the skill intensity of South Africa's exporting firms. Figure 15 provides an initial illustration of the relationship between South Africa's exports and skill intensity (top panel) and capital intensity (bottom panel). The downward [upward] trend between an industry's exports volume and skill [capital] intensity suggests that higher exports are associated with lower skill [higher capital] intensity.

We adapt Nunn's (2007) method to model the relationship between a country's exports and its industries' dependence on factors.[18] A positive relationship between industries' dependence on skills and the country's exports suggests that industries intensive in human capital are thriving and contribute more to the country's exports. On the other hand, a negative relationship between exports and industries' skill dependence variable indicates that industries intensive in the factor under study contribute less to country exports, and hence may be struggling to grow.

To perform this analysis, a country's cross-sectional economic sector (or product) level data on trade flows needs to be merged with the country's factor endowment (at least human capital and physical capital, but also other factors of interest for the study), and data on factor intensity by economic sector. Data on a country's factor endowment is often published – common sources include Hall & Jones (1999), Antweiler & Trefler (2002).[19] The World Bank's human capital index (Angrist, Djankov, Goldberg & Patrinos 2019) measuring learning outcomes can be useful to adjust human capital endowment measures, which are normally based on years of schooling. The most recent version of the Penn World Tables also has a human capital index. Data on industries' physical and human capital intensity are published by Bartelsman & Gray (1996); Nunn (2007) and Rajan & Zingales (1998) published sectoral contract-intensity and financial-intensity measures, respectively. Sectoral intensity in other factors of interest may need to be constructed.

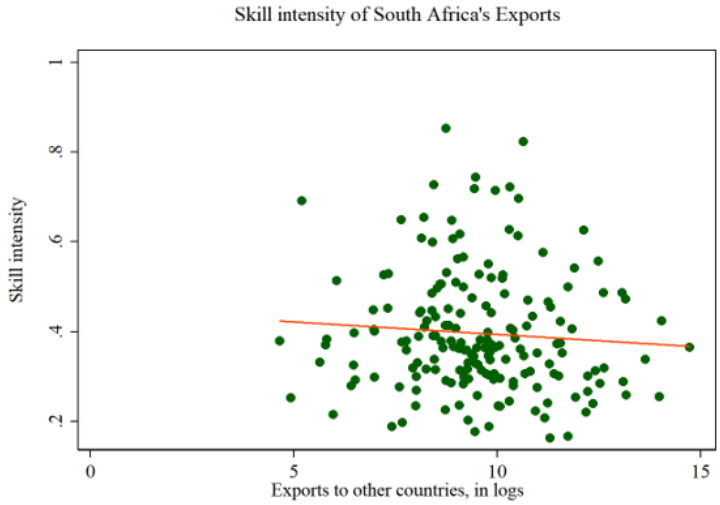
[18] This can be done through a simple regression of a country's product exports on country factors and collecting the regression coefficients. This is demonstrated in Appendix 4.

[19] We used Hall and Jones (1999) estimate of physical and human capital for both panels of Figure 16.

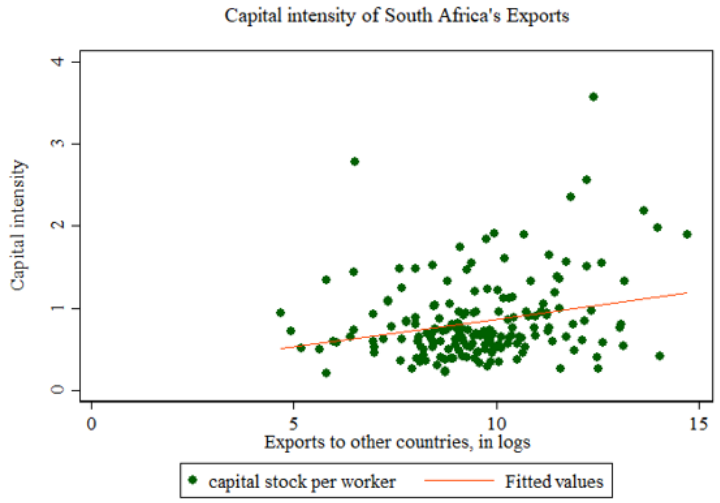
Figure 16 (top panel) shows the result of this analysis for South Africa and a group of chosen peers. The contribution of a country's skill-intensive industries to its exports is plotted on the horizontal axis. South Africa has a higher human capital stock than Brazil, Colombia, Mexico, and Indonesia (Hall and Jones, 1999), but the contributions to exports of skill-intensive industries is lower than in Colombia, Mexico and Indonesia. Additionally, while the contributions of skill intensive industries in these countries does not appear to be statistically different from zero, the contribution in South Africa is negative and statistically significant.

Figure 15: South Africa's product exports: Factor intensity versus level of exports

(a)



(b)



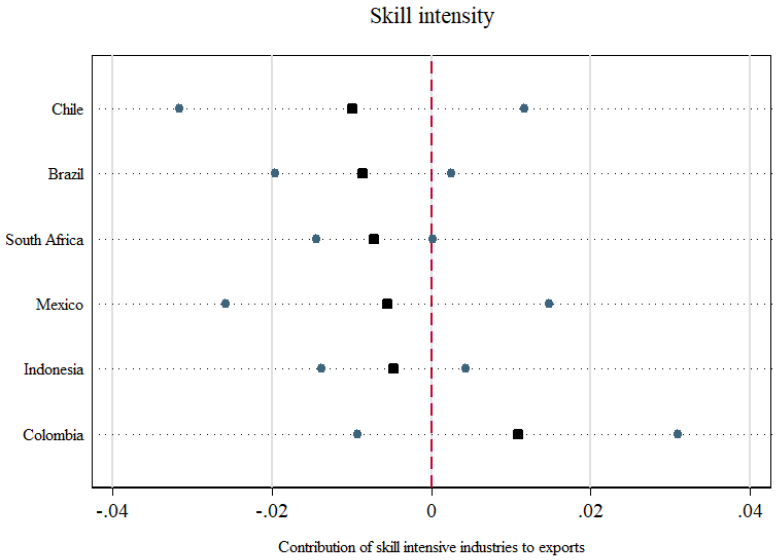
Source: Own calculation using Nunn (2007) database

The bottom panel of Figure 16 models the relationship between countries' exports and industries' physical capital intensity. The contribution of capital-intensive industries to countries' exports is plotted on the horizontal axis. Similar to the top panel, a positive contribution implies industries with higher capital-intensity are associated with a larger share of a country's export basket and a negative contribution implies industries with higher capital-intensity are associated with a lower share in a

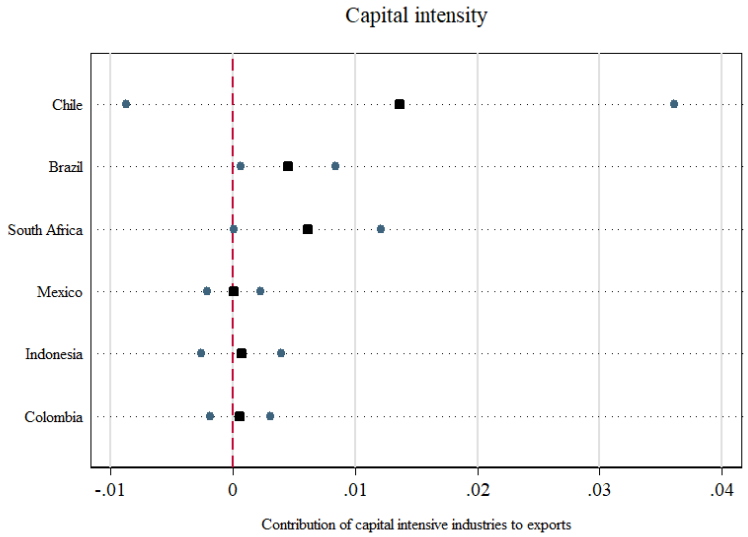
country's export basket. The result indicates that despite having a physical capital stock below that of Brazil, Chile and Mexico (Hall and Jones, 1999), the contribution of South Africa's capital-intensive sectors to exports is higher – note that while the contribution of capital-intensive industries in Chile is larger in magnitude that South Africa, the contribution is not statistically different from zero.

Figure 16: South Africa and benchmark countries: Contribution of factor-intensive industries to country exports

(a)



(b)



Source: Own calculation using Nunn (2007) database

Note: A contribution coefficient is statistically significant if the confidence interval does not cross the zero line

The lower prevalence of skill-intensive firms in exports, coupled with high youth unemployment as well as positive wage premiums and high employment for skilled workers (Hanusch, World Bank, 2018), supports the hypothesis that human capital is potentially a binding constraint in South Africa. The fact that these trends coexist with high unemployment rates among college graduates or educated youth suggests that the skills businesses are willing to pay high premiums for are not being acquired through the formal education system.

As a matter of fact, the World Bank's human capital index reveals that despite receiving an average of 10 years of schooling, these 10 years are equivalent to 5 years of schooling only – after adjusting for South Africans' learning outcomes.[20] This is evidence that the quality of skills may be inadequate to meet firms' needs. Additionally, spatial distribution patterns of South Africans have persisted after long after dismantling the apartheid, meaning that Black South Africans remain at the periphery of commercial centers.

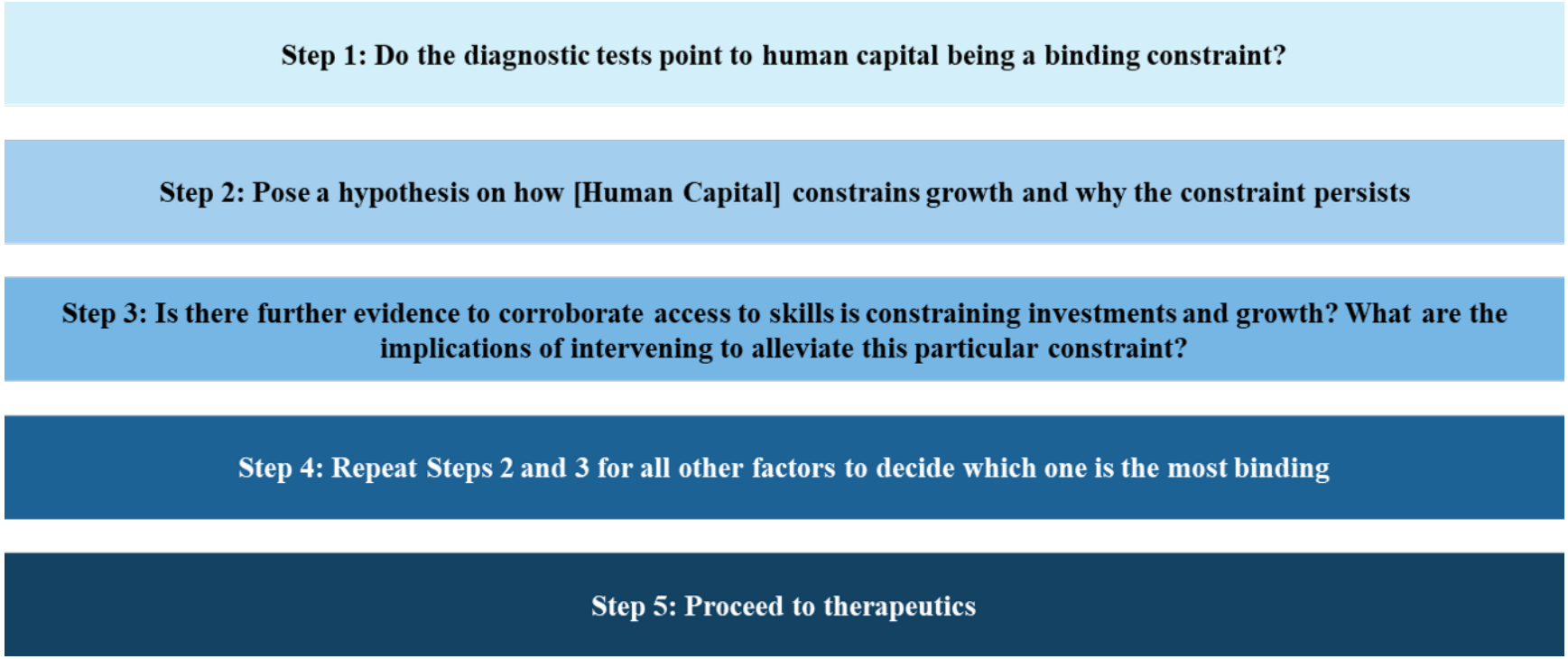
These results – suggesting that human capital is indeed a binding constraint in South Africa – are consistent with the empirical evidence reported in the economic literature. Subramanian & Alleyne (2001) documented that, despite its comparative advantage in labor-intensive activity, South Africa is a net exporter of capital-intensive goods. The authors conclude that South African firms continue to favor physical capital over human capital and present a hypothesis of a malfunctioning labor market, where the cost of labor is high relative to the cost of capital. Levinsohn (2008) argues that structural deficiencies keep South African labor unemployable and proposes wage subsidies to lower the cost of labor as well as importing skills through immigration. Lastly, Banerjee et al. (2008) offer a variety of hypothesis to explain the unemployability of South African labor, ranging from malfunctioning of labor market institutions which hinder the possibilities of the Black majority to participate in labor force to a mismatch in supply and demand of skills.

3 From Diagnostic Symptoms to the Syndrome and Therapeutics

In *Section 2*, we demonstrate the deployment of the four diagnostic principles to test for human capital as a binding constraint to growth. This is the first of five steps of the growth diagnostic process (Figure 17) and enables to determine any symptoms that point towards human capital being binding. Next, and based on the evidence revealed through the diagnostic signals, an analyst shall pose a hypothesis explaining the equilibrium state in the country and how human capital is binding (step 2); proving or disproving that policy interventions targeting human capital (stock or allocation) will indeed have the highest impact on investment or growth rates (step 3), compared to other potential constraints (step 4). Only then can the analyst proceed to therapeutics – or elements of public policy that can serve to address human capital constraints present in an economy (step 5).

[20] Learning-adjusted years of schooling (LAYS) are defined for country C as the product of average years of schooling (s_c) and a measure of learning (international standardized test score) relative to the average score of the top performing country (L_n, in the case of the 2018 World Bank Survey, Singapore).

Figure 17: The Growth Diagnostic Process



3.1 The Syndrome: Why Does This Equilibrium Persist?

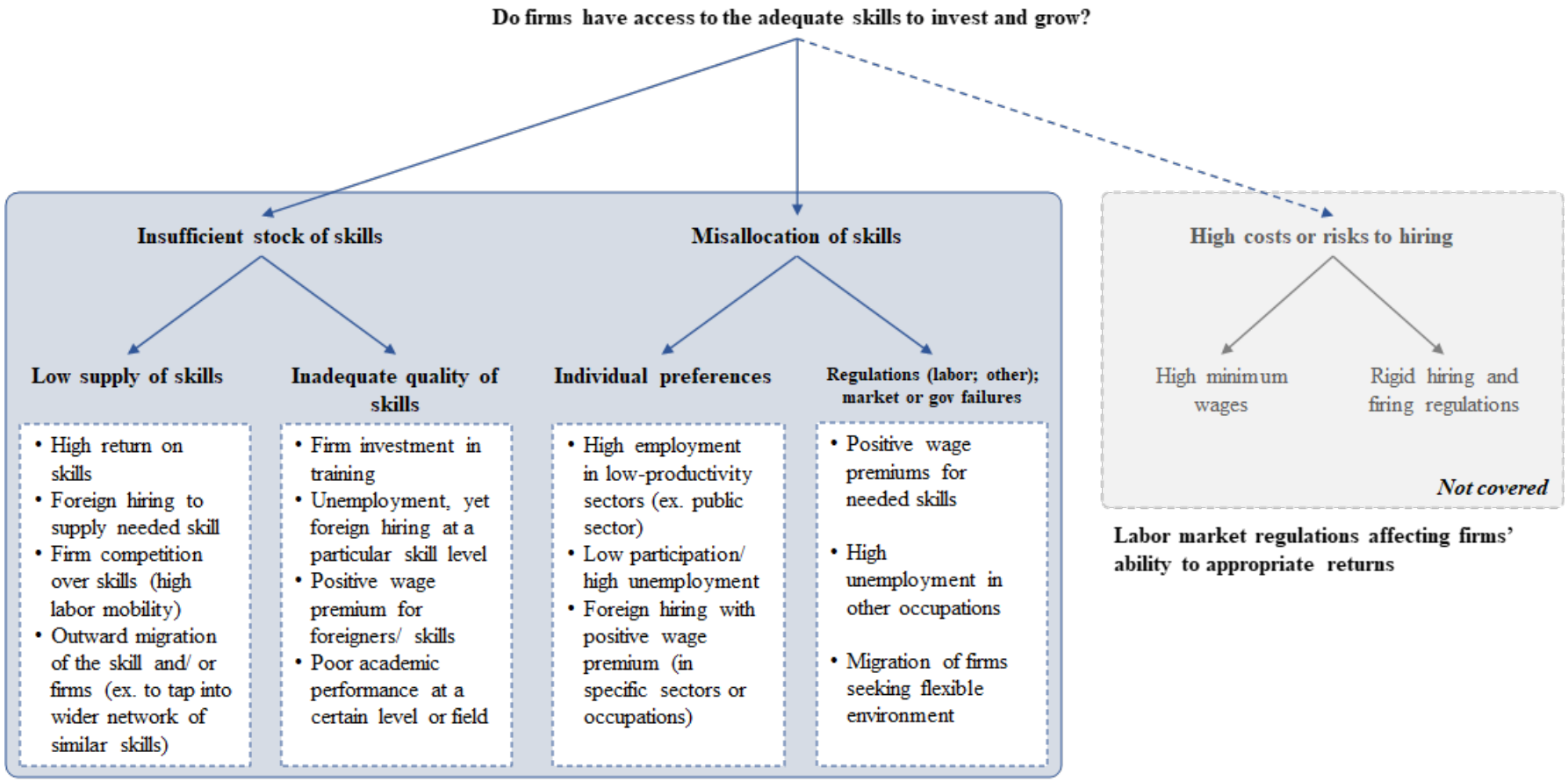
Establishing human capital as a binding constraint requires formulating a hypothesis, based on the deployment of the diagnostic signals, explaining (1) the mechanism by which human capital is effectively constraining investment and growth and (2) why this equilibrium persists. We call this hypothesis a syndrome. In the case where human capital is a binding constraint, the syndrome can start with one of two premises. First, the supply of skills is inadequate and does not meet the demand coming from existing firms. The second is that firms are unable to hire the workers or skills they need due to market failures leading to misallocation of skills (Figure 18). The diagnostic tests presented in *Section 2* provide the evidence necessary to characterize the symptoms and shall be used as entry points to formulate a hypothesis on the state of human capital in the country.

Insufficient quantities of a skill: A combination of high Mincerian returns in general or on one or more specific skills in particular, high employment rates among individuals possessing those skills, in addition to foreign hiring or similar efforts by firms to increase their access to specific skills, may signal that human capital is a potential binding constraint. High attrition of firm employees and movement between competing firms is another signal in favor of insufficient quantities of skills being a constraint. Alternatively, the skill shortage can be binding to an extent that it forces firms and available skills to migrate outside the country. In this case, an analyst can find high Mincerian return on the skill in shortage, yet with attrition as skills move abroad.

Low quality of available skills: If the quality of available skills – say, engineering – is low, one can expect to see relatively higher unemployment rates among engineers (compared to the case where the quantity of engineers is binding). Yet, stronger signals include large investments in training reported by firms. A situation of low quality of available skills could be mistaken for a problem of technological coordination failure, and vice versa. In several developing countries, degree holders – in this example, engineers – may be unable to work in their fields of specialization. Is this a signal of low quality of their skills, or rather the result of low demand? The hiring of foreign engineers may signal low quality of domestic skills while emigration of domestic engineers or demand for their skills abroad may signal low demand for high skills in the country, and hence signals a technological coordination constraint rather than a human capital constraint.

Misallocation due to preferences or reservation wage or labor market regulations (such as in the case of restrictive professional licensing): In the case where certain firms lack access to the required skills due to misallocation, an analyst can expect to see employment of skills in shortage concentrated in one or a few sectors, with little movement to firms in need of skills over the years. This situation can coexist with a premium on the skill in other sectors and even unemployment. For example, if individuals prefer to work in a specific sector, say the public sector, an analyst can observe high unemployment of skilled individuals, due to distortions preventing the matching of existing skills to opportunities or jobs. In the meantime, firms may be willing to pay a premium on skills.

Figure 18: Evidence corresponding to a human capital constraint



3.2 Policy Options to Address Human Capital Constraints

If the analyst concludes that human capital is indeed a binding constraint to growth, the policy strategy to alleviate or release the constraint will depend on the hypothesis or syndrome. This section maps each of the hypothesis above to several policies. It is important to note that this mapping is not a general recommendation of these specific policies to foster private investments and ultimately growth. Instead, the policy options discussed here should be embedded in a more comprehensive strategy to foster investment and ignite economic growth in situations where human capital is indeed the most binding constraint.

The actual impact of the policies discussed in this section will depend almost exclusively on the country context – more specifically the administrative capabilities and political landscapes. As such, a serious analysis of a bureaucracy's implementation capacity, its ability to coordinate with the private sector, and political space should guide the decision to adopt any policy and its implementation strategy (Pritchett, Samji and Hammer, 2013). The process of selecting and implementing a course of action and monitoring its impact can help policymakers capture nuanced information and knowledge about the human capital shortages facing the country, and further improve the policymaking process.

Education Reform

The policy elements discussed in this section are short- or medium-term solutions to address skill shortages within a specific country, especially as they may support youth employment by lowering the barriers to finding a first job through which new labor market entrants can then build experience and skills. This leaves out the question of reform of the education system. While we do not discuss education reform here, it is important to note that a country's long-term skills spectrum is dependent on its undertaking of education reform at the appropriate schooling levels, to equip future generations with the needed skillset; hence expanding the country's spectrum of skills. As a matter of fact, investments in the education system have the potential to preempt human capital constraints in the long run, by ensuring an adequate supply of skills as generations currently in schools begin to enter the labor market.

Yet, education reform is not a pragmatic solution when human capital is constraining investment and growth in a place at present, as it cannot impact the country's skills spectrum in the present but promises augmented skills in the future. As such, alleviating human capital constraints will unlikely be achieved through education reform solely. This is not a reason to discard investments to improve the education system, but policymakers ought to prepare for the future while making policy choices to support short-term growth.

3.2.1 Training Programs and Subsidies to Support Skills Formation

The most common intervention for country governments facing skill shortages has been supplying technical and vocational education and training (TVET). TVET often seek to provide specific skills lacking in the economy that are required by existing firms, on the premise that workers lack these needed skills or are, for one reason or another, unable to acquire them (think of inability to seek education or training due to credit constraints). As such, governments have traditionally attempted to supply TVET by establishing national training programs or on-the-job training, to help would-be

workers in acquiring required skills. The latter could happen through a variety of mechanisms, such as subsidies, training taxes, levies, etc.

The evidence for the effectiveness of such traditional policy interventions is limited. McKenzie (2017) surveyed an array of traditional labor market policies, including programs that provide TVET to the unemployed. He documented that training programs have a very modest impact on employment of a country's workforce by firms. One possible explanation of this finding is that if firms do not hire workers due to skill gaps that impacts their employability, training programs may in the short-term fill specific sets of skill gaps but are unlikely to change the long-run outlook in terms of skills availability. This is corroborated by South Korea's experience with TVET, where national (public) standards for training were not always able to meet demand.

Also, the drive to subsidize on-the-job training and require employers to train employees is often met with push back and little take up from employers. Again, South Korea's early experience with TVET –as well as South Africa's– show the limitations of publicly subsidizing on the-job-training where firms often lack the incentive to or interest in providing on-the-job training or are burdened by the often-complex implementation requirements (Hanusch, World Bank, 2018). This situation is often exacerbated if firms are unsure whether they can reap the benefit from their investment in employees, if employees are likely to exit and move to another job or firm once trained.

This does not mean training programs will never be effective, but rather emphasizes that the ultimate result depends on the program design and its suitability to the context of the country. South Korea is one example where industrialization implied an increase in the demand for specialized skills to an extent that trained workers were in shortage. For decades, South Korea experimented with and iterated the design of TVET programs to arrive at a suitable design. After attempting subsidizing training, requiring on-the-job training, and offering publicly funded training, South Korea launched publicly funded training consortiums which leverage the country's large companies (such as Samsung, Hyundai, etc.) and well as universities to lead the training design by providing: the curriculum, instructors and material needed for the material. These consortiums have been successful in addressing skill gaps (Uh, 2018).

3.2.2 Immigration Policy

While addressing human capital constraints by means of improving the coverage and quality of education require a long-term horizon, countries are still urged to grow, and firms still require skills to be able to carry on their economic activity at a competitive return on investment. Firms unable to meet their needs for specific skills and knowhow in the domestic market may be able to overcome that constraint by means of foreign labor and sourcing talent abroad that complements local workers. This strategy has been pursued by many countries.

In such scenarios, immigrants can be relied on to supply the country with skill, perform activities that tend to be essential for firms' survival and proliferation, ultimately contributing to growth and job creation. If the skills needed by firms to invest, innovate and grow are lacking, the scope for innovation and growth is limited. As such, instead of innovating and introducing new products to the economy, firms would be limited to compete in sectors/products for which available skills are suited. That is the challenge often posed by structural transformation in developing countries. When firms are able to access foreign talent, they are then able to build the capabilities needed to innovate, by

innovating they are able to grow and export, by firms exporting and completing globally, countries grow.

A main concern for policymakers, with regards to using immigration policy to attract needed skills, is whether foreigners would displace the local workforce. That would depend on the extent to which immigrants substitute or complement for domestic workers across the skill spectrum. When immigrants bring complementary skills, they contribute to easing out the human capital constraint, thus allowing countries to grow and creating jobs for domestic workers that would not have been generated otherwise. We see evidence of the complementary of low and high skilled immigrants in the case of Panama as immigrants experience positive wage premia across occupations (See Section 2.4). Similarly, in 2017 one individual firm in Jordan launched a software development branch and by mid-2018 employed around 100 high-skilled Jordanian software engineers. Due to restrictions on high-skilled migration, the firm initially struggled to hire just two foreign managers with the knowhow and on-the-job experience on the firm's business model - a form of human capital lacking in Jordan. The absence of this experience would have hindered this significant investment that later generated jobs for 100 high-skilled Jordanians. Had this firm been unable to overcome the challenge, it would have most likely moved its investment to another country. In this particular case, the experience and skills provided by each of the two foreign workers were complementary to the talent of 50 Jordanians (Hausmann *et al.*, 2019).

3.2.3 Foreign Direct Investment

Similar to migration, foreign direct investment (FDI) is another channel through which foreign knowhow can be deployed to build up the domestic skills spectrum. While FDI by itself is not a channel used to introduce skills (rather it is a channel for technology transfer), FDI can have positive spillovers, adding to the types and level of skills available in a country (Javorcik and Spatareanu, 2008).

The case of Bangladesh's garment sector success is an example of how FDI can spur sector growth, primarily by infusing technical skills and knowhow of the sector into the economy. Bangladesh's textile sector miracle started with a joint venture between a domestic firm, DESH, and Korean manufacturer Daewoo. Rhee (1990) describes how 115 of the initial 130 Bangladeshi workers trained by Daewoo in Korea, left DESH to set up, at different moments in time, their own garment exporting firms. This transfer of skills from Daewoo to DESH employees was essential for the Bangladeshi economy to form a working population able to compete in and grow the garments sector in the country.

To the extent that FDI brings in immigrants or transfers specialized skills allowing the relevant sectors to expand and growth, it is a channel to enhance a country's skills spectrum.

3.2.4 Wage Subsidies

An alternative view to active labor market policies to address skill gaps in the economy, is helping them to overcome excessive labor regulations and reduce the associated costs that are preventing them from hiring and developing talent. Within the context of this paper, we are only focused on labor market regulations that may hinder or restrict skill formation.

Policymakers may find themselves in a situation where human capital constraints derive from limited employability of certain population groups (typically, youth graduating from schools and colleges), whose productivity or skill level is low relative to labor market wages (or minimum wages). For this population, securing employment is by itself an investment in their human capital, given the skills they build through learning-by-doing and on-the-job experience. In such a scenario, firms' may be reluctant to hire these workers. Their reluctance will vary based on the cost of investing in the workers (through hiring and training) and the likelihood of appropriating the return on the investment. If the cost of this initial investment in hiring and investing in workers is high, firms may not accept the uncertainty about a worker's quality and productivity. Hiring needed talent, and further building their skills, becomes a risky undertaking.

In such instances, when risks with regards to worker productivity or the cost of the initial investment are preventing firms from accessing would-be talent, wage subsidies and reduced regulations can help alleviate the issue. Wage subsidies would encourage firms to undertake this initial risky investment of hiring, and workers would be able to expand their skillset through learning-by-doing on the job (Levinsohn, 2008). In 1994, the government of Mexican President Ernesto Zedillo successfully convinced Japanese harness manufacturing Yazaki to open operation in Chiapas, by offering wage subsidies over a training period of three months. That year, the first Yazaki plant opened in Tuxtla Gutierrez, Chiapas' capital, employing 600 domestic workers. Twenty years down the road, Yazaki had five production facilities in different municipalities of Chiapas and employed more than 3,000 workers (Hausmann, Pan and Santos, 2020).

The drawbacks of wage subsidies are the possibility of rent-seeking and their potential to introduce direct or indirect distortions in the economy. Similar to the other policies we discuss in this section, country context and implementation capabilities will determine a wage subsidies' success.

3.2.5 Other: Easing Labor Market Misallocations

The above policy proposals might be helpful when the quantity or quality of available skills is insufficient. Yet, there may be situations where human capital constraints are driven by market failures, where the extensive margin of labor supply does not respond to firm demand, leaving firms unable to locate and hire skills. Spatial and sectoral misallocation of labor are two scenarios to exemplify this problem. For example, if the working population at the managerial level displays a preference to work in the public sector or specific sectors, firms may be deprived of the required managerial skills. In these cases, policy interventions to correct the market failure can potentially alleviate the constraint.

The case of South Africa is one where sectors have favored the use of capital relative to labor following the historical and deliberate exclusion of Blacks. Specifically, Black South Africans were prevented from relocating closer to urban areas – the center of economic activity. Until the present day, the spatial patterns perpetuated by apartheid leave Blacks at the periphery of urban centers and pose a serious challenge to their ability to access employment opportunities (Levinsohn, 2008). Jordan's universally low female labor participation can be another example of a country where a large stock of highly qualified human capital is available but remains out of specific sectors or occupations because of a combination of cultural norms and labor regulations making it onerous for firms to hire and retain women (Kasoolu *et al.*, 2019).

McKenzie (2017) describes the sectoral and spatial misallocation of labor as the largest market failure in labor markets, as individual skills' may be located in one market but demanded in another. There are situations where certain groups experience high costs in entering the labor market or specific sectors within the economy. That effectively excludes them from participating, preventing firms that may be searching for those skills from accessing them. In these cases, policymakers must consider interventions that are targeted to reducing the cost of entry of these groups into the labor market or specific sectors. These might include housing subsidies or investment in transportation systems to facilitate workers' mobility. Alternatively, governments can design incentives encouraging firms to relocate closer to workers (Banerjee *et al.*, 2008).

4 Conclusion

Investments in human capital should be expected to deliver growth dividends when other capabilities or inputs aren't missing. We develop a framework based on the principles of Growth Diagnostics (Hausmann, Rodrik and Velasco, 2008) and illustrate the deployment of four diagnostic signals to enable practitioners to test if human capital is indeed the most binding constraint and shall be a policy priority for a country's growth strategy.

The question of human capital as a binding constraint to growth is whether the skill spectrum in the country is sufficient for firms to engage in productive economic activities in a competitive way. In such situations, improvements in human capital are likely to lead to a growth acceleration. The answer to this question is ultimately an empirical endeavor that seeks to understand country-specific factors and their underlying dynamics. Econometric analysis at the aggregate [national] level can tell us a lot about the dynamics of output and human capital; however, assessing the adequacy of a country's specific need for human capital requires an observation of firm and worker behavior and decisions at a micro-level. This is why our framework relies on econometric analyses performed using what is usually the most granular data available for a country –population and economic censuses, household surveys, labor force surveys, business surveys– but not amenable to comparisons across countries.

The nature of human capital makes the diagnostic exercise a real challenge. On one hand, characterizing a country's human capital stock is difficult due to the varied and continuous nature of the skills spectrum. Contrary to other production factors such as electricity, water, finance or infrastructure, human capital is not directly observable. On the other hand, and perhaps even more problematic, a country's skill spectrum is highly heterogenous, with different types and levels of skills easing or constraining different economic activities. Some of the examples we have provided documented cases where human capital was binding across industries and occupations, as signaled by the large wage premiums paid to foreigners and complaints about high turnover; however, this is a rare occurrence. More often, the shortage of human capital is present in a specific set of occupations and constrains investment within a subset of industries that are more reliant on those skills. In order to navigate these complexities, we recommend a deductive approach, going from the more general definitions and aggregates to the more specific (at the industry or occupational level), and let the process be informed by a comprehensive set of interviews with decision makers at the most relevant industries.

Not all diagnostic signals characterizing the most binding constraints can be unequivocally tested. A good rule is to rely on rigorous econometric analyses to test if the shadow price of a factor is high (the first diagnostic signal), or if more skill-intensive businesses tend to contribute less to value added,

employment or exports (the fourth diagnostic signal). Other signals such as observing changes in policies affecting human capital and the corresponding changes in investment or growth (the second diagnostic signal) require delving through historical country data to pinpoint meaningful movements in human capital that could be referenced. Yet, such changes need to be interpreted with care, as countries seldomly experience policy changes in a vacuum. Instead, they tend to occur alongside several other parallel fluctuations and these relationships are prone to suffer from endogeneity and omitted variable biases that makes it difficult to assert causality. Finally, in our experience, engaging in interviews with private actors and policymakers is essential to capture the country context and particularly useful in understanding agents' efforts to bypass the constraint (the third diagnostic signal). An exercise that is usually helpful when it comes to identifying these practices is to locate positive deviants in the country: businesses that we would not expect to be there –as they are very intensive in the use of the potential binding constraint– but have somehow figure out a way to get around it.

Growth diagnostics are as much an art as a science. The framework provides a combination of rigorous quantitative methods, back-of-the-envelope calculations, and suggestions on where to look for anecdotal evidence. Policy practitioners shall assemble a variety of quantitative and qualitative evidence based on these methods and weigh the merits of the available evidence for each factor vis-a-vis alternative production inputs. Judging whether human capital is the most binding constraint can only be made by the analyst once the evidence available on all production inputs has been factored in.

If there is significant evidence pointing out to shortages of human capital as the most binding constraint in the economy, we need a policy response with potential to yield results in the short-term. Accordingly, our toolkit focuses on policies that rely on public-private coordination to address shortages of human capital of different nature, either due to insufficient skills (training programs or subsidies to support skill formation, a dynamic immigration policy to facilitate the import of missing skills, fostering foreign direct investment) or misallocation of existing skills (wage subsidies to compensate hefty labor regulations, or active policies to ease misallocations of resources in the labor market).

Pursuing our goal of providing a practical analytical framework for policymakers to assess whether human capital is indeed the most binding constraint has come at the price of two important limitations. First, in our diagnostic tree we have separated for analytical purposes two different drivers of human capital shortages: insufficient skills and distortions or misallocations driven by labor regulations or cultural norms. In doing so, we have assumed that you can test for one isolating from the other, as well as in isolation from labor market regulations, when in fact these are potentially related and reinforce each other. Second, the very nature of the tests and underlying data allows the analyst to determine if human capital is constraining investment for existing business (the intensive margin) but is not directly informative on whether human capital is constraining the advent of new industries (the extensive margin). Productive diversification to drive economic growth entails sorting a chicken-and-egg dilemma: new industries might be missing because the place lacks the skill spectrum required, which in turn will not develop as long as these industries are missing. Thus, the policy toolkit we have outlined will likely apply to situations where insufficient skills are constraining the appearance of new economic activities, but the process of determining if human capital is indeed the most binding constraint to productive diversification will likely require a further refinement.

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Appendix 1: Mincer Regression for Mexico and Chiapas

A Tobit model or a censored regression model is used to estimate the relationship between income and years of schooling, modelled according to equation (1) below. The purpose is to estimate the returns on an additional year of schooling in Chiapas versus the rest of Mexico.

Equation (1)

$$Log\_income = \alpha + \beta_1 * years\ of\ schooling + \beta_2 * years\ of\ experience + \beta_3 * (years\ of\ experience)^2 + \beta_4 * female + \beta_5 * (indigenous\ language) + \beta_6 * Chiapas$$

- *Female* –a dummy variable for gender: 0 – male; 1 - female
- *Indigenous language* –a dummy variable for speaking an indigenous language (proxy for ethnic origin): 0 – does not speak an indigenous language; 1 – speaks an indigenous language
- *Chiapas* – is a dummy variable for the state: 0 – rest of Mexico; 1- Chiapas

The data used to perform this regression is cross-sectional data from the Mexican Population Census. Note that a Tobit model is deployed given that income data is censored at the top (income at and above P$ 999,999 recorded at P$ 999,9999 in the dataset).

Equation (2) is used to construct the return to schooling at **each year of schooling**, after generating the average year of experience held by individuals at each year of schooling.

Equation (2)

$$Log\_return_{year} = \alpha + \beta_1 * years\ of\ schooling + \beta_2 * AVERAGE\_years\ of\ experience + \beta_3 * (AVERAGE\_years\ of\ experience)^2 + \beta_6 * Chiapas$$

The results of regression – equation (1) is reported in *Table 2*.

Table 2: Mincer regression for Mexico and Chiapas

	Income (1)	**Income (2)**
Schooling	0.0978***	0.0970***
	(0.000336)	(0.000329)
Experience	0.0328***	0.0326***
	(0.000105)	(0.000105)
Experience squared	-0.000441***	-0.000439***
	(1.78e-06)	(1.77e-06)
Female	-0.334***	-0.336***
	(0.00134)	(0.00130)
Indigenous Language	-0.277***	-0.259***
	(0.00877)	(0.00775)
Chiapas		-0.358***
		(0.0121)
Constant	7.113***	7.133***
	(0.00382)	(0.00367)
Observations	2,965,928	2,965,928
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1		

Source: 10% Microdata sample of 2010 Population Census, National Institute of Statistics and Geography (INEGI).

Appendix 2: Incorporating Quality in Mincer Regressions

Adjusting the estimated Mincerian return to schooling correcting by quality is a two-step endeavor. The first step is to establish an acceptable measure of schooling quality *(Step 1)*, and the next step is to estimate the relationship between income and schooling, schooling quality, while controlling for several variables (*Step 2)*.

Step 1: Measuring Quality Of Schooling

In the case of Mexico, the Ministry of Education runs the National Evaluation of Academic Achievement in School Establishments (ENLACE), to measure proficiency in Math and Spanish language of students in public and private schools, at all pre-college levels: primary, secondary, and media-superior (last grade). The results of the test are reported at locality-level. This has two important implications: first, as the data is reported at the level of localities, it is then possible to estimate the relative quality of schooling for each municipality in each state. Second, as the test is taken by students at all pre-college level, it is possible to compare the relative quality of schooling by level of schooling.

As quality measures, the practitioner has the option of using raw test scores by municipality/ state.

Another option is to estimate the relationship between test scores and observed characteristics at the state, municipality and household levels to isolate the quality component from the test scores. The rationale being that test scores are unlikely to only reflect the quality of schooling students are receiving. Instead, test scores are affected by a number of variables, such as family income, parents' highest level of schooling, in the case of Mexico, the ethnic background is also part of the variables that may affect students' schooling outcomes.

This second option requires merging the test score data with the Mexican Population Census, and using an OLS regression model to estimate the relationship between the ENLACE test scores and these variables, using the following regression:

Equation (3)

$$test\ score_{municipality;schooling\ level} = \alpha + \beta_1 * years\ of\ schooling + \beta_2 * family\ income + \beta_3 * maximum\ family\ schooling + \beta_4 * Indigenous\ language + \varepsilon,$$

where ε captures the quality of schooling, being the difference between the observed test score and the predicted test score, based on observed characteristics, such as years of schooling and family profile. Hence, we use equation (4) to estimate quality (ε)

Equation (4)

$$\varepsilon_{municipality;schooling\ level} = test\ score_{(m;s)} - predicted\ test\ score_{(m,s)}$$

$Predicted\ test\ score_i$ is the test score estimated by substituting for the variable and regression coefficients in equation (3).

Step 2: Incorporating Quality of Schooling in Mincer Regressions

A Tobit model or censored regression model is used to estimate the relationship between income and years of schooling, adjusted quality of schooling, as modelled in equation (5). The purpose is to estimate the Mincerian returns on an additional year of schooling in Chiapas versus the rest of Mexico, adjusted for schooling quality in each state. This regression can be estimated at state or municipal level, depending on available data.

Equation (5)

$$Log\_income_{(person\ at\ m,s\ levels)} = \alpha + \beta_1 * years\ of\ schooling_{person} + \beta_2 * years\ of\ experience_{person} + \beta_3 * \left(years\ of\ experience_{person}\right)^2 + \beta_4 * quality_{spanish\ (at\ m,s\ levels)} + \beta_5 * quality_{math\ (at\ m,s\ levels)} + \beta_6 * Chiapas$$

$Quality_{spanish}$ and $Quality_{math}$ are quality measure computed using the test scores of ENLACE Spanish and Math components, respectively. Both quality measures are calculated according to *Step 1*.

The regression results of equation (5) are reported in *Table 3*.

Table 3: Mincer regression in Mexico and Chiapas – adjusted for quality of schooling

	Chiapas == 1	**Chiapas == 0**
	(1)	**(2)**
Schooling	0.0989	0.0765
	(0.002302)***	(0.000323)***
Experience	0.0306	0.0339
	(0.000665)***	(0.000114)***
Experience squared	-0.0004015	-0.000493
	(0.00001)***	(1.98*10^-6)***
$Quality_{Spanish}$	0.21861	0.13128
	(0.01421)***	(0.00329)***
$Quality_{Math}$	-0.1202	-0.0507
	(0.01706)***	(0.00346)***
Constant	6.589	7.1505
	(0.03512)***	(0.00387)***
Observations	511,079	7,281,494
Standard error in parentheses *** p<0.01, ** p<0.05, * p<0.1		

Equation (6) is used to construct the expected wage schedule in each state (our variable of interest), adjusted for schooling quality, **each level of schooling**:

Equation (6)

$$Log\_return_{state,year} = \alpha + \beta_1 * years\ of\ schooling + \beta_2 * AVERAGE\ years\ of\ experience_{at\ state\ and\ schooling\ level} + \beta_3 * \left(AVERAGE_{years} of\ experience_{at\ state\ and\ schooling\ level}\right)^2 + \beta_4 * quality_{spanish;at\ state\ and\ schooling\ levels} + \beta_5 * quality_{math;at\ state\ and\ schooling\ levels} + \beta_6 * Chiapas$$

Note on schooling quality at state level: quality at state and schooling levels can be calculated as per step 1. Alternatively, the quality at municipality and schooling levels can be used to aggregate at state level, by taking the average quality (in Spanish and Math) across municipalities, at **each level of schooling**.

Appendix 3: Wage Premia by Industry and Occupation

A simple OLS regression model is used to estimate the wage premium on foreign labor in a given country, modelled according to equation (7). A representative micro-level labor force survey, reporting wages, demographics, educational attainments, occupations, is needed to estimate this equation.

Equation (7)

$$Log\_income_{state,year} = \alpha + \beta_1 * foreign + \beta_2 * female + \beta_3 * schooling + \beta_4 * occupation + \beta_5 * industry + \Sigma\beta_i X_i$$

- *Foreign* – a dummy variable: 1 – foreign workers; 0 – national workers
- *Female* – a dummy variable for gender: 1 – female; 0 – male
- *Schooling* – a continuous variable for years of schooling; might also be a categorical variable indicating a certain level of school (0: illiterate; 1: primary schooling; 2: secondary schooling; 3: tertiary; 4: PhD)
- *Occupation* – a categorical variable referring to individuals' occupation type. Example: 1 – Managers; 2 - Professionals; 3 – Technicians; 4 – Clerks, etc. (not included in the regression when estimating the wage premiums by occupation)
- *Industry* – a categorical variable referring to the industry in which individuals work (not included in the regression when estimating the wage premiums by industry)
- $\Sigma\beta_i X_i$ – a matrix of other observable characteristics that may influence income, such as age, experience, region of the country, etc.

The Wage Premium

The wage premium of foreigners by industry is β_1, when equation (7) is estimated by industry. The wage premium of foreigners by occupation is β_1, when equation (7) is estimated by occupation.

By capturing β_1, as well as the standard error of term β_1, the practitioner is able to estimate the lower and upper bounds of foreigners' wage premia, relative to national labor, according to equation (8)

Equation (8)

$$Lower\ bound\ of\ foreigner\ wage\ premium_{by\ industry\ or\ occupation} = \beta_1 - 1.96 * standard\ error\ on\ foreigner\ coefficient\ (\beta_1)$$

$$Upper\ bound\ of\ foreigner\ wage\ premium_{by\ industry\ or\ occupation} = \beta_1 + 1.96 * standard\ error\ on\ foreigner\ coefficient\ (\beta_1)$$

Appendix 4: Factor-Intensity and Relationship to Exports

A simple OLS regression model is used to model the relationship between a country's exports and the country's industry factor-intensity (i.e. industry specialization in skills or physical capital). The goal is to estimate the contribution of skill-intensive industries versus capital-intensive industries to a country's exports. A comparison of the contribution of skill-intensive and capital-intensive industries to exports is informative of whether agents in the economy (firms) are moving away from or towards industries intensive in a particular factor. This can reveal a comparative advantage in leveraging a factor or can reveal constraints in the factor firms move away from.

We leverage the database made available by Nunn (2007) to demonstrate the example of South Africa in Section 2.4. The database includes disaggregated country export and import data, at the 3-digit product-level for year 1997, an industry skill measure based on prevalent wages of the sector, capital stock per worker for each sector. We do not elaborate on the mechanics of constructing the skill and capital per worker measures of the sectors; these are estimated according to input-output tables reported by the U.S Bureau of Economic Analysis, by industry classification.

The OLS model is based on equation (9) presented below and is estimated separately for each factor (skills versus capital):

Equation (9)

$$\frac{Exports_{industry,country}}{Total\ exports_{country}} = \alpha + \beta_c * FACTOR\_INTENSITY_{industry} + \beta_1 * D_{industry} * \ln\left(Total\ exports_{country}\right) + \beta_3 * D_{industry} + \beta_4 * D_{country} + \varepsilon_{i,c}$$

- $\frac{Exports_{industry,country}}{Total\ exports_{country}}$ – the dependent variable is an industry's share of country exports. This can also be substituted for, by an industry's share in gross value added. This variable is unique for each industry *i*, in a country *c*.
- *FACTOR INSTENSITY* – a continuous variable of the industry's factor intensity. In regressions estimating skill intensity, this would be the variable indicating an industry's skill intensity. In regressions estimating capital intensity, this variable would indicate the industry's capital stock per worker. This variable is unique to the industry.
- $D_{industry}$ – a categorical dummy variable for industries. For the purposes of this model, we use industry 6-digit codes to encode the industries ordinal (dummy) variable
- $D_{country}$ – a categorical dummy variable for countries. We rely on country ISO codes to produce this variable for each country.
- *Total export* $_{country}$ – a continuous variable of a country's total product exports, in log levels. We assume that richer countries are likely to have stronger patterns of factor specialization. To account for this association between country's level of development and its factor intensity, we use a country's total exports as a control variable for the country's wealth level. This can also be substituted for by using GDP per capita.

Ideally, the above model aims to detect significant positive or negative β_c coefficients. A positive β_c coefficient implies that industries more intensive in the factor under consideration (skills or capital in this case) are associated with a greater share of the country's exports, controlling for the country's

level of wealth. This suggests that industries intensive in the factor under study are thriving. On the other hand, a negative β_c coefficient indicates that industries more intensive in the factor under study are associated with a lower share of the country's exports. This suggests these industries contribute less to country exports, and hence may be struggling to grow.

In the example of South Africa discussed in Section 2.4, the β_c coefficient, for both regressions modelling the relationship between exports and industries' skill-intensity as well as capital-intensity, is not statistically significant for comparator countries: Brazil, Chile, Colombia, Mexico and Indonesia. Therefore, for these countries, we cannot infer a relationship significantly different that zero between industries' skill-intensity and these industries' share of exports; and similarly, between industries' capital-intensity and their share in exports. Meanwhile, the β_c coefficient, in both skill-intensity and capital-intensity regressions, are significant for South Africa. The higher an industry's skill-intensity is the lower its share of South Africa's exports is. Whereas the higher an industry's capital-intensity is the greater its share of South Africa's exports is. These respective negative and positive relationships are statistically significant, providing evidence that there is reason to believe South Africa's industries could be specializing away from industries dependent on skills, and preferring activities that rely predominantly on machines.