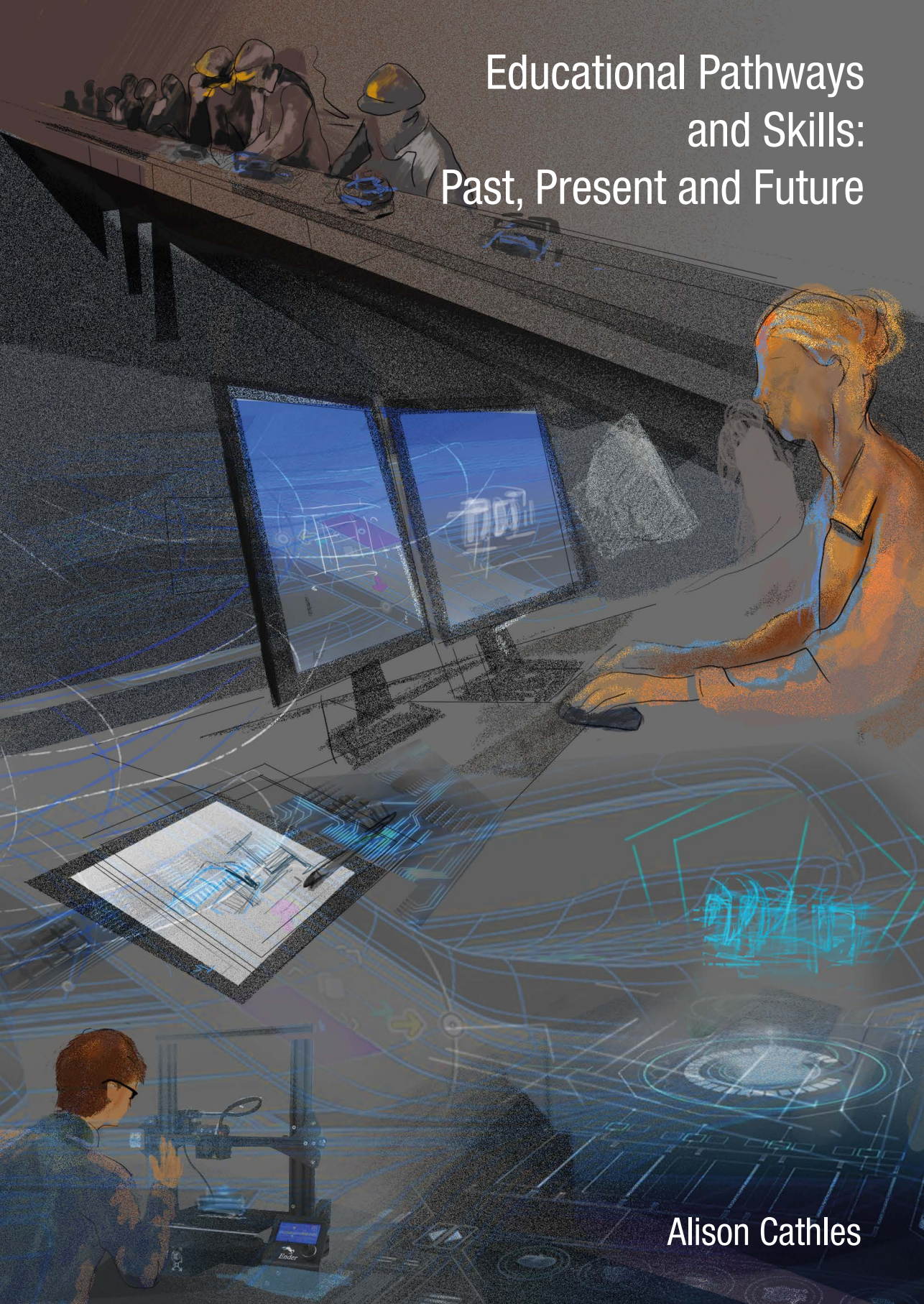
Educational Pathways and Skills: Past, Present and Future



Alison Cathles

Educational Pathways and Skills: Past, Present, and Future

DISSERTATION

to obtain the degree of Doctor at the Maastricht University,
on the authority of the Rector Magnificus Prof. Dr. Rianne M. Letschert,
in accordance with the decision of the Board of Deans,
to be defended in public on Wednesday, 17 April 2019, at 14:00 hours
by

Alison Cathles

Author: Alison Cathles
Illustration cover: Melanie Waidler
Layout and printing: Proefschriftmaken
ISBN: 978-94-6380-434-9

Educational Pathways and Skills: Past, Present, and Future

by
Alison Cathles

Supervisors

Prof. Dr. Jo Ritzen (Promoter)
Prof. Dr. Adam Szirmai

Assessment Committee

Prof. Dr. Bart Verspagen (Chair)
Dr. Elena Arias Ortiz (Education Specialist, IDB)
Prof. Dr. Joop Hartog (Emeritus Professor of Economics at Amsterdam University)
Prof. Dr. Henriëtte Maassen van den Brink
Prof. Dr. Rolf van der Velden
Dr. Stéphan Vincent-Lancrin (Senior Analyst, OECD)

Acknowledgements

The path that led to and through my PhD was a non-linear one. Along my path I was influenced by a series of people to whom I am forever grateful.

My two supervisors formed an excellent team. Prof. Jo Ritzen, my promoter, is someone who I believe is an academic entrepreneur. He is enthusiastically supportive of new ideas, but always seems to have a back-up card to play if an idea does not blossom according to expectation. He has a positive entrepreneurial spirit which is combined with high standards. When drafts did not meet these standards, he was unequivocally the steward of the thesis. However challenging it may have been at the time, I am very grateful to Prof. Jo Ritzen for driving me to improve this dissertation. Prof. Eddy Szirmai is someone who I believe has a secret power of thesis-omnipotence. In the early and middle days of my time at UNU-MERIT, he somehow always stopped by my office or asked me to meet him, when he sensed things were stalled and not moving forward as they should be. He has a knack for getting to the root of the problem. He was patiently persistent in helping me figure out how I could surmount the obstacle, so I could move on to the next step. His attention to detail and his inclination toward systematic approaches were extremely useful in guiding me through different parts of the thesis. His dedication to his students and to the people who are fortunate enough to work with him is unassailable. I am lucky and thankful to have had two excellent supervisors guiding my PhD.

I would also like to thank the members of my reading/assessment committee: Prof. Bart Verspagen, Prof. Joop Hartog, Dr. Elena Arias Ortiz, Prof. Rolf van der Velden, Prof. Henriëtte Maassen van den Brink and Dr. Stéphan Vincent-Lancrin. I admire the many accomplishments each of you has. Imagining the numerous tasks that must await you every day, I am deeply appreciative of the time you took to read my thesis, comment on and approve it!

UNU-MERIT is a home away from home for many of the PhD students and the administrative staff at UNU-MERIT are truly wonderful people who make us feel welcomed and supported. Thank you to Marc, Liesbeth, and Susan for doing everything you do to keep the institute running and still smiling and making time for a friendly conversation at the coffee corner or end-of-year party. Thank you to Herman and Mourik for being the best IT team I have ever encountered and for always addressing even the smallest issues with gracious expedience. Thank you to Ad for being willing to hunt down books such as UNESCO's 1950 World Survey of Education that made the first part of my thesis much more meaningful. Thank you to student affairs: Danny, Kim, Muriël, Janneke for facilitating supervision and instruction of MPP students.

Thank you to Monique for a big smile on a day when I needed one. Thank you to Ingrid, Ingeborg, Mieke, Marlies, and Mitie for being great companions on the ground floor. Thank you to Sueli, Diego, and Howard for involving and highlighting PhD fellows in the institute's communication with the rest of the world. It may be impossible for each of you to know just how much your friendliness can uplift a person's spirits during thesis doldrums. I personally have memorable smile from each of you and I have seen many other fellows' spirits uplifted by you too.

Eveline, I'm not the first and I'll not be the last to emphasize my thanks to you in particular. If we did a text mining exercise of the acknowledgements sections of all the institute's theses, I am quite sure that your name would come out huge and in the center - like the THANK YOU in the last slide of our presentation templates. And Eveline, you deserve every thanks you get. Like many before me, I have benefited from your counsel. You always made time for me. Your selfless support during all my years in Maastricht means a lot to me.

A special thanks to Robin for his advice over the years. Thank you to Neil, Fred Gault, Pierre Mohnen, Rene Belderbos, Carlo, Anthony Arundel, Julieta, Noi, Tom van Veen, Serdar, Micheline, Lonneke, Michiko, Mindel, Bruno, Fransizka, Rene Kemp, Melissa, Shyama, Michaella, Maty, Zina, Kirsten Haaland, Nyasha, Lili, Thomas Ziesemer, and Hampton for (in no particular order) imparting wisdom, trusting me with responsibility, and/or facilitating or discussing the value of physical exercise and healthy habits.

"Just walk beside me and be my friend" attributed to Albert Camus. Many friends have walked beside me and they (collectively and individually) have made my years in Maastricht (and pre-Maastricht) more successful. Here I invoke Emerson's definition of success, to which I subscribe. With gratitude, I thank the following people:

For barbeques, dinners and laughter, Circo: Agustín, Andi, Carmen, Elisa, Fernando, Jenny W., Juanca, Julieta, Mary, Santana and Simone.

For being risk takers and consuming my 'innovative' recipes, WLC: Andrea F., Bea, Danilo, Elisa, Emanuelle, Giacomo, Jenny, Iulia, JuanK., Mary, Michelle, Paula N., Shivani, Simone and Tobias.

For memorable moments over the Maastricht years: Alejandro, Andres, Charlotte G., Chen, Cheng, Clotilde, Daniel O., Davina, Emmanuel M., Francesca G., Francesca R.,

François, Gintare, Giorgio, Hibret, Iman H., Iman R., Jennifer T., Josy, Julien, Katrin, Nasser, Ortrun, Patima, Richard, Sergio, Sheng, Solomon, Tatevik and Victor.

For being wonderful Bosscherweg neighbors: Petra and Coen, Jeroen and Laura, Marijn and Erik, Jan and Irma and the rest. And for being my yoga teachers: Lisalotte and her talented Saturday class and Aliana.

For living with me in Maastricht: Baer, Erika, and especially Elisa and Mary.

For teaching me so many things, a profound thank you to my batch: Ayla, Charlotte K., Elisa, Elise, Elvis, Ibrahima, Iulia, Hassen, Jenny W., Mary, Mira, Mueid, Nana, Tamer and Youssef.

My life would not be what it is without my great companions from my pre-Maastricht days: my DC friends, my IDB friends and colleagues, my CIPA and Bolivia friends, my Ohio experiences, my Boston friends, i-to-i, my Portlandia adventurers, my CC girls, and my most beloved Ithaca friends. Thank you for making this world an inhabited garden.

If I trace my steps backwards, I can identify a few key turns in my path that serendipitously led me to where I am now. When Ionela took a gamble and hired me as the Job Developer at the YMCA International Learning Center, it was because I 'smiled a lot' during my interview. My job was to help people who were usually more than twice my age and recently laid off from manufacturing companies find new jobs in the Boston area. They needed to reskill and find employment in an unforgiving economic slump. I found jobs for at least three of our students at the Dunkin' Donuts down the street from our school; the pay was worse, the hours were worse, and work was worse than their previous jobs. But to find a job at all, was considerably better than not finding one. My experience with these students (some more successful), who trusted me to help them navigate re-employment, engrained in me images and real life stories to go along with dry terms like 'displaced workers' and the 'difference between manufacturing and services'. Collectively these students taught me that it's never too late to learn new skills for a changed workplace, and that a positive attitude and persistence are crucial to adaptation.

If I had never moved to Ohio, I never would have worked for David Harrington. Sharing an office with a brilliant economist who relies on you for data collection is the rarest of fortunes. During this 'apprenticeship' which was better than any education I

could have paid for, David taught me the foundations of economics and the excel skills that I have relied upon ever since.

It is at the IDB that I began to understand innovation. I also began to understand how difficult it is to facilitate innovation. The friendships I formed over my working years and the admiration I have for my colleagues and their pursuit of a better world has shaped my approach to the research in this thesis and my understanding of its importance.

Something that has been on my mind is the role of extracurricular activities in educational formation. As I was finishing my thesis, I had the following phrases recurring through my mind. They were phrases that various soccer coaches of mine yelled across the field from the sidelines during games: "Anticipate!", "ohh, that was UGLY", "dig deep", "look up", "finish strong", "fiiiiinish!", "you are as good as anyone else out there on the field; you just have to believe that about yourself". How these phrases cropped up years later when I did indeed have to 'dig deep' tells me (at least anecdotally) that 'extracurricular training' and other important elements of educational pathways (such as teacher quality) which fell outside the scope of what I could cover in the thesis, are important and still need to be addressed.

On a final note, I am not sure I would have started or finished this thesis without the love and support of my family. It was my Uncle Michael who suggested years ago that I should get a PhD. His opinion of my capacity to do so has carried me through some moments when I doubted myself. My Uncle Vince has unwaveringly supported all my educational endeavors. My brother Mac and his wife Elizabeth, who were just married when I started this thesis, have made my life more enjoyable as they now have two amazing children and an (almost) fully renovated Farm house. I never could have anticipated meeting Ludo in Belgium just before I started my final year in Maastricht. I consider him my 'partner in crime' and a great addition to my family.

Part of my nonlinear path took me back to Ithaca briefly and as Cavafy suggested of the Greek Ithaka: it is always on your mind, it is the reason for setting out, and it is what gives you such a marvelous journey. It is because of my parents, how they raised me and the examples that they set for me that I never would have given up on my thesis. But there can be no doubt that their support during the final stages was paramount. Mom and Dad, thank you for everything.

This thesis is dedicated to: the little people in my life - Tegan, Sanne, and all my friends' children - for it is their education that lies mostly in the future. To Gabi and Andrew Charles, who left this world too soon. And to all past, present, and future Glahns, Lysaghts and Cathles.

I hope they find merit in the content.

Table of content

Chapter 1

Introduction

1.1 Introduction and Motivation

Technology is challenging education. Think tanks and political actors debate how an educated person will be defined in the future. International organizations, governments, private sector entities, and media are calling for education reform. There is general agreement that education will continue to instruct and be the place for learning the foundations of knowledge and mastery of core subjects. But increasingly there is also the notion that a high-quality education will develop the skills (in the broadest sense, including behavioral skills) for employment opportunities shaped in tandem with capable and rapidly evolving technology (see e.g. Harvard University Advanced Leadership Initiative, 2014; Brookings, 2017). The extent to which the competences acquired through education match the competences required by the labor market (a la Ryan's 2001 school-to-work transition) fall along a broad spectrum. But there can be little doubt that technological education is becoming an increasingly important part of what is viewed as a quality education.

Vocational education and training (VET) is defined as "education and training programmes designed for, and typically leading to, a particular job or type of job." (OECD 2010, p. 26), and lies at the furthest end of the educational spectrum, where the purpose of education is explicitly the development of job-skills. VET should equip people with knowledge, know-how and skills related to a specific, occupation, job or vocation (CEDEFOP, 2008; OECD, 2009; EU Commission (Eurostat), 2016). According to UNESCO, general education is designed to "develop learners' general knowledge, skills and competencies and literacy and numeracy skills, often to prepare students for more advanced educational programmes…General education includes educational programmes that are designed to prepare students for entry into vocational education, but that do not prepare for employment in a particular occupation or trade or class of occupations or trades, nor lead directly to a labour market relevant qualification." (UNESCO UIS, 2011). While it is clear that there is some overlap between the two types of education, it is also clear that overarching purpose of the two educational pathways is distinct.

Vocational education is widely recognized as an under-studied component of education quality which is potentially relevant for macro-economic performance, but difficult to assess (McGrath, 2012; Sianesi and Van Reenen, 2003). Vocational education is receiving increasing attention by leaders who are worried about how best to equip students and graduates with the relevant skills for jobs that do not presently exist (WEF, 2016). Employers increasingly demand immediately useable skills that are attuned to new production methods and products. By and large, new expectations for both skills and higher-order competencies are not being met by current schooling processes around

the world (Scott, 2015). Companies like IBM are open about shifting their hiring focus from credential-based to skills-based education for 'new collar jobs', and advocate for acquiring skills through vocational education.[1] Coding bootcamps are a good example of a proliferation of a new form of vocational training programs, outside the formal education system, which have emerged to facilitate reskilling and upskilling to supply talent for job vacancies in the tech-industry.[2]

Before sweeping education reform toward a better alignment of education pedagogy and workplace relevance, we need a more comprehensive understanding of how vocational and general education pathways within the formal education system relate to the development of skills and benefit the economy. This thesis addresses this issue.

There is a reason for the paucity of research on vocational education, at least in the long-run macroeconomic literature. Until recently, data which distinguish education pathways with different emphasis on workplace skills have not existed on a scale comparable to data on the quantity of education (i.e., years of schooling). The bulk of the education quality literature concentrates on either inputs (i.e., teacher quality, class-size, infrastructure, school autonomy), or outputs (i.e., educational attainment). Scholars acknowledge that education quality is not something that can be addressed using one indicator or model (Cheng and Tam, 1997). Yet there has been little emphasis on measuring the outcomes of different types of educational processes and distinguishing the outcomes of vocational and general pathways. This information is vital for policy makers to respond effectively to the urgent need to improve education quality and the relevance of the skills developed through the different educational processes (Szirmai, 2015).

This thesis develops novel ways to isolate and measure the outcomes of different educational pathways. A central focus is on vocational education pathways, because vocational pathways are definitionally most directly connected to the labor market. The thesis compiles new data from existing sources, uses existing data in new ways, and generates new data from surveys. The chapters in this thesis draw on a range of

[1] IBM has partnered with community colleges in the United States: https://www.ibm.com/blogs/policy/ibm-ceo-ginni-romettys-letter

[2] Coding bootcamps are intensive three to six month programs typically offered by commercial and non-profit enterprises (ITU, 2016). They teach students the practical foundations of computer programming in a hands-on learning environment which combines traditional vocational training with socioemotional tech skills to prepare students for entry-level tech positions (Mulas et al., 2017). In 2018, there will be about twenty thousand people graduating from these bootcamps representing an estimated 748 percent increase over the number of graduates from bootcamps in 2013. About 75 percent of alumni from bootcamps report being employed within 4 months of graduation and graduates tend to report a median salary of seventy-thousand dollars in the United States. (Course Report, 2018)

methodological approaches and units of analysis to investigate how skills obtained from educational processes are related to:

- economic growth and technological catch-up,
- public investment decisions, and institutional flexibility.

The different chapters provide a deeper understanding of the utility of work-related skills in and across economies, how the quality and timing of education influences skill development, and identifies challenges and opportunities that educational institutions face when they try to anticipate the future skills needed by a rapidly changing labor market.

Implicitly framing the research in this thesis is the notion that educational institutions and services are part of national systems of innovation. Therefore, the most interesting outcomes of the educational process are the competences attained by the learners, particularly those skills that are influenced by education quality that could strengthen links to the private sector. In some countries, for example Australia, over fifty percent of inventors have vocational education backgrounds, yet skills (particularly VET skills) have been neglected or left out of the national innovation policy documents, and the role of vocational education in economic prosperity is practically invisible in the public eye (Dalitz and Toner, 2016; Jones, 2018).

There are, of course, many elements of education quality that are not defined by its link with the workplace which may have an influence on a person's overall educational formation and preparedness for the labor market. First and foremost, teacher quality is fundamental to school quality (see for example, Hanushek and Rivkin, 2006). One potential issue in systematically distinguishing vocational education pathways is that there may be inherent differences in teacher quality between different education tracks that might also vary according to a country's stage of economic development. It is also plausible that the extent to which a vocational curriculum incorporates either academic/theoretical training or socio-skill development (such as critical thinking, problem solving, persistence, etc.) in the curriculum may vary with stages of overall economic development. This is something that could be addressed in future research closely related to various chapters in this thesis.

Perhaps opportunities for learning that occur outside or peripheral to formal education (i.e., involvement in sports or other extracurricular activities). The role of coaches or mentors at different stages of the educational process may shape the development of

skills (i.e., teamwork, perseverance, creativity, etc.) that are relevant for the workplace. But these fall outside the scope of the research undertaken in this thesis.

Under the larger umbrella of education quality, this thesis investigates in three different ways how education pathways engender skills and economic outcomes. Each approach disentangles a quality of education from measures of quantity of education in a different time period: the past, present, and future. A brief overview of the chapters now presented. This is followed by a more extensive discussion of the chapters (in sections 1.2 to 1.4) which includes the conclusions reached.

- Chapters 2 and 3, define the quality of the education process in terms of its relation to the workplace. The context is global and the time period spans from 1950-2010. Chapter 2 defines a new variable that distinguishes vocational and general education. It is a 'building block' chapter that develops the dataset that is used in Chapter 3 to carry out the macroeconomic cross-country growth regressions in Chapter 3 that ask whether the type of education matters.

- Chapter 4 measures the quality of the education process by adult numeracy skills. Cognitive skills/competences such as numeracy are a more accurate reflection of educational achievement than educational attainment, e.g., years of schooling (Hanushek and Woessmann 2012). Skill accumulation over an educational lifetime is a function of many inputs, but perhaps the easiest one for national policy makers to manipulate is investment. They seek a careful balance in the allocation of (sometimes scarce) financial resources between primary, secondary and tertiary education (Szirmai, 2015). The context of this chapter is 12 OECD countries and the time period is contemporary.[3] We ask whether public investment and its timing matter for adult competences.

- Chapter 5 defines quality of education in two ways. In the first part of the chapter, quality of education is defined by education's ability to facilitate an appropriate job match and engender numeracy skills frequently used on the job. In the second part of the chapter quality of education is defined as a form of organizational learning and we ask to what extent are the educational institutions able to play a special role in the system of education? Are they aware of external labor markets, changes, and barriers to adaptation and continuous improvement? When employability is one of the goals of education, anticipation and nimble institutional responses are key (McKinsey, 2017). What kind of support do these institutions need and what are the challenges they are face

[3] Adults were tested in 2011/12 and received public investment spanning the years 1971 to 1993.

in seeking to adapt quickly? Our aim is to help policy makers think about what kind of support education institutions will need, and the objective is exploratory only. The context is two advanced economies (the Netherlands and New York State in the United States) with very distinct education systems, and the time period is both contemporary and anticipated future. We ask the education institutions about the challenges they face when they try to adapt their educational programming to cultivate skills anticipated to be valuable in the labor market of the future.

- Chapter 6 contains a summary overview, the main conclusions and a discussion thereof.

1.2 Measuring Education Pathways and Skills by their Relevance to the Workplace

The purpose of Chapter 2 is to extract that part of education which is deemed most closely 'fitted' to the workplace from overall years of education, and test whether that education segment can be more precisely related to economic growth over relatively long horizons. It makes sense that some education, while useful in life is superfluous for the work world. By isolating vocational education around the globe for more than half a century from the most commonly used education data structure 'years of schooling', we are able to design an indicator to capture the portion of human capital at the secondary level purposefully devoted to educating people for their jobs.

Chapter 2 reveals that while educational attainment has increased in practically every country and region, the proportion of vocational secondary education has declined or plateaued in many countries and in almost all regions. Vocational secondary schooling data moves within and between countries in a less uniform way than, for example, a straight count of years of schooling. This allows comparative analysis.

We hypothesize that macro-economic growth models that use years of schooling as a proxy for human capital in their studies may not be optimal. If the goal is to explain variation in economic growth, and if we take as a given that at least a portion of education is not and was never intended to be related to the productive capacity of the student or worker, then years of schooling is not the correct variable. A more appropriate variable could be the part of education with the specified goal of educating for the workplace. We suspect that this absence of this kind of specification is primarily

due to inaccessibility of the needed data which would cover a sufficient time span. Chapter 2 develops the needed data.

In Chapter 3 we use the data from Chapter 2 to test whether vocational secondary schooling tells us something more or different about the relationship between education and economic growth. We find that yes indeed, when education has the specified purpose of being linked with the workplace it does have a different and perhaps more precise relationship with economic growth or technological catch-up than overall years of schooling does. But there is an underlying empirical challenge in this chapter. At the macro-economic level, the relationship between overall years of schooling and economic growth or technological catch-up does not follow the consistent empirical regularities of the relationship found at the individual level (i.e., between education and wages found by Becker, Mincer and many others) which we would intuitively expect to 'aggregate up'. We know from various sources, summarized by Durlauf and Johnson (2005), macro-models are often very sensitive to small changes, and publications tend not to yield consistent results (Psacharopoulos, 2011). Despite this general challenge in macro growth economics, we find that vocational secondary schooling is consistently related to growth. We also find that counter to our expectations, the growth effect from vocational secondary schooling happens when economies are already fairly close to the technological frontier. The dataset developed in Chapter 2 provides many avenues for future research.

1.3 Measuring Education Pathways and Skills by Adult Competences

There are different schools of thought about whether the value of education is solely its capacity to train people for the workplace. Many people would argue that the 'job' of the education system is to instruct learners in key competences (i.e., the 3 R's of Reading, writing and Arithmetic; see chapter 7 in Szirmai, 2015 for a longer discussion). It is argued that once competency in the 3 R's us attained it can be applied to a variety of settings and may be more resilient to risks of over-specialization.

In Chapter 4, we take a broader stance and analyze the quality of the education process through the lens of adult competences and the effectiveness of cumulative investment over educational lifetime. The skills that an education system produces can be seen as a measure of its effectiveness. Not all education is tasked with preparing learners for a specific job. Rather, it is tasked with developing the skills students will need to enter a more highly skilled adult population. Cognitive skills should be indicative of the success of a school system's effort. The development of cognitive skills is affected by a range of factors. Empirically, family background is the dominant determinant. Among the factors that can be manipulated by policy makers, the amount of public investment and the size

of the resources directed at different educational stages (primary, secondary, or tertiary) is the most important. In this chapter we find that more public financial resources invested over an educational lifetime do translate to greater adult competences in numeracy, after controlling for family background, educational attainment and country fixed effects. The timing of that investment, and the educational stage in which more public resources are invested matters. Students need to have a sufficient skill base to build on in order to take full advantage of investments that come later in their educational trajectory, but investment in the various levels of education interact in non-obvious ways.

1.4 Measuring Education Pathways and Skills by Institutional Flexibility

Looking to the future, the quality of education may be defined by the adaptability of educational institutions to environmental changes and internal barriers (continuous improvement). Today's context of automation and rapid technological change means that the education system must change, and constantly rethink how to prepare graduates for the work world. But the education system is not generally regarded as nimble, and there is scant literature about innovation in education (Arundel, 2016). Where it exists, it is limited to higher academic education (i.e., GAIHE, 2016). Do education institutions anticipate changes in the labor market? How do they do it? What are the obstacles they face when trying to change? We target the part of the education system that is designed to be the most aligned with the labor market and focus on higher professional education institutions at the tertiary level in the Netherlands and in New York State. In both cases these are the institutions that are supposed to be the most aligned with the labor market and are tasked with staying abreast of training their graduates for a changing workplace. We survey these institutions to ask directly whether they monitor the labor market. We ask them about the challenges and opportunities when adapting their educational programming to meet the needs of the labor market. We find that the most commonly cited obstacles in New York State are related to lack of sufficiently disaggregated data. The Netherlands reports a heavy reliance on its instructors as the agents who transmit up-to-date knowledge about the labor market to their students, and they report this both as an advantage and as a challenge.

Concluding

The concluding chapter recasts the work of this thesis in a way that assesses how different educational pathways have led to different skill and economic outcomes: different compositions of general and vocational, different numeracy skills in adulthood, different education-job match and skill use profiles. The closing paragraphs engage in a critical discussion of the different chapters and identify avenues for further research.

Chapter 2

New Variables for Vocational Secondary Schooling: Patterns around the World from 1950-2010*

*This chapter is based on Cathles, A., 2016. New variables for vocational secondary schooling: Pattern around the world from 1950-2010. MERIT Working Papers #2016-002, United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT). Available at: http://www.merit.unu.edu/publications/working-papers/abstract/?id=5911

Abstract

Despite longstanding global academic and policy interest, cross-country data to investigate the long-term economic effects of the mix between vocational and general education have not been readily available. We combine UNESCO enrolment data and Barro and Lee (2013) secondary years of schooling data to introduce a new data set of three internationally comparable vocational secondary education variables covering the period 1950-2010 for 129 countries. The methods used to construct these variables are described and trends over the past 60 years are reported. The data are fully presented in a freely accessible appendix, so that they can be used to study questions related to vocational education and economic growth.

Keywords: Vocational Education • Education and Economic Development • Human Capital • Skills

JEL Classification Codes: I25 • J24 • 010

2.1 Introduction

There is a general sentiment in policy circles that vocationally trained workers play an important role in the economy.[4] Empirically, however, little is known about the contribution of this type of education to macroeconomic growth. This gap in the macroeconomic literature stems from data constraints. A long time series that distinguishes between vocational and general education comparable across countries did not exist (Sianesi and Van Reenen, 2003), even though the importance of long time horizons for capturing macroeconomic growth effects and societal returns of secondary education has been highlighted in recent research (Marconi, 2018). This chapter introduces a dataset of vocational secondary schooling variables that can be used to empirically investigate the role of vocational education in economic growth.

The newly constructed time series uses secondary vocational enrolment data to create measures of vocational education at the secondary level for 129 countries for the period 1955-2010. The data are presented at 5-year intervals for the population aged 25 and over. This chapter is structured as follows. Section 2.1 briefly defines vocational education and outlines measurement challenges. Section 2.2 describes the construction of the Vocational Secondary Schooling variables, the data sources that were used, and caveats with respect to the consistency and validity of the constructed measure. Section 2.3 presents a descriptive assessment of changes over time in vocational secondary schooling around the world, focusing on differences between and within regions. The full data by country and year are included in Appendix A.5.

2.2 Defining and Measuring Vocational Education

The OECD definition that is used throughout this thesis is also the guiding definitional reference for this chapter: "Vocational education and training (VET) includes education and training programmes designed for, and typically leading to, a particular job or type of job." (2010, page 26). One empirical issue that immediately arises in a cross-country assessment of vocational education is that education systems and VET programs vary in terms of their organization and structure as well as the relative importance of general and specialized training (Kuczera, 2008). There are plenty of examples of why these differences complicate internationally comparable data collection. For instance, the education and training that medical doctors receive meets the OECD's definition of VET, but that education is not usually regarded (or statistically reported) as VET (OECD,

[4] Several reports have been generated calling for 'the right skill mix' in the population so that employers and society will benefit. Often - vocational, technical or middle skills are the center of attention in skill-mix (UNESCO, 2013; OECD, 2010; CEDEFOP, 2010; European Commission, 2010; Brookings, 2009).

2010). Another example is that some countries have separate institutions for vocational training, while in other countries general and vocational education are delivered at the same institution. Some countries have a mixture of separated and combined educational institutions. Structural differences in vocational education delivery systems in different countries pose a statistical challenge, because if administrative tracking of the two types of education at the national level differs widely from international standards, it could influence how the data are reported. Furthermore, the distinction is not merely administrative, but typically can imply distinction between institutions, teachers, coursework and/or curricula.

Fortunately, the United Nations Educational, Scientific and Cultural Organization (UNESCO) has established internationally agreed upon definitions and classifications which are then carefully implemented through a standardized data collection process that is guided by detailed operational instruction manuals.[5] Since the 1950s, UNESCO has maintained and updated an International Standard Classification of Education (ISCED) statistical framework in a consistent manner over time. The ISCED 1958 is linked to ISCED 1976 which is linked to the ISCED 1997 classification. It is important to bear in mind that although these classification systems map onto each other, there may be some differences in the data due to changes in the classifications, or other reporting or recording issues. For example, data on vocational education at the secondary level for the United States are reported as missing, but this does not mean that there is no vocational secondary education at the secondary level.

The vast majority of the UNESCO data (from 1970-2010) used in our dataset are reported under the 1997 ISCED classification.[6] Appendix A.1 summarizes the demarcation of program orientation (general, vocational, pre-vocational) and educational trajectories at different levels of schooling according to the ISCED 1997 classification. The 1997 ISCED classification changes represent a major revision from the 1976 ISCED classification. One of the biggest classification changes was the introduction of demarcations to distinguish between general, pre-vocational and vocational education programs.

Even though the 1976 classification did not provide clear demarcations of program orientation, the data from 1950-1965 were reported separately by type of education in

[5] For reference, see the ISCED 1997 manual which details this process (http://www.uis.unesco.org/Library/Documents/isced97-en.pdf).

[6] Data from 1970-1995 were adjusted to the 1997 classification when they are reported in the 1999 statistical yearbook. The most recent ISCED classification is 2011, but this classification was not in place for the data used in this paper, which end in 2010.

the 1969 UNESCO Statistical Yearbook. The definitions used distinguish education type are as follows:

> "*General education.* Data presented under this heading cover academic secondary schools and academic secondary classes attached to institutions at other levels. Some vocational education may be included since a number of schools in certain countries offer courses combining the academic and vocational types of education…[7]" (UNESCO 1969, p.g. 194).
>
> "*Vocational education.* Data presented under this heading cover all vocational education at the second level, e.g. technical, industrial, arts and crafts, trade, commercial, agriculture, fishery, forestry, domestic science, music, fine arts, etc., provided in vocational schools as well as in departments and classes attached to institutions whose main concern is education of other types and/or levels. Correspondence courses have generally been excluded, but various part-time courses, sometimes of very short duration, are included…[8]"(UNESCO 1969, pg. 194). Teacher training is not included.[9]

Under the definitions being used in this chapter, technical education is a sub-set of vocational education. The proportion of technical to vocational education may vary by country.[10] The consistency over time and international harmonization of our vocational variables rely on the consistency between the 1969 definitions and the ISCED 1997 classification and on UNESCO's oversight in the application of a consistent statistical framework for data collection and reporting.

The vocational variables introduced in this chapter are at the secondary level of education. Although vocational education clearly extends beyond secondary to tertiary education, the very low percentage of the population attaining tertiary education across all countries and regions in the 1950s and 1960s led to a focus on vocational education at the secondary level. In 1950, for example, the proportion of the population who attained tertiary levels of education was less than 1 percent in South Asia and Sub-

---

7 "…Primary classes attached to secondary schools have been excluded as well as evening schools and correspondence courses whenever this is feasible..." (UNESCO 1969, p.g. 194)

8 "…It should be kept in mind that the proportion of…part-time students is particularly important here and the available information does not allow a clear delimitation in this respect…"(UNESCO 1969, p.g. 194)

9 Although the third education type recorded in UNESCO 1969, '*Teacher training*' would definitely be considered vocational education, the enrolments recorded under teacher training have not been added to the vocational enrolments. This is because, over time most of the teacher training offered at the second level shifted to the third level and was discontinued at the second level (UNESCO 1969). Since this transition was happening at different times for different countries, including teacher training enrolments at the secondary level risks violating internal consistency. Therefore it is excluded.

10 An example of the distribution of VET between technical and all other vocational education for the Netherlands is highlighted in Appendix A.4.

Saharan Africa and barely over 3 percent in Advanced Economies, on average. Given the huge expansion of higher education world-wide, a similar set of variables could be constructed for higher vocational education, albeit covering a shorter time span. Future research could explore this undertaking.

General education is designed to instruct in general knowledge, skills and competencies. General education includes programs in primary school that prepare students for entry into more advanced educational programs (including vocational tracks in upper secondary or higher-education), but general education programs do not prepare students for employment in a particular occupation, trade, nor lead directly to a labour market relevant qualification (UNESCO UIS, 2011). On the other hand, vocational education may include instruction in knowledge or theoretical understanding, so far as it pertains to a specific occupation or job.

2.3 Data Sources

The sources of data that were used in the construction of the vocational secondary schooling variables are as follows.

The data sources for vocational and total secondary enrolments for each country at 5-year intervals from 1950 to 2010 are UNESCO's 1969 and 1999 Statistical Yearbooks and the online UNESCO Institute for Statistics (UIS) database.[11]

From 1950-2000, enrolment data from the UNESCO 196912 and 1999 Statistical Yearbook13 are used:

(a) The total number of pupils in General Education at the second level.
(b) The total number of pupils in Vocational education at the second level.

For both of these types of education these data include both public and private education (UNESCO, 1969 and 1999).

From 2000-2010, enrolment data from the online UNESCO Institute for Statistics (UIS) are used:

[11] Accessed October, 2015.
[12] Most data from 1950 to 1965 are from Table 2.10: 'Education at the second level: general, vocational and teacher training: Teachers and pupils'.
[13] Most data from 1970 to 1995 are from Table II.6: 'Secondary education: teaching staff and pupils'.

(a) Enrolment in total secondary. Public and private. General programmes.
(b) Enrolment in total secondary. Public and private. Technical/vocational programmes.

Since the borders of some countries have changed since the 1950s, detailed notes about the decisions made regarding data entry have been recorded in Appendix A.2.

The source for data on secondary education attainment and secondary years of schooling is the Barro and Lee 2013 data set 'Educational attainment in the world from 1950 to 2010'. Like our vocational enrolment data, their data rely on UNESCO data almost exclusively.[14] The UNESCO data draw on national census data as a primary source. UNESCO statistical yearbooks refer to educational attainment as the *percentage distribution* of the highest level of education reached by the adult population (age 25 and over). For example, someone who undertook secondary level education, but did not proceed to tertiary education, is part of the percentage of the adult population who attained secondary education in that country. Levels of education attainment are grouped into broad categories conceptually grounded in the ISCED classification. The broad categories of attainment are: 'no schooling', 'primary', 'secondary' and 'post-secondary'.[15] Barro and Lee have filled in missing values from census data with forward and backward extrapolations on attainment by age group (when attainment data are unavailable i.e., for younger age groups, they use enrolment data)[16] and different mortality rates among more or less educated populations in countries at different stages of economic development. They have further broken down the three levels of school into 'complete' and 'incomplete' using completion ratios (Barro and Lee, 2013). Combining the attainment data with information on the duration corresponding to each level of schooling, they generate the average number of years of schooling at each level (primary, secondary and tertiary). The years of schooling at each level are summed to create the variable 'years of schooling'.

From 1950-2010 the following variables from the Barro and Lee 2013 data set are used:

(a) The proportion of the population that has attained secondary schooling, age 25 and over.
(b) The average years of secondary schooling, age 25 and over.

An important advantage in the approach we take in this paper is that UNESCO data are almost always the underlying data. The norms established in the ISCED are used

[14] For the countries in our dataset, except for Taiwan, the secondary source in Barro and Lee's data appendix is listed as UNESCO Statistical Yearbook (from various years) UN Demographic Yearbook (from various years), or the UNESCO Global Education Digest (from 2005).
[15] 'No schooling' is for those who have completed less than one year of school.
[16] For each 5 year age cohort (i.e., 25-29, 30-34…70-74 and 75+).

by UNECO to standardize international data collection and reporting manuals. These manuals are used for both educational attainment and enrolment by education type (or programme orientation) data. This is important because we use the vocational to total enrolment ratio to ascertain the percentage of the population with vocational secondary attainment and years of vocational secondary schooling from the Barro and Lee data. Since all the underlying data were collected and reported by the same institution, which is also the institution that oversees internationally standardized guidelines, our dataset should be internally consistent.

2.4 Vocational Secondary Schooling Variables

Variable 1 - Vocational to Total Secondary Enrolment Ratio[17]*:* The first variable was created by building a simple ratio of vocational to total secondary enrolments at the secondary level using data from UNESCO (1969, 1999 and UIS) at 5-year intervals. Countries with less than 4 observations were dropped, because 4 observations represents missing data for 20 years (either continuously or sporadically) over the whole 60 year time period (1950-2010).[18] To fill in missing data, linear interpolation and extrapolation were used. To avoid unreasonably long inter/extrapolation, a decision rule was introduced to limit the number of years over which the data could be extrapolated or interpolated to 2 time periods, which represents 10 years at the beginning or end of the time period for extrapolation, or 15 years in the middle of the time period for interpolation.

Variable 2 - Vocational Secondary Attainment: The vocational to total secondary enrolment ratio at time (t) is multiplied by Barro and Lee's secondary level educational attainment variable[19] in the subsequent time period. The enrolment ratio data are available starting in 1950, so the first period in which the ratio can be used to infer vocational attainment at the secondary level is in 1955. Barro and Lee (2013) also sometimes use "…enrolment data to estimate missing attainment data and assume that

[17] Bertocchi and Spagat (2004) constructed a similar ratio [although their ratio is Vocational to General secondary, not Vocational to Total secondary] using UNESCO data from 1950-1991. The Bertocchi and Spagat ratio for Italy follows a very similar pattern to the ratio as it is calculated here. For example, in 1990 they report a ratio of 0.71. Using the UNESCO data from the 1999 Statistical yearbook as we do for our ratio, but calculating the ratio as they do, we arrive at 0.65 in 1990.

[18] Nineteen countries with less than 4 'real observations' were dropped: Afghanistan, Algeria, Barbados (data were only available for 1955, 1960 and 2005), Cuba, Guyana, Haiti, Libyan Arab Jamahiriya, Maldives (data were only available for 2000), Myanmar, Namibia (data were only available for 1990 and 1995), Nepal Nicaragua, Papua New Guinea, Reunion, Sri Lanka (data were only available for 1970 and 2010), Tonga, United States of America, and United Arab Emirates.

[19] Their attainment variable incorporates survival/mortality rates by age and level of education.

the change in enrolment leads to a proportional change in attainment over time with a time lag" (p.g. 194).[20]

Variable 3 - Vocational Secondary Years of Schooling: Two approaches have been tried for the construction of the years of secondary vocational education variable. In method A. the vocational to total secondary enrolment ratio at time (t) is multiplied by the share of Barro and Lee's years of secondary schooling in the subsequent time period. Since the Barro and Lee data are reported every 5 years, the subsequent time period is 5 years after time (t). We selected this time span because we expect that vocational secondary education enrolees should complete within a 5-year period. We selected this time span because we expect that vocational secondary education enrolees should complete within a 5-year period. In doing so, we have to make a relatively strong assumption that there are no differences in completion rates and mortality rates between vocational secondary education and total secondary education. Method B. involves the incorporation of a uniform duration of 3.5 years for vocational training for all countries for all time periods which is then applied to the percentage of the population with vocational Secondary Attainment. The second approach follows the technique used by Barro and Lee (2013) when they applied a standard duration of 4 years for higher education to the proportion of the population with tertiary attainment, except that we do not adjust for completion rates. For the construction of the database, we have chosen method A. Data according to method B are available upon request.

Table 2.1 presents the contents of the vocational secondary school data set.

Variables included:	1. Vocational to Total Secondary Enrolment Ratio 2. Vocational Secondary Attainment 3. Vocational Secondary Years of Schooling
Countries included:	**Advanced Economies (23)** Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain Sweden, Switzerland, Turkey, United Kingdom. **East Asia and the Pacific (16)** Brunei Darussalam, Cambodia, China, Hong Kong SAR, Macao SAR, Fiji, Indonesia, Lao People's Democratic Republic, Malaysia, Mongolia, Philippines, South Korea, Singapore, Taiwan, Thailand, Viet Nam. **Europe and Central Asia (20)** Albania, Armenia, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Poland, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Tajikistan, Ukraine.

[20] For example, for adult population aged 15 and over, they use this technique to 'fill-in' missing attainment data for younger age groups (15-19 and 20-24).

Table 2.1 presents the contents of the vocational secondary school data set. *(continued)*

Countries included:	**Latin America and the Caribbean (20)** Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay Venezuela. **Middle East and North Africa (15)** Bahrain, Cyprus, Egypt, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Malta, Morocco, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Yemen. **South Asia (4)** Bangladesh, India, Nepal, Pakistan, Benin. **Sub-Saharan Africa (31)** Benin, Botswana, Burundi, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Gabon, Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mali, Mauritania, Mauritius, Mozambique Niger, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.
Time period:	1950-2010 in five year intervals. Variables 2 and 3 are available from 1955 onwards.

In order to check the validity of the construction of the vocational secondary schooling variables, we provide a detailed analysis of the Netherlands in Appendix A.3. To check the validity of the variables we use the original census data. The Netherlands is a good example, because the census data have a detailed breakdown of vocational attainment at the secondary level. With this information it is possible to illustrate (1) how the attainment data constructed by UNESCO relates to the Netherlands Census data, and (2) how the Barro and Lee data relate to the distribution of educational attainment in UNESCO Statistical Yearbooks. This helps to verify whether the constructed vocational variables are measuring what we actually want to measure.

2.5 Vocational Secondary Schooling around the World

This section presents a description of the global trends for each of the three vocational secondary schooling variables from 1955 to 2010. Table 2.2 presents the summary statistics for the first variable of the vocational to total secondary enrolment ratio by region[21] and for the world in 1955 and 2010. While the ratio declined in every region

[21] **In 1955**, the following countries from the following regions were missing data and, therefore were not included in the regional average: **Advanced Economies:** New Zealand, Switzerland, and the United Kingdom. **East Asia and the Pacific:** Malaysia and Mongolia. **Europe and Central Asia:** Armenia, Croatia, Estonia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Serbia, Slovakia, Slovenia, Tajikistan, and Ukraine. **Latin America and the Caribbean:** Costa Rica, Dominican Republic, Guatemala, and Honduras. **Middle East and North Africa:** Egypt, Malta, Qatar, and Yemen. **South Asia**: Bangladesh and Nepal. **Sub-Saharan Africa:** Benin, Burundi, Central African Republic, Liberia, Mauritania, South Africa, Tanzania, and Zimbabwe. **In 2010**, the following countries from the following regions were missing data and, therefore were not included in the regional average: **Advanced Economies:** Canada. **East Asia and**

in the world, the starting and ending points differ starkly by region. Globally, in 1955 an average of 28 percent of pupils enrolled in secondary education were enrolled in vocational programs. At that time, the fraction of vocational to total secondary enrolments ranged from 1 to 86 percent. The regional averages of vocational enrolments in Europe and Central Asia were slightly more than half (52 percent) of total secondary school enrolments. In every other region in the world less than half of the secondary enrolments were in vocational programs. In 1955, South Asia was the region with the smallest fraction of secondary enrolments in vocational education. The standard deviations, minimum and maximum underscore the variation within every region.

From 1955 to 2010, the mean vocational to total secondary enrolment in the world declined from 28 to 15 percent. Europe and Central Asia is the region with the sharpest decline, from 52 percent to 21 percent in 2010. By the end of the time period, the region with largest fraction of secondary enrolments in vocational programs is Advanced Economies (26 percent). By 2010, in most regions East Asia and the Pacific, Latin America and the Caribbean, Middle East and North Africa, and Sub-Saharan Africa, the fraction of vocational to secondary enrolments hovers around 10 percent. South Asia remains the region with the smallest fraction of secondary enrolments in vocational education.

Table 2.2 Vocational to Total Secondary Enrolment Ratio by Region, in 1955 and 2010

		Vocational to Total Secondary Enrolment Ratio			
Region	**year**	**Mean**	**SD**	**Min**	**Max**
World	1955	0.28	0.21	0.01	0.86
	2010	0.15	0.12	0.01	0.48
Advanced Economies	1955	0.36	0.19	0.02	0.73
	2010	0.26	0.10	0.12	0.47
East Asia and the Pacific	1955	0.15	0.11	0.01	0.39
	2010	0.10	0.06	0.01	0.21
Europe and Central Asia	1955	0.52	0.17	0.27	0.70
	2010	0.21	0.13	0.02	0.40

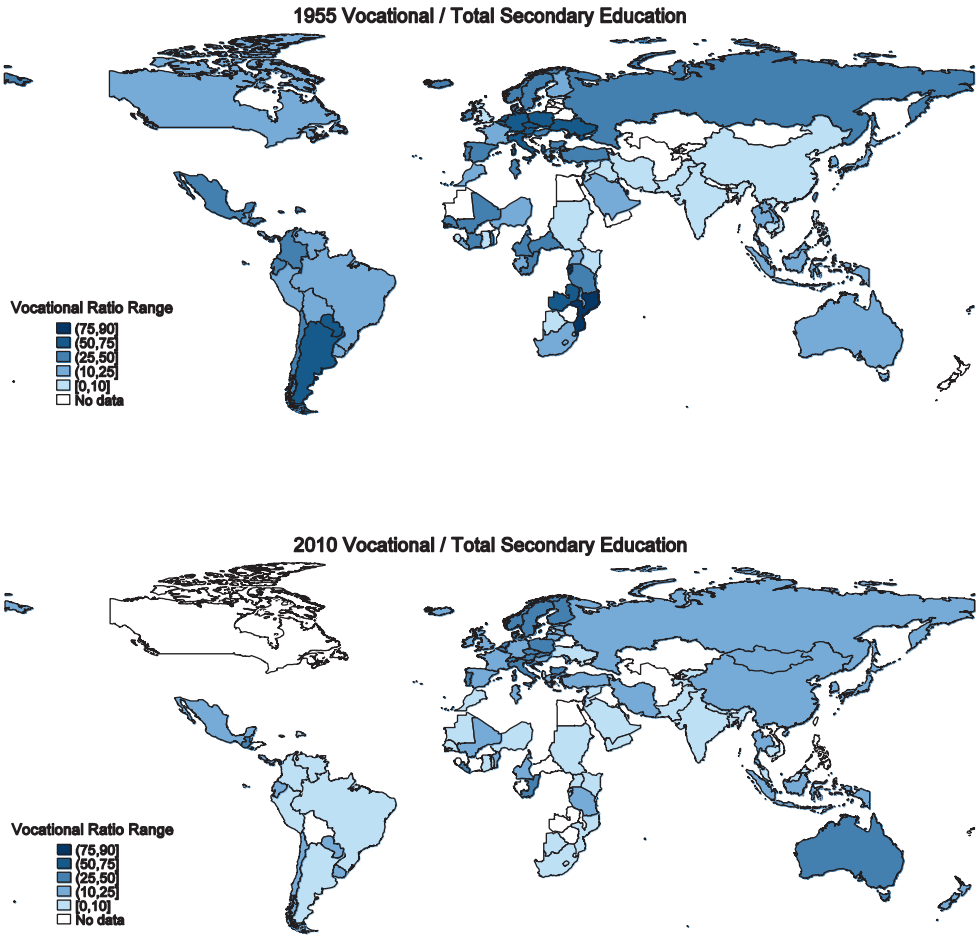
[21 (continue)] **the Pacific:** Cambodia, Fiji, Philippines, Singapore, Taiwan, and Viet Nam. **Europe and Central Asia:** Kazakhstan, and Russian Federation. **Latin America and the Caribbean:** Bolivia, Honduras, Jamaica, and Trinidad and Tobago. **Middle East and North Africa:** Egypt, Iraq, and Saudi Arabia. **South Asia:** India and Nepal. **Sub-Saharan Africa:** Benin, Botswana, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Gabon, Gambia, Ghana, Kenya, Liberia, Malawi, Mauritania, Mauritius, Rwanda, Sierra Leone, Swaziland, Togo, Zambia, and Zimbabwe.

Table 2.2 Vocational to Total Secondary Enrolment Ratio by Region, in 1955 and 2010 *(continued)*

		Vocational to Total Secondary Enrolment Ratio			
Region	**year**	**Mean**	**SD**	**Min**	**Max**
Latin America and the Caribbean	1955	0.30	0.17	0.01	0.70
	2010	0.12	0.08	0.01	0.28
Middle East and North Africa	1955	0.14	0.12	0.01	0.36
	2010	0.07	0.06	0.01	0.19
South Asia	1955	0.04	0.05	0.01	0.08
	2010	0.02	0.02	0.01	0.04
Sub-Saharan Africa	1955	0.29	0.24	0.01	0.86
	2010	0.11	0.11	0.02	0.48

Sources: Own calculations based on UNESCO and Barro and Lee (2013).
Notes: In 1955 and 2010 some countries were missing data and therefore were not included in the means. Countries excluded are listed by region in footnote 18.

The next page presents two maps of the vocational to total secondary enrolment ratio for 1955 and 2010. The borders of several countries in the world have changed since 1955. For information on data-entry decisions the reader is referred to the notes in Appendix A.2. In both maps, when there are no data the country appears as blank (or white) on the map. The darkest shade represents a ratio of vocational to total secondary schooling between 75 and 90 percent and the lightest shade represents a ratio between 0 and 10 percent. Many countries have a higher ratio (and thus a darker shade) in 1955 than they do in 2010. For example, Argentina has a ratio of 70 percent in 1955 which decreased to 8 percent in 2010. Italy is a less dramatic example: this country has a ratio of 52 percent in 1955 which decreased to 37 percent in 2010. Many of Italy's neighboring countries follow a similar trend with ratios that fall between 50 and 75 in 1955 and ratios that fall between 25 and 50 in 2010. On the other hand, some countries have a lower ratio (and thus a lighter shade) in 1955 than they do in 2010. Notably, China has a ratio of 7 percent in 1955 which increased to 21 percent in 2010. Australia has a ratio of 13 percent in 1955 which increased to 33 percent in 2010.



Sources: Own calculations based on UNESCO and Barro and Lee (2013).

The maps give a snapshot overview of how different countries' vocational to total secondary enrolment ratio changed from the beginning to the end of the dataset. While the prevailing worldwide trend of decline in the ratio of vocational to total secondary enrolments is apparent in the maps, variation is also discernible.

Although the vocational to total secondary enrolment ratio declined around the world from 1955 to 2010, over the same time period, educational attainment increased in nearly every country in the world. So, despite the decline in the vocational to total secondary enrolment ratio, the portion of the population over the age of 25 with vocational secondary attainment increased. Figure 1.2 shows the trends in vocational and general secondary

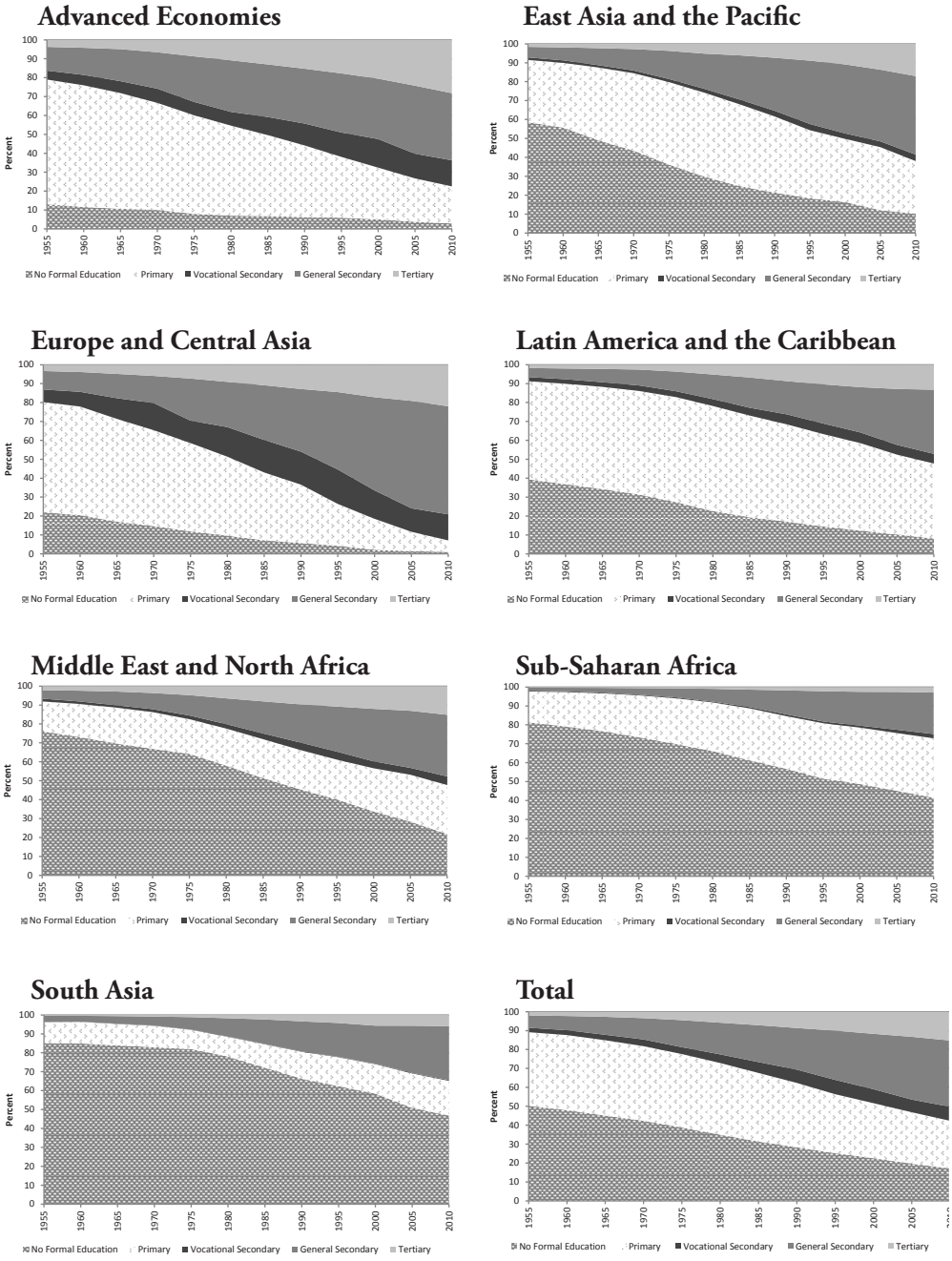
attainment relative to the other levels of education (primary and tertiary) in the regions as they have been defined. The picture that unfolds is quite revealing.

In advanced economies, the share of the population with vocational secondary education has clearly increased. However, the adult population with secondary education attainment grew from 17 percent in 1955 to 49 percent in 2010. Since secondary attainment in the adult population increased by more than 30 percentage points, the adult population with vocational secondary attainment increased from 4.7 to 13.8 percent (see Table 2.3).

In Sub-Saharan Africa, although the trends in schooling are improving consistently throughout the time period a striking proportion of the population still remains without formal education. In terms of levels, Sub-Saharan Africa, together with South Asia, performs worse than all other regions. There is very little vocational education at the secondary level. Give the urgent need for middle level technical and professional qualifications, this reflects a failure in educational policies.

The differences between East Asia and the Pacific, and Latin America and the Caribbean require a more nuanced understanding. Although, the share of the population with at least primary school attainment in Latin America and the Caribbean has been greater than in East Asia and the Pacific over the entire time period, the expansion of the share of the population with higher levels of education (secondary and tertiary) appears to have been slower in Latin America and the Caribbean. In all regions, the share of the population with Vocational secondary schooling appears to be relatively stable over time or even increasing, but it does not keep up with the overall increases in secondary schooling. Therefore, the share of vocational secondary schooling in total secondary schooling decreases in relative terms over the last 55 years.

Figure 2.1 Regional Trends in Vocational Secondary Schooling and other Levels of Educational Attainment, 1955 to 2010 (as percentage of the population of 25 years and over)



Sources: Own calculations based on UNESCO and Barro and Lee (2013).

Figure 2.1 shows that globally since 1955 a greater proportion of the population is attaining higher and higher levels of education. What is also clear is that while greater proportions of people have attained secondary schooling, in many regions a smaller percentage of these people are pursuing vocational education. Vocational education appears to be systematically declining in relative teerms. While this appears to be systematic when we aggregate to the regional averages, we know from the maps that there are some notable exceptions such as Australia.

Table 2.3 reports the summary statistics for vocational secondary attainment, vocational secondary years of schooling and years of secondary schooling (for reference) in 1995 and 2010. The vocational secondary schooling variable is based on the secondary enrolment ratio (from 1950), which is applied to the variables on secondary attainment and years of schooling that are available in the Barro and Lee dataset with a one time period (or, 5-year) lag; 1955.

One surprising thing is how small the years of secondary schooling are in 1955. Around the world there was just a half a year (0.53) of secondary schooling, which reflects the relatively small proportion of people with a high school education at that time. By 2010, the global average is about 3 years of schooling (3.02 in Table 2.3). The Barro and Lee calculation for secondary years of schooling accounts for the duration of secondary school (which is typically about four years). While the global years of secondary schooling has more than quintupled from 1955 to 2010, vocational secondary schooling has quadrupled, but remains quite small (0.54) relative to total secondary years of schooling.

Table 2.3 Vocational Secondary Schooling Summary Statistics in 1955 and 2010

		Vocational Secondary Attainment				Years of Vocational Secondary Schooling				Years of Secondary Schooling (for reference)			
Region	**Year**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
World	1955	2.35	3.06	0.01	12.77	0.13	0.17	0.001	0.92	0.53	0.60	0.01	3.53
	2010	7.42	8.04	0.09	32.67	0.54	0.57	0.01	2.41	3.02	1.62	0.17	6.90
Advanced Economies	1955	4.72	3.53	0.22	12.77	0.27	0.17	0.01	0.62	1.04	0.72	0.19	2.92
	2010	13.78	1.74	4.21	31.23	1.22	0.57	0.31	2.41	4.50	1.09	1.92	6.90
East Asia and the Pacific	1955	1.34	3.61	0.09	5.30	0.07	0.10	0.01	0.29	0.40	0.32	0.04	1.07
	2010	3.46	1.93	0.36	11.12	0.22	0.17	0.02	0.62	3.12	1.37	0.81	5.22
Europe and Central Asia	1955	6.63	3.09	2.45	11.33	0.32	0.14	0.12	0.51	0.95	0.71	0.18	3.53
	2010	13.79	0.10	1.39	32.67	0.80	0.52	0.10	1.58	4.65	1.14	3.14	6.69
Latin America and the Caribbean	1955	2.21	1.00	0.08	6.63	0.13	0.09	0.004	0.34	0.42	0.23	0.12	1.07
	2010	5.10	7.32	0.89	13.90	0.35	0.32	0.07	1.21	2.53	0.78	1.04	3.78
Middle East and North Africa	1955	1.48	3.01	0.03	10.63	0.12	0.27	0.002	0.92	0.46	0.59	0.00	2.37
	2010	4.55	10.50	0.10	23.12	0.33	0.40	0.01	1.42	2.81	1.11	0.83	5.09
South Asia	1955	0.11	3.98	0.04	0.18	0.01	0.00	0.002	0.01	0.17	0.12	0.03	0.31
	2010	0.43	6.01	0.25	0.63	0.03	0.01	0.01	0.04	1.80	0.47	1.14	2.25
Sub-Saharan Africa	1955	0.42	0.20	0.01	5.15	0.02	0.04	0.001	0.19	0.10	0.17	0.01	0.91
	2010	2.27	2.89	0.09	9.01	0.13	0.17	0.01	0.57	1.33	0.91	0.17	3.34

Sources: Own calculations based on UNESCO and Barro and Lee (2013).
Notes: In 1955 and 2010 some countries were missing data and therefore were not included in the means. Countries excluded are listed by region in footnote 18.

2.6 Conclusions

Since 1950, greater and greater shares of the global population have been reaching secondary school. Vocational secondary attainment has not kept pace with the increases in secondary attainment. Regional averages show a decline in the ratio of vocational to total secondary schooling, the maps confirm the overall trend of de-vocationalization over the last half of the century, but also illustrate some notable exceptions. What cannot be easily seen from the descriptive analysis presented in this chapter but can be seen in the data freely available in Appendix A.5, is that there is often quite a bit of fluctuation in the ratio of vocational to total secondary schooling over the time period within countries.

The potential utility of a macro level data set that distinguishes vocational and general types of education has been expressed in the literature. Until now, such a dataset has not existed. This chapter describes the creation of three vocational secondary schooling variables for 129 countries from the early 1950s until 2010. Decisions made along the way are explained so that important caveats can be taken into consideration by other potential users of the data. Our goal is to use the data to analyse of the role of vocational education in innovation and macro-economic growth. Since it is widely recognized that a deeper understanding of the skill mixes needed in an economy is important, this chapter represents a first step in developing and characterising a set of data that can examine this from a recent historical perspective.

Chapter 3

Testing the Relationship between Vocational Secondary Schooling and Economic Performance*

* This chapter is based on Cathles, A. and A. Szirmai. 2018. Testing the Relationship between Vocational Secondary Schooling and Economic Performance. Paper prepared for the 35th IARIW General Conference presented in Copenhagen, Denmark August 2018. We thank Prof. Jo Ritzen, Dr. Hassen Wako, Dr. Sabrina Wulff Pabilonia (Bureau of Labor Statistics, discussant at IARIW), attendees at the Midwest Economics Association (MEA) in Cincinnati April 2017 and members of the UNU-MERIT 'Economic Development, Innovation, Governance and Institutions Research Group 3' for valuable comments and suggestions.

Abstract:

Vocational education is assumed to be important for growth, absorptive capacity, innovation and technological diffusion. Yet empirically, little is known about the contribution of vocational education to macroeconomic performance. This chapter makes use of a newly constructed dataset of vocational secondary schooling for 129 countries from 1950-2010. By replicating and building upon four classical cross-country analyses, this chapter systematically and comprehensively tests whether participation in secondary vocational education contributes to economic performance and how it interacts with other variables known to be important for economic growth and technological change. We find that vocational secondary schooling is consistently related to economic performance. The relationship between vocational secondary schooling and economic growth changes with proximity to the frontier and countries have to be relatively closer to the frontier to see positive growth effects from additional vocational secondary schooling.

Keywords: Vocational Education • Education and Economic Development • Returns to Education • Human Capital • Economic Growth • Industrialisation

JEL Classification Codes: • I25 • I26 •J01 •J24 •O10 •O14

3.1 Introduction

Education serves many purposes, but vocational education is explicitly designed to educate for a particular job. Therefore, it represents the part of education most directly linked with the labor market in an economy. We hypothesize that vocational education has a distinct relationship from other types of education when related to dependent variables measuring the economic performance of an economy.

In order to test whether this is the case, we start by replicating four classical cross-country analyses of the relationship between education and economic performance. We first reconstruct the original data used in these studies and replicate their results. We then update the data, distinguish between vocational and non-vocational education and test whether vocational education makes a specific contribution to economic performance. Where possible, we explore how vocational education may interact with other variables in our specifications.

We find that the relationship between vocational secondary education and economic performance is quite sensitive to changes in data, specifications, number of countries, and time period. This is also true for other measures of education. In nearly all specifications, however, vocational education helps to explain variation in economic performance and often it offers a more consistent explanation than non-vocational years of schooling. We synthesize the conclusions and formulate our own relationship between the vocational and non-vocational education and economic performance. Our analysis suggests that in order for an economy to take advantage of vocational education, the economy must be relatively close to the technological frontier.

3.2 Education and Economic Performance

There is a vast literature that, in varying ways, attempts to link education with economic performance. The empirical findings are inconsistent (Sunde, 2015), ranging from no effect to large macro returns (see Patrinos & Psacharopoulos 2011 for a comprehensive review). Identifying the relationship between education and economic performance is complicated because of the wide variety of methodologies, dependent variables, other regressors[22], and the various samples that are used in different studies (Sianesi & Van

[22] In a review of growth economics, Durlauf et al. (2005) found well over 60 regressors proposed by the literature as viable determinants of growth. Studies that estimate the relationship between human capital or education and economic performance represent a relatively small subset of these studies.

Reenen, 2003). Empirical choices often reflect altogether different investigative aims stemming from different theoretical approaches (Savvides & Stengos, 2009).

As a first step we replicate studies with diverse theoretical and empirical approaches to analyzing the role of education in cross-country economic performance over long time horizons. To select studies to analyze, we consulted recent reviews of education and macroeconomic growth by Benos and Zotou (2014), Savvides and Stengos (2009), Sianesi and Van Reenen (2003), and also Durlauf et al. (2005) who synthesize growth econometrics more generally. The selected studies capture four distinct dimensions of the relationship between education and economic performance: education as a determinant; education as a structural variable; growth promoting spillovers from education; and education as a conduit for technology diffusion.

Table 3.1 briefly summarizes key traits of the selected studies and the mechanism that we believe the original authors had in mind for the role of education in their macroeconomic study. The column furthest to the right indicates our hypothesis for the distinct role of vocational education, given the empirical setting of the original study. For each replication, we introduce our vocational education variable and each time, the research question is as follows: does vocational education reveal a different relationship with macroeconomic performance indicators than non-vocational education?

Table 3.1 Macroeconomic Studies with Education Selected for Replication

Original Author(s)	Dependent Variable	Empirical Approach	Time Period	Mechanism	Vocational Edu Hypothesis
Barro and Lee (2010)	GDP per Worker	Panel, Fixed and Random Effects	1970-2005	Education is a determinant of GDP	Vocational education is a determinant of GDP and employment
Szirmai & Verspagen (2015)	Growth of GDP per Capita	Hausman-Taylor (preferred specification)	1950-2005	Education is a proxy for absorptive capacity	Vocational education is a better proxy for absorptive capacity
Pritchett (2001)	Growth of GDP per Worker	First, for each variable, log least squares growth is calculated over the entire period. Then, cross-sectional OLS	1960-1985	Education should promote growth externalities beyond aggregation of individual impact	In this empirical setting, if a 10% constant wage increment is assumed we do not expect a big difference between vocational and non-vocational education
Benhabib & Spiegel (2005)	Growth of TFP	Non-linear cross-sectional long-term growth specification. Estimated using maximum likelihood	1960-1995	Education increases capacity for (1) innovation, and (2) imitation	Vocational education is important for imitation and catch up; but its importance changes with the distance to the technology frontier

Source / notes: The dependent variable, empirical approach and time periods are from the original studies.

3.2.1 Determinants – Replication of Barro and Lee (2010)

We begin with replicating Barro and Lee's 2010 NBER working paper, Rate of Return to Schooling. As argued by Durlauf et al. (2005), the baseline of much of growth econometrics starts with what is referred to as 'Barro regressions'. Prompted by Barro's (1991) contribution in which he employed cross-country growth regressions to explore alternative growth theories, Barro's general empirical specification (in various forms) has become the workhorse of empirical work on growth. Empirical studies often take Barro's specification in its general form as the point of departure, rather than deriving a formal expression for the steady-state level of output per worker (Savvides & Stengos, 2009). In this empirical setting, researchers often use education as a measure of human capital and they seek to quantify the magnitude of the effect of greater amounts of education on economic growth. A recent meta-analysis highlights measurement as the most important issue inhibiting a consensus on the contribution of education to economic

growth, and specifically mentions the omission of empirically accounting for vocational education (Benos and Zotou, 2014).

We hypothesize that since vocational education is more explicitly linked with the labor market than general education it has a direct effect on the efficiency of labor (GDP per worker). Alternatively, a greater presence of vocational education in an economy might facilitate job entry and lead to higher employment levels, indirectly affecting economic performance. In which case, GDP per capita is the more appropriate dependent variable.

3.2.2 Structural Change – Replication of Szirmai and Verspagen (2015)

What if human capital were treated as a structural variable? Where, in a given economy, the structure of the education system is more or less effectively delivering human capital that is 'useful' for the productive structure of the economy. The article by Szirmai and Verspagen (2015) takes the view that education can be used as a proxy for absorptive capacity and argues that education increases the ability of a society to absorb and benefit from technological change. For example, when education is interacted with manufacturing, it increases the marginal effect of that sector's ability to drive growth.

Theoretically, absorptive capacity is what developing economies and firms need in order to catch-up (Abramovitz, 1993; Cohen and Levinthal 1989), and absorptive capacity is part of a self-reinforcing cycle (Soete, 2006) which, together with other factors, leads to greater technological and innovation performance in an economy. As Szirmai and Verspagen point out, the theoretical concept of absorptive capability put forth by Abramovitz in 1986 is very broad. It can include elements, such as infrastructure and political stability, that go far beyond general education levels in an economy. Education, as a proxy for absorptive capability, captures the efficiency with which catching-up economies obtain and integrate knowledge from more technologically-advanced economies.

In the tradition of Abramovitz and Gerschenkron, catching up depends on the extent to which an economy that is technologically backward can grow faster than the economies that are at the technological frontier. One way in which economies can do this is to take advantage of technology and knowledge that has been developed at the frontier in order to catch up or 'leap-frog'. This can be done in a variety of ways, but none of them are costless and they often involve technical know-how (Lee and Kim, 2001) or 'absorptive capacity'.

We hypothesize that vocational education might be a better proxy of absorptive capacity than overall years of schooling. Increasing the number of technically-educated people in workforce might lead to the faster introduction and/or diffusion of new technologies

(Toner, 2010; Tether et al., 2005). This role for vocational secondary schooling has not been empirically tested in a cross country analysis of economic growth.

3.2.3 Spillovers – A Replication of Pritchett (2001)

In 2001, Pritchett published a highly cited paper that asks 'Where has all the Education Gone?' In this paper, Pritchett argues that since the 1960s, educational attainment has increased in nearly all economies and yet, on average, education has not contributed as much to economic growth as expected. This paper has been identified as a classical reference, because it is the paper people cite for the oppositional view that education is *not* as important for economic output as many think. We revisit Pritchett's analysis 15 years later, and we first replicate Pritchett's original findings as exactly as possible. Then, we update the data and add our vocational variable(s) to see how vocational education may affect the results. Pritchett's empirical approach and even his use of 'years of schooling' is rather dramatically different from the other replications analyzed in this chapter.

The construction of what Pritchett calls 'Education Capital' applies a wage increment *r* of 10 percent across all years of schooling, in all countries, and in all time periods to the same 'Years of Schooling'[23] measure from Barro and Lee. Pritchett justifies the assumed *r* of 10 percent by citing surveys of micro-evidence.

Pritchett tests whether 'Education Capital' promotes economic growth. By incorporating the wage increment to education from micro evidence, Pritchett attempts to make micro and macro models of the impact of education consistent. From the perspective of this approach, if the gains from education (assumed to be 10 percent per year of education) are incorporated into the adjusted variable 'education capital' at the aggregate (macro) level, then we could expect the coefficient of 'Education Capital' to be zero; or, not statistically different from zero. A positive and statistically significant coefficient on 'Education Capital' supports the notion that the impact of additional schooling has a greater than expected effect, indicating positive externalities from education for economic growth. In fact, in most of his growth regressions, Pritchett finds negative coefficients for 'Education Capital' that are not statistically different from zero. Pritchett subsequently uses Total Factor Productivity (TFP) as a dependent variable, with assumed factor shares, and concludes that the failure to reject the null hypothesis - that 'Education Capital' is statistically different from zero and positive - is a high-powered failure. He concludes that a more highly educated workforce has not had the positive effect on growth and

[23] Pritchett uses the variable Years of Schooling in the population ages 25 and over from the 1993 Barro and Lee dataset; we have typically be using a more recent version of the dataset released in 2010 and updated up until 2013.

productivity that would be expected in the macroeconomic growth context. Above the 10 percent a year rate of return, which is higher than the market rate of return.

Recently, Pritchett (2016) has pointed out that part of the reason why macroeconomic growth models may have a difficult time in 'explaining' growth, is that you need variation to explain variation. In many cases, the right-hand-side education variables that are used to explain growth change very slowly. Measured schooling evolves smoothly and therefore, does not do much to explain changes in growth over time, unless interacted with other variables (page 10). In all of the countries, over time – years of schooling is increasing. This is not the case for vocational secondary schooling, however, where the patterns within countries and between countries tend to show a lot more variation. The question is whether this variation can be used to assess the impact of vocational and non-vocational education.

3.2.4 Technology Diffusion – A Replication of Benhabib and Spiegel (2005)

As Benhabib and Spiegel describe in their 2005 paper 'Human Capital and Technology Diffusion', the way in which education is conceptualized in a model has important implications for policy. When we consider education as a factor of production, the value of an increase in 'years of education (schooling)' is essentially equal to its marginal product. The major limitation to these Solow-inspired growth models is that - eventually - there are diminishing returns (Savvides and Stengos, 2009). In endogenous growth models (á la Lucas 1988 and Romer 1990), the accumulation of knowledge is derived from the features of the model. Therefore, it is not constant, or predetermined. Benhabib and Spiegel's model builds on the Nelson and Phelps (1966) model which explicitly distinguishes between a technological leader and follower in the model. Thus, in Benhabib and Spiegel's model, human capital does not enter directly into the production process. Rather, its role is to facilitate technology diffusion, which means that it affects total factor productivity. When its value is carried over into the future, it affects aggregate growth.

The key difference in the Nelson-Phelps inspired models is that there is a dual role for human capital and that dual role is built into the model. That means that there are two channels (or mechanisms) through which education can affect growth (a) innovation and (b) imitation (adoption of technology invented elsewhere), and usually highly-skilled human capital is expected to affect growth through channel (a) whereas other forms of human capital can affect growth through channel (b). Ang et al. (2011) and Vandenbussche, Aghion & Meghir (2006) found that it is possible to empirically test

whether the growth-enhancing effects of education are mitigated by the composition of education and the proximity to the frontier.

Thus far, studies have tested this by distinguishing human capital measures into higher or lower education groups (to proxy skills). This has never been tested with data that distinguishes human capital measures by type of education. We hypothesize that in the context of this model, we can more thoroughly test whether vocational secondary schooling affects technology diffusion through the channel of imitation and whether its effect changes with proximity to the frontier.

3.3 Vocational Secondary Schooling Data

Our analysis of the impact of vocational schooling uses various educational data sets, including one we have assembled. We start with an overview of the data sets used. For the data on vocational secondary schooling, we make use of new internationally comparable variables on vocational secondary schooling now available for 129 countries from 1950-2010 (for the details of the construction of this dataset see: Cathles, 2016). The variable on vocational secondary schooling was constructed using UNESCO Statistical Yearbooks (1969 and 1999) and the online UNESCO Institute for Statistics (UIS) data to build a ratio of vocational-to-total secondary schooling enrolments for each country at 5-year intervals. As the vocational education ratio is based on enrolment and the Barro and Lee data on attainment, we apply the ratios to secondary education figures in the subsequent 5-year period (when enrolment presumably has been transformed into attainment). This ratio serves as our measure for vocational attainment at secondary school level of schooling. There are justifications and caveats for the manner in which the vocational secondary schooling variable was constructed.

Barro and Lee construct 'years of Schooling' by first calculating the share of the population that has attained three broad educational levels (a) primary, (b) secondary and (c) tertiary and the duration of those levels of school in a given economy in a given year. They use enrolment data to fill-in any gaps in attainment data, which implies that when attainment data are not available, enrolment data (with the appropriate time lag for completion), can be cautiously used as a substitute. After correcting for differing completion ratios and mortality rates, Barro and Lee sum the years of schooling from primary, secondary and tertiary to create their an overall measure for average 'years of schooling'. Our measure of the number of years of vocational secondary schooling is

naturally a subset of secondary years of schooling and is distinguished on the basis of the vocational secondary enrolments in the preceding 5 years.

Our calculation absorbs all assumptions and possible measurement errors in Barro and Lee's 'average years of secondary schooling' data plus any that might be present in the UNESCO enrolment data. Furthermore, an **important assumption** is that there are no unobservable differences or attributes that might systematically alter the completion and/or mortality rates of vocational versus general education attainment.

The first question that arises in relating the vocational secondary schooling variable to existing macro growth models is: why should we expect this variable to make any difference? Our analysis of the literature on education and macroeconomic performance suggests theoretical reasons for paying attention to vocational education. Different types of educational formation have different distances from the labor market. Vocational education is thought to be most closely linked with the labour market. Therefore, we expect it to have a direct influence on economic performance, independently from other forms of education. Vocational educational formation could also play a distinct and an important role in absorptive capacities and what is referred to as acquisition of technology in the context of the innovation literature. Therefore, we suspect vocational education could affect economic catch-up in a developing country context.

One might object that our variable of vocational secondary schooling is derived from the overall variable 'years of schooling' typically used in many empirical analyses. So, hasn't it already been captured? While it is part of the overall years of schooling, the distribution of the variables do not behave in the same way. The distribution of total years of schooling is far less skewed than years of schooling in vocational secondary education.

The mean ratio of vocational to total secondary schooling in our 128 countries is about 20 percent. The ratio ranges from 1 to 93 percent. Total years of schooling range from 0.01 to 13.42 years. Since 'years of schooling' changes fairly smoothly and its range is rather small, the relative contribution of vocational secondary education depends on the base of secondary education and the base of total years of schooling. There is more variation in the way in which the vocational education variable 'moves' through our dataset, and this is a crucial observation. See Appendix B.1 for a full set of descriptive statistics.

Table 3.2 Descriptive Statistics of the Education Variables

Variable		Mean	S.D.	Min	Max	Observations
Years of Schooling 25 +	overall	5.06	3.32	0.01	13.42	N = 1572
	between		2.73	0.55	10.79	n = 121
	within		1.92	0.41	10.43	T = 12.99
Years of Secondary Schooling 25 +	overall	1.52	1.43	0.01	6.90	N = 1565
	between		1.04	0.06	4.39	n = 121
	within		0.98	-1.43	6.07	T = 12.93
Ratio Vocational to Total Secondary 25 +	overall	0.20	0.18	0.01	0.93	N = 1331
	between		0.14	0.01	0.63	n = 121
	within		0.11	-0.31	0.77	T = 11
Vocational Secondary Schooling 25+	overall	0.35	0.46	0.01	2.43	N = 1181
	between		0.38	0.01	1.39	n = 121
	within		0.26	-0.74	1.55	T = 9.76
Years of Primary Schooling 25 +	overall	3.32	2.00	0.01	8.99	N = 1572
	between		1.78	0.38	8.24	n = 121
	within		0.93	0.85	6.52	T = 12.99
Years of Tertiary Schooling 25 +	overall	0.24	0.27	0.01	1.76	N = 1481
	between		0.18	0.01	0.77	n = 121
	within		0.20	-0.35	1.31	T = 12.24

Source: Own elaboration based on Barro and Lee 2010 and Cathles 2016. The between standard deviation refers to cross country variation in average values of the variables. The within standard deviation refers to the average of the pooled standard deviations with countries. T-bar refers to average number of observations per country.

Examining some maximum and minimums is instructive. The maximum ratio of 93 percent of vocational to secondary school occurred in Romania in 1985. At that time, Romania had an average of 8.41 'years of schooling' of which 1.83 years were of secondary schooling. Since the ratio is based on enrollments, it is applied to the component 'secondary years of schooling 5 years later. In 1990, the total years of schooling in Romania was 9.05, of which 2.16 were of secondary schooling and 2.01 years of this was vocational.

The country with the maximum of 13.42 'years of schooling' in our dataset was Switzerland in 2010, of which 5.94 years were secondary schooling. The ratio of

vocational to total secondary five years before (in 2005) was 31.3 percent, which means the vocational secondary schooling component was 1.86 years.

The correlation matrix of our educational data (Table 3.3) shows that, as we would expect, the years of each of the sub-components (primary, secondary, and tertiary) are highly correlated to the overall years of schooling. This has to be true because of the way in which years of schooling is constructed. On the other hand, the ratio of vocational schooling to total years of secondary education is barely correlated, and it is also not highly correlated (only 0.25) with overall years of schooling.

Table 3.3 Correlation Matrix of the Education Variables

	Years of Schooling 25 +	**Ratio Vocational to Total Secondary**	**Years of Vocational Secondary Schooling**	**Years of Secondary Schooling**	**Years of Primary Schooling**	**Years of Tertiary Schooling**
Years of Schooling 25 +	1					
Ratio Vocational to Total Secondary **Enrolments**	0.25	1				
Years of Vocational Secondary Schooling	0.68	0.58	1			
Years of Secondary Schooling	0.89	0.06	0.64	1		
Years of Primary Schooling	0.92	0.38	0.60	0.63	1	
Years of Tertiary Schooling	0.81	0.08	0.57	0.84	0.595	1

Source: Own elaboration based on Barro and Lee 2010 and Cathles 2016.
Notes: The matrix is based on data for all countries for all years.

Using total years of education in empirical analyses, as is customary, therefore disregards differences in the structure of education (e.g., more or less vocational education relative to total education). The implicit assumption is that vocational and non-vocational education have the same, uniform effect on economic performance. As we have argued, this is not likely correct. The new vocational secondary schooling variable allows us to examine the effects of more or less vocational secondary education in a systematic fashion.

3.4 Analytical Approach

We start by replicating results of important studies relating years of schooling to economic performance. Although replicability is always an important criterion of scientific method, replications of earlier studies in economics are scarce. In part, this has to do with the fact that replication is difficult and challenging. We should be able to replicate earlier studies with our data set, but since many of the analyses that we replicate were published years ago, our data for all the key variables has been updated and theirs has not. We need to be sure that any changes in results are due to the introduction of our vocational education variable and not to more recent/different data, changes in the number of countries in the sample, differences in econometric procedures, or the use of other measures for explanatory variables (i.e., differences in measures of capital stocks). In each replication we therefore tried to access the original data that the author(s) used. Sometimes we were not able to recover the exact data and had to make do with data from other sources, or from different versions of the same dataset. The description of the data and variables used is presented along with each replication. Then, we modify the replicated models, by distinguishing years of vocational education from years of non-vocational secondary education. In this manner, we examine whether vocational years of schooling make an additional contribution to economic performance. Finally, we develop our own empirical approach based on the experience with these replications.

During the replication process, it became clear that seemingly small changes can affect the results rather dramatically. This effect is well known and documented (Dulauf, 2005). Therefore, before introducing our vocational education variable, we have to check whether we have been able to replicate the original findings and the original conclusions. Usually, we cannot reproduce the exact same coefficients, but we can check whether the size and significance of the coefficients is consistent with the original study. Only once we are reasonably confident that our results are in line with the original study, do we start using newer datasets and adding our new variable.

3.5 Replications

In this section, we present and discuss results from the replication and extension of four seminal works we have chosen: Barro and Lee (2010), Szirmai and Verspagen (2015), Pritchet (2001) and Benhabib and Spiegel (2005).

3.5.1 Replication of Barro and Lee (2010)

The Barro and Lee specification that we replicate is:

$$\log(y_{it}) = \beta_0 + \beta_1 \log(k_{it}) + \beta_2(s_{it}) + \beta_3 X + \varepsilon_{it} \quad (1)$$

where y_{it} is GDP per Worker. The regressors are the Log of Capital per Worker (k) and Years of Schooling (s) in the adult population above the age of fifteen. The regression includes a set of Xs, which are a dummy variable for oil exporters and a period dummy variable, which Barro and Lee claim represents total factor productivity and is assumed to vary over time. In this specification, Barro and Lee say that β_1 represents the share of capital in total output and β_2 represents the marginal rate-of-return to an additional year of schooling. This equation is clearly a variation on the classical 'Barro regressions', primarily because the specification does not include a lagged dependent variable. We go ahead with replicating this version, because they extend their analysis to include returns to human capital across regional groups. We suspect regional groups have important implications for the analysis of vocational secondary schooling.

The original results from Barro and Lee (2010) are presented in Appendix B.2. In their original study, they have an unbalanced panel of 962 observations at 5-year intervals from 1970-2005 for 127 countries. We follow their use of GDP per worker and Capital per worker data from Penn World Tables (PWT) version 6.3. We follow their procedure to construct a capital stock variable from the 5 year average annual growth of capital flows around the initial year, with a depreciation rate of 0.06, which is assumed to be the same across countries. After discarding the first 5 years, as they do, we use a perpetual inventory method to construct the series of capital stock. We use World Development Indicator (WDI) data to create a dummy variable for 'major oil exporters' that takes a value of 1 if oil represents more than 50% of exports in a given country and roughly follow the methodology described in Ross and Voeten (2015), which we assume to be similar to the approach that Barro and Lee took to create their dummy variable for oil exporters. Following the variables they use as closely as we can, we also drop countries for which there are less than six observations for any variable used in the regression and we arrive at 122 countries and 892 observations.

The results we obtain from our replication are similar enough to theirs to convince us that we can move forward with (1) updating the data and (2) incorporating our vocational education variable. We begin by using a subset of countries for which we have vocational data available (in order to compare with the original results). We lose an additional 19 countries for which we do not have vocational data. This reduces our total number of countries to 103 and either 755 or 670 observations depending on whether the vocational variable is included. The only other change to the replication

presented in Table 3.4 is to modify the years of schooling variable to be the measure for the population 25 years and older (rather than 15 years and older). Our vocational variable is constructed on the basis of the years of schooling for the population 25 years and older and therefore, making this change will facilitate comparison. These two modifications (dropping countries for which we do not have vocational secondary schooling data and changing the years of schooling from 15+ to 25+), do not change the results much. (See Table B.2.1 in Appendix B.2 which contains the results from the original study and our first most exact replication).

Table 3.4 presents the Barro and Lee replication results (on the left) and the results when we include vocational secondary schooling (on the right). We find that introducing vocational secondary schooling has a positive and significant effect in both the random (column 1) and fixed effects settings (column 2). Since the Hausman test suggests that the fixed effects model is preferred over the random effects model, we must rely more on the results from those specifications, but it is understood that variables lose some of their explanatory power when we move from random to fixed effects and are no longer able to compare the 'between country' effects.

Following Barro and Lee's interpretation of the estimates, in the fixed effects setting, holding other factors constant, the output per worker would increase by around 9 percent for each additional year of non-vocational schooling and by 11 percent for each additional year of vocational schooling, on average. We tested whether this difference in the size of coefficients is significant, and it is not. So, in this empirical setting, we cannot say that vocational secondary schooling is more important for economic performance than non-vocational schooling. However, when we standardized the beta coefficients, a one standard deviation increase in non-vocational years of schooling has a larger effect on GDP per worker than a one standard deviation increase in vocational secondary schooling.

It is well known that, when analyzing the relationship between economic output and human capital, there is a potential for reverse causality. Barro and Lee introduce lagged education variables (using a 10 year lag) of the population ages 40-75 to capture parental education. In columns 3 and 4, they use these lags as instrumental variables for 'years of schooling', to address possible simultaneity bias. We follow them, but we simplify the instruments by using just the 10 year lags without restricting the education variables to the age range (40-75), since it is not possible for us to restrict our vocational secondary schooling variable to a range of ages with our current data set. Future research to further develop vocational variables, could address this limitation. In our replication results, the simplification of the instruments does not seem to affect the results for overall 'years of schooling'. When we introduce 10 year lags for vocational secondary schooling in

this specification; however, the variable loses its significance. In columns 5-8, we notice that the results for the regional rate of return to vocational secondary schooling do differ from the regional rate of return to overall years of schooling. Typically, the rate of return to any kind of schooling appears to be higher in advanced economies. In the next section, when we change our dependent variable to GDP per capita, we find some more nuanced results and believe these results to have important implications for the relationship between vocational education and economic performance.

Table 3.4 Returns to Education: Replication and Extension of the Barro and Lee Analysis

Replication of Barro and Lee (B&L, 2010):				
Rate of Return to Schooling: Population 25+				
Dependent Variable = Log GDP per Worker PWT 6.3				
	OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
Log K per Worker PWT 6.3	0.52***	0.49***	0.38***	0.22***
	(0.05)	(0.07)	(0.04)	(0.06)
Average years of schooling 25+	0.06***	0.07**	0.11***	0.07**
	(0.02)	(0.03)	(0.02)	(0.03)
Oil exporter and time dummies	Yes	yes	yes	yes
Constant	7.58***	7.66***	8.01***	8.62***
	(0.10)	(0.19)	(0.11)	(0.21)
Observations	755	755	599	599
Countries	103	103	103	103
R-sq. within	0.49	0.49	0.22	0.23
R-sq. between	0.87	0.86	0.85	0.85
R-sq. overall	0.85	0.84	0.83	0.82
B. Rate of Return by Region				
	(5)	(6)	(7)	(8)
Log Capital per Worker PWT 6.3	0.49***	0.38***	0.32***	0.10
	(0.06)	(0.08)	(0.04)	(0.07)
Average Years of Schooling (25+)				
Advanced Economies	0.08***	0.10***	0.14***	0.12***
	(0.02)	(0.02)	(0.02)	(0.03)
East Asia and the Pacific	0.10***	0.17***	0.15***	0.19***
	(0.03)	(0.03)	(0.04)	(0.04)
Europe and Central Asia	0.04**	0.11***	0.06*	0.06
	(0.02)	(0.03)	(0.03)	(0.07)
Latin America and the Caribbean	0.04**	0.04	0.08***	-0.01
	(0.02)	(0.03)	(0.02)	(0.04)
North Africa and Middle East	0.05	0.01	0.11***	0.04
	(0.04)	(0.06)	(0.04)	(0.05)
South Asia	0.03	0.08	0.14***	0.18***
	(0.05)	(0.06)	(0.06)	(0.06)
Sub-Saharan Africa	0.02	0.03	0.01	-0.03
	(0.03)	(0.04)	(0.03)	(0.05)
Oil exporter and time dummies	Yes	yes	yes	yes
Constant	7.67***	7.90***	8.19***	8.92***
	(0.12)	(0.25)	(0.12)	(0.24)
Observations	755	755	599	599
Countries	103	103	103	103
R-sq. within	0.51	0.54	0.30	0.36
R-sq. between	0.86	0.72	0.83	0.49
R-sq. overall	0.84	0.72	0.82	0.50

Adding Vocational to Barro and Lee (B&L, 2010):				
Time period 1960-2005				
Dependent Variable = Log GDP per Worker PWT 6.3				
	OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
Log K per Worker PWT 6.3	0.38***	0.32***	0.28***	0.16***
	(0.06)	(0.06)	(0.05)	(0.05)
Non-vocational Years of Schooling	0.10***	0.09***	0.15***	0.09***
	(0.03)	(0.03)	(0.03)	(0.03)
Vocational Years of Secondary Schooling	0.11**	0.11**	0.09	0.03
	(0.05)	(0.05)	(0.08)	(0.08)
Oil exporter and time dummies	yes	yes	yes	yes
Constant	7.68***	7.90***	8.14***	8.66***
	(0.11)	(0.17)	(0.11)	(0.15)
Observations	756	756	630	630
Countries	100	100	99	99
R-sq. within	0.62	0.63	0.34	0.37
R-sq. between	0.84	0.83	0.82	0.81
R-sq. overall	0.82	0.80	0.79	0.77
B. Rate of Return by Region				
	(5)	(6)	(7)	(8)
Log Capital per Worker PWT 6.3	0.37***	0.29***	0.27***	0.14**
	(0.06)	(0.07)	(0.05)	(0.06)
Average Years of Schooling (25+)	0.10***	0.08**	0.15***	0.07**
	(0.02)	(0.03)	(0.02)	(0.03)
Vocational Years of Schooling				
Advanced Economies	0.20***	0.15***	0.20***	0.09
	(0.05)	(0.05)	(0.07)	(0.07)
East Asia and the Pacific	0.40	0.88	0.43	1.14**
	(0.40)	(0.54)	(0.42)	(0.49)
Europe and Central Asia	-0.01	0.08	-0.11	-0.05
	(0.05)	(0.07)	(0.16)	(0.20)
Latin America and the Caribbean	0.01	-0.13	-0.12	-0.37*
	(0.18)	(0.23)	(0.18)	(0.20)
North Africa and Middle East	-0.01	-0.07	0.01	-0.06
	(0.25)	(0.30)	(0.22)	(0.24)
South Asia	0.72	20.45***	3.39	35.78***
	(7.10)	(4.20)	(11.82)	(3.98)
Sub-Saharan Africa	-1.02	-0.99	-2.07**	-1.55*
	(0.72)	(0.84)	(0.83)	(0.79)
Oil exporter and time dummies	yes	yes	yes	yes
Constant	7.73***	8.00***	8.20***	8.77***
	(0.11)	(0.18)	(0.11)	(0.15)
Observations	756	756	630	630
Countries	100	100	99	99
R-sq. within	0.63	0.65	0.37	0.41
R-sq. between	0.85	0.81	0.82	0.74
R-sq. overall	0.82	0.78	0.79	0.70

Notes: Robust standard errors in parentheses.
K stands for Physical Capital. PWT stands for Penn World Tables 6.3. * p<0.10, ** p<0.05, *** p<0.01.

Modification of the B&L Replication: Changing the Dependent Variable to GDP per Capita

The most important modification we make in this section is to test our vocational secondary schooling variable using GDP per Capita instead of GDP per worker. We use the Maddison project data set (Bolt and van Zanden, 2014) which has GDP per capita data up to and including 2015, although most of our other variables are only available until 2010.[24] In our opinion, these data are to be preferred to the PWT data, because of their stronger reliance on national sources. Our strategy is generally to replicate using PWT and then shift to the Maddison dataset. When we switch our dependent variable to GDP per Capita (Table 3.5), we see that the coefficient on vocational secondary schooling jumps in magnitude. We take this as evidence for an indirect effect of vocational education on economic performance. As noted previously, vocational education could affect economic performance by (a) increasing the efficiency of workers, which would be captured by GDP per worker, or by (b) facilitating smoother linkages between school and work, which is more likely to be captured by GDP per Capita.

That is, rewriting GDP per Capita as a product of GDP per Worker and Worker-to-Population ratio implies: $\left(\frac{GDP}{Population}\right) = \log\left(\frac{GDP}{Worker}\right) + \log\left(\frac{Worker}{Population}\right)$ and makes it evident that the effect on GDP per Capita can be larger than the effect on GDP per Worker.

From this replication, we learn that changes to other variables and datasets can alter the results (sometimes dramatically). The implications for the relationship between years of schooling and economic performance can be very different. When we include the vocational variable, we find differences and see that the two types of education may also influence each other. Including the vocational secondary schooling variable often gives a 'bump' to the coefficient on non-vocational years of schooling. It seems the two types of education have some complementarities (i.e., the greater the overall levels of education in an economy, the greater the value added of vocational education). The construction of the vocational variable as a partial partition of the years of schooling variable makes the two variables additive in nature. To treat them as a multiplicative term may be stretching the limits of the data. The key takeaway from this first replication is that vocational secondary schooling does make a difference for economic performance and to support the notion that its economic effect is likely to be indirect and, therefore, better captured by GDP per Capita than by GDP per Worker.

[24] When we replicate Szirmai and Verspagen (2015) we use the same Maddison (2009) database they use, the differences are small and mainly lie in the fact that the Bolt and van Zanden data set covers a longer period.

Table 3.5 Converting the Dependent Variable to GDP per Capita in the Barro & Lee Model

Time period 1960-2005 Dependent Variable = Log GDP per Capita				
	OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
Log K per Worker PWT 6.3	0.34***	0.30***	0.26***	0.18***
	(0.05)	(0.06)	(0.04)	(0.05)
Non-vocational Years of Schooling	0.14***	0.12***	0.15***	0.09***
	(0.02)	(0.03)	(0.02)	(0.03)
Vocational Years of Secondary Schooling	0.22***	0.19***	0.13*	0.05
	(0.05)	(0.06)	(0.07)	(0.08)
Constant	6.29***	6.45***	6.76***	7.18***
	(0.09)	(0.16)	(0.10)	(0.18)
Observations	756	756	693	693
Countries	100	100	99	99
R-sq. within	0.69	0.69	0.55	0.57
R-sq. between	0.85	0.84	0.83	0.82
R-sq. overall	0.82	0.81	0.79	0.76
B. Rate of Return by Region				
	(5)	(6)	(7)	(8)
Log K per Worker PWT 6.3	0.32***	0.27***	0.24***	0.16***
	(0.05)	(0.06)	(0.04)	(0.05)
Average Years of Schooling (25+)	0.14***	0.10***	0.15***	0.07**
	(0.02)	(0.03)	(0.02)	(0.03)
Vocational Years of Schooling				
Advanced Economies	0.31***	0.23***	0.21***	0.07
	(0.05)	(0.05)	(0.06)	(0.06)
East Asia and the Pacific	1.08***	1.52***	0.90***	1.46***
	(0.27)	(0.34)	(0.33)	(0.39)
Europe and Central Asia	-0.01	-0.02	-0.11	-0.15
	(0.12)	(0.11)	(0.18)	(0.18)
Latin America and the Caribbean	0.24	0.14	0.14	-0.02
	(0.17)	(0.21)	(0.20)	(0.23)
North Africa and Middle East	0.13	0.16	0.07	0.10
	(0.17)	(0.19)	(0.19)	(0.17)
South Asia	-1.54	23.00***	10.06	43.97***
	(12.94)	(4.17)	(18.30)	(4.10)
Sub-Saharan Africa	-0.97**	-0.91**	-3.00***	-2.59***
	(0.43)	(0.45)	(0.76)	(0.74)
Constant	6.37***	6.62***	6.84***	7.32***
	(0.10)	(0.16)	(0.10)	(0.14)
Observations	756	756	693	693
Countries	100	100	99	99
R-sq. within	0.71	0.72	0.60	0.63
R-sq. between	0.85	0.82	0.84	0.73
R-sq. overall	0.83	0.79	0.81	0.69

Notes: Robust standard errors in parentheses.
K stands for Physical Capital. PWT stands for Penn World Tables 6.3. * p<0.10, ** p<0.05, *** p<0.01.

3.5.2 Replication of Szirmai and Verspagen (2015)

In this sub-section, we move toward a more complex analysis that merges our interest in VET human capital with structural change and closer to the underpinnings of the theories that support the notion that vocational education formation may play a special role in catch-up. Szirmai and Verspagen (2015) already found evidence that when interacting years of schooling (as a proxy for absorptive capacities) with an economy's share of manufacturing while also interacting that same share of manufacturing with the relative distance of the economy to the front-runner (in this case the U.S.), that 'years of schooling' do matter for the pace of growth.

We use the same dataset that Szirmai and Verspagen use and describe in their paper (Table 3.6). The sector shares are value added shares at current prices and are from UN national accounts statistics; WDI; Groningen Growth and Development Centre 60-industry, 10-industry and EUKLEMS databases; and UNIDO Industrial Statistics database. The data on manufacturing are described in more detail in Szirmai (2015). The openness indicator is in current prices and is expressed as a percent (exports plus imports as a percent of GDP). The climate zone data are from Gallup et al. (1999), where the following two variables were combined: "Dry Temperate (% land area)" + "Wet Temperate (% land area)" to create a dummy variable (following Szirmai & Verspagen) where the variable takes a 1 if >50% of the land area is in the temperate zone. The initial replication uses the same data from Barro and Lee (2010) on the average years of schooling for the adult population above the age of fifteen and supplemented with data from Lutz et al. (2007) and Cohen and Soto (2007). We subsequently switch to the Barro and Lee (2010) dataset on the average years of schooling for the adult population above the age of 25 and introduce our vocational variables. Note that we do not have the same number of countries and observations (N), primarily due to the fact that there are fewer countries for which vocational data are available. The change in N seems to affect some variables more than others, particularly the education variables and the openness variable.

Table 3.6 Descriptive Statistics of the panel dataset 1950-2015

Variable		Mean	Std. Dev.	Min	Max	Observations	
GR	overall	2.23	2.87	-17.41	13.58	No. of Obs.	818
(Growth Rate (5-year) of Per Capita GDP (Maddison)	between		1.33	-0.26	5.65	No. of Countries	76
	within		2.54	-14.92	13.50	T-bar	10.76
MANU	overall	17.78	8.12	0.00	44.80	No. of Obs.	724
(Manufacturing value-added share at Current Prices)	between		6.26	5.53	30.66	No. of Countries	76
	within		5.29	-4.26	45.58	T-bar	9.53
SER	overall	48.86	12.33	0.00	86.50	No. of Obs.	721
(Services value-added share at Current Prices)	between		9.73	24.32	74.03	No. of Countries	76
	within		8.24	-4.46	90.70	T-bar	9.49
RELUS	overall	30.49	26.74	1.40	115.70	No. of Obs.	818
(GDP per Capita Relative to the U.S.)	between		26.00	2.95	98.35	No. of Countries	76
	within		7.36	-7.65	65.71	T-bar	10.76
EDU	overall	4.77	2.70	0.10	11.85	No. of Obs.	809
Education 15+ (S&V dataset)	between		2.42	1.01	10.09	No. of Countries	76
	within		1.31	1.24	8.63	T-bar	10.64
KGATEMP	overall	0.28	0.45	0.00	1.00	No. of Obs.	1694
	between		0.45	0.00	1.00	No. of Countries	121
	within		0.00	0.28	0.28	T-bar	14
Openness	overall	69.31	50.66	5.05	446.06	No. of Obs.	1179
	between		46.57	13.91	350.29	No. of Countries	121
	within		22.45	-32.82	228.33	T-bar	9.74
Years of Secondary	overall	0.18	0.26	0.00	2.06	No. of Obs.	1234
Vocational Schooling	between		0.22	0.00	0.93	No. of Countries	121
	within		0.13	-0.57	1.38	T-bar	10.20
Years of Schooling (15+)	overall	5.45	3.21	0.02	13.02	No. of Obs.	1573
Barro and Lee	between		2.62	0.75	10.95	No. of Countries	121
	within		1.88	1.15	10.33	T-bar	13
Years of Schooling (25+)	overall	5.06	3.32	0.00	13.42	No. of Obs.	1573
Barro and Lee	between		2.73	0.52	10.79	No. of Countries	121
	within		1.92	0.41	10.43	T-bar	13
ln(pop)	overall	9.31	1.51	5.69	14.05	No. of Obs.	836
	between		1.48	5.87	13.67	No. of Countries	76
	within		0.36	8.02	10.35	T-bar	11

Source: Own elaboration based on data collected by Szirmai and Verspagen and primary sources described in Section 3 of this paper.
Notes: The between standard deviation refers to cross country variation in average values of the variables. Within standard deviation refers to the average of the pooled standard deviations with countries. T-bar refers to average number of observations per country.[25]

Appendix B.3 shows the replication of Szirmai and Verspagen 2015. We ran regressions to make sure that our adjustments (fewer N) do not compromise the original results found by Szirmai and Verspagen. The results are quite similar, though as expected, with some notable differences with respect to the significance of manufacturing in the

[25] Recall, kgatemp is a dummy variable that takes a 1 if >50% of the land area is in the temperate zone. Openness is exports plus imports as a percent of GDP (current prices). gr is the growth of GDP per capita per 5 year period. Man and Ser are the value added shares of manufacturing and service sectors in the economy's GDP at the start of the five year period. Relus is the GDP per Capita relative to the U.S. at the start of each five year period. Edu_15+(S&V dataset) is the years of schooling variable that was used by Szirmai and Verspagen. Ln(pop) is the log of the population size at the start of the period.

Hausman-Taylor and Between Effects estimations (Appendix B.3, Table B.3.1, columns 3 and 4). With the larger number of countries they were using, Szirmai and Verspagen found that the effect of the share of manufacturing was significant at the 5 percent level in both the Hausman-Taylor and Between Effects estimations. With a reduced number of countries, we find that the coefficient of the share of manufacturing is only significant at the 10 percent level in the Between Effects estimation, and not significant in the Hausman-Taylor estimation. Interestingly, we find the share of manufacturing to be a significant factor/determinant at the 10 percent level in the Fixed Effects estimation, whereas they did not find it was significant. We have the most similar results for this variable in the Random Effects setting, where we both find it is significant at the 5 percent level and the coefficients are similar in magnitude.

We continue to follow Szirmai and Verspagen and introduce interaction terms and estimate variations on the equation they estimate:

$$GR = \alpha MANU + \beta RELUS + \gamma EDU + \varphi MANREL + \phi MANEDU + \nu X \qquad (2)$$

Where MANU is the manufacturing value-added share in the economy at current prices, RELUS is the GDP per Capita relative to the United States, and EDU stands for Education (years of schooling). The initial interaction terms are MANREL and MANEDU. MANREL is the interaction between the Manufacturing value added share in the economy's GDP multiplied by the distance of the country to the frontier (the economy's GDP relative to the U.S. at the start of the period). The second interaction term is MANEDU, which is the interaction between the Manufacturing value-added share multiplied by the average years of schooling in the population 15 years and above. Hausman-Taylor specification is used in all of the subsequent regressions and Openness and the Population size of the economy are treated as exogenous, and the variable KGATEMP (a dummy variable taking the value of 1 if more than 50 percent of the land in the country is in the temperate zone) is taken as time invariant. Subscripts i and t are suppressed for simplicity.

We also followed Szirmai and Verspagen in introducing slope shift dummies for three relevant sub-periods (1950-1970; 1970-1990; 1990-2005). As they note, by using the slope shift dummies rather than running separate estimations for each of the time periods, we are assuming that the country fixed effects are constant over the entire time period (1950-2005).

Results in Table 3.7 are comparable with the results they present in their Table 4. In the results presented here, the exogenous and time invariant variables are included in all specifications, but are not reported. The slope shift coefficients are likewise suppressed.

A full table of results is available upon request. Column 1 in Table 3.7 is our replication of their Hausman-Taylor estimation that includes the slope shift dummies (50-70, 70-90 and 90-05), but does not include any interaction terms. Column 2 is our replication of their final specification which incorporates both the slope shift dummies and interaction terms. The results are similar with some notable differences. They find that when both interaction terms are used, education (overall years of schooling 15+) is significant in all the three time periods. Using the same education data as they use, but with a reduced number of countries, we find that education is only significant in the first time period (1950-1970) and not significant after 1970. Similarly, our results for the interaction terms tend to follow theirs, although we do not find significance for MANREL or MANEDU in the period 1970-1990. Generally speaking, the time period 1970-1990 appears to have different trends from the rest of the periods. It is the period in which the service sector consistently becomes significant across all specifications. The distance to the frontier (RELUS) is robust across the later periods (from 1970 onward).

Table 3.7 Growth Estimations for 3 Periods using Hausman Taylor: Replication and Extension of Szirmai and Verspagen Analysis

Dependent Variable: Growth of per capita GDP (Maddison 2009)					
	Replication S&V			Add Vocational Secondary	
	No Interactions	Interactions		No Interactions	Interactions
	(1)	(2)		(3)	(4)
Edu 50-70 (S&V)	-0.10	-0.86**	Non-Vocational 50-70	-0.04	-1.48***
	(0.16)	(0.35)		(0.27)	(0.49)
Edu 70-90 (S&V)	0.24	-0.05	Non-Vocational 70-90	0.17	-0.21
	(0.19)	(0.40)		(0.25)	(0.39)
Edu 90-05 (S&V)	0.28	-0.59	Non-Vocational 90-05	0.31	0.12
	(0.18)	(0.48)		(0.22)	(0.38)
			Vocational 50-70	1.76	7.00*
				(1.47)	(3.61)
			Vocational 70-90	-0.57	-8.38***
				(0.90)	(2.37)
			Vocational 90-05	0.17	-2.91**
				(0.66)	(1.36)
manu50_70	-0.03	-0.09	manu50_70	-0.07	-0.20***
	(0.04)	(0.06)		(0.05)	(0.06)
manu70_90	0.04	0.00	manu70_90	0.05	0.01
	(0.04)	(0.07)		(0.04)	(0.07)
manu90_05	0.02	-0.12	manu90_05	-0.01	-0.04
	(0.03)	(0.11)		(0.04)	(0.10)
ser50_70	-0.00	0.00	ser50_70	-0.02	-0.03
	(0.02)	(0.02)		(0.03)	(0.03)
ser70_90	0.07***	0.07***	ser70_90	0.05**	0.06**
	(0.03)	(0.03)		(0.03)	(0.03)
ser90_05	-0.01	-0.01	ser90_05	-0.02	-0.01
	(0.02)	(0.02)		(0.03)	(0.03)
relus50_70	-0.06***	-0.02	relus50_70	-0.08***	-0.07***
	(0.02)	(0.03)		(0.02)	(0.02)
relus70_90	-0.13***	-0.10**	relus70_90	-0.13***	-0.17***
	(0.02)	(0.04)		(0.02)	(0.02)
relus90_05	-0.12***	-0.03	relus90_05	-0.13***	-0.16***
	(0.02)	(0.05)		(0.02)	(0.03)
manrel50_70		-0.002*			
		(0.00)			
manrel70_90		-0.001			
		(0.00)			
manrel90_05		-0.004*			
		(0.00)			
manedu50_70		0.04**	manedu* 50_70		0.05***
		(0.02)			(0.02)
manedu70_90		0.01	manedu* 70_90		0.02
		(0.02)			(0.02)
manedu90_05		0.04*	manedu* 90_05		0.01
		(0.02)			(0.02)
			relvoc50_70		-0.09
					(0.06)
			relvoc70_90		0.13***
					(0.04)
			relvoc90_05		0.05***
					(0.02)
Constant	14.87***	13.77***		10.39*	19.09***
	(4.60)	(4.43)		(6.01)	(5.61)
Observations	679	679		588	588
Countries	76	76		76	76
Rho	0.91	0.90		0.93	0.93

Notes: Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

The next step is to introduce our vocational education variable, which initially does not seem to have a big effect. Column 3 shows the results are qualitatively quite similar to the results in column 1 – the results without vocational secondary schooling. When we introduce the interaction terms, we find that the interaction term between share of manufacturing and vocational secondary schooling appears to be perfectly correlated with the set of other regressors and therefore it is omitted from the regression results in two periods. This result might have been anticipated (especially for the earlier periods), but it lends some credence to the notion that there is a relationship between vocational education and the productive structure of the economy. To test our hypothesis that vocational education plays a crucial role in absorptive capacity and catch-up, we decided to interact vocational secondary schooling with RELUS.

The interaction term between RELUS and Vocational secondary schooling, RELVOC, tends to be positive and significant, indicating that more vocational secondary schooling may help countries to 'run faster' to catch the leading economy, but this help comes as countries are already getting closer to the frontier. There is an interesting pattern in how vocational secondary schooling behaves in the different time periods. From 1950-1970, the partial effect of vocational secondary schooling is positively associated with growth, but the interaction term, while negative – is insignificant. This means that vocational secondary schooling in that period had a positive effect on growth, regardless of the economy's distance to the frontier. In the later periods, the partial effect of vocational secondary schooling is negatively associated with growth, but the interaction term is positive and significant. This means that the growth effect of vocational education changes and improves as the economy gets closer to the frontier. These results, coupled with structural argument from Szirmai and Verspagen's original findings, suggest that, as the structure of the economy changes, the relationship between education and growth also changes.

3.5.3 Replication of Pritchett (2001)

In this sub-section, we describe (a) Pritchett's analysis and the steps we took to replicate it, (b) what happens when we update the data and introduce our vocational variable, and (c) the potential contribution his work could make to refining the 'Educational Capital' variable to allow the *r* to vary with levels of educational attainment.

Following Pritchett, we calculate the growth of the stock of education capital as:

$$\dot{hk}(t) \cong d\ln(\exp^{RN(t)} - 1)/dt \quad (3)$$

Where hk is 'Education Capital', R is the wage increment to a year's schooling which is assumed to be 10 percent[26] and a constant across all years of schooling, and N is the number of years of schooling at a given time, *t*. As Pritchett notes in his paper, the growth of each variable is calculated as the logarithmic least squares growth rate over the entire period. We follow the same methodology. This means that the growth rate is estimated by fitting a least squares regression line to the logarithmic annual (or 5-year interval) values of the variable over time:

$$\ln X_t = a + bt, \quad (4)$$

where X is the variable (it is estimated for each variable separately) and t is time. The parameters to be estimated[27] are: a = ln X_0 and b= ln(1+r). We calculate the least squares growth for each variable from 1960-1985. We calculate these growth rates by country[28] and then use OLS to regress the calculated growth of GDP per worker on the Growth of Education Capital and Physical capital. We include the natural log of GDP per Worker in 1960 in all columns labeled (2) in Table 3.8 below.

Pritchett used Barro and Lee's 1993 data set on Average Years of Schooling in the population aged 25 and older[29] for most of his analysis. We were able to access the 1993 dataset through the Barroandlee.com website. This ensures that we are using the same data as Pritchett used to construct his Educational Capital variable. Pritchett used Penn World Tables (PWT) Mark 5 for the dependent variable of GDP per worker. The Barro and Lee 1993 dataset preserves the PWT 5 data (GDP and Employment) in 5 year intervals. Pritchett may have used annual data from the original source, but we are comfortable with using the 5-year intervals, since Educational Capital is also in 5-year intervals. Pritchett used two series for physical 'capital stock' (King and Levine 1994 and Nehru and Dhareshawr 1993). We were not able to recover those data sets and so we use a measure of capital stock computed using the PWT 6.3 dataset following a Perpetual Inventory Method (PIM) and estimation of Initial Capital to Output ratios

[26] Pritchett defends this assumption on the basis of a survey of wage increments by region, arguing that cross-national differences in the growth rate of educational capital are robust when r is changed.

[27] The World Bank (http://econ.worldbank.org/) describes this method in more detail and explains that equation 2 is equivalent to the logarithmic transformation of a compound growth equation $X_{t=} X_0 (1+r)^t$ and that if b* is the least-squares estimate of b, the average annual growth rate can be obtained by [exp(b*)-1] and multiplying by 100 for a percent.

[28] We are assuming this is a necessary step in order to run the OLS on the entire sample (as Pritchett indicates in columns 1 and 2 of his regression table); but we also tried using the annualized change in logs as Cohen and Soto (2007) did when they replicated Pritchett and we arrive a similar estimates to theirs which are also close to Pritchett's results.

[29] Pritchett restricted 'Years of Schooling' to age 25-65 (robustness check) and 'instrumented' B&L data by using a similar dataset from Nehru et al. (1995).

that seem to approximate the second PIM methodology described by King and Levine in their 1994 paper. We know that specifications are particularly sensitive to changes in the physical capital variable, so we also try using the most updated and comparable capital variable available from PWT 9.

Our sample consists of 91 countries (the same number of countries as Pritchett), when we use PWT 6.3 for Capital per worker. We lose one country when we include initial GDP per worker. For comparative purposes, the results from Pritchett (2001) are presented in the first two columns of Table 3.8 and are highlighted in grey. In columns 1a and 2a, we present our first replication results where we get a coefficient on Education Capital that is very close to Pritchett's. Using PWT 6.3, however, our coefficient for Capital per Worker is much smaller than Pritchett's and smaller than expected in this type of regression.

Table 3.8 Growth-Accounting of GDP per Worker Growth: Replication of Pritchett Analysis

	PRITCHETT RESULTS		Replication (USING LOG LEAST SQUARES of EACH VAR)			
DV: Per annum growth of GDP per Worker (PWT 5)	**OLS**		**K = PWT 6.3**		**K = PWT 9**	
	Pritchett	**Pritchett**	**(1a)**	**(2a)**	**(1b)**	**(2b)**
Growth of 'Education Capital' per Worker (B&L 1993)	-0.049	-0.038	-0.004	-0.02	0.038	-0.028
	(1.07)	(0.795)	(0.07)	(0.07)	(0.06)	-0.06
Growth in Capital+ per Worker	0.524	0.526	0.205***	0.201***	0.357***	0.392***
	(12.8)	(12.8)	(0.05)	(0.05)	(0.05)	-0.05
ln (initial GDP per Worker)		0.0009		-0.001		-0.006***
		(0.625)		(0.002)		(0.002)
Constant			0.016***	0.026*	0.013***	0.056***
			(0.003)	(0.01)	(0.003)	(0.02)
Countries	91	91	91	90	90	89
R-squared	0.653	0.655	0.307	0.308	0.326	0.391

Notes: Pritchett has t-statistics in parentheses and we have Standard errors in parentheses. +Pritchett calls Capital Cumulated Depreciated Investment Effort 'CUDIE' in his results table. * p<0.10, ** p<0.05, *** p<0.01.

In columns 1b and 2b, we repeat the same estimations changing only the capital per worker variable to PWT 9. We find, as we have found in other parts of this chapter that changing the capital variable changes the results. When we switch to PWT 9 for

the Capital per Worker variable, the results have a larger coefficient, not quite as large as Pritchett's, but the coefficients are more in line with expectations.

When we update the data (tables available upon request), we arrive at coefficients for growth of Capital per Worker that are more in line with Pritchett's original findings and the R-squared also increases to 0.73 when we use Capital from PWT 9. The results thus far convince us that we have reasonably approximated Pritchett's methodology and have confirmed his findings. We therefore move on to consider how distinguishing vocational and non-vocational education in the Education Capital variable affects the results. This is done in Table 3.9. In this table, we continue to assume a 10 percent rate of return to all types of schooling. Bear in mind that the part of educational capital that can be attributed to vocational schooling is always much smaller than non-vocational years of schooling, regardless of whether we find differences in how the two educational capital variables behave. The coefficient of vocational education capital is positive. It remains insignificant in all cases, except when using PWT 6.3 with initial GDP (column 4a), and even then, it is only significant at the 10 percent level. The coefficient on non-vocational educational capital remains negative and insignificant.

Table 3.9 Growth-Accounting of GDP per Worker Growth: Extension of Pritchett Analysis

	Distinguishing Non-Vocational and Vocational Education			
DV: Per annum growth of GDP per Worker	**GDP and K = PWT 6.3**		**GDP and K = PWT 9**	
	(3a)	**(4a)**	**(3b)**	**(4b)**
Growth of 'Non-vocational Education Capital' per Worker	-0.12	-0.12	-0.06	-0.12
	(0.10)	(0.14)	(0.06)	(0.10)
Growth of 'Vocational Education Capital' per Worker	0.04	0.11*	0.01	0.03
	(0.07)	(0.06)	(0.04)	(0.04)
Growth in Capital* per Worker	0.36***	0.26***	0.63***	0.54***
	(0.08)	(0.06)	(0.06)	(0.08)
ln (initial GDP per Worker)		-0.002		-0.004**
		(0.002)		(0.002)
Constant	0.01**	0.03	0.004	0.04**
	(0.004)	(0.02)	(0.002)	(0.02)
Countries	95	77	95	64
R-squared	0.38	0.40	0.73	0.73

Notes: Pritchett has t-statistics in parentheses and I have Standard errors in parentheses. *Pritchett calls Capital 'CUDIE' in his results table: Cumulated Depreciated Investment Effort. * p<0.10, ** p<0.05, *** p<0.01.

In Table 3.10 and Appendix C.4 Table C.4.1, we make use of data which (somewhat surprisingly) Pritchett did not use himself. Within the Barro and Lee data, it is possible to have Years of Schooling in Primary, Secondary and Tertiary (and it was also possible to have that information in the 1993 dataset). In his first descriptive table, Pritchett shows the calculated wage premiums of different levels of educational attainment and changes the assumed constant r to vary with primary, secondary, and tertiary attainment. In the regressions, however, he used only the constant 10 percent rate of return. Something interesting happens when we divide education capital into primary, secondary and tertiary (including a differentiation between non-vocational and vocational at the secondary level). We see that the negative coefficients on primary become significant. This finding may at first seem contrary to the literature. But, as Pritchett himself points out, although the literature often repeats that the greatest returns are highest for primary schooling (for example, in Psacharopolous 1993) this is not because the increment in wages is higher for one year of primary school, but rather because the opportunity cost is lower (Pritchett, 2001: pg 373).

The coefficients on non-vocational secondary schooling are mostly negative and insignificant. The coefficients are positive almost consistently across the board for vocational secondary schooling. The coefficients on Tertiary are positive, often large and significant. This is the case when we assume the highest return to primary (as Pritchett does in his first table; adjusting his wage r assumption to account for international evidence from Psacharopoulos 1993), but the results also hold when we assume the highest return to tertiary. This implies that the externalities (at the macro level) vary with the level of education achieved, and that tertiary education does indeed have a higher than expected return (implying positive externalities). Furthermore, when more of the workforce is limited to just a primary education, then there is indeed some evidence of negative externalities (as far as growth is concerned). This just makes sense.

What is interesting is that, although mostly statistically insignificant, the transition from negative to positive coefficients seems to occur with vocational secondary education capital. For now we have kept the assumed return to vocational secondary the same as for non-vocational secondary, but a sensitivity analysis could be performed to see how much changing the assumed rates of return could affect the results.

Table 3.10 Education Capital Broken down into Primary, Secondary (Non-vocational), Secondary Vocational) and Tertiary | Highest r to Primary

	Split Educational Capital into Primary, Secondary (Vocational and Non-Vocational) and Tertiary			
	GDP and K = PWT 6.3		GDP and K = PWT 9	
	(5a)	(6a)	(5b)	(6b)
Growth of 'Primary Capital' per Worker (r = 0.16)	-0.25**	-0.24*	-0.14**	-0.13
	(0.11)	(0.14)	(0.06)	(0.08)
Growth of 'Secondary Non-Vocational Capital' per Worker (r=0.12)	-0.02	-0.14	0.04	-0.04
	(0.09)	(0.10)	(0.04)	(0.06)
Growth of 'Secondary Vocational Capital' per Worker (r=0.12)	0.03	0.11*	0.02	0.03
	(0.07)	(0.06)	(0.04)	(0.04)
Growth of 'Tertiary Capital' per Worker (r = 0.08)	0.37***	0.24**	0.14*	0.03
	(0.13)	(0.10)	(0.08)	(0.09)
Growth in Capital* per Worker	0.33***	0.25***	0.60***	0.52***
	(0.07)	(0.06)	(0.06)	(0.08)
ln (initial GDP per Worker)		-0.004*		-0.005**
		(0.002)		(0.002)
Constant	-0.003	0.05*	-0.003	0.05**
	(0.01)	(0.03)	(0.004)	(0.02)
Countries	95	77	95	64
R-squared	0.47	0.48	0.75	0.74

Notes: Pritchett has t-statistics in parentheses and I have Standard errors in parentheses. *Pritchett calls Capital 'CUDIE' in his results table: Cumulated Depreciated Investment Effort. * p<0.10, ** p<0.05, *** p<0.01.

In replicating Pritchett, we find empirical evidence that the social returns to human capital might not be uniform for different educational groups. Ang et al., (2011) argue there is no reason to think a priori that the social returns would be the same, as is assumed when they are combined in one measure in macroeconomic studies. Ang et al. employ a system GMM estimator for a panel of 87 countries from 1970-2004 and divide educational categories into Primary, Secondary and Tertiary. They find growth enhancing effects of tertiary education when countries move closer to the frontier in high and medium income countries. This is something we will continue to explore as we move into the next section and our own empirical approach.

3.5.4 Replication of Benhabib and Spiegel (2005)

The Benhabib and Spiegel model represents our preferred way of looking at the relationship between vocational education formation and economic performance, because it has an explicit theoretical grounding (see section 3.2.4). Nevertheless, this specification is limiting in the sense that it only examines the relationship between

human capital and total factor productivity (TFP). TFP is important, but it is only one of the factors driving growth in an economy. So in our own empirical approach we will return to the broader measure for economic performance, GDP per capita.

The Benhabib and Spiegel model is a variation of the original Nelson-Phelps model of technology diffusion:

$$\frac{A_i(t)}{A_i(t)} = g\big(H_i(t)\big) + c\big(\big(H_i(t)\big)\Big(\frac{A_m(t)}{A_i(t)} - 1\Big) \tag{5}$$

Where $A_i(t)$ is TFP, g_i $(H_i(t))$ is the part of TFP growth that relies on education in country i, and $c((H_i(t))\left(\frac{A_m(t)}{A_i(t)} - 1\right)$ is the rate at which the technology diffuses between country m (leader) and country i (follower). This rate at which technology is absorbed from abroad also depends on education in country i.

Benhabib and Spiegel assume that $g_i(\cdot)$ and $c_i(\cdot)$ are increasing functions and they model education as a factor that facilitates technology diffusion in the following non-linear cross-sectional specification:

$$\Delta a_i = \beta_1 h_i - \beta_2 h_i \left(\frac{A_i}{A_m}\right)^s + \varepsilon_i \tag{6}$$

In their specification Δa_i is the average annual growth in TFP in country *i,* and h_i is the log of human capital stock of country *i* which is measured as either the initial human capital stock or its average over the time period. They use maximum likelihood to estimate: β_1 the parameter whose coefficient is meant to capture the country's capacity to conduct innovative activity, and β_2 the parameter whose coefficient represents the catch-up term and is meant to capture the capacity for technology adoption from abroad. In the catch-up term, h_i is multiplied by the ratio of the country's TFP (A_i) to the TFP of the productivity leader nation (A_m). The TFP ratio is a proxy of the distance from the technological frontier. In the logistic model, *s* equals 1, and in the exponential model, *s* equals -1. Since Benhabib and Spiegel favor the logistic specification, we replicate the logistic model (setting *s* equal to 1), and make our modifications from there.

In essence, Benhabib and Spiegel say that they have distinguished human capital a la Romer (1990) within a Nelson-Phelps framework and they abstract from issues regarding the distribution of H_i to innovation or imitation (catch-up) and assume that all of it enters in both terms. However, they do allude to an interest in considering how the distribution between imitative and innovative uses of human capital might change with the distance to the frontier. It is this idea of the different functions of human capital as represented by the two terms that makes their model particularly interesting

for exploring how their results might change if we can distinguish vocational and non-vocational education. As we have argued above, vocational human capital can make a special contribution to absorptive capacity, and may thus be related to the technology absorption from abroad (imitation) that contributes to catch up.

In order to assess the importance of the vocational variable from this conceptual vantage point, we first try to replicate Benhabib and Spiegel's results as closely as possible and then we experiment with distinguishing the contributions of vocational and non-vocational human capital.

Table 3.11 Education and Technology Diffusion: Replication of the Benhabib and Spiegel Analysis

	Dependent Variable: Log Average annual growth of TFP (1960–1995)							
	B&S: Table 2		Replication		B&S: Table 3		Replication (H= 1960-1985)	
$\ln(H_{1960})$	0.0100**	0.0134**	0.0058**	0.0121***				
	(0.0023)	(0.0025)	(0.002)	(0.001)				
$\ln(H_{1960})^* (TFP_i / TFP_m)^s$	-0.0089**	-0.0072**	-0.0222***	-0.0416***				
	(0.0036)	(0.0025)	(0.01)	(0.01)				
$\ln(\bar{H}_{1960\text{-}1995})$					0.0184**	0.0159**	0.0066***	0.0095***
					(0.0026)	(0.0017)	(0.001)	(0.0009)
$\ln(\bar{H}_{1960\text{-}1995})^* (TFP_i / TFP_m)^s$					-0.0135**	-0.0122**	-0.0260***	-0.0343***
					(0.0031)	(0.0029)	(0.01)	(0.004)
Constant	0.0085**	--	0.0093**	--	-0.0030	--	0.0054	--
	(0.0016)		(0.004)		(0.0024)		(0.003)	
S	1	1	1	1	1	1	1	1
Observations	84	84	80	80	84	84	83	83
Log likelihood	263.9	263.9	212.4	209.2	274.4	273.6	225.7	224.1
Wald P-value	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00

Notes: Following Benhabib and Spiegel (B&S); estimation is by maximum likelihood with standard errors in parenthesis. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01. Results reported from B&S Table 3 calculate the average human capital levels as the simple averages beginning in 1960 and ending in 1995. In the 2 columns furthest to the right, simple averages for human capital begin in 1960 and end in 1985.

For this replication, we used exactly the same TFP data as Benhabib and Spiegel. The Barro and Lee data that they used for Human Capital are from the 1993 dataset (the same data we used for the Pritchett replication, but updated to 1995). Unfortunately,

we could only find data from the 1993 dataset up to 1985 and the updated Barro and Lee dataset from 2010 (which incorporated many changes in the way in which the variable is constructed). Therefore, we use the 1993 Barro and Lee data for the first replication, which limits the replications to the years 1960-1985.

In the model which uses initial levels of human capital, ln (H_{1960}), this should not make any difference. In fact it does, because we have fewer observations (countries) in Table 3.11. The explanation for this is probably that the 'updated 1993 dataset' included some countries which were not yet included in the original 1993 B&L dataset. Nevertheless, our results are similar to those of Behabib and Spiegel in terms of signs and significance. We conclude that we have a close enough approximation to move forward with updating and modifying the data.

In Table 3.12, we first update the data for TFP to cover the full time period 1960-2010. In the first three models, we leave the human capital variable as the Barro and Lee Years of Schooling (either initial or simple average over the time period) in both the first term and second term. Using the extended time period, when the constant term is incorporated (Models 1 and 2) the model as a whole is no longer fitting well. We can see that the p-values for the Wald are 0.26 and 0.24 respectively. Although Benhabib and Spiegel initially say that they are agnostic about including a constant term for *b*, later they state that their theory does not call for "a constant term independent of human capital to account for total factor productivity growth" (page 955). Nevertheless, they dutifully report all of their results with both with and without a constant term (as a kind of robustness check). In our case, since there is no theoretical reason that demands the inclusion of the constant term, we decided to drop the constant term for the rest of the models. We find that (Model 3) dropping the constant term improves the Wald p-value and makes the results qualitatively similar to those obtained from 1960-1995.

In Models 4 and 5, we replace years of schooling by non-vocational years of schooling (25+) in the first term representing innovative Human Capital. We use our vocational portion of years of schooling (at the secondary level) as a second catch-up term. We can see that qualitatively the results are similar.

Table 3.12 Vocational Education: Extension of the Benhabib and Spiegel Analysis

Dependent Variable = Average annual log growth of TFP (1960–2010)							
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
$\ln(H_{1960})$ (Year of Schooling 25+)	-0.0003						
	(0.0003)						
$\ln(H_{1960})*(TFP_i / TFP_m)^s$	0.0008						
	(0.001)						
$\ln(\bar{H}_{1960\text{-}2010})$ Years of Schooling 25+		0.0005	0.001***				
		(0.0003)	(0.0001)				
$\ln(\bar{H}_{1960\text{-}1995})*(TFP_i / TFP_m)$ Years of Schooling 25+)^s		-0.002*	-0.003***				
		(0.001)	(0.0005)				
$\ln(H_{1960})$ Non-vocational years of Schooling				0.0004***			
				(0.0001)			
$\ln(H_{1960})*(TFP_i / TFP_m)^s$ Vocational Secondary schooling				-0.001***		-0.001***	
				(0.0002)		(0.0001)	
$\ln(\bar{H}_{1960\text{-}2010})$ Non-vocational years of Schooling					0.0004***		
					(0.0001)		
$\ln(\bar{H}_{1960\text{-}1995})*(TFP_i / TFP_m)^s$ Vocational Secondary schooling					-0.0009***		-0.001***
					(0.0002)		(0.0002)
$\ln(H_{1960})$ Tertiary Schooling (25+)						0.03***	
						(0.004)	
$\ln(\bar{H}_{1960\text{-}2010})$ Tertiary Schooling (25+)							0.008***
							(0.0010)
Constant	0.003***	0.002*					
	(0.0007)	(0.001)					
S	1	1	1	1	1	1	1
Observations	89	89	89	73	89	89	89
Log likelihood	390.43	390.90	387.68	315.52	385.48	378.20	372.17
Wald P-value	0.26	0.24	0.00	0.00	0.00	0.00	0.00

Notes: Following Benhabib and Spiegel (B&S); estimation is by maximum likelihood with standard errors in parenthesis. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

In Models 6 and 7, we decided to enter years of tertiary schooling in the first term instead of total years of schooling, together with a catch up term for vocational education. We obtain similar results. The specifications with tertiary schooling seem to 'fit the data' at least as well as specifications with total education. The interpretation of columns 4 through 7 is that vocational education contributes significantly to absorptive capacity and catch up.

The results of the Benhabib and Spiegel replications, combined with our analysis of the role of vocational human capital in a catch-up incorporating the role of sectoral changes (Szirmai and Verspagen 2015), leads us to the conclusion that including vocational education in regressions of economic performance is a promising approach towards a better specification of the relation between education and the dynamics of production.

3.6 Own Empirical Approach

This section further investigates the mechanism through which vocational secondary schooling affects economic performance. Following systematic testing of the vocational variable in a variety of theoretical and empirical contexts, we reached the preliminary conclusion that vocational secondary schooling affects economic performance through the role it plays in equipping economies with the absorptive capacity needed for technology diffusion and catch-up. We already found some evidence that this role is mitigated by the economy's distance to the technological frontier. We have tested the vocational variable in settings that allow for some between country variation and treated some of our explanatory variables as endogenous (i.e., the Hausman-Taylor specification in section 3.3). However, we have not addressed autoregressive dynamics, or the likely persistence of our variables. In other words, we have not specified models where y is a function of its own lag, our Xs, and lags of some of our Xs.

GMM offers a methodology to deal with explanatory variables that are not strictly exogenous and are persistent over time (Bond, 2002). Even if some scholars remain skeptical of a methodology which uses lags as instruments, GMM is now the most common alternative to a fixed effects model in the growth literature (Durlauf et al., 2005). So, it is useful to test our vocational variable using the GMM methodology. In our final specification, we are interested in explicitly assessing the joint relationship between vocational secondary schooling and the relative distance to the frontier.

In Table 3.13, we revisit the relationship between vocational secondary schooling and economic performance as measured by GDP per capita in levels (Panel A) and growth of GDP per capita (Panel B). For the sake of comparison, we include OLS fixed effects models in columns 1 and 2, without and with lags of our explanatory variables,

respectively. When we initially introduce a lag of GDP per capita (see Appendix B.5), the effects of most other explanatory variables are washed out. This is a common consequence of including the lagged dependent variable in OLS, regardless of whether the true causal effect of lag is strong, weak or impotent (Achen, 2001).

The GMM analysis shows that vocational secondary schooling is clearly associated with a contemporaneous positive and significant increase in GDP (columns 3 and 4) and growth of GDP per capita (column 6). The lagged coefficients, however, are negative and (often) significantly associated with economic performance. There appears to be a dynamic relationship between vocational education and economic performance over time. When we hold contemporaneous vocational secondary schooling constant, the marginal effect on economic performance of an increase in vocational secondary 5 years prior (t-1) is negative. This suggests that for two countries with the same amount of vocational secondary schooling in time t, the country with more vocational secondary schooling 5 years before (t-1) is associated with lower economic performance. In other words, countries with less vocational secondary schooling 5 years prior (t-1), but the same vocational secondary schooling in time t, accumulated vocational secondary schooling more rapidly and thus, reaped higher growth rates 5 to 10 years later.[30] Our results show that the backward trajectory of vocational secondary schooling matters for its effect on economic performance. Vocational secondary schooling always appears to be more relevant for economic performance than non-vocational years of schooling.

[30] Recall that the growth rate in time t, projects forward (t+1) and that each period represents 5 years.

Table 3.13 Vocational Secondary Schooling: GMM Results & Interaction with Distance to the Frontier

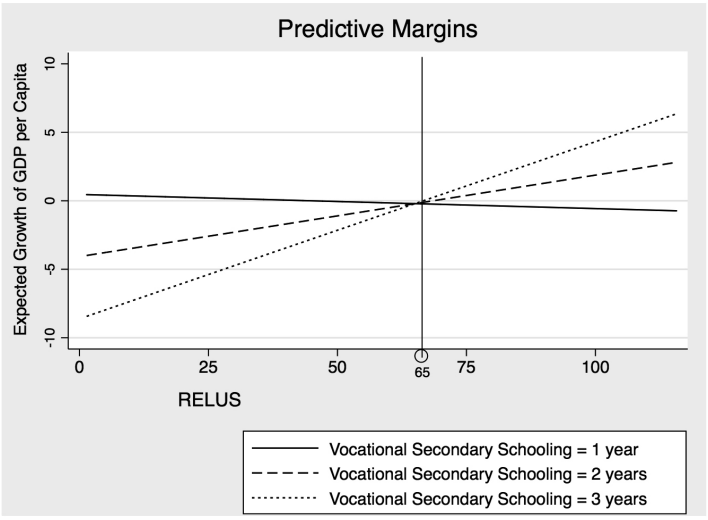
	Panel A LEVELS:				**Panel B GROWTH:**			
	Log GDP per capita 1960-2010				**Growth of GDP per capita* 1960-2005**			
	OLS FE	OLS FE	GMM DIF	GMM SYS	GMM DIF	GMM SYS	GMM SYS + interactions	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-vocational Years of Schooling	0.02	0.01	-0.004	-0.01	-0.16	1.10***	0.67*	0.95**
	(0.02)	(0.03)	(0.02)	(0.02)	(0.83)	(0.22)	(0.39)	(0.37)
Vocational Secondary Schooling	0.07	0.10*	0.07**	0.08**	1.78	1.56***	4.03**	5.99***
	(0.06)	(0.06)	(0.03)	(0.04)	(1.41)	(0.56)	(1.58)	(1.80)
Lag (1 period) Non-vocational Years of Schooling		0.02	0.005	0.02	-0.12	-0.66***	0.10	-0.10
		(0.03)	(0.02)	(0.02)	(0.73)	(0.23)	(0.44)	(0.41)
Lag (1 period) Vocational Secondary Schooling		0.02	-0.05	-0.11***	-0.73	-1.81***	-7.17***	-10.53***
		(0.06)	(0.04)	(0.04)	(1.60)	(0.53)	(1.48)	(2.19)
Log K per Worker PWT 9.0	0.52***	0.83***	0.35***	0.53***	1.16	2.53***	2.57***	2.24**
	(0.08)	(0.12)	(0.10)	(0.07)	(3.82)	(0.38)	(0.82)	(1.01)
Lag (1 period) Log K per Worker PWT 9.0		-0.34***	-0.24***	-0.49***	1.16	-3.39***	-3.27***	-3.57***
		(0.12)	(0.09)	(0.06)	(3.10)	(0.35)	(0.73)	(0.81)
Initial Log GDP per capita (start of 5 yr period)					-6.88***		0.83**	1.69***
					(2.26)		(0.34)	(0.50)
Lag (1 period) Log GDP per capita			0.70***	0.95***				
			(0.03)	(0.03)				
Lag (1 period) Growth of GDP per capita					0.08	0.10***	0.02	0.02
					(0.06)	(0.01)	(0.03)	(0.06)
RELUS							0.04*	0.02
							(0.03)	(0.06)
Lag (1 period) RELUS							-0.11***	-0.10
							(0.02)	(0.07)
Non-vocational # Relus								-0.01
								(0.01)
Lag (1 period) Non-vocational # Relus								0.01
								(0.01)
Vocational # Relus							-0.04**	-0.07***
							(0.02)	(0.02)
Lag (1 period) Vocational # Relus							0.09***	0.14***
							(0.02)	(0.03)
Oil exporter, time dummies and constant included	**y**	**y**	**y**	**y**	**y**	**y**	**y**	**y**
Observations	901	774	657	774	384	467	467	467
Countries	105	105	99	105	70	76	76	76
R-sq.	0.76	0.74						
sarganp			0.00	0.01	0.00	0.01	0.01	0.00
hansenp			1.00	1.00	1.00	1.00	1.00	1.00
ar1p			0.00	0.00	0.00	0.00	0.00	0.00
ar2p			0.63	0.71	0.23	0.46	0.38	0.49

Notes: Growth of GDP per capita is per 5-year period (i.e. t+1, where each period represents 5 years). Robust Standard errors are in parentheses, with the exception of the two-step System GMM, where the co-variance matrix is already robust in theory (adding 'robust' requests Windmeijer's finite-sample correction for the two-step covariance matrix). Results for column 8 with Windmeijer's finite-sample correction are qualitatively similar for our vocational schooling variables. For columns 1-7 the GMM system instruments are the lags from t-2. For column 8, the GMM instruments are the lags from t-3.

We include results from both the first-differenced GMM and system GMM in Table 3.13 to illustrate the relatively consistent results for vocational secondary schooling using both approaches. The literature notes that first-differenced GMM may be downward biased, especially if the estimate is below or close to the within groups estimate (Bond et al., 2001). Therefore, we adopt the system GMM approach when we include the interaction terms in columns 7 and 8 to test whether the effect of vocational secondary schooling on growth depends on the economy's relative distance to the frontier.

In column 7, we introduce an interaction term between vocational secondary schooling and the distance to the frontier. The distance to the frontier is defined as the GDP per capita relative to the United States (RELUS) at the beginning of the 5 year period based on Maddison (2009). In column 8, we include an interaction between non-vocational schooling and the relative distance to the frontier. The relationship between contemporaneous vocational secondary schooling and growth of GDP per capita is positive and significant and the interaction between contemporaneous vocational secondary schooling and RELUS is negative and significant. The partial effect of lag of vocational secondary schooling is negative and significant, and the lagged interaction with RELUS is positive and significant. When coefficients for the partial effects are summed and tested for significance, the lagged effect dominates. The same is true of the coefficients of the interaction terms between vocational secondary schooling and RELUS. Taking everything together, the relationship suggests that there can be significant growth gains from additional vocational secondary schooling, but these gains tend to occur when the economy is already relatively close to the frontier and when levels of vocational secondary schooling are high and have accumulated relatively quickly in the previous period. Figure 3.1shows the distance from the frontier at which vocational secondary schooling contributes more to the predicted growth rate of the economy in the subsequent 5 years.

Figure 3.1 Predicted Growth Effects of Vocational Education at Different Distances to the Frontier



When the per capita GDP of the economy is roughly 65 percent of the per capita GDP of the U.S., an increase in vocational secondary schooling is associated with a positive and significant effect on the subsequent 5 year growth rate. The predicted marginal effects presented in Figure 3.1 are the post-estimation effects from our specification in column 8 of Table 3.13. Therefore, the predicted margins reflect both the contemporaneous and the lagged effects of the interaction between vocational secondary schooling and the relative distance to the frontier.

To summarize, we hypothesized that vocational secondary schooling is important for absorptive capacity. GMM analysis shows this hypothesis to be credible, but in order to take advantage of gains from absorptive capacity developed through vocational secondary schooling; the economy already has to be relatively close to the frontier. In our dataset, the mean for RELUS is 31 percent, but the median is 21 percent. That means that most of the economies in our dataset have not yet reached the distance at which they can take advantage of additional vocational secondary schooling. We believe that we can link this finding to our regional analysis in the first part of this chapter. In those results, the regions that benefited most from additional vocational secondary schooling were Advanced economies and the East Asian region. In sub-Saharan Africa, additional vocational secondary schooling was found to be negatively associated with economic performance. This finding is rather striking, given our anticipation that vocational education should play a role especially in catching-up economies. But in this chapter, we are only capturing vocational education that is part of the formal school

system at the secondary level. Therefore, it may be the case that the quality of vocational secondary school in countries further from the frontier was lower and thus did not spur growth in the same way. We find that economies closer to the frontier gain more from increased vocational secondary schooling.

3.7 Discussion, Conclusions and Implications for Future Research

This chapter systematically tested the role of vocational secondary schooling in economic development. We found that it is consistently related to macroeconomic performance. Through the process of replicating four studies that are emblematic of distinct theoretical and empirical approaches, we covered much of the analytic ground of the relationship between education and macroeconomic performance. The first replication was the study by Barro and Lee. They found a positive return to additional years of schooling with expected patterns in different regions around the world. We found that vocational secondary schooling has a strong additive effect above education as such on the relationship with GDP per worker. The relationship is even stronger with GDP per capita. We argue that since vocational education is linked with the labor market, it facilitates an 'employment effect' which boosts GDP per capita in the same periods. A second replication of Szirmai and Verspagen focused on the interaction between education and the relative distance to the frontier. In their study they related education to structural change variables and found a positive manufacturing growth effect in in developing countries that had higher levels of education. We found evidence to support the notion that education and economic structure work together to affect per capita GDP growth. Education could be a structural variable which contributes more or less to growth when it is 'well matched' with the economy. We find evidence that vocational secondary schooling is a good proxy for absorptive capability and we also note that the returns to these capabilities vary with the distance to the frontier. These results are supported in our final replication of Benhabib and Spiegel, using a different methodology, dependent variable and estimation strategy. In our replication of Pritchett, we similarly find that, once a wage return is embedded in education (i.e., once it is converted to education capital), we do not see macro returns that are over and above what are assumed to be recouped by the people who invest in further education. When we further divide schooling levels, we find preliminary evidence that there may be spillovers to tertiary education that are not found at other levels of schooling. Since this is not part of our primary objective for this chapter, we do not dwell or delve further into this finding.

Synthesizing the results from our adjusted replications that take vocational secondary schooling into account, we look to fill the methodological and theoretical gaps in our

own empirical approach. The most important piece of ground not covered in our replications is the possible persistence of our variables. In our own empirical approach, we handle this persistence with GMM models and reach the conclusion that the true effect of vocational secondary schooling should be understood by its contemporaneous and its lagged effect. That means that, for growth, not only is the amount of vocational schooling in an economy today important, but how fast it has increased its vocational secondary schooling over the past 5 years is also important. Countries that accumulated vocational secondary schooling more rapidly see a higher growth payoff. We also find that while vocational secondary schooling does seem to be important for catch-up, the economy already has to be close to the frontier to benefit from additional vocational secondary schooling.

There are several possible reasons why being closer to the frontier means that an increase in vocational secondary schooling would be more beneficial for growth. The first has to do with the quality of the vocational education. In this chapter, we have always analyzed vocational secondary schooling at the secondary level that is part of the formal education system. The data do not include vocational training programs or vocational education at the tertiary level. This means that if, in some economies, the vocational track is neglected in terms of funding, or weak in terms of its linkages to the true needs of the labor market, we could not expect it to be as effective in delivering a better 'match' for the productive sector than alternative education pathways. In this chapter, we cannot and have not addressed the issue of the relative quality of vocational education in different economies. Another explanation could be that, as Szirmai and Verspagen point out, the theory of absorptive capacity is a broad concept that encompasses many elements that facilitate knowledge transfer from the frontier to catching-up economies. Examples include, but are not limited to: infrastructure, political stability, and other elements of the national innovation system. These might need to be 'healthy' in order for an economy to be able to take advantage of knowledge developed at the frontier for the sake of its own growth. If these other elements are weaker, it may mitigate the role of vocational education to facilitate knowledge transfer, and thus limit its relationship with growth to negligible, nil, or even negative effects.

This chapter has taken a big step toward identifying and analyzing the relationship between vocational secondary schooling and macroeconomic performance over long time horizons. By exploiting the value of the scientific method, we have systematically replicated and tested our hypotheses in different empirical settings. By doing this, we have established that vocational secondary schooling has a clear impact on macro-economic performance, but that gains from additional vocational schooling are only realized once an economy is already pretty close to the frontier. We identified the threshold at which vocational secondary schooling has a positive growth payoff is when

an economy already has a per capita GDP of 65 percent of the per capita GDP of the United States. Future research could investigate more deeply into the issue of whether it is the quality of vocational education or other elements known to be important for absorptive capacity that are the most relevant for getting an economy to this crucial threshold. After an economy reaches 65 percent of the frontier economy (GDP of the U.S.), vocational education does help economies grow faster to catch-up and maybe even surpass the frontier. Since we noticed considerable regional differences for the relationship between vocational education and economic performance, another avenue for future research could be to explore different and possibly multiple frontiers at which the threshold for the positive growth effect of vocational education can change.

Chapter 4

Money Counts, but so does Timing: Public Investment and Adult Competencies*

*This chapter is based on Cathles, A. and J. Ritzen. 2017. Money Counts, But so Does Timing: Public Investment and Adult Competencies, IZA Discussion Paper No. 10565. Project support for this paper comes from IZA (Institute for the Study of Labor). We are grateful to Adam Szirmai for valuable comments and suggestions throughout the process of working on this paper. We would also like to express gratitude to Gesis for a useful training on PIAAC data, with a special thanks to Anja Perry and Jan Heisig for sharing their experience, insights, and programming advice. We also thank Rene Belderbos for technical advice on the implementation of the test for complementarity. All imprecision, oversights, or errors that remain in the paper are our own.

Abstract

Numeracy skills of adults within and across 12 different countries in 2011 are strongly associated with the accumulated public investments in education received by these adults during their schooling. This paper confirms existing evidence that the timing of educational investments is important, with early investments playing the most fundamental role. Adults who received higher public investment in primary education were more likely to complete secondary school and attain tertiary education. Higher investments in tertiary education are needed in order to fully realize the benefits of the investments in primary school. Family background is a decisive factor in relation to numeracy skills of these adults, in line with all available evidence. Being born outside the country is strongly and negatively associated with adult numeracy skills. This research refutes earlier studies indicating that the amount of financial resources available for education may not be that important for the development of competences.

Keywords: Government Expenditures and Education • Education and Economic Development • Returns to Education • Human Capital • Cognitive Skills

JEL Classification Codes: H52 • I25 • I26 •J01 •J24

4.1 Introduction: Does Money Matter?

Education is the fourth largest government expenditure in the OECD (Organization for Economic Cooperation and Development), it is twice as high as public spending on defense and almost triple the expenditure on public safety and order (OECD, 2015a, p. 73). In 2013, on average, governments in OECD countries spent roughly 2,000 current PPP dollars per capita on education, which translates to more than 5 percent of the average per capita income.[31]

So, is the large public expenditure on education worth the money? Politicians and public opinion alike have debated this question. Citizens are torn between, on the one hand, the notion of bloated bureaucracy in schools and on the other hand, general awareness of the positive effects of investment in education. The commonly held perception is that better educated individuals are better able to perform more complicated tasks, or adapt to changing conditions and tasks (i.e., Nelson and Phelps, 1966). Or simply, that a more educated population is beneficial for society.

Research in education economics has been inconclusive. Serious studies allege that additional public resources are not necessarily associated with better student performance (Hanushek et al., 2003). One such study shows "no relationship between increases in expenditure and changes in performance" (OECD, 2013a, p. 42). Recently, Woessmann (2016) finds that resource inputs such as investment are only a small piece of the puzzle in explaining international differences in student achievement, while measures of teacher and school quality are much more important. Around 90 percent of public expenditures per student are accounted for by teacher salaries and class size.[32] Teacher salaries are – within overall labor conditions, including class size, vacations, available time for retraining etc. - important in attracting those best qualified for the teaching profession. And so, it may not be realistic to delineate between teacher quality and public investment resources. With respect to class size, the educational community, including parents and (unions of) teachers, plead in favor of smaller class-sizes as a means to raise student performance, however, evidence shows that class-size in the range between 15 and 35 did not seem to matter for the development in competencies (Hattie, 2008 reviews 200 meta studies on this topic). Expenditure on reduction of

[31] In 2013, the weighted average of the 'General government expenditures per capita' in the OECD was 16,491 PPP (OECD, 2015a, page 71) and 12.5 percent of those expenditures were allocated to education (OECD, 2015a, page 73). Data on average income per capita are from the World Development Indicators (accessed June, 2016).

[32] On average, compensation for teachers and other staff in OECD countries in 2012, represented from 67 percent (at the tertiary level) to 79 percent (at primary and secondary levels) of current expenditure (OECD, 2015b, p. 288).

class size seems to have been less important for competences than parents and teachers originally thought.

OECD (2013a) and Woessmann (2016) conclude that institutional factors such as school autonomy and accountability, in combination with goal orientation, determine the school's success in developing competencies. These findings, however, are based on data from the Programme for International Student Achievement (PISA) which measures competencies of 15 year olds and so the cumulative investments only extend up to the age of 15, which is typically long before students complete secondary school. Therefore, the findings do not account for how greater investments may facilitate skill accumulation later on, or higher educational attainment.

In fact, recent empirical evidence at the sub-national level finds that more public investment does indeed facilitate higher educational attainment. Candelaria and Shores (2015) show that financial reforms in some states in the United States led to an increase in per-pupil expenditure which was robustly associated with an increase in high school graduation rates in the poorest districts. Hyman (2017) finds that following a reform in Michigan in the mid-90s to redistribute per-pupil expenditure, students who had an additional 10 percent public investment in their primary education were significantly more likely to enroll in college and complete a tertiary degree.

We were fortunate to be able to access data from the UNESCO's Institute for Statistics (UIS) on public investments made from 1971-2011 in education and relate that investment information to the observed competences of adults from the Programme for the International Assessment of Adult Competencies (PIAAC) measuring numeracy skills of adults in 2011 for 12 countries, refuting the earlier evidence from student achievement scores and showing that money does count for adult competences. Of course: as found in previous studies, many other variables such as family background, work experience, and institutional settings influence the competences of adults. Hence "money" only explains part of the development of competences.

Subsequently we ask ourselves whether the timing of the investment matters. The awareness that competences at the end of the school career are the result of a long-run process of sequential investment was early on introduced by Ritzen and Winkler (1977a; 1977b; and 1979) using pupil data on school progress and school input data over the full school career. Later Cunha and Heckman (2007) put this into a theoretical framework of a state space model: competency at some point in time is the result of the competency at some previous moment and the new inputs into competency at that point in time (what they call self-productivity). They argue with this model that investments in skill development are – in this way - complementary. Of course, if this

were not the case, then the wise investment decision would be to defer investment to the latest possible period. If, however, investments are complementary, two things happen – the early period investment is essential and cannot easily be made up for in a later period investment, and – later period investments are necessary to realize the payoff to the first period investment. In the context of education, this makes a lot of sense. If you only invest heavily in later periods in those who have already made it to secondary or tertiary education, you may be unfairly jeopardize the chances of those with less cognitive skills by not sufficiently investing in them in the early period. On the other hand, if you only invest in the first period (i.e., primary school), the payoff of the investment is contingent on later period investments.

Our public investment series can be broken down into three streams of investment per student in; Primary, Secondary and Tertiary education. We use this information to analyze the possible complementarity of investments in different periods.

We find that investments in education are contributing in two ways to adult competencies (1) directly, in terms of higher numeracy scores among adult populations and (2) indirectly, because higher investments in earlier periods (primary education in particular) holding other things constant (like family background) increase the chances of persisting into higher levels of education attainment. We find that complementarities between investment periods do exist, but there are thresholds beyond which investments can become substitutes. A striking result is that being born outside the country has such a strong negative impact on competencies as an adult, even when immigration occurs before the age of 6 and education takes place in the destination country. This result may be partially driven by the fact that individuals with foreign educational qualifications have been excluded from this analysis, since public investments can only be accurately assigned to people who obtained domestic educational qualifications. Other studies have used PISA and PIAAC data to show that existing gaps between youth with different immigrant backgrounds at the age of 15 can be at least partially mitigated by the quality of the school system in the destination country (van Veen et al., 2018).

The paper is structured as follows. The next section will describe the model we use. It is the standard educational production function used to assess the impact of education investments on competencies. We describe how we have made this general model fit for empirical estimation and introduce our key variables of interest. We then analyze (a) whether larger early period investments in primary and secondary education increase the probability of higher educational attainment using Logit regressions and (b) complementarity between investments in primary, secondary and tertiary education using interaction terms in OLS regressions. In section 4.3 we present the data that have been used. We detail how the UIS investment data have been converted into the

cumulated investment in the educational lifetimes of individuals of the adults in PIAAC. In section 4.4 we describe our results. In section 4.5 we discuss the main conclusions and their policy implications, focusing on the need to ensure teachers' salaries remain competitive in national labor markets to attract those best suited for teaching jobs and to ensure sufficient time for teachers to keep up with their profession.

Competences are important for the individual and for society as a whole. We limit ourselves here to the relation between investments in education and competences well recognizing the substantial literature on the impact of competences on earnings, employment or on economic growth (i.e., Patrinos and Psacharopoulos, 2011, Hanushek & Woessmann, 2012, OECD, 2013b or Hanushek et al., 2015).

4.2 Modelling the Influence of Public Investment on Skills and Education

In this section we describe the three ways we model the relationship between public investment and two important outcomes; numeracy skills and educational attainment.

4.2.1 Modelling the Contribution of Public Investment to Adult Numeracy Skills

To begin with, we follow the traditional "Education Production Function" approach, developed since the 1960's (see, for example, Hanushek, 1986, for an overview of the literature).

We use the simplest form (following Hanushek et al., 2015) as our point of departure:

$$H=\lambda F+\phi Q(S)+\delta A+\alpha X+ v \qquad (1)$$

Here H is the output of the education system of an individual (say competencies). F denotes Family Background. Q(S) stands for the Quantity and Quality of schooling and A for individual ability. X is a vector of all other personal traits that may impact the person's competencies (like the individual's health or invested non-school resources). The term v indicates the stochastic nature of learning and $\lambda,\varphi,\delta,and\ \alpha$ tare parameters.

For our empirical specification we transform Eq. (1) into the following:

$$Num = \beta_0 + \beta_1 Inv + \beta_2 Edu + \beta_3 Family + \beta_4 Born\ Outside\ Country + \beta_5 Age + \beta_6 Age^2 + \beta_6 Work\ Exp + \beta_7 Work\ Exp^2 + Country\ dummies + \varepsilon \quad (2)$$

In our approach, educational output is proxied by *Numeracy skills* of adults (Num) as measured by PIAAC's assessment of numeracy skills. In section 4.3.1 we describe the data used to measure this variable in detail.

Quality and Quantity of Schooling (Q(S)) of Eq. (1) are proxied (in Eq. 2) by cumulated investment (denoted by Inv) and a categorical variable for the level of education attained (denoted by Edu) in three categories: uncompleted secondary, completed secondary and completed tertiary education. We only kept individuals who attained at least some secondary education. We made this decision in order to align our analysis with other studies on public investment and assessment based educational outcomes (i.e., Woessmann, 2003 and 2016; OECD, 2013a). In an extension of the present analysis, it would be possible to incorporate individuals whose highest level of educational attainment is primary school in the analysis. In the countries in our study, however, this tends to represent less than two percent of the sample. Taken together these variables can be thought of as a quality-enhanced measure of the quantity of schooling.

Family is a set of three variables. Parental education is commonly used as a measure of family inputs (i.e., Hanushek and Zhang, 2009). It has been shown to be a good indicator of family income (Carneiro and Heckman, 2002) and to have far reaching consequences on returns to education and on the attitudes, abilities and beliefs of children (Brunello and Rocco, 2015). The first Family variable is mother's education which is highly correlated with father's education but, in some contexts, has been found to be a better predictor of achievement than father's education (Wamani et al., 2004) and more closely related to the child's education (Haveman and Wolfe, 1995). Mother's education is operationalized as a categorical variable for three broad educational groups: uncompleted secondary, secondary and tertiary. The second Family variable is also a categorical variable for the estimated number of books in the household as a child. This can be seen as a proxy of socio-economic status and a reflection of parents' attitude toward education (Brunello, Weber and Weiss, 2012). The third Family variable is a dummy variable "Born Outside Country" which indicates whether the respondent is foreign born. People with foreign education qualifications are not included in our analysis, because we do not have public investment information for the foreign qualification for those individuals. This variable is therefore restricted to people who immigrated before

the age of 6 and obtained their highest educational qualification in the country in which the assessment of adult competencies (PIAAC) was taken.

The vector X (personal traits) is transformed into: the variables "Age" (the age of the individual at the time of the PIAAC assessment) and "Work Experience". We include squared terms for both. Literature suggests that skill improvement and skill loss (obsolescence) can be associated with age. "Age Squared" is an important variable because results from previous adult literacy assessments (IALS and ALL) found that the expected gains from increased quantity and quality of education could be offset by the 'depreciation' of skills at a later age (OECD, 2013c; Chapter 3). "Work Experience" is the number of years that the person has had paid employment for the majority of the year[33] and is included here as 'costless' investment to either maintain or develop skills (Destré, Lévy-Garboua and Sollogoub, 2008). Adult competencies are found to be positively related to work experience (Hanushek et al., 2015). Work experience refers to full-time or part-time work. There are some people in our sample who have zero years of work experience. This could be because the person is still in school and does not work part time, or may never have entered the workforce. "Work Experience Squared" is included because we expect a quadratic relationship for this variable; on average, we expect the effect of additional work experience on numeracy will lessen as work experience increases.

Country dummies have been included to control for 'fixed effects' and other unobservable differences among the different countries, such as inherent differences in the education system.

We cannot observe health or peer effects. Systematic differences in the distribution of health or of peer effects between the countries in our analysis are unlikely to exist. Similarly, individual Ability (A) in Eq (1) is left out of Eq (2), as we have no measures of it. This might imply that we have reverse causality as suggested by human capital theory (Becker, 1994). According to this theory, people invest in themselves and educational expenditures are the result perceived innate ability. We do not think that reverse causality is present in our study for two reasons: (1) in the compulsory school period the investment decisions are imposed and there is no choice and (2) there is no reason to think that the initial overall distribution of innate abilities would differ systematically

[33] The exact wording of the question in the PIAAC background questionnaire is, "In total, approximately how many years have you had paid work? Only include those years where 6 months or more was spent in either full-time or part-time work." We impose a threshold that stipulates the age of the person must be at least 10 years greater than reported number of years of work experience. Even if it seems unlikely that anyone under the age of 46 in these OECD countries began working at the age of 10, some spot checking shows a plausible situation: someone who is 45, whose occupation is in agriculture, has 35 years of work experience.

in the 12 relatively homogeneous OECD countries in our sample (i.e., why would the distribution of innate abilities in France systematically differ from those in Denmark?).

4.2.2 Modelling the Contribution of Investment to Educational Attainment

Using logit regressions, we explore whether greater amounts of investment at one stage increase the probability of making it to further stages of education. The dependent variable in these regressions is zero-one outcome variable for educational attainment. For example, when our dependent variable is completed secondary education, our logit model tests whether greater investment in primary education increases the probability of completing secondary education. In these regressions, we maintain our control variables: family background, personal traits, and country fixed effects. In this part of the analysis, it is also possible to 'control' for numeracy skills. Since many of the countries in our analysis have exit exams that are required in order to successfully graduate from secondary school and tertiary institutions that require entry exams, a concern could be that those people who have higher cognitive skills are more likely to persist in education anyway. By introducing PIAAC numeracy skills, we account for the differences in learned skills and we may also capture some pre-schooling skills. This allows us to be more secure that the effect of a marginal increase in public investment on the likelihood of attaining higher levels of education is truly related to investment and not pre-existing skills. As a point of departure, we use a logit model to estimate:

$$Logit\ (Education\ Attainment) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 PVNUM1_i + Controls_i + \varepsilon$$

Where Education Attainment is a binary dependent variable, defined first as Completed Secondary which takes a value of 1 for individuals who completed secondary education (or more) and a value of 0 for individuals who did not complete secondary school. x1 is public investment in primary school. PVNUM1 is the individual's adult numeracy score as measured by the first plausible value in the PIAAC dataset. The controls are the same as they were in Eq. 2. Subsequently, Education Attainment is defined as Tertiary which, restricting the sample to those who completed secondary education, takes a value of 1 if the person attained Tertiary education and a value of 0 if the person did not. x2 is only included when tertiary attainment is the dependent variable and is public investment in secondary school. In some iterations of the model, interactions and quadratic terms for the investment variables are included.

There is evidence (Bynner and Parsons, 1997) that low numeracy skills may affect the chances of leaving school early without qualifications. There is also evidence that preschoolers' approximate number system is correlated with school math ability (Libertus et al., 2011) which supports the notion that skills acquisition is cumulative in nature. This is our impetus for initially including adult numeracy scores (PVNUM1): to reduce

the chances that our educational persistence is purely a function the unobservable (and therefore omitted) variable of ability. Our measure of numeracy scores is chronologically backwards, meaning that the numeracy scores are measured after the realization of individuals' educational attainment. We know from the literature and our own baseline analysis that many of our control variables are associated with adult numeracy scores. So, when we include numeracy scores in our very imperfect attempt to control for ability, we risk high levels of collinearity in our predictor variables. In practice, introducing adult numeracy scores hardly changes the results, mainly by slightly raising the intercept and the pseudo r-squared. Therefore, Table 4.3 shows the results without adult numeracy scores maintaining a consistent set of controls with the other regression tables in which adult numeracy is the dependent variable.

4.2.3 Modelling Investment Complementarity in a Multi-Period Approach

Cunha and Heckman (2006) elaborate a clear theory for complementarity (or substitutability) of education investments; in the polar case, investments in different periods are perfect substitutes and deficiencies in early period investments can be made-up for (equalized) in later period investments. On the other hand, if investments are complementary, then there is an equity-efficiency trade off, because when there is strong complementarity (the authors point to the 'Leontief case') it is not possible to make up for deficient early period investments in later periods. When investments in different periods are complements, then the first period investment acts as a bottleneck from the investment *and* skill standpoint. Since skill begets skill, the skills gained in the first period are the foundation for skills gained in all subsequent periods. Learning new mathematical competencies at the tertiary level depends on how well you learned foundational mathematical competencies usually taught in primary and/or secondary school. Under these conditions, governments (as investors) are confronted with a dilemma, efficient investment would dictate that higher levels of investment should go to those who already received higher investment in period one (and thus are endowed with greater skills at the end of that period), but equity would dictate that an equalizing effort should occur to make up for deficient investments (and lower skills) in period one.

In order to operationalize the analysis of complementarity of investments in different periods in our sample we introduce a triple interaction term for the three periods of investment available in our data; investment in primary, investment in secondary and investment in tertiary. The introduction of the interaction term guarantees that the derivative of y with respect to investment in tertiary (for example) will depend on investment made at the primary and secondary levels; similar to a two-way interaction, this three-way interaction term indicates how the relationship between investment in tertiary (x_3) and numeracy scores (y) varies across levels of investment in primary (x_1)

and investment in secondary (x_2), and/or the combination of the two (x_1 x_2) (see Dawson and Richter, 2006). We use linear least squares approach and estimate the following:

$$Num = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_1 x_2 + \beta_5 x_1 x_3 + \beta_6 x_2 x_3 + \beta_7 x_1 x_2 x\_3 + \beta_8 x_1^2 + \beta_9 x_2^2 + \beta_{10} x_3^2 + Controls_i + \varepsilon \quad (3)$$

Where the controls are the same as they were in Eq. 2:

$$Controls = \beta_{11} Family + \beta_{12} Born\ Outside\ Country + \beta_{13} Edu + \beta_{14} Age + \beta_{15} Age^2 + \beta_{16} Work\ Exp + \beta_{17} Work\ Exp^2 + Country\ Dummies$$

When a multiplicative interaction term is introduced in symmetric models, it is not possible to tell whether one of the variables is the moderator variable, this must be determined by theory (Brambor et al., 2006; Dawson and Richter, 2006). Since theoretically, Cunha and Heckman identify period one investments as the 'bottleneck' period, we first assume that investment in primary education is the moderator variable and then we test the other relationships as well. At the same time, we introduced squared terms for our investment variables for each period.

4.3 Data on Competences and Investments

There are 12 countries or regions[34] for which we have both sufficient PIAAC and UIS investment data in order to assign cumulative investment to individuals. The 12 countries or regions are: Flanders (Region of Belgium), Denmark, Finland, France, Ireland, Italy, Japan, the Netherlands, Norway, Spain, Sweden, UK (England and N. Ireland). Both of our datasets contained many OECD countries, but it was not always possible to match the datasets, due to incomplete information from one or the other data source (see Appendix C.1).

4.3.1 Competences: Numeracy

In this chapter, the terms 'numeracy', 'numeracy skills', and 'numeracy competencies' are used as semantically interchangeable terms for the numeracy scores of adults, as assessed by PIAAC. The precise definitions of these terms emerged from past OECD experience assessing adult competences.[35] PIAAC closely follows constructs, methodologies, and

[34] In Belgium, only the Flanders region has been sampled by PIAAC (see OECD 2016, p. 13).

[35] For a more detailed explanation of the process, see Rychen & Salganic 2003, PIAAC Numeracy Expert Group, 2009;

definitions used in the Adult Literacy and Lifeskills Survey (ALL), a predecessor in the assessment of adult numeracy, where numeracy is defined as "the ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life" (Gal and Tout, 2014, page 15). The PIAAC assessment tasks range from easy to challenging and are meant to capture the skills of adults with very different backgrounds and life experience. To get a feel for range of questions and tasks, see Appendix C.2 where examples of tasks and questions associated with each PIAAC numeracy level have been excerpted from the OECD's Technical report.

The PIAAC methodology is designed to achieve representative samples in each country and internationally comparable measures and distributions of the cognitive skills of the adult population. In 2011, samples of at least 5,000 adults (from the ages 16 to 65) were surveyed. Although sampling methodologies can vary from country to country, sampling and replicate weights are used to get nationally representative and internationally comparable estimates (see Chapter 14 of OECD, 2013c). The PIAAC data also contain extensive background information about the respondents, such as data on educational attainment, work experience, age and family background. PIAAC employs the dominant methodology currently used for large scale assessments. A set of ten plausible values for individual respondents are derived from the assessments and the background questionnaire and these values are then used to generate a distribution of numeracy skills. Many times – individual respondents completed only part of the assessment. This means that the data are noisy at the individual level, but less noisy when considering the average performance of the group, or sub-groups. For more information regarding this methodology, please refer to von Davier, Gonzalez and Mislevy, 2009.

PIAAC assessed three domains; numeracy, literacy and problem solving in technology rich environments. The three measures are highly correlated, for example, Hanushek et al. (2015) point out that numeracy and literacy are 0.85 correlated at the individual-level. So, they elect to focus on numeracy which they deem the most internationally comparable domain of the three. We follow suit in our study.

Traditionally, evidence of the contribution of human capital measured by additional years of schooling in cross-country economic growth comparisons is varied. Numeracy scores are a proxy of cognitive skills. Furthermore, they do not measure non-cognitive skills, which can be important for economic outcomes of interest, such as employment and earnings. Despite these limitations, numeracy skills have recently been found to do a better job than other measures of human capital when explaining differences

[35 (continue)] OECD, 2013c; and Gal and Tout 2014).

in economic growth, employment outcomes, wage differentials and productivity (Hanushek & Woessmann, 2012; OECD, 2013b; Ritzen and Sasso, 2017). Hanushek et al., 2015 finds that a one standard deviation increase in numeracy scores in adults is associated with a nearly 20 percent increase in wages for prime-age (ages 35-54) working adults. These authors also find considerable variation in the distribution of numeracy skills and their relative returns in the OECD both between and within countries. Given the potential returns to higher numeracy competences in the adult population, it is important to understand the mechanisms that affect the ability of education systems to engender these skills; public investment is perhaps the mechanism most easily manipulated by national policy makers.

4.3.2 Cumulative Investments

Public expenditure per pupil in relation to GDP is a proxy for public effort to support education. The second data set used in this study was provided by UIS for a subset of OECD countries from 1971 to 2011, this dataset contains: (a) Government expenditure on education in Local Currency Unit (LCU) separated by primary, secondary and tertiary education levels, (b) enrolment in primary, secondary and tertiary education levels, and (c) GDP per capita in LCU for all countries. Both old LCU and current LCU-euro are available for Euro countries. These data are used to calculate government expenditure per student enrolled as a percent of GDP per capita for each year in our series for each of the three different education levels (primary, secondary, and tertiary). Linear interpolation and extrapolation were used to fill-in missing data over the time period; as long as there were sufficient data to do so.

We only have information on public investment in education. Private investments are not captured in our analysis. We do not know how this money is allocated and we also do not have information about school systems' autonomy over managing their resources, a variable that was found to be highly relevant for 15 year-olds' performance in mathematics (OECD, 2013a). Nor do we know whether resources are evenly allocated throughout the country. This is less concerning than it would be for a within-country analysis which could suffer from selection (sorting) issues, whereby talented students move to well-funded schools and/or might differ in unobservable ways from students educated in under-funded schools. In cross-country analysis, using average student expenditure per student to explain average achievement in a country tends to avert the selection issue, because it cancels out at the system level (Hanushek and Woessmann, 2017).

We use the UIS investment data to assign a proxy of public investment in each individual with the information about the respondent's age and highest level of educational attainment from the PIAAC data. Our method defines: 'Total Public Investment' as

the sum of 'Expenditure per Student as a percentage of GDP per Capita' over each year of the estimated time that the person was in school. To determine the year in which the person will start receiving public investment in his/her education ($Year_{Inv1}$), the following approach is used:

$$Year_{Inv1} = 2011 - x + 6 \tag{4}$$

Where x is the age of the individual in 2011, which is the PIAAC survey year for most countries in our sample. Some countries conducted the survey in 2012. Without information about the month of birth, it seems as good as random whether the person was been surveyed before or after his/her actual birthday. Therefore, consistently using 2011 for all countries, regardless of whether the survey was in 2011 or 2012, should compensate for early year versus late year birthdays. A standard number of 6 years is added to the age, under the assumption that everyone begins school at the age of 6 and standardized across countries (rather than using actual entry ages). Accumulated public investments can only be calculated for people aged 46 years or younger, because we only have investment data starting in 1971. In other words, the earliest possible year for $Year_{Inv1}$ in equation 4 is set to 1971, which forces the maximum to equal to 46. We further assume that schooling is continuous, that means that there are no breaks, skips or repetitions.

Then, depending on which level of education the person attained the following investments are added:

$$Inv_j^i = \sum_{K=1}^{N} Public\ Investment_j^k \tag{5}$$

i = individual

j = country

k = year

N = Highest level of Educational Qualification (HLQ)

Where Inv_j^i is the total public investment in individual i in country j, which is equal to the sum of the public expenditure per student as a percent of the country's GDP per capita for from the year of entry until the year of highest level of educational qualification (HLQ). In the PIAAC data, we have information on each individual's HLQ and the corresponding level according to the International Standard Classification of Education

(ISCED). Appendix C.3 provides more information about how the public investment was calculated and assigned to PIAAC survey respondents.

The rationale behind weighting per student expenditure by GDP per Capita in each year is as follows: we would like to observe relative investment effort. For example, when education expenditure is measured in PPP, advanced economies spend five times more than developing and emerging economies on primary and secondary education, but when expenditure is measured as a percentage of GDP, developing and emerging economies spend relatively more on primary education and relatively less on secondary education (see Grigoli, 2015). Our public investment is weighted by GDP per capita each year and therefore, our cumulative public investment variable is more like an index of relative government effort. From our point of view, it also captures a teacher quality effect, since the vast majority of public investment in education goes to teachers' salaries, greater expenditure in relation to GDP per capita is indicative of relatively greater compensation for the profession. GDP per capita is a good price indicator for education, since teachers' salaries tend to follow GDP per capita. Appendix C.4 presents the trends of investment in selected countries. The investment trends illustrate the variation in investment patterns between the different countries and within the same country, over the four-decade period.

The descriptive statistics for the variables used in the analysis are summarized in Table 4.1. The minimum value for cumulated public investment for an individual in the dataset is almost 80 and the maximum value is 842 (see the second illustrative example in Appendix C.3 for details on how we arrive at that value). The maximum age is 46 and the minimum age is 16 and the average work experience is 12 years with a minimum of zero work experience and a maximum of 35 years of work experience.

The plots of numeracy by mean public investment by country and at the different levels of educational attainment are presented in Appendix C.5. As expected, numeracy scores increase as the level of educational attainment increases, but the clustering of countries vis-à-vis their relative investment efforts becomes more pronounced as we move up the educational ladder. We observe that Spain, Italy, Ireland and the UK tend to cluster together with lower overall investment for people who have attained tertiary education and lower average numeracy scores, even among the population with a tertiary education. On the other hand, Japan, Belgium, France, the Netherlands, Finland, Sweden, Norway and Denmark cluster together as relatively higher amounts of overall investment for people who have attained tertiary education and higher average numeracy scores for that sub-group as well.

Table 4.1 Descriptive Statistics

Variable	Mean	S. D.	Min	Max
Dependent Variable: Numeracy	286	46	55	463
Total Public Investment	301	107	79	842
Family Background: Mother's Education				
Uncompleted Secondary	0.44	0.50	*Reference Category*	
Completed Secondary	0.36	0.48		
Tertiary	0.21	0.41		
Books in the House (Childhood)				
10 or less	0.10	0.30	*Reference Category*	
11 to 25	0.13	0.34		
26 to 100	0.32	0.47		
101 to 200	0.19	0.39		
201 to 500	0.17	0.37		
More than 500	0.09	0.29		
Born Outside Country (immigrated age 6 or younger)	0.02	0.16	*Dummy; 1 = yes*	
Personal Traits: Education Group				
Uncompleted Secondary	0.13	0.34		
Completed Secondary	0.41	0.49	*Reference Category*	
Tertiary	0.46	0.50		
Age	33	8	16	46
Work Experience	12	8	0	35
N= 30,739				

Countries in our sample	N	Mean Numeracy	S. D.	Min	Max
Belgium (Flanders)	2,866	290	47	107	423
Denmark	3,565	283	52	75	449
Finland	3,105	296	48	47	449
France	3,820	269	52	41	424
Ireland	3,786	267	49	53	427
Italy	2,711	260	47	92	409
Japan	3,103	295	41	132	441
Netherlands	2,652	293	45	49	424
Norway	3,099	287	53	56	431
Spain	3,261	261	44	64	396
Sweden	2,614	289	54	50	463
United Kingdom	4,727	270	49	64	445

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS. *Notes:* S.D. stands for Standard Deviation. We follow Hanushek and use the first Plausible Value (PVNUM1) for Numeracy. The PIAAC scale is from zero to 500[36]. Country descriptive statistics include the entire sample for which we have investment and numeracy data.

[36] The range of scores in the data is squeezed between 100 and 400. The distribution of each of the 10 plausible values is normal with very few plausible values falling below 100 or above 400 and absolutely no plausible values for scores that are either zero or 500.

4.4 Analysis

We structure the analysis in three parts following the outline of the section 4.2. The first part of the analysis is focused on ascertaining whether greater public investment in education could be considered a determinant of higher numeracy skills in the adult population. The second part of the analysis seeks to establish whether more public investment in early stages of the educational process increases the chance of higher levels of educational attainment. The last part of the analysis tests whether complementarities exist between different periods of investment in three stages of the educational process: primary, secondary and tertiary.

4.4.1 Baseline Analysis – Public Investment and Adult Numeracy Skills

As Table 4.2 shows, the results from the estimation of Eq. 2 reveal a positive and significant relation between the accumulated stream of investments and the competence level. The results of the first two columns are highly interesting: money counts. When family background is taken into account: the coefficient for investments only drops slightly. Countries perform very differently, with Japan and the Netherlands being able to boost skills more than the average and the others being unable to produce the same skills with the same money under the same circumstances.

In column three, the effect of investments is less apparent because of the introduction of the completion of secondary and higher education. Age and work-experience are decreasingly contributing to skills. Of course, total investment is highly correlated with participation and completion of education, so that the impact of investment is substantially reduced.

In the second part of our analysis we show that increased investment not only increases numeracy through direct means, but increases the chances of higher levels of educational attainment which in turn contributes indirectly to increasing numeracy skills.

The family background variables behave as we would expect. Higher levels of mother's education are positively and significantly associated with higher numeracy scores. We tried including father's education as well as (and instead of) mother's education and the two variables perform very similarly. So, we decided to keep only mother's education for the remainder of the analysis. A greater number of books in the household is robustly related to higher numeracy scores. Being born outside the country is strongly and negatively associated with adult numeracy skills. This is a rather striking result since we restricted the sample to people who immigrated before the age of 6, and thus were educated in the same schools as the native-born students. Even if striking, it confirms

findings as for example in Volante (2018), in the OECD test scores for 15 year olds show differences of about 33 points or one full year of schooling[37].

Work experience is positively associated with numeracy skills, but as expected, the square of the work experience indicates a concave quadratic function. Age is not significantly related to numeracy skills for the age groups up to 46 included here, but the age squared term is significant and negative also indicating a concave shape in the relationship between age and numeracy for the people in this sample, controlling for other factors. The results for age are always not robust to different specifications. But we found that when we added our other explanatory variables public investment remains strongly and significantly associated with numeracy skills and remains robust across the specifications we tried.

Table 4.2 Baseline and Education Production Function Specifications

Dependent Variable - NUMERACY SCALE SCORE (PLAUSIBLE VALUE 1)				
	(1)	**(2)**	**(3)**	**(4)**
Total Public Investment	0.20***	0.16***	0.08***	0.04***
	(0.003)	(0.003)	(0.004)	(0.01)
Mother's Education Secondary		4.40***	4.99***	5.02***
		(0.54)	(0.57)	(0.57)
Mother's Education Tertiary		10.56***	11.72***	11.71***
		(0.64)	(0.71)	(0.71)
Books (11-25)		10.06***	8.08***	8.13***
		(0.96)	(0.98)	(0.98)
Books (26-100)		19.66***	16.67***	16.78***
		(0.85)	(0.87)	(0.87)
Books (101-200)		26.18***	22.91***	22.99***
		(0.92)	(0.95)	(0.95)
Books (201-500)		31.95***	28.57***	28.61***
		(0.97)	(1.00)	(1.00)
Books (more than 500)		32.51***	29.46***	29.42***
		(1.11)	(1.14)	(1.15)
Born Outside Country (imm. <6 yrs.)		-8.95***	-8.05***	-8.02***
		(1.60)	(1.61)	(1.61)
Uncompleted Secondary				-21.40***
				(3.09)
Completed Secondary			12.76***	Reference
			(0.85)	
Tertiary			26.90***	3.13
			(1.14)	(2.18)

[37] The range of scores in the data is squeezed between 100 and 400. The distribution of each of the 10 plausible values is normal with very few plausible values falling below 100 or above 400 and absolutely no plausible values for scores that are either zero or 500.

Dependent Variable - NUMERACY SCALE SCORE (PLAUSIBLE VALUE 1)				
	(1)	**(2)**	**(3)**	**(4)**
Age			0.28	0.27
			(0.31)	(0.31)
Age Squared			-0.01***	-0.01***
			(0.00)	(0.00)
Work Experience			1.00***	1.01***
			(0.14)	(0.14)
Work Exp. Squared			-0.01**	-0.01**
			(0.005)	(0.005)
Total Public Investment x Uncompleted Secondary				0.03*
				(0.02)
Total Public Investment x Completed Secondary				Reference
Total Public Investment x Tertiary				0.04***
				(0.01)
Denmark	-28.03***	-25.27***	-14.53***	-12.93***
	(1.19)	(1.12)	(1.27)	(1.33)
Finland	-2.51**	-9.18***	-3.04**	-2.43**
	(1.14)	(1.09)	(1.18)	(1.19)
France	-14.49***	-16.34***	-16.76***	-17.16***
	(1.10)	(1.07)	(1.15)	(1.15)
Ireland	-14.22***	-17.14***	-23.06***	-23.63***
	(1.10)	(1.10)	(1.18)	(1.19)
Italy	-17.77***	-18.47***	-14.33***	-14.97***
	(1.20)	(1.19)	(1.30)	(1.30)
Japan	11.52***	5.24***	1.50	1.02
	(1.07)	(1.05)	(1.13)	(1.13)
Netherlands	7.55***	2.66**	3.45***	2.70**
	(1.14)	(1.11)	(1.16)	(1.17)
Norway	-15.42***	-18.96***	-12.39***	-11.49***
	(1.21)	(1.12)	(1.21)	(1.22)
Spain	-9.05***	-12.61***	-15.62***	-16.53***
	(1.13)	(1.13)	(1.24)	(1.29)
Sweden	-18.68***	-20.02***	-9.66***	-8.32***
	(1.31)	(1.17)	(1.29)	(1.32)
United Kingdom	-14.86***	-17.69***	-21.25***	-21.98***
	(1.06)	(1.05)	(1.11)	(1.11)
Constant	231.64***	223.48***	228.90***	253.28***
	(1.18)	(1.25)	(4.51)	(5.36)
N	39,309	33,969	30,671	30,671
Adj. R-squared	0.18	0.27	0.28	0.28

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: We follow Hanushek and use Plausible Value 1 for Numeracy as the dependent variable. Country dummy variables are included to control for 'fixed effects'. Belgium is taken the reference country. Work Exp. stands for Work Experience. Total Public Investment x Uncompleted Secondary and Total Public Investment x Secondary and Total Public Investment x Tertiary are interaction terms. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Explained variance is relatively low, as is usually the case in these kinds of analyses, indicating that many other factors might be at work. These are likely to be the individual school and class characteristics and the distribution of funds over pupils as well as individual student characteristics and household characteristics not caught in the included variables, for example the reaction of households to changes in school inputs (Das et al., 2013). To some extent, the differences between expresses countries differences in the organization of the school system. PISA 2012 finds that the highest-performing school systems are those that allocate educational resources more equitably among advantaged and disadvantaged schools and that grant more autonomy over curricula and assessments to individual schools. A belief that all students can achieve at a high level and a willingness to engage all stakeholders in education – including students, through such channels as seeking student feedback on teaching practices – are hallmarks of successful school systems. (OECD, 2013a, p. 4).

It is important to point out that while we control for educational attainment, we do so with a broad categorical variable.[38] Generally speaking, since people with tertiary education have been in the education system for longer, they benefit from greater cumulative public investment. But, depending on the time period and the country, some people with completed secondary education (and no tertiary education) have received more cumulative public investment than people with tertiary education. People with uncompleted secondary education have been assumed to have three years of high school education, whereas those people with completed secondary education consistently have 6 years of high school education in our sample. Individuals with tertiary education, may have attended anywhere from one year (short cycle program) to 6 years (doctorate program) which means that we do not perfectly control for each additional year of investment in education at the tertiary level, because at this level there are varying levels of qualifications which require a different number of years, but all fall within the category of tertiary education.

We hypothesized that the relationship between investment and numeracy might vary with different levels of educational attainment. Since we have established that there is a relationship between public investment and numeracy scores after controlling for educational attainment, the question is whether the relationship between investment and adult numeracy is stronger for some levels of educational attainment. In column 4, we therefore introduce an interaction term between our continuous investment variable and our categorical educational attainment variable. We decided to use high school graduates (secondary) as a reference group, because only 13 percent of our sample falls into the category of uncompleted secondary. The results indicate a non-linearity

[38] See Appendix C.3 and Appendix C.5 for detailed information about how the ISCED classification system has been used in order to assign consistent investments across the different countries in our sample.

between public investment and different levels of education. For example, the slope of the relationship between public investment and numeracy is significantly steeper for the group of people who have attended tertiary education (Total Public Investment times Tertiary) than those whose highest educational qualification is a high school degree (Total Public Investment times Secondary). That means that vis-à-vis high school graduates the coefficient on the relationship between investment and numeracy will be 0.04 greater for those who attend tertiary, ceteris paribus. Surprisingly, increased investment for people without a high school degree (Total Public Investment times Uncompleted Secondary) also tends to benefit their numeracy score significantly more so than high school graduates (our reference category). That means that higher levels of investment in people who do not manage to graduate from high school still has a positive payoff in terms of adult numeracy skills. This is well known from the literature: also uncompleted levels of education contribute to skills (but to a lesser extent) (see Hartog, 1983) We tested the interaction term on individual country samples and it produced quite different results among the different countries, as might be expected given the stark differences in investment patterns between countries. While non-linearity is consistently apparent, the results of the interaction term are somewhat sensitive and should therefore be interpreted with caution. Nevertheless, it is our first clue that the marginal effect of additional investment on adult numeracy is different at different stages of education with greater marginal effects for those people who make it to tertiary education. Further testing is needed to make any strong claims in this regard.

4.4.2 Analyzing Investment and Educational Attainment

Subsequently we look for the impact of investments on educational attainment. These are reported in Table 4.3. In the first two columns, the dependent variable is a dummy variable that takes a 1 for completed secondary education. The results from column 1 show that higher levels of primary investment are consistently positively and significantly imply a greater probability of completing high school. Holding everything else constant, a one unit[39] increase of investment in primary education increases the chances of completing secondary education by about 2 percent. Since this is a logit regression, we have to interpret the beta coefficients with care. For example, the coefficient of 0.014 on investment in primary school in column 1 tells us the amount by which the predicted probability of completing secondary school would increase with a one unit increase in primary investment. To get the odds ratio we can exponentiate the coefficient on primary investment which gives us 1.02 or roughly a 2 percent greater

[39] A one unit increase in the proxy for investment in primary education represents a one percent increase in the public expenditure per student enrolled in a given year over GDP per capita in that same year.

chance of completing secondary school for a one unit increase in public investment in primary school.

The next two columns (3 and 4) report, conditional on graduating from high school, how the chances of attaining tertiary education (a binary outcome variable taking the value 1 if the individual achieved tertiary education levels and a zero if not) are related to relatively higher amounts of investment in primary and secondary education.

The results from the logistic regression suggest that when we hold all our other explanatory variables constant, and interact our primary and secondary investments, relatively higher amounts of investment in primary school actually increase the chances of making it to tertiary education by around 1%. This is consistent across columns 1 through 4. When we consider the relationship between investment in primary education on the chances of attaining tertiary education conditional on high school graduation (column 4), the square of the investment in primary is positive and significant, indicating 'the more the better'. However, from the sign and significance of the interaction term, additional investment in secondary education does not contribute to the chances of attaining tertiary. Nevertheless, taken together primary and secondary investment still have a positive overall effect on the probability of entry into tertiary education. Since we cannot know a-priori whether students will complete high school, it appears that both higher primary and secondary investments are important in leading people to tertiary education.

In the regression tables that follow we include the same control variables and country fixed effects as we did in our baseline regressions, but we do not report the coefficients in the tables, because they are stable across the different analyses. For example, mother's education, and all the other control variables are incredibly consistent in terms of their signs, magnitudes and significance.

Table 4.3 Public Investment and Educational Attainment

	Completed Secondary		Tertiary	
			Restricted to those who Completed Secondary	
	(1)	(2)	(3)	(4)
Investment Primary	0.014***	0.020***	0.007***	0.014***
	(0.001)	(0.004)	(0.001)	(0.003)
Investment Secondary			0.0004	-0.01***
			(0.0007)	(0.004)
Inv. Primary x Inv. Secondary		-0.00002		-0.00003***
		(0.00001)		(0.00001)
Inv. Primary x Inv. Primary				0.00003**
				(0.00001)
Inv. Secondary x Inv. Secondary				0.00003**
				(0.00001)
Constant	-12.11***	-12.53***	-13.44***	-13.03***
	(0.36)	(0.46)	(0.38)	(0.51)
N	30,671	30,671	26,710	26,710
Pseudo R-squared	0.26	0.26	0.17	0.17

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: Robust standard errors in parentheses. The same control variables and country 'fixed effects' as our baseline regressions are included, but not reported. * p<0.10, ** p<0.05, *** p<0.01

4.4.3 Analyzing Complementarity between Primary, Secondary and Tertiary Investments

We run OLS regressions to evaluate the three periods of investment and how they interact with one another. In a simple correlation matrix between the three investments, we can see that they are not highly correlated with one another (Table 4.4). So, we do not have reason to believe that there are issues of collinearity between the different investment periods.

Table 4.4 Correlation Matrix between Public Investments in Different Periods

	Primary	Secondary	Tertiary
Primary	1		
Secondary	-0.03	1	
Tertiary	0.4	0.1	1

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.

In the first column of Table 4.5 we do not include any interaction terms. We separate total public investment into the three periods, primary, secondary and tertiary, and include squared terms for each investment period. The coefficient on investment in primary is negative but not significant. Investment in secondary is negative and just barely significant at ten percent level. Investment in tertiary is positively and significantly related to adult numeracy scores at the 1 percent level, but the square of tertiary investment is negative and significant, suggesting possible diminishing returns to very high levels of investment in tertiary.

In columns 2 through 4, we introduce the cross term interactions in a stepwise fashion. The only cross-term that is significant by itself is the interaction between primary and tertiary. By itself the interaction between primary and tertiary is negative, but we know that between primary and tertiary education, a person must necessarily pass through secondary education. So, in order to assess the complementarity between investments in primary and tertiary education, we must consider the relationship of both investments to a third variable; secondary education. Likewise, we can consider the possible complementarity of investments in secondary and tertiary education with respect to investment in primary education. Carree, Lokshin and Belderbos (2011) developed an empirical test for ascertaining the complementarity (or substitutability) of two continuous variables in the presence of third continuous variable using a three-way interaction term. As the authors describe the mechanics of the test, x_1 and x_2 are considered complementary if the cross-derivative of the cross-term $(\partial^2 f/\partial x_1 \partial x_2)$ is greater than or equal to zero and the functional form is as we describe in Eq. 3. The operationalization of this test suggests that using linear regression and considering the significance of the coefficients of the cross-terms and the triple interaction term, we can ascertain whether the results indicate complementarity or substitutability between x_1 and x_2. A negative coefficient for x1 times x2 means the two investments indicates substitutability and a positive coefficient indicates complementarity. We find (significant) substitutability for investments in primary and tertiary (x1 times x3), which reflects the unrealistic option, in the case of investment in education, of deferring investment to the final period. This is unrealistic for the clear practical reason that in order for a person to go from primary to tertiary education, it is imperative to pass through secondary education. So we cannot consider the investments in primary and tertiary, without considering the investments in secondary.

Table 4.5 Interaction Investments in Primary, Secondary and Tertiary

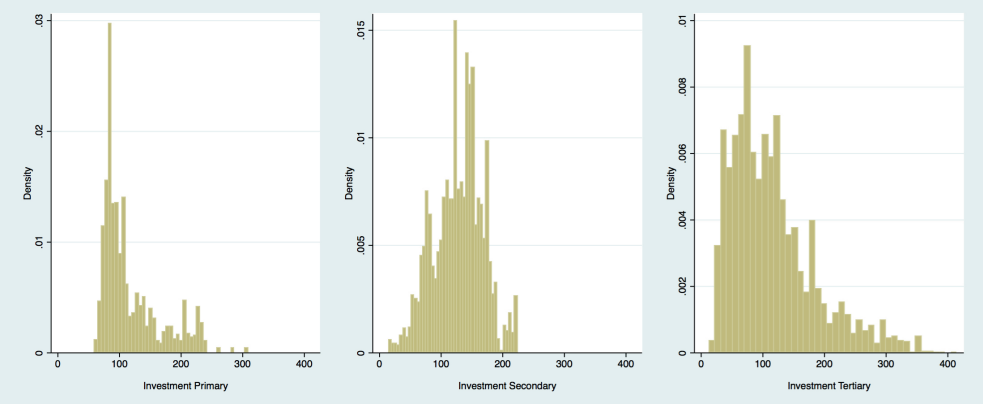
Dependent Variable = Numeracy scale score					
	(1)	(2)	(3)	(4)	(5)
Investment Primary	-0.08	-0.07	-0.07	-0.08	-0.11**
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Investment Secondary	-0.08*	-0.07	-0.08*	-0.08*	-0.10**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Investment Tertiary	0.31***	0.31***	0.32***	0.32***	0.19***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)
Cross-terms					
Inv. Primary x Inv. Secondary [x1x2]		-0.0001			0.0003
		(0.0002)			(0.0002)
Inv. Primary x Inv. Tertiary [x1x3]			-0.0002***		0.0006***
			(0.00006)		(0.0002)
Inv. Secondary x Inv. Tertiary [x2x3]				-0.00006	0.001***
				(0.00009)	(0.0003)
Inv. Primary x Inv. Secondary x Inv. Tertiary [x1x2x3]					-0.000006***
Squared Terms					(0.000002)
Inv. Primary x Inv. Primary	-0.000006	0.0000007	0.00001	0.000002	0.00004
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Inv. Secondary x Inv. Secondary	0.0001	0.0001	0.0001	0.0001	0.00005
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Inv. Tertiary x Inv. Tertiary	-0.0006***	-0.0006***	-0.0005***	-0.0006***	-0.0005***
	(0.00005)	(0.00005)	(0.00006)	(0.00005)	(0.00006)
Constant	253.46***	251.26***	252.74***	252.94***	256.26***
	(6.09)	(6.65)	(6.09)	(6.15)	(6.84)
Observations	30,671	30,671	30,671	30,671	30,671
Adjusted R-squared	0.29	0.29	0.29	0.29	0.29

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: Control variables and country 'fixed effects' are included, but not reported in the table; their coefficients and significance consistently follow the patterns established in the first regression table. Robust standard errors are in parentheses. We follow Hanushek and use Plausible Value 1 for Numeracy as the dependent variable. Control variables and country 'fixed effects' are included, but not reported. * p<0.10, ** p<0.05, *** p<0.01

Table 4.5 presents the regression results from the full specification (Eq. 3) in column 5. The triple interaction term between the three investments provides empirical evidence for the notion that the effect on numeracy of investment in a particular period does differ across the range of investments made in the other periods. We find that the three-way interaction term is statistically different from zero at the one percent level. This means that the investments in the three periods are linked. Once we tether investments in primary and tertiary to investment in secondary education via the triple interaction term, the coefficient on x1 times x3 is positive, which indicates that the investments in primary (x1) and tertiary (x3) are complementary.

In the application of the Carree et al., 2011 test, we relaxed the constraint that the variables tested must range between zero and one. If we rescaled our investment variables and restricted the range to be between zero and one, we could test for strict complementarity. In the presence of our triple interaction term, two of our cross-terms are positive and significant: investment in primary times investment in tertiary (x1x3) and investment in secondary times investment in tertiary (x2x3). The cross-term of investment in primary and secondary (x1x2) is not statistically different from zero, so it is not possible to conclude whether there is complementarity (or substitutability) between these two investments. Although we find evidence of complementarity between some cross-terms, the negative coefficient on the triple interaction term already indicates that the cross-term complementarity between two investments may change along the distribution of the third investment. Each level of schooling has a slightly different distribution of cumulative investments. Figure 4.1 presents histograms showing the distribution of investments at each level of schooling, primary, secondary and tertiary.

Figure 4.1 Histograms for Cumulative Investments in Primary, Secondary and Tertiary



Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.

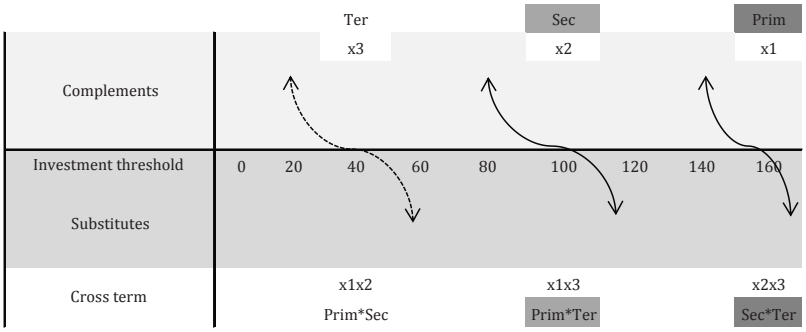
We are not able to establish that the cross-terms between primary and tertiary are complements for any investment in secondary education and likewise we cannot establish that the investments in secondary and tertiary are compliments for any value of investment in primary education. But, we can gain further insights if we consider thresholds. Based on our findings that there could be diminishing returns to very high levels of investment, we hypothesize that there might be some threshold values for the complementarity of investments. For example, there may be some amounts of primary education investment for which investments in secondary and tertiary are complements and other investment amounts for which they could be substitutes.

Table 4.6 and Figure 4.2 show the threshold investment at which each cross-term can become a substitute. To calculate the thresholds, we used the coefficients from the results of our regression of interacted investments in Table 4.5. For example, to calculate the threshold of complementarity between Secondary and Tertiary investments, we divided the estimated coefficient for the cross-term x2x3 (~0.001) by the estimated coefficient for the interaction term x1x2x3 (~0.000006). If you calculate this using the numbers as they are presented in Table 4.5, you will get 167, but this is because of rounding. When we do the post-estimation calculation without rounding off, the result is 158. When cumulated investment in primary is below 158, investments in secondary and tertiary are considered complementary. But when investment in primary is relatively high, 158 is above the mean the median and the 75th percentile of public investment in primary in our sample, and the investments in secondary and tertiary become substitutes. When investments in secondary education are below 102, then the investments in primary and tertiary are complements, but when the investments in secondary school are above 102, the primary and tertiary investments can be considered substitutes. The cross-term for primary and secondary investments is not significant, so it is not possible to evaluate the value of tertiary investment at which we could have complementarity or substitutability between primary and secondary investments.

Table 4.6 Investment Thresholds for Complementarity

	Cross-term Coefficient ≥ 0	Complements when:	Substitutes when:
Secondary x Tertiary (x2x3)	reject the null, significant at 1%	Primary **≤ 158**	Primary **> 158**
Primary x Tertiary (x1x3)	reject the null, significant at 1%	Secondary **≤ 102**	Secondary **> 102**
Primary x Secondary (x1x2)	Fail to reject the null, not significant	Not possible to evaluate	Not possible to evaluate

Figure 4.2 Investment Thresholds for Complementarity



Notes: The threshold is calculated by dividing the coefficient of the cross-term by the coefficient on the triple interaction term, which is the value at which the sum of the coefficients is equal to zero.

Figure 4.2 shows the thresholds schematically. For example, as primary investment rises from below to above 158 (far right of figure), investments in secondary and tertiary switch from being complements to being substitutes. A cumulative investment in primary of 158 is a relatively high investment. The mean cumulative investment in primary in the dataset is 118. Up to a cumulative primary investment of 158, investments in secondary and tertiary are complementary (with each other). For example, if you invest the same in both secondary and tertiary, the benefit will be more than the benefit from either investment alone. Beyond the 158 threshold, investments in secondary and tertiary can be seen as substitutes. Now if you invest the same in secondary and tertiary there is no added benefit. The benefit is the same as investing is either secondary or tertiary alone. The exact threshold value is specific to this dataset and the thresholds themselves represent cumulated investments per student over GDP per capita. So, interpreting the exact threshold is not (by itself) meaningful. What this analysis shows is that investments in different phases of schooling are related to one another. High investment in primary schooling enables big payoffs for investments in subsequent schooling levels. But there is a threshold in primary investment beyond which the benefits of investment in higher levels of schooling taper off.

In summary: tertiary education investment is consistently strongly and positively associated with higher numeracy scores, but the key from an investment standpoint seems to be the spread of investments. Investments in the context of education can never be 100 percent substitutes, because earlier period investments facilitate not only later learning but also the attainment of the higher levels of higher education. Our complementarity analysis shows that the investments in the three periods do interact with each other. Once a high threshold of investment in primary has been reached, it may engender a skill base that allows some coasting in the interchangeability of investments

in secondary and tertiary. Investments between primary and tertiary are complements once we factor in investments in secondary. Once a certain level of investment in secondary is reached, investments in primary and tertiary can be considered substitutes. One curious finding is that investment in secondary education seems to have a less straightforward relationship with adult numeracy skills than investment in primary and tertiary education. This may be due to the fact that there is less variation in our secondary investment data, both within and between the countries in our sample. These results should be further calibrated and could be further investigated in future studies that look at the relationship between investment and adult numeracy skills.

4.5 Conclusions and Policy Implications

This chapter contributes to the literature in three ways. First, using cumulated investments, we find a positive relationship between public investment and adult numeracy scores. Second, we find that this relationship is not the same at all levels of education. Third, we find evidence that when governments invest in primary education, those investments may be realized by pushing more people to pursue higher educational attainment and the help of strong investments in tertiary education. These two things together will shift the overall distribution of numeracy skills toward higher levels of achievement in the adult population.

If, as recent empirical evidence shows, higher numeracy skills are associated with higher wages and economic growth, it implies that higher numeracy scores can grow the economy which will provide a larger tax base for the public sector. This larger tax base can be used to increase public investment in education. If these larger public investments are associated with higher numeracy scores, those countries that invest more will continually have a larger economy from which to perpetuate the investment.

Tertiary investment might receive more public attention, precisely because it may be seen as a ticket to increasing the innovative potential of an economy. And primary education receives public attention, because of the Heckman type notion that the earliest investments have the greatest returns, especially in offsetting inequities for children from disadvantaged backgrounds. There is plenty of evidence that skill gaps that exist at the start of upper secondary school (around the age of 15) and at the start of university are quite persistent (van Veen et al., 2018; Crawford et al., 2016). The ability of education to be a true equalizer lies in the quality of the resourcing all the way along the entire educational path.

Chapter 5

Higher-Professional Education Institutions and the Labor Market*

*This chapter would not have been possible without the help of, Baer van de Kerkhof, who made follow-up phone calls in Dutch and translated survey instruments into Dutch. I would like to thank all the people who gave me professional advice during the development of the survey instruments used in this chapter.

Abstract:

The first part of this chapter explores whether vocational and general higher education pathways are differently related to education-job match and the use of numeracy skills on the job. Using data from the OECD's Programme for the International Assessment of Adult Competencies (PIAAC) to estimate linear probability and ordinary least squares models, we found that vocational higher education is associated with a greater chance of having less education than currently required by the job and less frequent use of numeracy skills at work. This result is reversed in Denmark, which has a vocational apprenticeship-based system. We speculate that the results are the consequence of changing requirements in the labor market. The second part of the chapter surveys higher professional education institutions in the Netherlands (vocational school-based) and in New York State (non-vocational) to discover their strategy for adapting to changing labor market requirements. Two actionable policy recommendations are formulated.

JEL Codes: I23 I26 O30 O39

5.1 Introduction and Motivation

The workplace relevance of a university degree is increasingly under public scrutiny and there is no consensus about which skills are most relevant for the future workplace. Around the world, enrolment in higher education has doubled in the last decade (UNESCO 2016) and in parallel the costs are going up for governments and individuals. If graduate skills do not have the expected productive payoff, it could be costly for society (OECD, 2017a). The changing structure and diversification of higher education and its modes of delivery will force governments to decide how to balance the potential trade-off of uniform improvement for all programs (i.e., short-cycle tertiary to doctoral) with enhancing individual program performance (OECD, 2017b). This chapter evaluates some of the metrics which might be used in these decisions.

It is generally assumed that productivity is highest when workers' skills are well-matched with the skills needed by their workplace. Vocational education seeks to improve this match. Broadly speaking, at the bachelor's level, the vocational tracks tend to be the ones affiliated with specific technical skills. General academic tracks tend to be geared more toward transversal skills, with notable exceptions in science and engineering. The new skills agenda set forth by the European Union (2016) calls for enhancing both transversal (general education) and technical (job-specific vocational) skills.

In Part A of this chapter, we analyze data from the PIAAC background questionnaire to determine whether different types of educational formation at the tertiary level contribute to better education matches with the productive world. We use different metrics to assess how well education qualifications match those required by the job and the use of skills on the job. Finally, we examine the education-job match and skill use outcomes vary for country groupings with different intensities of vocational training. From these analyses we find that different types of higher education do associate differently with education-job match and skill use. We find that vocational higher education is associated with an increased probability of having less education than required by employers. We find the vocational intensity of the national education system matters. Denmark, a country with an apprenticeship-based school system, achieves by far the best education-job match for people with vocational higher education.

It is well known that the skill mix demanded by the labor market is subject to change and supply (Handel, 2012). In order for higher education to stay relevant for the workplace, it must be able to adapt to these changes in the labor market. Many argue that to keep up with today's rapid technological change, the education system needs to upgrade and become more flexible (The Economist, 2016; Holzer, 2017). It has to innovate. Despite innovation being touted as a promising solution, there is a surprisingly small amount

of literature on innovation in education and training, especially in higher education (Arundel et al., 2016). We simply do not have much published information about the institutional effort required to adapt educational programming to meet current needs or anticipate future needs of the labor market.

Therefore, in Part B, we survey higher professional education (HPE) institutions in two distinct national education systems: one that is considered non-vocational (in one state in the United States) and one that has a school-based vocational system (the Netherlands). We find that in the Netherlands teachers are expected to be engaged in the profession in which they instruct. Teachers are entrusted with transmitting this information to the students through their instruction. We find that community colleges in New York State are in need of more granular data and information to help them keep up to date with the needs of the labor market and respond to its changes.

5.2 Part A: Education-job Match and Skill Use for Vocational and Academic Tertiary Education in Different Institutional Contexts

In this section, we ask two questions: First, do higher education pathways in vocational and academic tracks associate differently with education-job match and skill use outcomes? Second, does the institutional context, specifically the way in which the education system is organized, affect these relationships?

A qualification from a higher education institution is a requirement for many jobs, and students often enroll in higher education with the expectation that it will lead to a good job (OECD, 2017b). But there is growing concern that higher education qualifications do not carry the same market value as they did in the past. Some worry that because more and more people are attaining higher education, graduates are taking jobs that could be done without the qualifications they have earned. Recent evidence from Europe shows that around 25 percent of higher education graduates have jobs that do not require a higher education qualification (OECD, 2017b). This is concerning, because the notion is that higher education graduates who are well matched with their jobs are likely to experience a better wage return, greater job satisfaction, reduced turnover and higher levels of productivity.

Literature that compares labor market outcomes associated with vocational and general education at the tertiary level tends to concentrate on employment and earnings. Hampf and Woessmann (2016) find empirical evidence that while vocational education facilitates job entry, this employment advantage tends to diminish with age. The cross-over age where people with general education are more likely to be employed is as

young as 44. Hanushek et al., 2017 find similar trends with respect to employment. They analyze lifetime earnings for people with vocational versus general education and find that initial relative gains for people with vocational education are offset by later relative losses (except in Switzerland). Brunello and Rocco (2015) also found a negative earnings gap for those with vocational training, but they found a positive gap when considering the share of working life in paid employment, which is in contrast with the declining age-employment pattern described in the other two studies. Using regression discontinuity design on individuals from the same age-cohort Silliman and Virtanen (2018) find that employment and earnings premiums from upper secondary vocational education in Finland persist for at least 15 years after admission into the program.

Although education is not a perfect proxy for skills, it is commonly used as an indicator to assess (mis)match between the qualifications required by a job and those possessed by employees. Traditionally education-job match has been theoretically linked with wage premiums (for those who are matched or have 'excess' education) and penalties (for those who have less education than is required for the job). Depending on the time period or country analyzed, empirical evidence is not always consistent with this theoretical direction of the wage premium/penalty (Hartog, 2000). To the extent that different types of higher education are affiliated with fostering different types of skills, we are curious about whether there are systematic differences in education-job match.

Qualification mismatch is one thing, under-utilization of skills acquired through the educational process is another. Education qualifications may only roughly indicate the underlying skills of those who possess education credentials. Laczik and Mayhew (2015) argue that, despite mixed evidence, a significant proportion of graduates from the higher education system are under-utilizing their skills.

The job requirement approach (JRA) provides another means to assess job-skills match. It assumes that the frequency and complexity of skills used on the job accurately reflect the level of skills required by the job. This approach avoids using education qualifications as a proxy for skills. The combination of skill proficiency and skill use is a novel concept termed skill effort by van der Velden and Bijlsma (2017). They argue that skills can only affect productivity if they are actually used. That is to say, if you possess skills over and above the ones you use at your job, your extra skills might make you more productive but the full potential of your skills are not exploited. There could be 'skills left on the table'. Similarly, proficiency moderates the productive impact of using skills. For example, imagine there are two co-workers, one with a lower numeracy score than the other. The co-worker with lower numeracy scores will probably be less effective executing tasks requiring numeracy skills, even if the two co-workers are required to use numeracy skills with the same frequency. For this reason, they generate the multiplicative term skill

effort, which combines frequency of skill usage with proficiency (numeracy score) from the PIAAC data. Van der Velden and Bijlsma (2017) find that skill effort is associated with a wage premium, but they do not make any distinction between how different types of education might relate to skill use or effort.

The cross-sectional nature of the data constrains their analysis to a particular point in time. It is implicitly assumed that employers are rigid and do not adjust their production to better exploit potentially under-utilized skills of their employees. The wage return to skill effort (or use) may change over time and/or be different for employees in different economies, as has been shown to be the case for education-job match (Hartog, 2000). Our analysis is subject to the same constraint and should be understood as a static. But our analysis is a relatively current assessment of education-job match and skill use for employees who pursued different types of higher education.

From both the education-job match and skill use perspectives, the relevance of skills for the workplace is typically assumed to have broad implications. In our analysis, however, we simply explore how different pathways in higher education systems associate with education-job match or skill use. We find that people with vocational higher education are less likely to have qualifications that are matched with the educational requirements of their employers and they are likely to have less education, not more education, than required. People with vocational higher education tend to use the numeracy skills identified in the PIAAC questionnaire less than those who have pursued general higher education.

Laczik and Mayhew (2015) indicate that in official circles there is a strong sentiment that the structure of the national education and training system is important for integrating skills with the labor market. Recent research comparing labor market outcomes between people with vocational versus general higher education (i.e., Hanushek et al., 2017 and Hampf and Woessman, 2016) includes a mechanism for classifying the structure of national education systems by their vocational intensity: non-vocational, school-based vocational and apprenticeship-based. We use their classification to group countries in our dataset on the basis of the vocational intensity of their national education systems and find that vocational intensity can greatly improve the job-skills match, if the experience in Denmark is typical.

5.3 Education-job Match and Skill Use Model

The empirical model we use closely follows the models used by Hanushek et al., 2017 and Hampf and Woessman, 2016 to compare the differences in labor market outcomes for people with vocational versus general tertiary education.

$$M_i = \beta_0 + \beta_1 V_i + \beta_2 Inv_i + \beta_3 Wexp_i + X_i \gamma + \varepsilon_i \quad (5.1)$$

In our model the dependent variable M_i captures education-job match or skill use, rather than employment or earnings. The dependent variable is a binary outcome variable when education-job match measures are used. The dependent variable is a continuous variable when skill use measure are used. The measures we use for match and use are described in more detail in the data section.

Recent papers that examine the differences between outcomes from vocational versus academic tracks in higher education use the 1997 International Standard Classification of Education (ISCED) to classify tertiary-type B programs (ISCED 5B) as vocational and tertiary-type A programs (ISCED 5A) as general (Hanushek et al., 2017; Hampf and Woessman, 2016; and Brunello and Rocco, 2015). V_i is a dummy variable that takes the value of one if the individual's highest level of education is ISCED 5B and a value of zero if the individual's highest level of education is ISCED 5A.

Inv_i is the cumulated public investment in PPPs.[40] This variable has been constructed using UNESCO data and is equal to the sum of the public expenditure per student in PPP for each level of schooling the individual passed through after the year of entry until the year of highest level of educational qualification (HLQ).[41] We use government expenditure per student in PPP, rather than as a percent of GDP, because in the context of this model we are interested in using investment as a control variable, not in assessing relative government effort. We do not have detailed information about whether the two educational tracks we are investigating receive more or less funding per student, but it is likely to differ by country (OECD, 2016). To the extent this funding is awarded at the national level, our country 'fixed effects' should capture systematic differences. We want to know if different educational pathways associate with education-job match and/or skill use differently when we hold cumulated investment in purchasing power parity constant. Since our investment data begin in 1971, we are only able to calculate cumulated public investment for people under or equal to the age of 46. This restricts

[40] PPPs are in constant (not current) values and have a common base year of 2010.

[41] We assume that all individuals entered primary school at the age of 6 and that all sequencing of schooling was consecutive (i.e., no repeats, skips or breaks between secondary and tertiary).

our age range in this sample to fall between 20 (because individuals must have attained tertiary level education) and 46.

$Wexp_i$ stands for work experience and is important to include because skill match may vary with the number of years of experience in the work world.

X is a set of control variables which include numeracy scores and other commonly used measures for skill attainment.

We include country 'fixed effects'. In addition to fixed effects, Hanushek et al., 2017 and Hampf and Woessman, 2016 include a mechanism for considering the structure of the education systems in the countries analyzed. They run their regressions on sub-group samples of countries classified on the basis of the vocational intensity of their national education systems. The sub-groups are classified as countries with: non-vocational systems, school-based vocational systems, or apprenticeship-based vocational systems. We follow suit. When there was a difference between how authors classified countries, for example with respect to the UK, we followed Hampf and Woessmann. In our sample, we classified 5 countries (Ireland, Italy, Japan, Spain and the UK) as "non-vocational" systems. We classified 6 countries as ones with school-based vocational education systems (Belgium (Flanders), Finland, France, Netherlands, Norway and Sweden). In our sample, we only have one country that can be classified as an "apprenticeship vocational system" and that country is Denmark.

5.4 Education-job Match and Skill Use with PIAAC Data

Skills are notoriously difficult to measure over time and across countries. Although there have been several initiatives such as the AHELO (Assessing Higher Education Learning Outcomes) project, there is some resistance on the part of higher education insiders to measure higher education learning outcomes (van Damme, 2015). The OECD's PIAAC data offers one of the first opportunities to assess skills and education mismatches with the same internationally harmonized dataset.

Using data from in the PIAAC background questionnaire, we construct two measures to indicate skill-match or use for our outcome (dependent) variables: (a) required education (RE) match based on the worker self-assessment approach, and (b) skill use which is based on the frequency with which different skills (in this case numeracy) are used on the job (and skill effort which takes the perspective that the best measure is the product of frequency of skill use and skill proficiency).

5.4.1 Education-job Match

The education-job match variables are constructed using the following questions from PIAAC's background questionnaire:

1. "Which of the qualifications on this card is the highest you have obtained?" Response Choices correspond to the International Standard Classification of Education (ISCED) 1997 levels and are coded by PIAAC.
2. "[Talking about your current job:] If applying today, what would be the usual qualifications, if any that someone would need to GET this type of job?" Response Choices correspond to the ISCED levels of education qualifications and are coded by PIAAC.

Those who report that they have more education than required by their current job are considered over-qualified. Those who report having less education than the current education required for their job are considered under-qualified. Those who have the exact level they as currently required by their job are considered 'matched'. Those who report having more education that required for the job are considered over-qualified. The three possibilities are mutually exclusive. If someone takes a 1 for the (RE) under-qualified variable, this same individual will take a value of zero for (RE) Match and (RE) over-qualified. This approach is similar to the worker self-assessment measure described in Hartog (2000) and has the cited advantages that it is up-to-date and is specific to the respondent's job and not based on any kind of aggregate. Hartog argues that measures of match that are derived from means of an occupation indicate endogenous allocation and not the demand curve for a particular set of skills.

There are 9,615 individuals for whom we have information about the required education for their job today. Of these individuals, 4,650 have vocational (ISCED 5B) higher education qualifications and 4,965 have general (ISCED 5A) higher education qualifications.

5.4.2 Skill Use and Effort

The skill use and skill effort variables were constructed based loosely on methodology described in van der Velden and Bijlsma (2017). To minimize self-reporting inflation of importance bias the job requirements approach (JRA) module in PIAAC asks how often tasks in a particular domain are performed on the job, rather than about the importance of particular tasks/skills on the job (PIAAC technical report, 2014). Van der Velden and Bijlsma (2017) constructed a scale on the basis of 6 items of numeracy use and literacy skills at work. We used the same 6 items for numeracy skills and exclude literacy skills from our analysis at this time. The left-hand column of Table 5.1 lists the 6 items for numeracy skill use at work: 'Calculate costs or budgets' through 'Use advanced math or

statistics'. The columns to the right indicate the frequency with which respondents' can report using each numeracy skill: from 'Never' to 'Every day'. Using this information from the PIAAC dataset, we constructed a continuous variable for skill use on a scale with a minimum value of 6 and a maximum value of 30. For example, someone who reports using all numeracy skills every day at work would be assigned a 30 and someone who reports never using any of the numeracy skills at work would be assigned a 6.

Table 5.1 The Construction of the Skill Use Variable

	Frequency (time units)				
Skill use work - Numeracy: How often do/did you	**Never**	**Less than once a month**	**At least once a month**	**At least once a week**	**Every day**
Calculate costs or budgets	1	2	3	4	5
Use or calculate fractions or percentages	1	2	3	4	5
Use a calculator	1	2	3	4	5
Prepare charts graphs or tables	1	2	3	4	5
Use simple algebra or formulas	1	2	3	4	5
Use advanced math or statistics	1	2	3	4	5
	Min = 6				**Max = 30**

Van der Velden and Bijlsma (2017) then standardize skill use and proficiency by occupation (two-digit ISCO) and country to create a multiplicative term for skill effort, a variable that measures both (a) numeracy skills and their 'productive' use, and (b) the skill effort mismatch (i.e., whether the skill effort is over, typical, and under the country-specific occupation means). We follow suit in creating the multiplicative skill effort term, but in our analysis we do not standardize skill use (or effort) by occupation and country.

Table 5.2 presents descriptive statistics for each measure of skill-match and skill use, separated by type of education formation. The left-hand panel presents the descriptive statistics for people with vocational (ISCED 5B) and the right-hand panel presents the descriptive statistics for people with general (ISCED 5A) higher education.

At the means, we can already observe different patterns with respect to the education-job match and skill use variables for people with vocational and general higher education. For both groups, around 26 or 27 percent have more education than their jobs require. This is in line with recent evidence from the OECD and Europe. Around 47 percent

of people with general higher education report and exact education-job match, whereas only 35 percent of people with vocational higher education report an exact education-job match. Clearly, the main difference lies in the fact that a much greater proportion of people with vocational higher education (38 percent) have less education than their current job would require if they were to be hired today. On-the-job training may be a factor, but we cannot account for that in our analysis. Comparatively, far fewer (27 percent) of people with general higher education qualifications have less education than their current job would require if they were to be hired today. People with general higher education (ISCED 5A) have a higher average values on the skill use scale (15.27 versus 14.93) and skill effort scales.

The explanatory variables follow the patterns we would expect. At the means, less public money was spent on people with ISCED 5B as their highest educational qualification, a smaller percentage of their mothers attained tertiary education[42] and they had fewer books in their childhood household. People with ISCED 5B as their highest educational qualifications tend to have more work experience and are slightly older.

The numeracy scores of those with ISECD 5B are lower, on average, than those with ISCED 5A, but this may be a partially a function of selection mechanisms of the vocational education systems of the different countries. We will return to this in our regression analysis where we separate countries into groupings based on the intensity of their vocational systems.

Recall that the maximum age in our sample is 46 and that Hampf and Woessman (2016) found 44 to be the lower bound of the cross-over age where the ISCED 5B no longer increases the chances of being employed relative to people with ISCED 5A. This means that we are working with a sample in which the ISCED 5B qualification increases the likelihood of employment and it is in this age-range that (if Hampf and Woessman are correct) people with ISECD 5B might be at the peak of their productive life, more likely than 5A to be employed, and therefore more likely to be contributing to measures of productivity.

[42] Please note, for the mother's education it is not possible to differentiate between ISCED 5A and 5B.

Table 5.2 Descriptive Statistics Separated by ISCED 5B and 5A

	Tertiary ISCED 5B Vocational					Tertiary ISCED 5A General				
Variable	**N**	**Mean**	**S.D.**	**Min**	**Max**	**N**	**Mean**	**S.D.**	**Min**	**Max**
Match (Dependent Variables)										
(RE) MATCH	4650	0.35	0.48	0	1	4965	0.47	0.50	0	1
(RE) Over-Qualified	4650	0.27	0.44	0	1	4965	0.26	0.44	0	1
(RE) Under-Qualified	4650	0.38	0.49	0	1	4965	0.27	0.45	0	1
Skill Use	4199	14.93	6.18	6	30	4528	15.27	6.25	6	30
Skill Effort	4199	4401	2051	726	11321	4528	4719	2144	699	11465
Explanatory Variables										
Investment PPPs (Thousands)	4650	88	34	24	253	4965	111	48	28	279
Age	4650	35	7	20	46	4965	34	7	21	46
Work Experience	4486	14	7	1	34	4713	11	7	1	34
Numeracy Score (min. 0 to max. 500)	4648	290	42	102	426	4965	303	43	86	463
Mother's Education (Reference group: Uncompleted Secondary)										
Secondary	4510	0.38	0.49	0	1	4910	0.37	0.48	0	1
Tertiary	4510	0.21	0.41	0	1	4910	0.28	0.45	0	1
Number of Books (Reference group: 10 and less)										
11 to 25 Books	4632	0.13	0.34	0	1	4942	0.08	0.28	0	1
26 to 100 Books	4632	0.36	0.48	0	1	4942	0.30	0.46	0	1
101 to 200 Books	4632	0.19	0.39	0	1	4942	0.23	0.42	0	1
201 to 500 Books	4632	0.15	0.36	0	1	4942	0.22	0.41	0	1
More than 500 Books	4632	0.08	0.28	0	1	4942	0.13	0.34	0	1
Total N	4650					4965				

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: We follow Hanushek and use Plausible Value 1 for Numeracy Scores. SASM stands for Self-Assessed Skill Match.

5.5 Results for Education-job Match and Skill Use PIAAC

Our regression analyses test whether, after controlling for other factors, different types of educational formation still have a different relationship with our education-job match or skill use measures. To do this convincingly, we have to try to eliminate as many as possible unobservable (i.e. selection) issues that might influence both our key variable of interest and our dependent variable. We cannot solve this problem with panel data, since we do not have longitudinal data. By controlling for current numeracy skills, we can address some issues regarding 'innate' talent' that might affect sorting into vocational or academic higher education tracks. By including mother's education and number of books as child we are able to cover some element of family background. We use these data to try to control for these factors. Since some countries track their students into vocational schooling at a young age on the basis of test scores and academic promise, we cannot fully eliminate the issue of selection in the subsequent analysis.

In order to try to get around potential selection issues, we followed what Hanushek et al., (2017) and Hampf and Woessmann (2016) have done recently. We used propensity score matching to match otherwise observationally similar individuals with general and vocational education using nearest neighbor matching techniques based on our available explanatory variable data. The idea is to restrict to the sample to individuals who could be observationally similar regardless of which type of education they pursued. Whereas other authors lost 35 percent of their observations when they restricted the matched sample, we lost only around 12 percent. Therefore, for the time being, we present the estimates on the full sample and consider the results using the matched sample as a robustness check.

The results of our analysis are shown in Table 5.3. Entries in this table are on the full sample. Columns 1-3 present the results obtained using education-job match variables. Even when we control for many other factors, we find that the patterns we observed in our descriptive statistics are statistically relevant. Since our education-job match variables have binary outcomes, we use Linear Probabilities Models (LPM) for estimations with those dependent variables. In Column 1, the dependent variable is (RE) Match which takes a value of 1 when there is an exact match between the required education for the job and the education qualification possessed. Our explanatory variable of interest is vocational higher education, which takes a value of 1 when the education qualification possessed is Vocational (ISCED 5B). The results show that studying vocational higher education is associated with a 17 percent lower probability an exact education-job match. In column 2, the results show that studying vocational or general higher education makes no statistical difference in the chances of being over-

qualified. In column 3, studying vocational higher education is associated with an 18 percent greater chance of having less education than required for the job.

Clearly, the education-match dependent variables from columns could be treated as a categorical variable and analyzed with a multinomial logit model, we present the three columns for the sake of simplicity of interpretation. Nevertheless, we ran such a multinomial logit model, using (RE) Match as the base category. As indicated by the linear probability models, people with ISCED 5B qualifications are significantly more likely to be under-educated than matched, and least likely to be over-educated for their jobs.

Column 4 shows the results when the frequency of skill use is the dependent variable and column 5 shows the results when skill effort (frequency of skill use is multiplied by the numeracy score) is the dependent variable. Skill use and effort variables are continuous variables, so when they are our dependent variables, we use OLS estimations. On average, ISCED 5B is associated with lower use of numeracy skills on the job and also a lower skill effort vis-à-vis ISCED 5A. The magnitude of the coefficient on skill use is relatively small. People in our sample with vocational higher education use the numeracy skills identified by PIAAC about 0.5 less (on a scale from 6 to 30) frequently than people with general higher education. Since skill effort is a multiplicative term based on skill use and numeracy scores, and people with vocational higher education tend to have lower numeracy scores and use the numeracy skills slightly less frequently on the job, it is not surprising that the coefficient for vocational higher education is negatively associated with skill effort. These results should correspond to the type of educational formation (ISCED 5A or B), but it is quite likely that we have not managed to isolate this effect completely from selection issues.

Table 5.3 Education Job Match and Skill Use

Dependent Variable | Different Measures of Education-job Match and Skill Use	(RE) Match (1) LPM	(RE) OE (2) LPM	(RE) UE (3) LPM	Skill Use (4) OLS	Skill Effort (5) OLS
Vocational (ISCED 5B) = 1	-0.17***	-0.01	0.18***	-0.46***	-498.80***
	(0.01)	(0.01)	(0.01)	(0.16)	(55.12)
Investment PPPs (Hundred Thousand)	-0.17***	0.05	0.12***	-0.10**	-616.43***
	(0.03)	(0.03)	(0.03)	(0.04)	(148.71)
Age (Years)	-0.01***	-0.01***	0.02***	-0.10***	-50.06***
	(0.001)	(0.001)	(0.001)	(0.02)	(7.12)
Work Experience (Years)	0.03***	0.01**	-0.03***	0.25***	109.88***
	(0.003)	(0.003)	(0.003)	(0.04)	(13.64)
Work Experience Squared	-0.0005***	-0.00009	0.0005***	-0.002*	-1.34***
	(0.0001)	(0.0001)	(0.0001)	(0.001)	(0.44)
Numeracy Score (Range 0-500)	0.0006***	-0.0008***	0.0001	0.04***	
	(0.0001)	(0.0001)	(0.0001)	(0.00)	
Constant	0.97***	0.63***	-0.61***	5.96***	5905.38***
	(0.09)	(0.08)	(0.08)	(1.15)	(356.88)
Country fixed effects	yes	yes	yes	yes	yes
Observations	8990	8990	8990	8368	8368
Countries	12	12	12	12	12
Adjusted R-squared	0.08	0.05	0.08	0.10	0.06

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: LPM stands for Linear Probability Models used in Models 1-3. Models 4 and 5 are OLS. We follow Hanushek and use Plausible Value 1 for Numeracy Scores. Control variables 'Mother's Education' and 'Number of Books in the Household at age 16', and country dummies where Belgium (Flanders) is taken the reference country for fixed effects are included, but not reported. Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

When we look at the investment variable, we also see an interesting pattern. It is negatively associated with those individuals who matched by conventional (RE) match criteria and again positively associated with those who are under-educated. It stands to reason that if you received more public funding over the course of your educational lifetime, the quality of your education might have been higher, allowing you to perform at a level higher than the 'standard' qualification suggests. However, public investment is negatively associated with higher skill use at work, which is a bit puzzling. A possible explanation emerges when we group countries by the vocational intensity which may capture something beyond the country 'fixed effects'.

Table 5.4 presents the results separated by country groupings. The country groupings are based on the vocational intensity of the national education system in the countries described in section 5.3. We observe that in the non-vocational countries, ISCED 5B is negatively and significantly associated with being matched by conventional (RE) criteria. This is driven by the positive and significant association with being under-educated for the job (Column 4).

Table 5.4 Skill Match Differences between Country Groupings with Different Vocational Intensity

	Dependent Variable: (RE) Match			Dependent Variable: (RE) Under-Educated			Dependent Variable: Skill Use (SU)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Non-vocational	School-Based Vocational	Denmark	Non-vocational	School-Based Vocational	Denmark	Non-vocational	School-Based Vocational	Denmark
Vocational (ISCED 5B) = 1	-0.13***	-0.29***	0.25***	0.12***	0.29***	-0.02	-1.63***	0.65***	0.46
	(0.02)	(0.02)	(0.05)	(0.02)	(0.02)	(0.04)	(0.26)	(0.24)	(0.62)
Investment PPPs (Hundred Thousands)	-0.03	-0.15***	0.00	0.07	0.09**	0.07	-2.55**	-0.63	3.53*
	(0.10)	(0.05)	(0.15)	(0.09)	(0.04)	(0.14)	(1.25)	(0.57)	(1.96)
Age (Years)	-0.02	0.02	0.04	0.06***	0.01	0.03	-0.08	0.17	-0.47
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.03)	(0.20)	(0.18)	(0.42)
Age Squared	0.0001	-0.0005**	-0.001	-0.0004**	0.0001	-0.0003	-0.004	-0.004	0.01
	(0.0002)	(0.0002)	(0.0004)	(0.0002)	(0.0002)	(0.0005)	(0.003)	(0.003)	(0.01)
Work Experience (Years)	0.02***	0.03***	0.01	-0.05***	-0.03***	-0.02**	0.27***	0.15**	0.28**
	(0.005)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.07)	(0.07)	(0.13)
Work Experience Squared	-0.0004**	-0.0005***	-0.0003	0.001***	0.001***	0.001**	-0.004	0.001	-0.002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0020)	(0.0003)	(0.002)	(0.002)	(0.004)
Numeracy Score	0.0007***	0.0003*	0.0004**	-0.00001	0.001**	0.0003	0.03***	0.04***	0.04***
	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.00)	(0.00)	(0.00)
Observations	4035	4085	870	4035	4085	870	3606	3943	819
Countries	5	6	1	5	6	1	5	6	1
Adjusted R-squared	0.047	0.112	0.087	0.084	0.123	0.015	0.089	0.110	0.119

Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.

Notes: Columns 1-5 are estimated using Linear Probability Models and columns 5 and 6 are estimated using OLS models. We follow Hanushek and use Plausible Value 1 for Numeracy Scores. Control variables 'Mother's Education' and 'Number of Books in the Household at age 16', the Constant term, and country dummies where Belgium (Flanders) is taken the reference country for fixed effects are always included, but for reasons of visualization their coefficients and standard errors are not reported. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

In the school based vocational systems we see similar patterns in the non-vocational countries with respect to our education-job match measures as we did when all countries were grouped together. The coefficient on under-education is positive, significant, and larger than in the non-vocational countries, suggesting that the vocational ISCED 5B training in those countries may indeed provide stronger preparation for the workforce and make employers willing to hire (or keep) them with less education than would be currently required. The results for over-education are not presented in Table 5.4, because the results were qualitatively less interesting.

Interestingly, in the school-based vocational countries, additional public investment at the margins increases the chances that people will be under-educated for their jobs. This is logical if one considers that the quality of the education (with additional funding) might have been higher, partially compensating for the lower 'level' of educational qualification (at least from the perspective of the employer). It is notable that it is in the school-based vocational countries that ISCED 5B is positively and significantly associated with numeracy skill use and, in these countries, an increase in public investment at the margins is not significant. There may be both efficiency and productivity gains associated with vocational education formation in those countries.

The non-vocational countries are driving the negative and significant results found in our pooled regression with respect to skill use. Furthermore, it is in those countries that a larger amount of public investment at the margins is negatively associated with skill use. One possible explanation is that in the non-vocational education systems, the people with ISCED 5B have not received the same quality of vocational training as their counterparts in more intensive vocational education systems. It is also possible that, at the margins, the additional public money has not been 'well spent' in the sense that more students may have been left behind, so that with our host of controls, an additional PPP dollar at the margins is not well spent, at least with respect to cultivating the use of numeracy skills at work.

Denmark is the only country in our sample that is classified as an apprenticeship vocational country, and indeed the patterns with respect to our dependent variables are quite different in Denmark. In Denmark, having a vocational higher education qualification is associated with a 25 percent greater chance of an exact education-job match and 23 percent lower chance of being over-educated. In Denmark, there is no significant difference between those with 5B and 5A regarding the chances of being under-educated. In Denmark having studied vocational higher education makes no statistical difference in numeracy skill use at work, but in this country, additional public investment at the margins, is associated with an increase in numeracy skill use at work, which is the relationship we would expect. Differentiating the countries according

to the vocational intensity of the education systems seems crucial to understanding differences between vocational and general higher education qualifications and their relationships with our measures of skill-match and skill-use.

5.6 Part A: Discussion

We have established that vocational and general education tracks in higher education have different patterns with respect to education-job match and skill use. However, it is important to appreciate that this conclusion depends on the task selection. Numeracy tasks used to build our skill use variable could be tasks that are more likely associated with the kinds of jobs typically accessed from general academic tracks. An electrician (for example) might use numeracy skills such as geometry, angles and measurement on the job (a numeracy task not directly listed in the 6 items), but not necessarily 'prepare charts and graphs and tables' which is listed but is something that might be associated with a consultancy or a similar kind of job that is more typically accessed through studying general higher education. The types of numeracy tasks listed in the JRA module of PIAAC are crucial for the respondent to identify the actual frequency of numeracy skill use on the job. This is less likely to be a problem for the numeracy scores determined from PIAAC, because the PIAAC test is designed to assess the numeracy skills applied to real-life circumstances. Nevertheless, it could also be a consideration in the skill effort measure which is partially based on the frequency of skill use on the job.

Our results indicate that the structure of the overall education system (non-vocational, school-based, or apprenticeship-based vocational) is an important factor which influences the results. For example, while vocational higher education tends to be negatively associated with numeracy skill-use on the job when all countries are clumped together, it is positively associated with numeracy-skill use on the job when we consider the overall vocational intensity of the national education system.

We found that vocational and general academic tracks do have a different relationship with education-job match. People with vocational higher education in our dataset are more likely to have less education than would be required if their employer were to hire someone for their job today. This implies that, either (a) the skills generated from this type of education are so desirable for the employer they disregard the education qualification, or (b) the education qualifications have changed over time and, even though we control for age and work experience, there are a number of people in our dataset who would not be able to get the jobs they have today with their vocational higher education qualification. In either case, this finding could be of interest for policy makers. In his review of the education-job match (ORU) research, Hartog (2000)

found that 'under-education' was less severely punished (wage penalty) than theorized. He hypothesized that being 'undereducated' could be an indication of a creaming process, whereby capable workers move up, regardless of their education level. If this is happening, the value of the vocational higher education training is high. If the labor market requirements themselves are changing, it raises the question of how the educational institutions will keep up.

How higher professional education institutions such as the ones that train people in ISCED 5B (vocational higher education) monitor changing educational requirements in the labor market is the topic of the next section of this chapter.

Part B

"Education is the passport to the future, for tomorrow belongs to those who prepare for it today"

–Malcolm X.

Malcolm X said that in 1964. Today, the big question seems to be: how can education prepare people for a future world in which we are likely to be working alongside machines and robots? Media and policy makers believe the education system needs to transform itself and instill values of continuous improvement in students. In short, both students and their educational institutions will be expected to excel in 'learning to re-learn'. But the literature on innovation in education is scant, especially in higher education, and we do not know much about the institutional effort required to adapt.

This section describes a survey that we developed and implemented in the Netherlands and New York State. The main research questions we addressed with the surveys were:

> Research Question 1: How do higher professional education institutions in the Netherlands/U.S. collect information about job opportunities and skills required by potential jobs for their graduates?
>
> Research Question 2: What are the challenges and opportunities when making changes to educational programming based on requirements of potential jobs for graduates?

The survey results may aid communication between the surveyed institutions, but the results and discussion of the results should be regarded as a preliminary effort to glean information about an under-studied topic. Since we do not have representative data, we do not aim to test causal hypotheses, rather we focus on learning about what kinds of challenges and opportunities higher professional education institutions face when they try to innovate educational services in response to cues from the labor market.

5.7 Part B: Overview of the Literature

5.7.1 Why We Focus on Higher Professional Education Institutions

Sixty six percent of employment growth in the European Union is projected to be in the category "technicians and associate professionals". In the United States, about one third of job vacancies are expected to require more than high school and less than a four-year college degree (OECD, 2014). Not only are higher professional education institutions the ones that tend provide these mid-skill qualifications, at least in the U.S. context, they also create upward mobility opportunities for disadvantaged students (Chetty et al., 2017; Holzer and Baum 2017). Benson (1997) highlights community colleges as the institutions most able to implement 'new vocationalism' which will better align classroom education with skills needed in the labor market. Benson stresses that the hurdles for 'new vocationalism' are high, listing barriers that range from insufficient student preparation in secondary school to parental attitudes toward vocational education.

The OECD's 2014 report on Skills beyond School addresses the 'hidden world of professional education', identifying a void of policy measures to engage industry stakeholders and make them close partners in professional education and training. When industry needs and the educational qualifications grow too remote the graduates lose their 'currency' in the labor market. Most of the countries covered in the OECD's Learning for Jobs study faced difficulties in this regard. The OECD report synthesizes country level studies, and the country level studies (for example, the one for the Netherlands) mostly rely on indicators aggregated to the national level.[43] Higher professional education institutions, however, are diverse and sometimes fragmented. The burden of the 'policy void' identified by the OECD has therefore fallen on the shoulders of the education institutions themselves. We believe that surveying the higher professional education institutions individually will yield insights regarding challenges

[43] This is not a criticism - the OECD has done this purposefully. Country level studies assess strengths for the purposes of sharing good practices with the broader OECD community and assess weaknesses for the purposes of identifying where policy could intervene to improve the system. Rather, the point is meant to illustrate how the information collected in this study is quite distinct from what can be found in existing reports and literature on the topic.

and opportunities for professional higher education to successfully keep up with changes in the labor market.

5.7.2 Education and the Labor Market: Information Flows Matter

The innovation system is interdependent with education, labor markets, and the welfare system. Lundvall states that his "analysis indicates that investing in higher education will be much less efficient if the economy does not establish the prerequisites for establishing learning dynamics" (Lundvall, 2007a; page 22). The university-industry link is a knowledge transfer mechanism that must co-evolve. Feldman and Stewart (2008) identify the lack of alignment of local economy and local education as a bottle neck for knowledge transfer. A local focus matters because in both the Netherlands and in New York State there are wide regional disparities between regions. In the Netherlands the Limburg region has a different economy, and labor market prospects, from North Holland. The economy in New York City is a world apart from the economy in Cortland County in the middle of the state.

Given fast-changing work requirements and environments, it is also possible that even if education and the labor market are linked at one point in time, they may not evolve together. What was once a strong link could be broken; weak links can develop and strengthen. The learning economy (distinct from the knowledge economy) emphasizes that 'halving' period for skills acquired during education is getting shorter and shorter. So, for example a computer engineer's newly acquired knowledge may be obsolete as soon as one year after graduation (Lundvall, 2007a). Signaling and network theory suggests that more information about employment opportunities will make the transition from education to the labor market easier for graduates (Raffe, 2011). But getting information often takes effort, time, and money. The OECD sees the ability of the education system to respond effectively to the changing needs of the labor market as a continuing challenge.

5.7.3 Innovation in Higher Education

This section refers to innovation in higher education in general. Research on innovation in higher education is scarce and largely focused on teaching innovations or specific technology adoptions such as Massive Open Online Courses (MOOC). The kinds of issues raised by the Community Innovation Survey (CIS) on obstacles and public support for firm innovation have not been researched in the context of higher education (Arundel et al., 2016). Research on innovation in firms has been around for years, but research in a similar vein on innovation in higher education is new and so far, it concentrates on academic universities. There has been a push to be more explicit about innovation processes and strategies in agencies and the organizational level (Smink, 2013) and public sector innovation is on the agenda for people and places that work

on the innovation scoreboard (comment at a seminar given by Peter Dröll, Director at European Commission's Research and Innovation Department October 19, 2017). As far as we know, there is no other study that surveys higher professional education institutions and asks them about changes in their organizational or educational programming practices.

Typically academic universities are thought of as being rather slow to change (Mehaffy, 2012; Dennison, 2014). Universities have been likened to mature enterprises, increasingly risk adverse when it comes to innovation (White and Glickman, 2007). Recent survey research on innovation in universities (higher academic education) finds leadership and culture for innovation are important (GAIHE, 2016), but not strictly necessary for innovation to occur (Arundel et al., 2016). In a dissertation at Penn State University (PSU) on faculty perceptions of faculty-initiated course innovation projects sponsored by an innovation support unit at the PSU in the late 1990s, Lane (2001) found that it was difficult for faculty to separate the sustainability of the innovation from the innovation process itself, and likened this to notions of continuous improvement from management literature. Faculty reported that they drew on support from their close colleagues, both as sources of information for ideas about innovation and as assessors of the success of the innovation intervention. They often did not know about perceptions from faculty outside their own department, because there was not a forum for discussion or communication between departments. Student involvement and feedback was found to be a determinant for whether or not the innovation was later abandoned (for example, after funding ran out). (Lane, 2001)

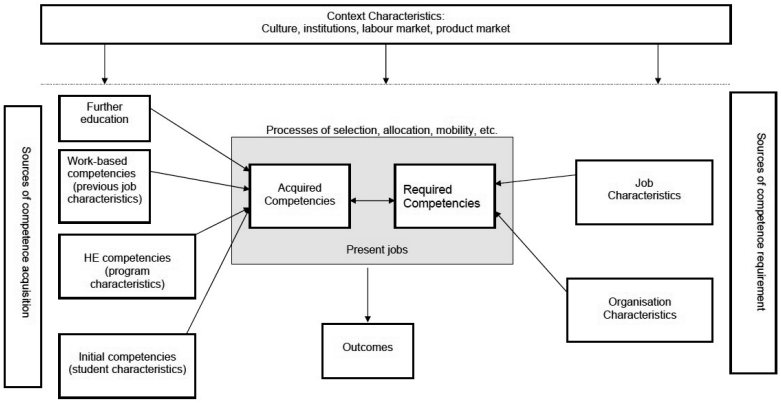
Making changes risks frustration on the part of support staff and faculty members if it is not managed well and if the goals and outcomes of the changes are not clearly established or communicated. Research on innovation in the public sector indicates that organizational change can meet with resistance from staff and this can act as a barrier to innovation (Torusga and Arundel, 2016). White and Glickman (2007) also highlight increasing financial pressure on universities, as public funding has waned over the years. What we know from other contexts (innovation in firms for example) is that financial support for innovation can help offset the cost of risky investment and encourage more innovative efforts, but we also know, stimulating innovative activity takes more than financial support (IDB, 2016; Navarro et al., 2016). In the context of innovation in higher education, risk is not a purely financial consequence, the real risk of trial and error will be the impact borne by the students educated during an experimental phase 'gone wrong'. The front line staff and senior management of the education institutions are likely to feel this burden of responsibility most directly.

5.8 Methodology

The research method selected for this chapter is a qualitative approach, because the goal of this research is to better understand the perspectives of the people who are working in higher-professional education institutions. They are the experts. We want to understand these issues from their perspective, rather than from a prescribed vantage point[44] and we want to understand particular aspects of the process of the phenomena we are investigating; Maxwell (2013) states that these are important criteria for selecting a qualitative research approach. Furthermore, since there is a paucity of previous research that targets the vantage point of the people working in higher professional education institutions and/or in the same vein as our line of investigation, our research is highly exploratory in nature and seeks to explain how and why the phenomena we wish to study occur.

5.8.1 Overall Conceptual Framework

The conceptual framework used in this study was developed by the REFLEX project. This conceptual framework illustrates the demands on higher education. We focus on the middle part of the diagram.



Source: Excerpted from REFLEX (2005).

The focus of our research is on better understanding how higher-professional education institutions (a) ascertain the required competencies (referred to as skills in our study) and (b) whether they anticipate changes (future skills required by potential employers

[44] A certain degree of researcher bias is difficult to avoid, we will return to this in the limitations section.

of their graduates) (c) whether they make adjustments to educational programming to strengthen the link between the educational programming characteristics, the acquired and required competencies (d) how rapidly they can do this and (e) what are the obstacles and opportunities confronting the institutions in this endeavor.

Drawing from the conceptual framework in order to operationalize and measure the elements we wish to better understand, we developed three survey instruments intended for people at different levels of the educational institutions. In accordance with the literature on survey design we clarify the objective of the surveys (Fink, 2009; Fink, 1995; Fowler, 2009; Salant & Dillman, 1994). We included questions about institutional prioritization, the degree of formalization of policy and/or procedures for collecting information about the labor market. We also asked about the resources (financial and personnel) dedicated to the task of collecting information about the labor market. We are curious as to whether institutions will try to anticipate changes in the labor market, or if they will tend to be more 'reactive'. We will investigate whether innovation is initiated by management of the institution, private sector, public sector, or students.

5.8.2 Population Selection

The target population is all publically funded higher professional education institutions in the Netherlands and in New York State in the United States and a subset of their department and programs in particular sectors. In both cases, we aimed for full coverage at the institutional level. This was feasible because the total number of higher professional institutions is relatively small. There are 37 publically funded higher professional education institutions in the Netherlands and 30 publically funded Community Colleges in New York State.

The justification for studying higher professional education institutions as elaborated above is that they have been identified by the literature as the mode of educational service delivery that awards the qualifications most likely to be in short supply in the labor market in the next 10-15 years. Furthermore, these institutions offer post-secondary training and qualifications that prepares students for particular occupations (OECD, 2014), which implies a 'shorter' distance to the labor market. The specific case locations (the Netherlands and New York State) are selected following partially because they represent diverse cases, in the sense that the Netherlands has a school-based vocational system and the United States has a non-vocational education system. The other consideration for cross-case selection was purely pragmatic, the research team is based in the Netherlands and the principal investigator is originally from New York State. This, in some cases, facilitated access, reduced the costs of in-person visits during the preliminary investigation, and allowed the research team to build on a base of knowledge regarding the localities, all of which Seawright and Gerring (2008)

acknowledge are perfectly legitimate factors in case selection, but they are not theoretical reasons.

Diverse cases are often understood to be exploratory and diversity may be understood as a variety of causal paths running from exogenous factors to the outcomes of interest and even though the cases differ along selected diverse categories, they may otherwise be internally homogenous Seawright and Gerring (2008, pages 300-301; Lor, 2011). The Netherlands and New York State differ along some specific dimensions that are closely related to, but not the same exact dimensions as the variables under investigation in our research questions and yet they are similar along some other important similarities. Throughout this study, pains are taken to make cautious comparisons between the two cases.

5.8.3 Cross-case Characteristics

The Netherlands and New York State have very different educational systems, but similar stages of economic development and population sizes.[45] Even though New York State is roughly double the size of the Netherlands in terms of square kilometers,[46] the two places share some similar regional differences with a concentration of business, finance and income in their respective major cities (Amsterdam and New York City), and in industry and government in the smaller 'second cities' (i.e., Rotterdam, Eindhoven, The Hague, and Utrecht in the Netherlands, and Rochester, Buffalo and Albany in New York State), other regions and small cities that are relatively rural and have been harder hit by the loss of 'middle' jobs and relative economic depression.

5.8.4 Differences in the Education Systems

The literature characterizes the Netherlands as dual[47] education system with school-based vocational education and relatively high vocational intensity and the United States is characterized as a single non-vocational education system (Hanushek et al., 2017).

Higher professional education institutions in the Netherlands are known as HBOs or Universities of Applied Sciences. They offer professional Bachelor's degrees classified as ISCED 655 in 2011 (CEDEFOP, 2016) and as either ISCED 5B or 5A under the 1997 classification system (CBS, 2008).[48] In the Netherlands, programs are rather strictly

[45] The per capita income in New York State in 2015 was $34,297 (Department of Numbers, accessed October 2017) and in the Netherlands in 2014 it was $36,441 (CEIC, accessed October 2017). The population of New York State is 19.75 (11.21 million without New York City) and the population of the Netherlands is 17.02 million.

[46] New York State is about 75,842 square kilometers of land area (NYS department of Health accessed October 2017 (and converted from Miles to Kilometers)) and the Netherlands is about 41,526 square kilometers (Encyclopedia of Nations, accessed October, 2017).

[47] As measured by clearly delineated vocational tracking in separate schools from lower secondary.

[48] HBOs also offer Master's degrees and (increasingly) associates degrees, but the majority of their students are Bachelor's students and in the surveys we ask them to focus on their Bachelor's degree programs.

defined through the Dutch-Flemish accreditation body (NAVO) and sometimes even through legislation, whereas schools are primarily responsible for curricula and their modernization (CEDEFOP, 2016 pages 36-48). So we might expect to find answers to our questions about program flexibility within these modes of innovation (curriculum delivery and content) rather than or in addition to changes in programs.

In New York State the education institutions providing higher professional education are often Community Colleges (CCs), which tend to offer shorter-cycle (typically 2-year) higher education programs. The programming is divided into more general Associates Degrees (A.A. Associate in Arts; A.S. Associate in Science) which often prepare students for transfer to a Bachelor's program and Associates in Applied Sciences (A.A.S.) a technical or vocational program designed for students seeking employment after the completion of the degree.[49]

It is these rather stark differences in the vocational intensity of the entire school system and the differences in the structure of the higher-professional education system that make these two cases different, it is the other characteristics of the economic spread of activities across the cases (country and state) selected, their similar population sizes and average wealth that make the cases otherwise similar.

5.8.5 Respondent Selection

For this study, the anticipated sample of institutions approached equals the full target population, which is the universe of HBOs in the Netherlands and CCs in the State University of New York (SUNY) system in New York State. The target respondents for the questionnaire at the institutional level are the Presidents of the Executive Boards of the HBOs and Presidents of CCs. The governance structure of the SUNY CCs is such that many of the institutions have offices of Institutional Research, Advancement or Effectiveness. In the follow-up phone calls that were placed, the research team identified whether the particular CC preferred to redirect the survey to one of these offices.

Maps illustrating the regional spread of the HBOs in the Netherlands and the Community Colleges are presented in Appendix D.2. In some cases, the same HBO institution has multiple locations (For example, Zuyd (easily visible in the South), has three locations, but it counts as one institution. The list sent by the Vereniging Hogescholen (VH) for HBOs in the Netherlands included contact information for 37 publicly funded higher professional education institutions. The research team has taken this to be the universe of higher-professional institutions in the Netherlands. The list sent by the SUNY central office in New York State included contact information for 30 publicly funded

[49] Community Colleges also offer certificate programs, in the surveys we asked them to focus on their A.A.S. degree programs.

Community Colleges. The SUNY system is made up 64 institutions; the other 34 institutions are four-year research universities or liberal arts colleges, academic medical centers, or colleges of technology.[50] Our focus is on the 30 Community Colleges, because they are the institutions most likely to provide higher professional education in the form of Associates of Applied Sciences (A.A.S.) degrees.[51] The research team has taken the list provided by the SUNY Central office to be the universe of Community Colleges in New York State. Private HBOs and community colleges and colleges that are part of the City University of New York (CUNY) remain outside the scope of our survey research.

In addition to a questionnaire at the institutional level, a survey was designed for senior department managers in the following four sectors in the HBOs (Bètatechniek, Gezondheidszorg, Sociale Studies and Economie) and parallel departments in the CCs (STEM – Science Technology, Engineering and Math, Health or Nursing, Business or Economics, and Social Studies). The target population for this survey was the universe of department heads in those four sectors. One of the expert practitioners in the HBO system, in a meeting regarding preliminary versions of the questionnaire and survey, suggested that many of the questions originally intended for the department (or domein) managers would be more appropriately collected at a more decentralized level within the organization. Therefore, a survey for HBO program [opleiding] level managers was also developed. The target population was the universe of programs (opleidingen) in the same four sectors described above.

Inclusion criteria: The respondent must be employed in a higher professional education institution (HBO) in the Netherlands, or (SUNY CC) in New York State in a leadership positions at the institutional, department or program level.

Exclusion criteria: there are three other sectors HBO-programs [opleidingen] and many other departments at the SUNY CCs for which education and training are offered, but respondents for departments and programs outside those 4 sectors have not been targeted in this study.

5.8.6 Survey Design

Before developing our own survey instrument, we contacted associations (the Vereniging Hogescholen in the Netherlands and the American Association of Community Colleges in the U.S.), the SUNY central office and researchers (from the Research Centre for Education and the Labour Market (ROA) at Maastricht University and the University

[50] http://www.suny.edu/about/

[51] As stated previously, direct comparison with higher professional education institutions in the Netherlands, also known as the Universities of Applied Sciences, is not possible - because they offer mainly Bachelor's degrees.

of Michigan who have conducted extensive research on the graduates of HBOs and community colleges respectively)[52] in search of an existing survey instruments. Everyone we contacted responded either (a) as far as they knew, no such survey instrument, or (b) redirecting us to one of the other entities mentioned here, or (c) with reference to one of the following survey instruments described below. This resulted in a compilation of similar survey instruments, but none that were designed with research objectives close enough to ours that we could adopt and adapt just one instrument.

The following existing survey instruments have been consulted and when possible, questions from these existing surveys have been adapted and used in our instruments:

(1) Survey of Higher Education Institutions. Developed by Governance and Adaptation to Innovative Modes of Higher Education Provision (GAIHE, 2016).
(2) Management and Service Innovations in Australian and New Zealand Universities Questionnaire. Developed by the Australian Innovation Research Centre and the LH Martin Institute (2016). Authors: Anthony Arundel, Dominique Bowen Butchart, Sarah Gatenby-Clark and Leo Goedegebuure.
(3) BuildPHE survey instrument sent to EURASHE member institutions to consult them "on criteria for self-reflection on achievement within Professional Higher Education… PHE specifically focuses on enhancing job related skills and competencies with a view to raising the employability of students."
(4) HBO-Monitor Questionnaire: copy in English was provided by ROA.

Preliminary versions of the questionnaire and survey instruments were shared with higher professional education experts and practitioners. We met with 5 people affiliated with the HBOs in Netherlands and 3 people affiliated with the CCs in New York State. These meetings resulted in many changes and iterations to the questionnaire and survey instruments.

5.8.6.1 Survey delivery and ethics

Following Arundel et al. (2016), we delivered the survey primarily via e-mail and followed-up with phone calls and reminder e-mails. We made a minimum of three attempts to follow-up with non-respondents, but we stopped whenever the potential respondent indicated a definitive non-response, and we never exceeded five attempts in order to comply with our ethics application. Prior to contacting respondents, an application describing the study was sent to Maastricht University's Ethics Committee

[52] We also contacted researchers affiliated with the CCRC (Community College Research Center) at Columbia University, but we did not receive a response from them.

(ERCIC). In order to encourage participation anonymity was stressed. Institutional leaders were also informed which departments and programs would be contacted.

The first e-mail inviting participation was sent to the Presidents of the Executive Boards of the HBOs in early July 2017 with a letter of support from UNU-MERIT attached and providing contact information for the research team and ERCIC. A follow-up e-mail sent one week later offering to conduct the questionnaires in person or over the phone. Due to the summer holidays, the research team paused follow-up until after the summer holidays. At that time the research team decided that in order to encourage participation, the e-mail invitation and letter of support should be sent in Dutch. This was implemented in the round of e-mails that were sent on August 24, 2017. From the end of August to mid-September, follow-up phone calls were placed in Dutch contacting the secretaries of the Presidents of the Executive Board and offering the option for the Presidents to conduct the questionnaire in person or over the phone. The follow-up phone calls in Dutch were instrumental in driving up the response rate, as was the option to conduct the questionnaire over the phone or in person. Two questionnaires were conducted in person and nine were conducted over the phone,[53] eventually representing more than half of the responses. A final round of e-mails was sent to non-respondents in the beginning of October.

Survey delivery at the department and HBO-opleidingen level was a little more complicated. A list of contact information for the 'Landelijk Opleidingsoverleg' (which translates to Heads of the National Degree Program Consultations) for each of the four sectors was provided by the Vereniging Hogescholen, but these contacts are not necessarily the department or program managers. In each sector, these contacts were asked to forward the e-mail to the department and program managers under their purview. After an initial e-mail was sent in early July 2017, the research team paused follow-up until after the summer holidays. It was determined that these surveys should be translated into Dutch (in addition to the e-mail inviting participation and letter of support). The e-mails in Dutch with the option to participate in the survey in Dutch or in English was sent in the first week of September and follow-up phone calls were placed in Dutch to the 'Landelijk Opleidingsoverleg' toward the end of September (until October) allowing the research team to discover that some of the 'Landelijk Opleidingsoverleg' had changed or were no longer serving in that position. A final e-mail was sent to non-respondents in the beginning of October.

On the U.S. side, the first e-mail inviting participation Presidents of the CCs was sent at the beginning of September 2017 with a letter of support from UNU-MERIT attached

[53] Two questionnaires were conducted over the phone in Dutch and responses translated into English. One respondent decided to withdraw from the study, therefore that response is not included in results.

and providing contact information for the research team and ERCIC. Follow-up phone calls were placed from the middle of September to mid-October.

For the department and program level surveys on the U.S. side, the research team was not provided with a list of contact information, therefore (following Arundel et al., 2016) we searched the SUNY CC's websites in order to identify the contact information for the department chairs in the four sectors. At some institutions, there may have been multiple departments that could fall under the STEM category (for example some institutions have both a Science and an Engineering department and other institutions have just one STEM department), in the cases of multiple departments, all departments were contacted. The department chair was invited to complete the department level survey and to distribute the program level survey to relevant programs in the department.

5.8.6.2 Informed consent

Informed consent was obtained by asking respondents to give consent directly on the second page of the survey or questionnaire with the statement "By taking the time to complete the survey we understand that you are willing to be part of this study." We chose to do it this way, because by participating in the survey the respondent is indicating consent. We make the statement explicit, but did not want to make it too cumbersome. The e-mails requesting participation provided information about the study and the second page of the survey provided the research team's contact information and informed respondents that the information collected will be kept confidential. The respondents are also offered a chance to receive a copy of the study.

5.8.7 Survey Questions

The full questionnaire at the institutional level and links to the departmental and program level surveys are available in Appendix D.1. Here, Table 5.5 presents a summary of the main topics covered in the institutional level questionnaire. Questions and specific response purpose were meaningfully grouped (Gliem & Gliem, 2003) and scales (and or sub-scales) were identified and checked for internal consistency. The table lists the question groups, provides details about the questions or rationale for the question group, indicates whether we adapted questions from existing survey instruments, and identifies the most relevant literature informing that question group.

Table 5.5: Questions included in the Institutional Questionnaire

Question Group	Details	Adapted from Survey	Literature
Basic Information (Institution)	Degree Programs Offered (Percentages Associates Degree (A.A., A.S., A.A.S), Bachelor's Masters, Other). Date of Establishment.		
Basic Information (Respondent)	Length of time in current position, number of professional staff reporting to the respondent.	Arundel et al. 2016	
Institutional Monitoring the Labor Market for Graduates	Questions are about policies and procedures. Can be taken as evidence of systemic monitoring of external environment and expectations. Active vs. reactive, and systematic vs. non-systematic. Sub-questions ask how the institution scans the external environment and the frequency of updating information. The frequency can indicate how well informed the institution might be regarding changes in the labor market.	BuildPHE	Schneider, 1989
Centralized, decentralized or both	To ascertain whether the level of the survey corresponds to the level of the organization in which labor market information is collected.	No	Lane, 2001
Communication among departments	Flow of information between departments is formal, informal, or both.	No	Dennison, 2014; Lane, 2001; Schneider 1989
Budget and Personnel for monitoring the Labor Market	Questions about the resources (Budget and Personnel) are intended to proxy institutional 'effort' as in firm innovation studies.	Innovation Surveys	IDB, 2016
Sources of Financial Support to adapt or innovate in courses or curriculum delivery	Financial support for innovation can be an important stimulus.	Arundel et al. 2016; Innovation Surveys	Innovation literature
Challenges and Opportunities aligning educational programming with the labor market.	Open-ended questions. If the goal of professional higher education for students is employment, outcome-based educational theory suggests that the system should be partly built around those goals	GAIHE	Spady, 1994
Future Skills	Open ended questions. If society and the work world are focused on occupationally specific qualifications to organize the allocation of jobs, then institutions will be likely to assess the 'match' based on the skills learned in the program. If the work world is less closely integrated with the education system, then the degrees conferred upon graduates are more likely to be the matching criteria. Sets the stage for subsequent questions regarding flexibility of the institution to adapt programming to the skills required in the labor market	Suggested addition by one of the experts consulted.	CEDEFOP, 2001; de Weert, 2011

Question Group	Details	Adapted from Survey	Literature
Collaboration	A range of actors can act as an impetus for innovation.	Innovation Surveys; GAIHE	Olsen, 2007; Arundel et al., 2016
Flexibility (adding or dropping courses)	Designed to ascertain whether education provision is adaptive to changes in the required competencies of external communities (i.e., employers). Program organization as one of the modes of innovation in higher education provision.	GAIHE	Jones et al., 2010
Flexibility (speed)	To establish some indicator of the speed with which the institution might be able to adapt is programming and whether or not this speed changes based on whether a program is being added or dropped.	GAIHE	GAIHE
Flexibility (other reasons for adding or dropping programs)	Establish a 'baseline' of how much innovation is happening within the department in general. A highly innovative department might be more likely to adapt programming to better align with competences required by firms and vice versa.	Arundel et al. 2016	Arundel et al. 2016
General Opportunities and Challenges	Open ended questions, to ascertain what other elements might act as barriers or support to the institutions operations	No	Similar to establishing a baseline described in Arundel et al., 2016 for innovation conditions

The surveys sent to the departmental and program level were more extensive and included more detailed questions about how the program considered the 'match' between employment opportunities and its graduates. The survey asked whether the 'match' was assessed on the basis of credentials, or on the basis of occupationally specific skills. These surveys also included questions about whether innovations were realized via curriculum delivery, and/or content, and/or in to changes in programming (i.e., adding or dropping entire programs). The program level surveys also included questions about apprenticeships, monitoring job outcomes and salaries of recent graduates that correspond to the HBO-monitor a survey of graduates which has been in existence for 26 years.

The institutional level questionnaire was designed to pick up institutional priorities and degree of support for monitoring the labor market and (broadly speaking) the perceived challenges and opportunities that the institution faces in the context of aligning their educational programming to the changing needs of the labor market. It was designed to be shorter and more like a semi-structured interview with many open ended questions. This structure is appropriate given the exploratory nature of the study (Volante, seminar

June 2016). For that reason the institutional level instrument is called a questionnaire rather than a survey. One shortcoming, which we will revisit in the limitations section is that due to the higher response rate to the institutional level questionnaire and low response rates to the department and program level surveys, some of the nuanced information we were interested in investigating has not been captured.[54]

5.9 Survey Results

The response rate for the Netherlands HBO institutional level survey was 54 percent (20 out of 37) and the response rate for the Community College institutional level survey was 40 percent (12 out of 30). All respondents to these surveys were part of top management in the institution. The response rate for the surveys at departments and program levels were less than 5 percent. So, that information has been used to complement the information gathered at the institutional level, rather than for a separate analysis. The responses have been fully anonymized and any comments that have been included in this section are given respondent pseudonyms and other identifying information that may have been provided, such as reference to a particular sector of instruction,[55] has been removed from the content.

This section is divided into two parts. First, we present the results from the Netherlands Institutions of Higher Professional Education. Then, we present the results from the SUNY Community Colleges in the U.S.

5.9.1 Results from the Higher Professional Institutions (HBOs) in the Netherlands

Although our response rate is 54 percent, one concern is that institutions that are more interested in education-labor market alignment would be more inclined to respond to the survey and this would be a source of bias. Only four institutions provided a reason for non-response: lack of time (3 institutions), ill health (1). On the basis of this information we cannot exclude bias and the reader should keep this caveat in mind.

Respondents were asked whether their institutions have a policy or formal procedure for collecting labor market information, or they 'do not have a formal procedure, but labor market information is collected'. Fourteen (70 percent) of the HBOs surveyed indicated that they have a policy about collecting information, 8 (40 percent) reported that they have a formal procedure and 6 (30 percent) indicated that although they do

[54] Particularly on the Dutch side, it should be noted that the failure to incorporate questions regarding nuances of modes of innovation (curriculum deliver and content) rather than changes in programming in the institutional level questionnaire was an oversight.

[55] Since the universe of institutions is small and known to each other, referencing a particular sector of work may reveal the institution giving the response and so we seek to prevent that from occurring.

not have a formal procedure, but labor market information is collected. These questions were asked to gauge the degree of formalization (Schneider, 1989), since the degree of formality may have implications for an organization's external environment scanning mechanisms (i.e., Active vs. reactive, and systematic vs. non-systematic). Please note that having a policy and a formal procedure are not necessarily mutually exclusive categories. Some institutions reported having both a policy and a formal procedure, some reported having just a policy or formal procedure.

If the respondent answered positively to any of these three questions, the respondent was then asked to briefly describe the policy, procedure, or the way in which they collect labor market information. Open-ended responses were then grouped together and analyzed using qualitative coding techniques (Meyer and Avery, 2009) to search for common themes in the responses. Table 5.6 tallies and reports the results. The most commonly reported mechanism is advisory boards and committees.

Table 5.6 Emergent Themes in Mechanisms used by HBOs to Monitor the Labor Market for Graduates

Emergent Themes	Percentage	Number
Advisory Board / Committee(s)	60%	12
Research[56]	50%	10
Alumni[57]	45%	9
Teachers are active professionals in the labor market	35%	7
Alliances with Companies	25%	5
Internships / traineeships	20%	4
Private sector involvement in curriculum development /projects	15%	3

Please note that some institutions mentioned using several of the mechanisms tallied in Table 5.6. There was no question on the questionnaire that took the 'object' approach described in Arundel et al. (2016), to ask, for example, about the most important mechanism used.

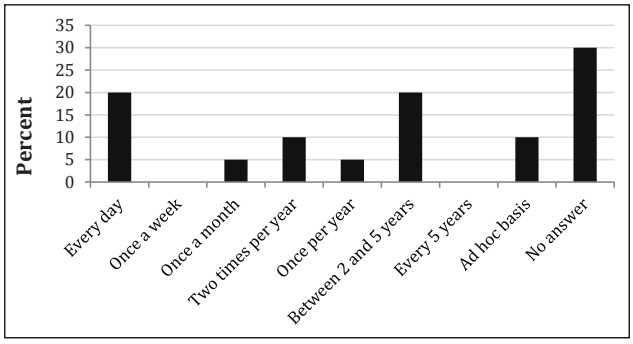
[56] Research (or data collection) was sometimes described as an in-house endeavor, but often respondents mentioned other sources: HBO-Raad (2), VH (1), ROA (2), CBS (1), PON (1), CDHO (1) in this answer. References may also have been made to these entities in other answers in the survey, but this count is for answers to questions about policy and procedures only.

[57] Some institutions collected information from their alumni on their own. Four institutions referred to the HBO-monitor (a survey of HBO graduates) as a source of information about their alumni used to collect in answers to questions about policy and procedures.

A sub-question in the group of questions about 'Institutional Monitoring of the Labor Market for Graduates' in the questionnaire asked respondents "How frequently does your institution update information about the labor market for its graduates?" In the questionnaires that were conducted over the phone or in person, it was clear that the frequency with which the institution updated information, depends on the mechanism being used. For example, many of the institutions that reported having teachers who are active professionals in the labor market consider this a very integrated approach and therefore, information (via that mechanism) is updated daily. When research was cited as the mechanism used to collect information about the labor market updates tended occur more periodically.

From the few responses to the program (opleiding) level survey (15 from all 4 sectors pooled), it seems that skills are equally if not more important than the degree for assessing the suitability of job opportunities. In response to the following question, "What criteria does your course (HBO-opleiding) use to assess whether a job opportunity would be suitable for its graduates?" the majority of respondents indicated "skills listed in the job opportunity correspond to the HBO course". Around half of the respondents indicated "the degree required for the job corresponds to the degree offered by the HBO course" and around one third of the respondents indicated "If alumni have found employment in the same occupation listed in a job vacancy, then the opportunity is suitable for graduates". Program level respondents indicated that they collected information about the specific skills required by jobs today and try to anticipate skills required by jobs in the future.

Figure 5.2 Frequency with which HBO institutions update Labor Market information



It was also noted by one respondent that the alignment mechanisms and frequency with which the information is updated can be very different in different sectors. Resp18[58] "The relationship between the different courses and the labor market can be very different in different sectors [for example] education vs. economics. We [they] still have courses that have a 1:1 relationship between the labor market and program, but more and more it is not 1:1 between the courses and the jobs the alumni occupy."

There was relatively even distribution of responses with respect to whether "monitoring the labor market' a centralized process at the institutional level, or is it decentralized at the departmental level?" Table 5.7 shows that 40 percent of the institutions we surveyed reported that this activity is conducted at the departmental level or another level of the organization. 60 percent of the respondents indicated that this activity takes place at the institutional level, or at both the institutional and departmental levels. Again, it is important to note that some institutions provided answers that indicated that, depending on the mechanism being used to collect information about the labor market; the process was either centralized, or decentralized. For example, Resp6 said the field committees were decentralized at the level of bachelor's programs, whereas market research and advisory board were centralized.

Table 5.7 HBO Monitoring the Labor Market is Centralized, Decentralized, or Both

Answer	Percentage	Count
It is centralized at the Institutional level	25%	5
It is decentralized at the departmental level	25%	5
If it is done at both levels	35%	7
It is done at another level of the organization	15%	3
Total	**100%**	**20**

The following comments reveal insights that are important to understanding the categorical responses tallied in Table 5.7. Resp8 indicated that, "Through the practicums (apprenticeships) the distance between the potential employers and the institution is very short; therefore the contact is very diffuse among all staff and students at the institution." Resp9 noted that, in addition to other mechanisms, the institution "has a Policy officer who collects data about the labor market; so there is a person who is in charge of that, because this is one important way to stay in touch and to know what is happening." Resp14 reported that, "This is done at every level; at the strategic level - the Executive Board is engaged with a variety of organizations in the society (i.e., professional

[58] To protect the anonymity of the respondents, a respondent number has been assigned to the respondent and the reference pseudonym is simply Resp#, short for Respondent + the number that has been assigned.

associations, labor organizations, economic development offices). The strategic plan is updated and they check to make sure courses are up to date and they assess what they have and what is missing. Meetings with the executive board occur every two months. The integration of the instructors with the labor market, by being active participants in the labor market is considered a crucial means by which up-to-date practices from the labor market flows directly from the instructors to the students." Resp17 stated that, "It is both centralized and decentralized, they are complementary approaches." These comments underscore the importance of collecting qualitative data during the phase of exploratory investigation regarding the practices at higher-professional organizations.

When asked about how communication between departments is organized, 45 percent of respondents indicated that it was done both formally and informally. A total of 15 percent of respondents indicated that communication between departments was organized through formal channels at regular (10 percent) or irregular (5 percent) intervals. Two respondents (or, 10 percent) indicated that communication is organized through informal channels. One respondent did not know how the communication between departments is organized and five of the respondents either did not select an answer for this question or indicated that it was not relevant for their institution (i.e., the institution does not have departments).

The questions on budget and personnel allocated to the activity collecting information about the labor market were designed to mimic questions in Innovation Surveys that ask about investment in innovation activities (for example, CIS 2012). Twelve respondents (60 percent) could not respond to these questions, at least not in the terms in which the questions were phrased (percent of last year's budget, number of staff, and FTE equivalent). Therefore, answers to these questions cannot be used as we originally intended, as some kind of proxy for institutional 'effort' to monitor the labor market.

Since the literature identifies that a range of actors can act as an impetus for innovation (Arundel et al., 2016; GAIHE, 2016) we asked about whether, in the past three years the institution had received any financial support from the private sector, other educational institutions, or the public sector to adapt or innovate in courses or curriculum delivery. All of the HBOs surveyed are publically funded to begin with, but 55 percent of the institutions responded that they had received additional financial support from the public sector specifically for this activity. 45 percent of the respondents noted that, apart from normal funding, they had not received additional funding for this activity. One respondent reported that the institution had not taken advantage of existing public funding opportunities for innovation, because the application and reporting process is too bureaucratic. Twenty percent of respondents reported that they received financial support from the private sector for innovation in courses or curriculum development

and 10 percent of respondents indicated that they received financial support from other educational institutions for this activity. In comments that correspond to this question, a running theme was that, even if funding was not attached, collaboration on projects or grants with other educational institutions, private or public sector entities tend to be seen as valuable connections by the HBO institutions.

In order to address our second research question for this study, we directly asked two open-ended questions (1) "In your own words, please briefly describe the most relevant opportunity for your institution for your institution in terms of aligning its educational programming with the labor market". (2) "In your own words, please briefly describe the most relevant challenge for your institution in terms of aligning its educational programming with the labor market". Using qualitative coding techniques, we then searched for and identified themes among the answers. Then, we tallied the number of institutions that mentioned a particular theme as either an opportunity or a challenge, Table 5.8 presents the results.

Table 5.8 Opportunities and Challenges for HBOs in Aligning Educational Programming with the Labor Market

	Opportunities		Challenges	
Emergent Themes	**Percentage**	**Number**	**Percentage**	**Number**
Cooperation (or Connection) with Industry / Labor Market	20%	4		
Even better fit with the profession	20%	4		
Teachers	15%	3	10%	2
Alumni / Students	10%	2	5%	1
Research / Collaboration with other Academic Institutions	10%	2		
Influence / shape the future LM	5%	1		
Life-long learning	5%	1	5%	1
Digitalization	5%	1	5%	1
Keeping up with changes in society, or staying informed			10%	2
Finance*			10%	2
Keep industry interested; pulled in different directions			10%	2
Identity			15%	3

*Investment costs for new equipment, or structure of funding for partnerships

Examples of respondents who indicated Cooperation with Industry or the Labor Market as the most relevant opportunity are statements such as the one from Resp5 "strong and constant collaboration and interaction with companies"; or from Resp2 "innovation in cooperation with the labor market". Examples of respondents who indicated teachers as the most relevant opportunity are statements such as the one from Resp14, "[they] try to work as much as possible with teachers who have one leg in the labor market and one leg in the institution. This makes the connection between the labor market and the education very strong." Examples of respondents who identified Keeping industry interested are statements such as the one from Resp3, "Keep the industry interested. Give the industry value for money/time" or being pulled in different directions, such as the statement from Resp5, "Different companies ask for different things".

When asked, "Beyond jobs and skills that might be required today, does your institution try to anticipate changes in skills required for jobs in the future?" 100% of the respondents answered 'yes'. Two subsequent open-ended questions were asked about opportunities and challenges in trying to anticipate skills required by jobs in the future. Table 5.9 presents the results. It is interesting to note that while many HBOs see their teachers as an asset in terms of aligning today's educational programming with the labor market, when asked about anticipating future skills, 35 percent of the respondents indicated something having to do with teachers as the most relevant challenge. Examples are statements such as Resp3, "Get support from our staff for a change", or Resp5 "culture change for the teachers, or Resp6 "create awareness by teaching staff for this kind of development", or Resp7, "To be digitally competent. Entrepreneurship. Both are competencies that [their] teachers and researchers have to obtain themselves. There is a gap to what is necessary and what is available.", or Resp12 "A high percentage of the teachers in the schools do not have open minds for new technology.", or Resp15 "To have lecturers that are up to date.", or Resp17, "…teachers need the skills…".

Table 5.9 Opportunities and Challenges for HBOs in Anticipating Skills Required by Future Jobs

	Opportunities		Challenges	
Emergent Themes	**Percentage**	**Number**	**Percentage**	**Number**
Alumni / Students	40%	8	50%	10
Cooperation (or Connection) with Industry / Labor Market	10%	2		
Even better fit with the profession	10%	2		
Teachers	5%	1	35%	7
Research / Collaboration with other Academic Institutions	5%	1		
Influence / shape the future LM	5%	1		
Life-long learning	5%	1		
Digitalization	5%	1	15%	3
Keeping up with changes in society, or future employment conditions			15%	3
Innovation in Education is not easy			10%	2
Finance			5%	1
Needs a Multi-disciplinary Approach			5%	1

The greatest percentage of HBO institutions indicated some thematic element related to their students or graduates (alumni) as the most relevant challenge for anticipating skills required by future jobs. Examples are statements such as the one from Resp14, "[they are educating] students partly for professions that do not exist yet. They have their own research institutions – to look into what (for example, robotics, AI) mean for their educational programming. They also look into what kind of skills their students have to learn (or gain) to be prepared. The biggest challenge is how in the future their students as workers have to think about their position in relation to robots and AI, the 'art of work' will change and the critical sense in which they have to learn and act is different from now." Other examples included references to: Personal Skills; what is needed for a student to enter future with confidence [translation of: "Wat is voor een student nodig om de toekomst met vertrouwen in te kunnen gaan?"], entrepreneurship; soft skills; social awareness; preparing for jobs that do not exist yet. Two of the institutions responding to this survey mentioned a desire not only to respond to the labor market, but also to help shape the labor market and the surrounding community and society (one respondent mentioned this in the context of the questions about current opportunities and the other mentioned this in the context of future opportunities). While some of the responses were anticipated (such as, staff resistance to change) from the literature, other responses such as the desire to shape the labor market were unexpected and underscore the relevance of conducting this kind of exploratory qualitative coding to generate themes. Pre-prepared response categories might have missed some important

information that the HBO institutions provided us with through their thoughtful answers to this questionnaire.

The majority of survey responses at the program (opleiding) level indicated that new modules were introduced in "Response to our monitoring of changes in skills required by potential employers", or in "Response to student requests". Many respondents also indicated, "Societal relevance" and "Strategic reasons (as perceived by Management)". The response patterns were quite similar for changes in curriculum delivery and curriculum content. It seems that student requests drove changes to curriculum delivery, whereas labor market changes in skills required by potential employers drove the introduction of new modules or changes to curriculum content. Only two respondents (out of 15) indicated that modules would not "add or drop modules (tasks, or projects) based on whether the content in the course provides training for the skills required in potential jobs for graduates". In general, it seems that adding a module could take about a year, and dropping a module might take closer to 2 years.

The open-ended responses at the department and program level echoed the information gathered at the institutional level. For example, in response to the question about how the program (opleiding) collects information about specific skills required for potential jobs for graduates, one respondent wrote, "Verzameld schrijf je in deze enquetevraag met een t ipv een d. Niet om lullig te doen, maar het wordt gezien. Vakgebied volgen, deskundigheid van docenten tav nieuwe ontwikkelingen in hun vakgebied via (in company) cursussen deze kennis wordt meegenomen in ons onderwijs." This response underscores what we found in the institutional level survey, because it indicates teachers, actively engaged in the profession, as the main conduit of current labor market information. Some challenges described by respondents when trying to anticipate skills required by jobs in the future were, "social media" and "The biggest challenge is to look into the future, to predict the skills required in the near future, in close consultation with our external network".

5.9.2 Results from the Community Colleges (CCs) in the SUNY System in New York State

Our CC response rate is 40 percent. Our concern is that institutions that are more interested in education-labor market alignment might be more inclined to respond to the survey, which could create an upward bias in our results. Despite the fact that a portion of our follow-up was conducted over the phone we were not able to obtain much information about reasons for non-response: one institution simply stated that it could not participate in our study at this time; in two cases the support staff to the President indicated that it would be brought to the attention of the President, but that a response could not be guaranteed.

In response to the questions about whether the higher-professional education institution has a policy, formal procedure, or if not having a formal procedure collects information about the labor market. Nine of the CCs surveyed (75 percent) indicated that they do not have a policy about collecting information, five reported that they have a formal procedure (40 percent). Seven CCs answered that they do not have a formal procedure, but that information about the labor market is collected (60 percent). Please note that having a policy and a formal procedure are not necessarily mutually exclusive categories. Some institutions reported having both a policy and a formal procedure, some reported having just a policy or formal procedure.

The descriptive information provided in open-ended responses to "Please briefly describe the policy, formal procedure, has for collecting information, or way in which your institution collects information about the labor market for your graduates" was then grouped together and analyzed using qualitative coding techniques to search for common themes in the responses. Table 5.10 tallies and reports the results. The most commonly reported mechanism is research.

Table 5.10 Emergent Themes in Mechanisms used by CCs to Monitor the Labor Market for Graduates

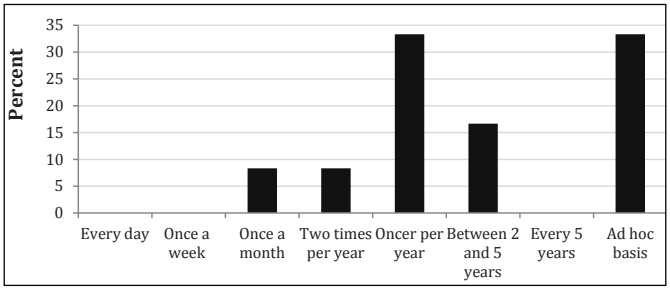
Emergent Themes	Percentage	Number
Research	67%	8
Alumni	17%	2
Regional Economic Boards	17%	2
Advisory Board / Committee	8%	1
Gainful Employment Disclosure Template managed by the US Department of Education	8%	1

The most commonly reported mechanism is research. Four of the respondents coded mentioned the New York State Department of Labor (NYS DOL) and U.S. Department of Labor (US DOL) job outlook in their responses, one respondent mentioned 'JobsEq by Chmura and SUNY', one respondent mentioned EMSI, and one respondent mentioned the census. Four of the 8 institutions that mentioned research in the open-ended answers had indicated 'We do not have a formal procedure, but labor market information is collected' to the previous question. An example of a response, is a statement from RespCC1, "Tri annual Environmental Scan is completed which includes occupational trends, industries sectors and projected growth locally and nationally." Two CCs who responded that they survey their own graduates were

coded under the emergent theme 'Alumni'. For example, Resp11 stated, "We also send out labor market related surveys to graduates from respective programs once a year on job placement." RespCC12 indicated that, "We do not collect this information for graduates; we use labor market data to create new credit and non-credit programs and for strategic planning."

In response to the question, "How frequently does your institution update information about the labor market for its graduates?" most respondents indicated that it was done once per year, or on an ad-hoc basis.

Figure 5.3 Frequency with which CC institutions update Labor Market Information



Eight respondents (67 percent) indicated that "monitoring the labor market' is done at both levels (institutional and departmental). Examples of comments given with respect to this question are from RespCC2"Institutional research and the President's Office at a central level, at the department level through advisory committees for curriculum", or from RespCC3 "Departments meet twice a year with external advisory boards to monitor the labor market and skills needed.", or from RespCCx "Office of Institutional Effectiveness obtains employment outcomes data and the Office of Applied Learning/ Job Development examines the labor market as it relates to internship and employment possibilities for current students."

Table 5.11 CC Monitoring the Labor Market is Centralized, Decentralized, or Both

Answer	Percentage	Count
It is centralized at the Institutional level	17%	2
It is decentralized at the departmental level	8%	1
If it is done at both levels	67%	8
It is done at another level of the organization	0%	0
No answer	8%	1
Total	100%	12

There was a relatively even distribution with respect to the question about how communication between departments is organized as can be seen in Table 5.12. Most of the respondents who added a comment with respect to this question mentioned meetings as the more formal means of communication. These meetings were described as being held with members of different departments and committees or advisory boards. Informal communication was described as conversations within senior administration, or 'as-needed' when departments review and modify curriculum.

Table 5.12 How is CC Communication among Departments Organized?

Answer	Percentage	Count
Through formal channels at regular intervals (at least once per year)	25%	3
Through formal channels at irregular intervals	8%	1
Through informal channels	33%	4
If it is done at both formally and informally	33%	4
Total	100%	12

Using qualitative coding techniques, we then searched for and identified themes among the answers to the open-ended questions about the most relevant opportunity and the most relevant challenge for the institution in terms of aligning its educational programming with the labor market. Then, we tallied the number of institutions that mentioned a particular theme as either an opportunity or a challenge, Table 5.13 presents the results. Three of the responses under challenges were coded as data challenges. These respondents mentioned that "Collecting labor market outcomes of graduates - no connection between State Labor data and State University system data", low response rates to the graduate follow-up surveys and "New job opportunities are often not reflected in labor market data from Department of Labor; it is based on SOC

codes. For example, new green technology jobs are hard to predict because they cross "old" technology job titles. Also this data isn't updated regularly, so it doesn't reflect new companies moving to the region or jobs that fluctuate (ex. teaching)."

Table 5.13 Opportunities and Challenges for CCs in Aligning Educational Programming with the Labor Market

	Opportunities		Challenges	
Emergent Themes	**Percentage**	**Number**	**Percentage**	**Number**
Alumni / Students	8%	1	8%	1
Teachers			8%	1
Cooperation (or Connection) with Industry / Labor Market	8%	1		
Funding for infrastructure development	8%	1	17%	2
Data	25%	3	25%	3
Digitalization	8%	1		
Influence / shape the future LM	8%	1		
Keeping up or staying ahead of changes			25%	3
Demand in the labor Market			8%	1
Time			8%	1

When asked, "Beyond jobs and skills that might be required today, does your institution try to anticipate changes in skills required for jobs in the future?" All of the respondents answered 'yes'. Two subsequent open-ended questions were asked about opportunities and challenges in trying to anticipate skills required by jobs in the future. Table 5.14 presents the results. It is interesting to note that while not many respondents indicated opportunities, the bulk of the challenges are in keeping up with the changes in society and labor market conditions.

Table 5.14 Opportunities and Challenges for CCs in Anticipating Skills Required by Future Jobs

	Opportunities		Challenges	
Emergent Themes	**Percentage**	**Number**	**Percentage**	**Number**
Alumni/Students	8%	1	8%	1
Teachers	8%	1	8%	1
Infrastructure redevelopment	8%	1		
Curriculum development (need Experts)			8%	1
Time			8%	1
Data			8%	1
Keeping up with changes in society and Future employment conditions			33%	4

The community college responses to the program and department level surveys were also very few in number. In total there were 5 complete department level responses and only one complete program level response. The answers to open-ended questions tended to echo the responses from the institutional level surveys. For example, when asked about the most relevant challenge for your program when trying to anticipate skills required by jobs in the future, one respondent wrote, "Obtaining reliable and useful data on future employment needs. If a new program is developed to meet anticipated new skills, the documentation required is very time consuming and the approval process is very long - usually more than a year." Another respondent wrote, "technology updates and improvements…" policies and procedures for collecting labor market information in community college departments tend to be less formal and more ad-hoc than in the HBOs in the Netherlands. The time required to adapt educational programing appears to be rather fast in both contexts.

5.10 Limitations

The limitations that have the greatest impact on the results presented in this study are that although we have a reasonably high response rate for this kind of study, we do not have enough information about our non-respondents to assess the representativeness of the responding institutions for the whole sample of higher professional education institutions in either the Netherlands, or New York State. Furthermore, the very low response rates to the department and program levels surveys do not allow us to analyze this information in a meaningful way independently of the institutional level survey. Since the department and program level surveys contained more extensive and more nuanced questions, we also did not collect (at a large enough scale) information that

could be used to make inferences about how the relative formalization of policies and procedures, frequency of updating information, or communication within institutions might impact outcomes such as job placement rates or average salaries of graduates. Since this study represents the first of its kind (as far as we know) it remains an exploratory investigation. We believe we have culled novel information from the surveys we developed and implemented, but as with any survey that is run for the first time, the results should be cautiously interpreted and therefore, in the discussion section we draw tentative conclusions.

5.11 Conclusions

In the first part of this chapter, we researched whether the type of higher educational formation (vocational or general) has any bearing on education-job match and skill use. We found that the institutional context and structure of the national education system does affect these labor market outcomes. We found that typically people who pursued vocational higher education have less education than would be required by their employers. People who studied in general academic tracks at the tertiary level tend to use numeracy skills at work more frequently. We found that the vocational intensity of the national education system matters. Denmark has an apprenticeship based vocational system and there we find studying vocational higher education increases the probability of an exact education-job match and is associated with greater use of numeracy skills at work. We conclude that the national structure of education institutions matters for education-job match and skill use.

The workplace relevance of higher education is a metric by which the performance of higher education systems is being evaluated. Looking toward the future, higher education institutions may need to adapt themselves more frequently and at a more rapid pace, in order to keep up with new technologies that are changing the landscape of many workplaces. There is very little information about the challenges for higher education institutions when they try to innovate or adapt to better align their educational services to engender skills in their soon-to-be graduates that are well matched with what employers need.

In an effort to gather information about the kinds of issues that higher professional education institutions face, we surveyed top management of HBOs in the Netherlands and Community Colleges in New York State. The results that emerged were different in the two contexts, but both have clear policy implications.

We have ascertained that many of the Netherlands HBO institutions that responded to our survey have policies and procedures for collecting information about the labor market for their graduates. The most common mechanism used for collecting this information is advisory boards and committees, although many institutions use multiple mechanisms including reliance on research provided by public agencies and research institutions as well as a strategy of employing teachers who are themselves active in the professional field. In the Netherlands many of the HBOs rely on their teachers' integration in the labor market as an information transmission mechanism. Some institutions highlighted this as a strong link and a way to keep up with the latest developments in specific fields. Other institutions highlighted this as a challenge, indicating that sometimes teachers own digital skills might be outdated, or that teachers might not always welcome innovation. This appears to be a bottleneck for some HBOs. This is something that could be undertaken by public entities wishing to support the overall infrastructure of higher-professional education in the Netherlands. Broad support for opportunities to upgrade skills and perhaps, for some teachers who may be reluctant, incentives should be offered to engage in acquiring new skills.

The Community Colleges in New York State's SUNY system tend to rely on data that are offered at aggregate levels and several respondents expressed either as a challenge or an opportunity access to data that is more specific to their own graduates. Data that are collected by the department of labor could be reported at a more disaggregated level. The system could also launch a community college graduate survey as the Netherlands has with information about how the graduates perceive the utility of their education at their place of employment.

In short, what the HBOs in the Netherlands seem to need to support their connection with the labor market, is support for their teachers. What the Community Colleges in NYS seem to need is useful data that can help them track and monitor changes that are relevant for their students and graduates.

There is ample opportunity to further investigate what higher education institutions need in order to innovate and what might help them to keep their educational services relevant for employers.

These results and conclusions are preliminary and have been circulated to respondents for any corrections or oversights in the write-up of the study.

Chapter 6

Conclusions: Education Pathways and Skills Outcomes: Past, Present and Future

In the past, when employers wanted skills immediately relevant for new technology, products, or production processes; this need was met by in-service training or (increasingly) vocational training. With time, the general education component in vocational training has increased to accommodate the broader skill sets needed by employers. For example, general communication skills are considered to be important and technical skills need to be broader. Rapid technological change, especially digital transformation, has provoked a new requisite for students to acquire the skills for continuous learning. Thus, the lines have become blurred between general (transversal) education and vocational education "designed for, and typically leading to, a particular job or type of job." (OECD, 2010 p. 26). This makes it even more important to assess the role of the vocational component of education.

This thesis evaluates educational pathways that have facilitated skill development relevant for the workforce, through different lenses: the past, the present, and the future. Analysis of the past is a two-step process. The first step establishes a method for the identifying vocational education through a recombination of existing datasets to generate new vocational variables. The second step uses this distinction to make a cross-country comparison of the long run economic benefits of vocational secondary education. With the historical contribution of vocational education more carefully understood, the thesis moves to the present and future. The present lens investigates (in a subset of countries) whether greater public investment in education facilitates superior cognitive skills in adulthood, and investigates whether vocational pathways presently result in comparatively different education-job matches and skill use on the job. The analysis from the lens of the future exploits qualitative techniques to inquire how higher professional education institutions can stay abreast of the changing educational requirements and skills needed by the workplace in the near future.

The following research questions are explored **(6.1) Over time at the aggregate level –** how does the composition of human capital and specifically the years of vocational secondary schooling affect GDP per Capita and economic growth at different stages of economic development? **(6.2) In a contemporary setting –** how does public funding for education affect adult cognitive abilities and does the spread and timing of investment over an educational lifetime matter? How do vocational higher educational pathways affect the education-job match and use of numeracy skills on the job? **(6.3) With an eye toward the future** – what are the challenges and opportunities for modifying current education options available? How can we qualitatively observe and gain insight from the efforts of higher professional education institutions to adapt and innovate to be attuned to the future?

6.1 Analysis of the Past: Time Series

The types of skills needed for the labor market vary over time, across the globe, and change in response to technology (OECD, 2017b). The debate about the economic relevance of vocational (job-specific) skills, typically generated through distinct educational pathways, is not new (McGrath, 2012; Oketch, 2007). But this debate has traditionally hinged on theoretical arguments, because the data with which to distinguish vocational education over long time horizons simply were not available. The issue of whether some compositions of aggregate human capital with more vocational education (measured in years of vocational secondary schooling) are better for economic growth is still a relatively open question. We need a data base that distinguishes between vocational and general education over a long time period. This is the first issue tackled by this thesis.

How has vocational education at the high school level affected economic performance over the past 50 years? To answer this, we first construct in Chapter 2 a data base which combines two existing datasets to create internationally comparable variables for vocational secondary education for 129 countries from 1950 to 2010. UNESCO has reported statistics on vocational enrolments since the 1950s, and so the vocational to total enrolment ratio has traditionally been available for anyone with access to those statistical yearbooks. With these data alone we can already observe how vocational to total secondary enrolment ratios have changed with time.

Since the early 1990s, Barro and Lee (1993, 2000, and 2013) have periodically released datasets on educational attainment and years of schooling. The data are also available separated by primary, secondary and tertiary levels for both attainment and years of schooling. We combine Barro and Lee (2013) with UNESCO enrolment data to create vocational secondary attainment and a variable for vocational secondary years of schooling. The trend in vocational secondary attainment relative to other levels of educational attainment has been stagnant or even declined in aggregate across the 129 countries. Although vocational secondary attainment has increased over the last 50 years, it has increased less rapidly than general education. The patterns for all three variables, (a) vocational to total secondary enrolments, (b) vocational secondary attainment and (c) vocational secondary years of schooling vary within and between countries and vary within and over the time period. This means that cross-country analysis could be very effective. As far as we know, this is the first attempt to combine two existing datasets to create internationally comparable variables for vocational secondary attainment and years of vocational secondary schooling.

In Chapter 3 we exploit the value of the scientific method and reproduce the results of four classic cross-country studies that explored the relationship between human

capital (proxied by overall years of schooling) and macroeconomic performance. The selected studies capture four distinct dimensions of the relationship between education and macroeconomic performance, covering much of the macroeconomic scholarly ground on human capital (Savvides & Stengos, 2009). The mechanism that we believe the original authors had in mind for the role of education in their study is as follows: education as a determinant (Barro and Lee, 2010); education as a structural variable (Szirmai & Verspagen, 2015); growth promoting spillovers from education (Pritchett, 2001); and education as a conduit for technology diffusion (Benhabib & Spiegel, 2005). Once we were satisfied with our replication of the original study, we updated the data, and introduced our new vocational secondary schooling variable, creating a distinction between vocational and non-vocational years of schooling in those analyses.

Re-running the analyses we find that our variable, years of vocational secondary schooling, consistently has a strongly significant and positive relationship with economic performance. As a determinant of GDP per worker, we find that vocational secondary schooling contributes to overall economic performance, but when we use GDP per capita as a dependent variable, the contribution of vocational secondary schooling is even greater. We expect that this is because of an employment effect. Theory tells us that vocational education should facilitate education to work transition and this appears to be borne out by the empirics. When we consider vocational secondary schooling as a proxy for absorptive capacity, we find that its contribution varies with the distance to the technological frontier (which is taken to be GDP per capita of the United States). We find this to be the case both when we take a structural approach (following Szirmai & Verspagen, 2015) and when we consider vocational secondary schooling a conduit for technology diffusion (following Benhabib and Spiegel, 2005). When we introduce vocational secondary education capital, building on methodology used by Pritchett (2001), we do not see macro-returns that are greater than what would be recouped by individual micro-returns.

In our own empirical approach, we address autoregressive dynamics and the likely persistence of our variables. We find that countries have to be close to the technological frontier (at least 65 percent of the GDP per Capita of the United States) to take advantage of vocational education. This is our interpretation at this point, but further research could be done to test and refine this finding. We revisit this in the discussion (section 6.4).

6.2 The "Present": Cross Sectional

A fresh urgency has emerged to understand whether job-specific skills are in demand in the labor market, or at risk of being displaced. The current wave of rapid technological change seems to have increased demand from employers for immediately useable skills attuned to new production methods and products. The World Economic Forum surveyed human resources, talent and strategy executives, from 371 companies across nine industry sectors in emerging and developed economies, for their views on how demand for core work-related skills will change by 2020. Respondents anticipate the highest growth in demand will be for cognitive abilities (i.e., mathematical and logical reasoning) and predict the most stability in technical skills (i.e., equipment operation, maintenance, and repair and programming); whereas physical abilities are expected to experience the greatest decline in demand (WEF, 2016). We know from past experience that investments in skills are central for people and economies to adjust to structural change, but a precondition for that investment to be effective, is good information about the skills needed (Bakhshi et al., 2017). How does public investment in primary, secondary and tertiary education relate to adult cognitive skills? This is the second issue tackled by this thesis.

Adult numeracy scores have been shown to be a better measure than years of schooling when explaining differences in cross-country economic performance (Hanushek et al., 2015; Sasso and Ritzen, 2016). Vocational (job-specific skills) are not the only skills valued in the workplace, however. Cognitive abilities in mathematical reasoning are also highly valued in the labor market and by economies. In Chapter 4 we use the adult numeracy skills as measured by the PIAAC data to determine how public investment over a person's educational lifetime impacts adult numeracy scores, controlling for family background, educational attainment, work experience, age, and country 'fixed effects'. We find that additional investment increases adult numeracy scores, but we also find that the spread of that investment matters. It is important to have high levels of investment in primary education not only because primary education is a prerequisite for higher levels of education attainment, but also because greater investments in primary education are shown to increase the chances of attaining higher education. Of course, as we move up the educational ladder, numeracy scores also increase, but investments all along the way matter, and they interact with each other. We use a three-way interaction term between investments in each educational phase to test the complementarity between investments in any two phases with respect to the third. Investments in primary and tertiary education are complementary in the presence of at least some investment in secondary education, but after a certain threshold, these investments can become substitutes. A representative investment threshold is calculated. The threshold itself is specific to our dataset, but should be of interest to policy makers who sometimes have to choose whether to invest

more or less in a particular stage of the educational process. Other variables that are known to contribute to adult numeracy scores follow the patterns we would expect. Being born outside the country has a perhaps surprisingly strong negative association with numeracy scores in adulthood. This is probably partially due to the fact that we had to exclude people with foreign education qualifications from the analysis, since we could not accurately assign investment information in those cases.

Chapter 5 turns attention to higher education. The number of students entering higher education in OECD (and G20) countries has increased by 45 percent and this trend is expected to continue (OECD, 2017a p. 10). There is a peek in enrolment following the 2008 financial crisis, which reflects an influx of post-recession students. The number of students in higher education plateaus after 2011 when many economies began to improve. The slowdown in expenditure in higher education after 2011 could be a reflection of tax-payer or public uncertainty regarding the 'value for money' of higher education. The third issue tackled by this thesis is; how does education-job match and cognitive skill use differ for people who pursued vocational higher education pathways?

As of 2014, more than a third of almost 40 thousand employers were having difficulty filling vacancies due to lack of available talent. This may be partially due to the fact that new technologies require specific new skills that are not yet taught in schools and not provided by employers (i.e., on-the-job training) (Bessen, 2014). As an example, Bessen describes how graphic designers needed to know Flash a few years ago, but now they need to know HTML5. Graphic arts schools struggle to keep up. Bessen goes on to argue that designers are presented with a conundrum, they have to teach themselves new skills on the job, but these will not be certified standardized skills and so they are difficult for prospective employers to evaluate. So, as the shelf-life of higher professional education today is getting shorter and shorter, the tendency has been to include general content and training to develop skills that are more resistant to change. Indeed, workforce analysts and educators suggest students need to be equipped with "21st Century Skills" which include communication skills, the ability to work in teams and solve problems, adjust easily to new work environments, technical/digital savviness, and critical thinking (Trilling and Fadel, 2012; Holzer, 2017). Although this indicates a blurring of the lines between what has been traditionally thought as vocational versus general higher education, there are still distinctions between the two educational pathways. A greater emphasis on the workplace relevance is built into the educational curriculum of higher professional education.

The first part of chapter 5 uses the PIAAC data to ask whether vocational and general higher education produce a systematically different education-job match and numeracy skill use outcome. We find systematic differences, although our ability to assess the

extent of these mismatches is limited by the cross-sectional nature of the PIAAC data. We find people with vocational higher education in 2011 had less education than required if their employer were to hire them today for the same job. We also find that on the job numeracy skill use for people with vocational higher education is less frequent than for those with general higher education. The structure of the education system is relevant. Grouping countries by the vocational intensity of their education systems can change the conclusions completely. In Denmark, a country with an apprenticeship-based vocational education system, people with vocational higher education have a greater chance of education-job match and use their numeracy skills on the job more than people with general higher education, for example. We will return to this finding in the discussion in section 6.4.

6.3 The Future: Adaptability of Higher Vocational Education

How do education institutions keep up with changing skill requirements? The 'halving' period for skills acquired during higher education is getting shorter and shorter (WEF, 2016). A computer engineer's newly acquired knowledge may be obsolete one year after graduation (Lundvall, 2007a). And although education has traditionally taken time to adapt to technological progress (Schleicher, 2015), if education and training systems can adapt more seamlessly to the changing skills needed in the workplace it will strengthen the growth opportunities presented by recent technological advances (Bakhshi et al., 2017).

We surveyed public higher professional education institutions in two countries with very different education systems. The results are reported in the second half of Chapter 5. The Netherlands is classified (i.e., Hanushek et al., 2017 and Hampf and Woessman, 2016) as a school-based education system and New York State (in the United States) is classified as a non-vocational school system. At the institutional level, we had a 54 percent response rate from the Universities of Applied Sciences in the Netherlands and a 40 percent response rate from the SUNY Community College in New York State.

We find that 100 percent of the vocational institutions we surveyed are paying acute attention to the workplace requirements for their graduates and are keen to anticipate the future needs. But the methods and vulnerabilities in the two places surveyed differ completely. The Universities of Applied Sciences in the Netherlands rely on their teachers to be conduits of up-to-date knowledge of the labor market for their graduates. The Netherlands institutions seem to have access to the type of data they might need, but a vulnerability is that the teacher may be frozen into the current job requirements. The Netherlands institutions worry about the challenge of teachers needing to skill-up

alongside the needs of the labor market. The challenges in New York State are different. The SUNY Community Colleges report that the challenge to labor market analysis and planning is that the data available to them are not disaggregated enough to be useful. There is not something equivalent to the Netherlands' HBO-monitor in New York State. The HBO-monitor is a Dutch survey that has monitored higher professional education graduates from different institutions and programs for the past 26 years and asks graduates a series of questions about employment, salary, skill use and the relevance of their education for their current job.

6.4 Summary of the Contributions

This thesis researched questions about how skills obtained from the educational process are related to economic growth and technological catch-up, public investment decisions, and institutional flexibility.

In brief, the primary contributions of this dissertation are as follows:

- We introduce a new dataset of three vocational secondary education variables covering as much of the globe as possible from 1950 to 2010 (Chapter 2).

- We find that years of vocational secondary schooling have a strong relationship with economic growth, but only if the economy is relatively close to the technological frontier (Chapter 3).

- We find that public investment in education has a strong relationship with adult numeracy scores. The investment allocations to primary, secondary and tertiary education interrelate and are also important for the resulting adult numeracy skills (Chapter 4).

- We find that vocational education at the tertiary level has produced a workforce with lower educational qualifications than would be required to be hired today, and a workforce that uses numeracy skills slightly less than individuals that are the product of a general education. This result seems to be dependent on the structure of the school system and the intensity of vocational education. (Chapter 5).

- A survey for higher professional education institutions intended to capture how these institutions adapt and innovate in response to changes in the labor market is reported in the second half of Chapter 5. The survey provides examples of how information about innovation in higher professional education institutions is collected in the Netherlands and New York State. All (100 percent) of

respondents try to anticipate the future needs of the labor market, they do so in very different ways, and the challenges they identify are different.

6.5 Discussion and Recommendations for Future Work

Chapter 2 considers vocational education at only the secondary level because the data that separate vocational from general enrolments at the tertiary level do not extend over the 50-year time period for most countries in dataset. Data exist at the tertiary level for the last two and half decades (approximately from the 1990's onward). Analysis of the data at the tertiary level is one way in which the work in chapter 2 could be extended. Additionally, we made the decision early on to create a secondary schooling variable that represents just the sliver of total years of schooling that could be attributed to vocational education at the secondary level. This implies that all primary education falls under non-vocational years of schooling, but this may not be the case. A different variable that attributes primary education to vocational and general could be created. Since we know that higher education attainment has expanded around the world in the past decade, and since innovation is a key function of higher education (OECD 2017b), a complete understanding of how vocational education affects economic growth and innovation would include a measure that distinguishes vocational education at the tertiary level.

Our conclusion in Chapter 3 that vocational secondary schooling benefits economic growth more only when countries get relatively close to the technological frontier contrasts with the conclusions of others who argue that the vocational contribution to absorptive capacity plays a crucial role in technological catch-up. This contrasting view suggests that technical education can be beneficial further from the technological frontier (e.g., Abramovitz, 1986; Moretti, 2012; Vandenbussche, Aghion & Meghir. 2006). Development economics tends to support this notion and we were surprised to find, for example, that a greater presence of vocational education in Sub-Saharan Africa is negatively associated with GDP per worker. We speculate that these findings may be related to the quality of the vocational secondary education in the schooling system in developing countries, which may receive fewer resources and be even more susceptible to negative perception. Advanced countries generally see an increase in access to both general and vocational tertiary education, but the increase in general higher education is often seen as the preferred path toward a better job. The analysis in this thesis suggests that the benefits of the vocational education is being overlooked in the accelerating prosperity that occurs as a country approaches the technological frontier.

If the vocational role is important further from the technogical frontier, we would expect it to show up more strongly in the imitation part of the equations specified by Benhabib

and Spiegel (2005). But this is not what we find. Our explanation is that the quality of vocational education in developing economies is not as high as the quality of vocational education in economies that are close to the frontier. One year of vocational secondary education in Denmark is not likely to be equivalent to one year of vocational secondary education in Ethiopia. It is also possible that the structure of vocational education in the overall education system may play a role. It could also be that teacher quality in the vocational system increases as countries become more advanced.

The methodology used to calculate the thresholds for complementarity and substitutability between the three investments in Chapter 4 has the advantage is that it considers the investments at each stage (primary, secondary and tertiary) jointly (i.e., all along the educational trajectory). But it is not easy to interpret exactly how the three relate to each other. Thresholds of investment in one stage may invoke a false sense of precision, because in reality investment in all three stages of education affect each other. With their own data and the information afforded by the PIAAC dataset, policy makers could calculate the optimal spread of investments over the three periods, in order to maximize the benefits. For example, if a country found that investments in primary and tertiary have strong complementarities as long as secondary investments are at the right 'bridging' magnitude, decisions regarding the appropriate level of investment in secondary education would be easier. Illustrating the potential utility of considering complementarity in investment in the various stages of education, although only an illustration, is considered an important contribution of this thesis.

If vocational secondary schooling is associated with better economic performance as found in the first half of Chapter 5, why are people with vocational higher education employed in jobs for which they are currently under-qualified, and why are they using numeracy skills less on the job (at least in some countries) than those with a general education? How can we reconcile these results with the results from value of vocational education found in the earlier chapters of this thesis? Possible resolutions of this dilemma include:

- Vocational secondary schooling may relate very differently to macroeconomic growth than vocational tertiary education. Tertiary vocational education may be at higher risk of over-specialization, for example.

- The set of countries analyzed is much smaller in the second part of the thesis than in the first part of the thesis. In chapters 4 and 5 our PIAAC and investment

data allow analysis of only 12 OECD countries. This set of countries may be too small to assess the value of vocational education.

- Given our findings that differ specifically for Denmark in Chapter 5, there could be issues related to the extent to which the vocational curriculum incorporates academic or socio-skills, or to the type of vocational system within the overall education system. These elements may vary along with the country's stage of economic development, or may vary within stages of economic development.

- The numeracy tasks respondents are asked to report in the PIAAC survey may biased. For example, the PIAAC questionnaire inquires about making graphs (important for an analyst) but not about calculating angles (important for a carpenter).

- A static comparison at a single year (2011) may be misleading. The education-job mismatch may be temporary, and one that that the labor market and individuals will quickly sort out. The static analysis in the first part of chapter 5 does not answer this question. The skills and education levels supplied may also have shaped the future demand of the labor market and the present mismatch may be an indication of vocational education success. The education requirements have changed and bumped up over the years.

- Employers clearly value the skills of those with vocational higher education because they have hired and continue to employ graduates from that track. The OECD reports that many are worried about over- rather than under-education in higher education (OECD 2017). The costs of higher education are high for individuals as well as governments. Considering costs, the under-education of people with vocational higher education may be societally preferable to hiring the expensive over-educated.

If and as educational services start to be delivered in shorter more acutely focused packages more akin to the type of education provided by professional (as opposed to general) higher education institutions rather, innovation and adaptation of educational services will become increasingly important. Innovation surveys in private sector firms have been a great resource there. Similar data collection instruments are needed for higher education. The analysis in this thesis emphasizes, it will be important to include higher professional education in future studies of innovation in higher education.

Since rapidly advancing technology require a constant reskilling and upskilling, the question of how general and vocational skills might complement each other will be

increasingly important. What would be the ideal sequencing of general and technical education? The introduction to this thesis raised this issue. Within and outside the formal education, we already see nanodegrees and short-term curricula designed to facilitate reskilling or upskilling carving out a 'market space'. These are vocational programs designed to teach people exactly (and only) what they need to know for a specific job. They concentrate on practical applications and do not delve into theory. And they are working, in the sense that the job placement outcomes from these programs are astonishingly successful. But, could they be more effective if added to a strong general education base? And what are the implications for secondary and primary schools?

This thesis arrives at a time when many international organizations and media are calling for reshaping the education system to deliver skills viewed as more compatible with known and unknown (future) technology. Taken together the chapters in the thesis contribute toward a deeper understanding of how different types of education foster different skill mixes that may be more or less attractive for employers.

The dissertation has added data resources and advanced our understanding of the contributions of vocational secondary schooling to economic growth. It has shown the value of distinguishing vocational and general education in new and existing data and analysis. Through a prototype survey, it probes higher professional education institutions about the challenges they face in adapting to the needs of an increasingly rapidly changing labor market. Generally, the dissertation has found that there is utility to distinguishing between vocational and general education pathways, but it has just scratched the surface. Along the way, the thesis has pointed to avenues for future research. Technology may inspire increasing vocational and general education fusion and future research is likely to face continuing challenges to parse educational pathways. Future research may, however, be aided by digital education tools that can collect and analyze student (competence building) data in real time.

References

Abramovitz, M., (1986). Catching up, forging ahead and falling behind. Journal of Economic History 46 (386), 406.

Abramovitz, M., (1993). "The Search for the Sources of Growth: Areas of Ignorance: Old and New" *Journal of Economic History,* Vol. 53, No. 2, 217-243.

Achen, C.H., (2001). Why lagged dependent variables can suppress the explanatory power of other independent variables. Ann Arbor: University of Michigan.

Allen, J. P., and , R. K. W. van der Velden. (2005). *The flexible professional in the knowledge society: conceptual framework of the REFLEX project*. (REFLEX Working Paper Series; No. 1).

Ang, J.B., Madsen, J.B. and M.R. Islam, (2011). The effects of human capital composition on technological convergence Journal of Macroeconomics, 33 (3), pp. 465-476

Arundel, A., Bowen-Butchart, D. and S. Gatenby-Clark. (2016). The role of an inclusive innovation culture and innovation support strategies in university managerial and service innovations: Survey results for Australia and New Zealand: https://www.oecd.org/sti/102%20-%20ARUNDEL%20innovation%20in%20universities.pdf

Bakhshi, H., Downing, J., Osborne, M. and Schneider, P. (2017). 'The Future of Skills: Employment in 2030.'

Barro, R and J.W. Lee, (2013). "A New Data Set of Educational Attainment in the World, 1950-2010." Journal of Development Economics. Vol. 104. Pgs. 184-198.

Barro, R. and J.W. Lee, (1993). "International comparisons of educational attainment". Journal of Monetary Economics 32, 363–394.

Barro, R. and J.W. Lee, (2010). A new data set of educational attainment in the world, 1950-2010. NBER Working Paper 15902. Cambridge, MA: National Bureau of Economic Research (April).

Barro, R., and X. Sala-i-Martin. (1991). "Convergence across states and regions". Brookings Papers on Economic Activity 1, 107–158.

Becker, G., (1994). Human Capital: A theoretical and empirical analysis with special reference to Education. The University of Chicago Press.

Benhabib, J. and M. Spiegel, (2005). "Human capital and technology diffusion." In Handbook of Economic Growth, edited by Philippe Aghion and Steven N. Durlauf. Amsterdam: North Holland: 935-966.

Benos, N. and S. Zotou, (2014). Education and Economic Growth: A Meta-Regression Analysis, World Development, 64, issue C, p. 669-689.

Benson, C. (1997). "New Vocationalism in the United States: Potential Problems and Outlook". Economics of Education Review, Vol. 16. No. 3: 201-212.

Bertocchi, G. and M. Spagat (2004), "The evolution of modern educational systems: Technical vs. academic education, distributional conflict, and growth", Journal of Development Economics, Elsevier, Vol. 73 (2), pp. 559-582.

Bessen, J. (2014). Employers Aren't Just Whining – the "Skills Gap" Is Real. Harvard Business Review, 14 August 25, [online]. Available from https://hbr.org/2014/08/employers-arent-just-whining-the-skills-gap-is-real.

Bolt, J. and J.L. van Zanden, (2014). The Maddison Project: collaborative research on historical national accounts. The Economic History Review, 67 (3): 627–651.

Bond, S., (2002). "Dynamic panel data models: A guide to micro data methods and practice". Portugese Economic Journal 1, 141–162.

Bond, S., Hoeffler, A., and J. Temple. (2001). "GMM estimation of empirical growth models". Centre for Economic Policy Research Discussion Paper No. 3048.

Brambor, T., Roberts, w. and G. Matt, (2006). 'Understanding Interaction Models: Improving Empirical Analyses', Political Analysis, 14 (2006), 63-82

Brookings Institute – Holzer, H & R. Lerman (2009). The Future of Middle-skill Jobs. Washington, D.C.

Brookings. 2017. How do we teach 21st century skills in classrooms?. First in a series on teaching 21st century skills in the classroom. Care, E. Kim, H. and A. Vista [online]. Available from https://www.brookings.edu/blog/education-plus-development/2017/10/17/how-do-we-teach-21st-century-skills-in-classrooms/

Brunello, G., and L. Rocco, (2015). "The effects of vocational education on adult skills and wages: What can we learn from PIAAC?", OECD Social, Employment and Migration Working Papers, No. 168, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jrxfmjvw9bt-en. Brunello, G., Weber G., and C. Weiss, (2012). "Books Are Forever: Early Life Conditions, Education and Lifetime Earnings in Europe", IZA Discussion Paper.

Bynner J. and S. Parsons. (1997). Does numeracy matter? Evidence from the national child development study on the impact of poor numeracy on adult life. The Basic Skills Agency. London (1997).

Candelaria, C., and K. Shores, (2015). The Sensitivity of Causal Estimates from Court-Ordered Finance Reform on Spending and Graduation Rates. CEPA, Stanford, CA.

Carneiro, P., and J. Heckman, (2002). "The Evidence on Credit Constraints in Post-secondary Schooling," Economic Journal, Royal Economic Society, Vol. 112 (482), pp. 705-734.

Carree, M., Lokshin B., and R. Belderbos (2011)., 'A note on testing for complementarity and substitutability in the case of multiple practices'. Journal of Productivity Analysis.

Cathles, A., (2016). New variables for vocational secondary schooling: Patterns around the world from 1950-2010. MERIT Working Papers #2016-002, United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT). Available at: http://www.merit.unu.edu/publications/working-papers/abstract/?id=5911.

CBS (Centraal bureau voor de statistiek netherlands). 2008. *Schaart, R., Bernelot Moens, M. and S. Westerman.* The Dutch Standard Classification of Education, SOI 2006.

CEDEFOP (European Centre for the Development of Vocational Training). 2008. Terminology of European education and training policy: A selection of 100 key terms. Luxembourg: Office for Official Publications of the European Communities, 2008

CEDEFOP (European Centre for the Development of Vocational Training). (2010). Skills Supply and Demand in Europe: Medium-term forecast up to 2020. Luxembourg Publications Office of the European Union.

CEDEFOP (European Centre for the Development of Vocational Training). (2016). Vocational education and training in the Netherlands: short description. Luxembourg: Publications Office. Cedefop information series. http://dx.doi.org/10.2801/476727

CEIC, retrieved from: https://www.ceicdata.com/en/indicator/netherlands/annual-household-income-per-capita.

Cheng, Y.C. and W. M. Tam. (1997). Multi-models of quality in education. Quality Assurance in Education, Vol. 5 Issue: 1, pp.22-31, https://doi.org/10.1108/09684889710156558

Chetty, R., Grusky, D., Hell, M., Hendren, N. Manduca, R. and J. Narang. (2017). The fading American dream: Trends in absolute income mobility since 1940. Science. April 24, 2017. DOI: 10.1126/science.aal4617.

CIS (Community Innovation Survey). 2012. The Harmonised Survey Questionnaire, July 23, 2012. Available online.

Cohen, D. and M. Soto, (2007). Growth and human capital: good data, good results. Journal of Economic Growth 12, 51–76.

Cohen, W. and D. Levinthal, (1989). "Innovation and learning: The two faces of R&D." Economic Journal 99: 569-596.

Cohen, W. and D. Levinthal, (1990). "Absorptive capacity: A new perspective on learning and innovation", Administrative Science Quarterly, vol. 35, No. 1, Special Issue: Technology, organization and innovation, pp. 128-152.

Course Report. (2018). "Coding Bootcamp Market Sizing Report 2018." [online]. Available from https://www.coursereport.com/reports/2018-coding-bootcamp-market-size-research

Crawford C., Dearden, L., Micklewright, J., and A. Vignoles, (2016). Family Background and University Success: Differences in Higher Education Access and Outcomes in England, Oxford: Oxford University Press.

Cunha, F., and J. Heckman, (2007). "The technology of skill formation." American Economic Review 97, no. 2: 31-47.

Cunha, F., Heckman J., Lochner L., and D. Masterov, (2006). "Interpreting the evidence on life cycle skill formation." In Handbook of the Economics of Education, edited by Eric A. Hanushek and Finis Welch. Amsterdam: North Holland: 697-812.

Dalitz, R. and P. Toner. (2016). Systems failure, market failure, or something else? The case of skills development in Australian innovation policy, Innovation and Development, 6:1, 51-66, DOI: 10.1080/2157930X.2015.1084116

Das, J., Dercon, s., Habyarimana, J., Krishnan, P., Muralidharan, K. and V. Sundararaman. (2013). School Inputs, Household Substitution, and Test Scores. American Economic Journal: Applied Economics, 5 (2): 29-57.

Dawson, J., and A. Richter, (2006). Probing three-way interactions in moderated multiple regression: De velopment and application of a slope difference test. Journal of Applied Psychology, 91: 917-926.

de Weert, E. 2011. Perspectives on Higher Education and the labour market Review of international policy developments. IHEM/ CHEPS Thematic report. C11EW158. December, 2011.

Deming, D. (2015). The Growing Importance of Social Skills in the Labor Market. CESifo Area Conference on Education Economics.

Dennison, T. (2014). "Critical Success Factors of Technological Innovation and Diffusion in Higher Education." Dissertation, Georgia State University, 2014. http://scholarworks.gsu.edu/msit_diss/118

Department of Numbers, retrieved from: http://www.deptofnumbers.com/income/new-york/

Destré, G., Lévy-Garboua, L., and M. Sollogoub. (2008). Learning from Experience or Learning from Others ? Inferring Informal Training from a Human Capital Earnings Function with Matched Employer-Employee Data." Journal of Socio-Economics 37, (2008), 919-938.

Dröll, P. (October 19, 2017). Director at European Commission's Research and Innovation Department seminar 'EU innovation policy - a view from the inside', Joint UNU-MERIT/ School of Governance Seminar.

Durlauf, S., Johnson, P. and J. Temple, (2005). "Growth Econometrics," Handbook of Economic Growth, in: Philippe Aghion & Steven Durlauf (ed.), Handbook of Economic Growth, edition 1, volume 1, chapter 8, pages 555-677 Elsevier.

Economist. (2016). Special Report Artificial Intelligence. (2016, June) The Economist.

Encyclopedia of Nations accessed from: http://www.nationsencyclopedia.com/economies/Europe/The-Netherlands.html

European Commission (2010). New skills for new jobs: action now. Report by the expert group on new skills for new jobs prepared for the European Commission. Luxembourg: Publications Office.

European Commission (Eurostat). 2016. Education and Training Glossary [online repository]. Available from https://ec.europa.eu/eurostat/statistics-explained/index.php/Category:Education_and_training_glossary

European Commission. (2016). New Skills Agenda for Europe: http://ec.europa.eu/social/main.jsp?catId=1223, accessed February, 2018.

Feenstra, R. C., Inklaar R. and M. P. Timmer. (2013). "The Next Generation of the Penn World Table" available for download at www.ggdc.net/pwt.

Feldman, M.P. and I. Stewart. (2008). "Wellsprings of Modern Economic Growth: Higher Education, Innovation, and Local Economic Development." Annual World Bank Conference on Development Economics- Regional 2008: Higher Education and Development. The International Bank for Reconstruction and Development/World Bank. pp. 177-200.

Fink, A. (1995). How to Design Surveys. Thousand Oaks: Sage Publications, Inc.

Fink, A. (2009). How to Conduct Surveys, A step-by-step guide. Thousand Oaks: Sage Publications, Inc.

Fowler, F. J. (2009). Survey Research Methods. Thousand Oaks: Sage Publications, Inc.

GAIHE (Governance and Adaptation to Innovative Modes of the Higher Education Provision Project). (2016). McGrath, C., Hofman, J., Bajziková, L., Harte, E., Lasakova, A., Pankowska, P. Sasso, S., Belanger, J., Florea, S. and J. Krivograd. Education, Audio-visual & Culture Executive Agency of the European Union, 2016. https://www.rand.org/pubs/research_reports/RR1571.html.

Gal, I., and D. Tout. (2014). "Comparison of PIAAC and PISA Frameworks for Numeracy and Mathematical Literacy", OECD Education Working Papers, No. 102, OECD Publishing. http://dx.doi.org/10.1787/5jz3wl63cs6f-en

Gallup, J.L., Sachs, J.D. and A.D. Mellinger. (1999). Geography and economic development. International Regional Science Review 22, 179–232.

Gliem J.A. and R.R. Gliem. (2003). Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales. 2003 Midwest Research to Practice Conference in Adult, Continuing, and Community Education, Columbus, 82-88.

Grigoli, F., (2015). A hybrid approach to estimating the efficiency of public spending on education in emerging and developing economies. Applied Economics and Finance Vol. 2 (1); February 2015.

Hampf, F. and L. Woessmann. (2016). Vocational vs. general education and employment over the life-cycle: New evidence from piaac.

Handel, M. (2012). "Trends in job skill demands in OECD countries", OECD Social, Employment and Migration Working Papers, No. 143, OECD Publishing. DOI: http://dx.doi.org/10.1787/5k8zk8pcq6td-en.

Hanushek, E., (1986). The Economics of Schooling: Production and Efficiency in Public Schools, Journal of Economic Literature, Vol. 24, no 3, pp 1141-1177

Hanushek, E. and S. Rivkin. (2006). Teacher quality. In E. A. Hanushek and F. Welch (Eds.), Handbook of the economics of education, vol. 2(pp. 1051-1078). Amsterdam: North Holland.

Hanushek, E., and L. Woessman, (2012). Do better schools lead to more growth? Cognitive skills, economic outcomes and causation. Journal Economic Growth, 17, 267-321.

Hanushek, E., and L. Zhang, (2009). Quality-Consistent Estimates of International Schooling and Skill Gradients Journal of Human Capital Vol. 3, Iss. 2, (July 2009): 107-143.

Hanushek, E., Kain, J., Markman, J., and S. Rivkin, (2003). Does peer ability affect student achievement? Journal of Applied Econometrics; Chichester Vol. 18, Iss. 5, (Sep 2003): 527-544.

Hanushek, E., Schwerdt, G., Wiederhold, S. and L. Woessmann, (2015). "Returns to skills around the world: Evidence from PIAAC," European Economic Review, Elsevier, vol. 73(C), pages 103-130.

Hanushek, E., Schwerdt, G., Woessmann, L., and L. Zhang. (2017). General education, vocational education, and labor-market outcomes over the lifecycle. Journal of Human Resources.

Hartog, J. (1983). To graduate or not: Does it matter? Economics Letters 12(2):193-199 • December 1983 DOI: 10.1016/0165-1765(83)90134-9.

Hartog, J. (2000). Overeducation and earnings: where are we, where should we go? Economics of Education Review, 19: 131–47.

Harvard Advanced Leadership Initiative. (2014). Education for the 21st Century. Executive Summary by Denomy, V. and M. Perry. President and Fellows of Harvard College. Cambridge, MA: April, 2014.

Haveman, R., and B. Wolfe, (1995). "The Determinants of Children Attainments: A Review of Methods and Findings." Journal of Economic Literature, December 1995, 33(4), pp. 1829-78.

Holzer, H. (2017). "Will Robots Make Job Training and Workers Obsolete Workforce Development in an Automating Labor Market". Brookings Report.

Holzer, H. and S. Baum. (2017). Making College Work: Pathways to Success for Disadvantaged Students. Brookings Institution Press, August 29, 2017.

Hyman, J., (2017). "Does Money Matter in the Long Run? Effects of School Spending on Educational Attainment," American Economic Journal: Economic Policy, American Economic Association, vol. 9(4), pages 256-280, November.

IBM. (November, 2017). IBM Shifts Focus from Degrees to Skills Based Hiring: https://www.hrdive.com/news/ibm-shifts-focus-from-degrees-to-skills-based-hiring/510520/

IDB (Inter-American Development Bank). (2016). Firm innovation and productivity in Latin America and the Caribbean: the engine of economic development. Eds (Grazzi, M. and C. Pietrobelli). Washington, D.C.: IDB.

ISCED (International Standard Classification of Education). (2011). United Nations Educational, Scientific and Cultural Organization (UNESCO). (http://www.uis.unesco.org/Education/Documents/isced-2011-en.pdf).

ISECD (International Standard Classification of Education). (1997). United Nations Educational, Scientific and Cultural Organization (UNESCO). (http://www.uis.unesco.org/Library/Documents/isced97-en.pdf).

ITU (International Telecommunications Union). (2016). Coding Bootcamps: A Strategy for Youth Employment. Geneva: International Telecommunication Union. http://www.itu.int/en/ITU-D/Digital-Inclusion/ Youth-and-Children/Documents/CodingBootcamps_E.pdf.

Jones, A. (2018). Vocational education for the twenty-first century. The University of Melbourne.

Jones, S., Lefoe G., Harvey M. & Ryland, K. (2012). *Distributed leadership: a collaborative framework for academics, executives and professionals in higher education.* Journal of Higher Education Policy and Management, 34(1), 67-78.

Kuczera, M. (2008). The OECD International Survey of VET Systems: First Results and Technical Report.

Laczik, A. and Mayhew, K. (2015). Labour market developments and their significance for vet in England: Current concerns and debates. Research in Comparative and International Education, 10(4):558–575.

Lane, J. L. (2001). Teaching and learning innovations in higher education: Faculty perceptions of sustainability (Unpublished doctoral dissertation). The Pennsylvania State University, University Park, PA.

Lee, K., and C. Lim, (2001), Technological regimes, catching-up and leapfrogging: findings from the Korean industries, Research Policy, 30(3), 459-483.

Libertus, M.E., Feigenson, L. and J. Halberda. (2011). Preschool acuity of the approximate number system correlates with school math ability Developmental Science, 14. pp. 1292-1300

Lor. P. (2011). International and Comparative Librarianship, Chapter 4 draft.

Lucas, R., (1988). "On the Mechanics of Economic Development," Journal of Monetary Economics 22 : 3-42.

Lundvall, B. (2007a). Higher Education, Innovation and Economic Development, Paper presented at the World Bank's Regional Bank Conference on Development Economics, Beijing, January 16-17, 2007.

Lundvall, B. (2007b). National Innovation Systems—Analytical Concept and Development Tool, Industry and Innovation, 14:1, 95-119.

Maddison, A., (2009). Historical Statistics, World Population, GDP and Per Capita GDP 1-2006 AD, http://www.ggdc.net/maddison/ (Down-loaded: July 2009).

Malcolm X. (1964). Malcolm X's Speech at the Founding Rally of the Organization of Afro-American Unity: https://blackpast.org/1964-malcolm-x-s-speech-founding-rally-organization-afro-american-unity

Marconi, G. (2018). Education as a Long-Term Investment: The Decisive Role of Age in the Education-Growth Relationship. Kyklos, 71: 132–161. doi: 10.1111/kykl.12165.

Maxwell, J. (2013). Qualitative Research Design: An Interactive Approach. Sage Publications: Thousand Oaks, California.

McGrath, S. (2012). Vocational education and training for development: A policy in need of a theory? International Journal of Educational Development 32 (5), 623–631.

McKinsey Global Institute. (2017). 'A future that works: Automation, Employment, and Productivity.' McKinsey & Company [online]. Available from: www. mckinsey.com/global-themes/digital-disruption/ harnessing-automation-for-a-future-that-works

McKinsey Global Institute. (2017). 'Jobs lost, jobs gained: Workforce transitions in a time of automation.' McKinsey & Company [online]. Available from www.mckinsey.com/global-themes/future-of- organizations-and-work/what-the-future-of-work-will- mean-for-jobs-skills-and-wages

Mehaffy, G. L. (2012). Challenge and change. EDUCAUSE Review, September/October, 25-42.

Meyer, D. and L. Avery. (2009). Excel as a qualitative data analysis tool. Field Methods, 21(1), 91-112.

Moretti, Enrico. (2012). The New Geography of Jobs, New York: Houghton Mifflin Harcourt.

Mulas, V., Paradi-Guilford, C., Allende Letona, E. and Z. Viatchaninova Dalphond. (2017). Coding Bootcamps: Building Future-Proof Skills through Rapid Skills Training.

Navarro, J. C., Benavente, J. M., and G.A. Crespi. (2016). *The New Imperative of Innovation: Policy Perspectives for Latin America and the Caribbean.* Washington DC: Inter-American Development Bank. Available from https://publications.iadb.org/handle/11319/7417

Nelson, R.R. and E.S. Phelps, (1966). "Investment in humans, technological diffusion, and economic growth". American Economic Review 56, 69–75.

Netherlands Census Data. (1971). Volkstelling A5A annex woningtelling, 28 februari, 1971 [Accessed April 2015 at: http://www.volkstellingen.nl/nl/volkstelling/jaarview/1971/index.html]

OECD. (2009). Glossary of terms used in the international survey of VET systems. Learning for Jobs OECD Reviews of Vocational Education and Training. Initial Report. Simon Field, S., Hoeckel, K. Kis, V. and M. Kuczera. OECD, 2009.

OECD. (2010). Learning for Jobs: Synthesis Report of the OECD Review of Vocational Education and Training. ISSN 2077-7736.

OECD. (2013a). PISA 2012 Results: What Makes Schools Successful? Resources, Policies and Practices (Volume IV), PISA , OECD Publishing. http://dx.doi.org/10.1787/9789264201156-en

OECD. (2013b). OECD Skills Outlook 2013: First Results from the Survey of Adult Skills, OECD Publishing. http://dx.doi.org/10.1787/9789264204256-en

OECD. (2013c). Programme for the International Assessment of Adult Competencies (PIAAC) International Public Use File. And the first version of the Technical Report of the Survey of Adult Skills (PIAAC). Pre-publication Copy, available at: http://www.oecd.org/site/piaac/_Technical%20Report_17OCT13.pdf

OECD. (2014). Skills Beyond School: Synthesis Report, OECD Reviews of Vocational Education and Training, OECD Publishing. http//dx.doi.org/10.1787/9789264214682-en

OECD. (2015). Survey of Adult Skills (PIAAC) (Database 2012, 2015): http://www.oecd.org/skills/piaac/publicdataandanalysis/

OECD. (2016). Technical Report of the Survey of Adult Skills (PIAAC) (2nd Edition) Pre-publication Copy, available at http://www.oecd.org/skills/piaac/PIAAC_Technical_Report_2nd_Edition_Full_Report.pdf

OECD. (2017a). Benchmarking higher education system performance: Conceptual framework and data, Enhancing Higher Education System Performance, OECD Paris.

OECD. (2017b). In-Depth Analysis of the Labour Market Relevance and Outcomes of Higher Education Systems: Analytical Framework and Country Practices Report, Enhancing Higher Education System Performance, OECD, Paris.

Oketch, M. (2007). To vocationalise or not to vocationalise? Perspectives on current trends and issues in technical and vocational education and training (TVET) in Africa International Journal of Educational Development, 27(2), 220–234. https://doi.org/10.1016/j.ijedudev.2006.07.004

Patrinos, H. and G. Psacharopoulos. (2011). "Education: Past, Present and Future Global Challenges" Policy Research Working Paper 5616.

Pritchett, L. (2001). Where has all the education gone? World Bank Economics Review 15(2001)367–391.

Pritchett, L. (2016). Institutions Growth Accelerations and Growth Collapses. EDI Working Paper Series WPI6/05.

Raffe, D. (2011) Cross-national differences in education-work transitions, pp. 312-328 in London, M. (ed) The Oxford Handbook of Lifelong Learning. New York: Oxford University Press.

Ritzen, J. and S. Sasso, (2017). Sectoral Cognitive Skills, R&D, and Productivity: A Cross-Country Cross-Sector Analysis. IZA Discussion Paper No. 10457.

Ritzen, J.M.M. and D.R. Winkler. (1977a). The production of human capital over time. Review of Economics and Statistics 4, pp.427-437.

Ritzen, J.M.M. and D.R. Winkler. (1977b). The revealed preferences of a local government. Journal of Urban Economics 4, pp.310-323.

Ritzen, J.M.M. and D.R. Winkler. (1979). 'On the Optimal Allocation of Resources in the Production of Human Capital,'Journal of the Operationel Research Society, 30 (1979).

Rivera-Batiz, L. and P. Romer. (1991). "Economic Integration and Endogenous Growth," The Quarterly Journal of Economics, MIT Press, vol. 106(2), pages 531-55, May.

Romer, P. (1990). "Endogenous technical change". Journal of Political Economy 98, S71–S102.

Ross, M.L. and E. Voeten. (2015). Oil and international cooperation. International Studies Quarterly, pp. 1-13.

Ryan, P. (2001), The School-to-Work Transition: A Cross-National Perspective, Journal of Economic Literature, 39, 34-92.

Salant, P. and D. A. Dillman. (1994). How to Conduct Your Own Survey. New York: John Wilery & Sons, Inc.

Savvides, A. and T. Stengos. (2009). Human Capital and Economic Growth. Stanford University Press, Stanford.

Schleicher, A. (2015). December 17. How can we equip the future workforce for technological change?. World Economic Forum Agenda (blog).

Schneider, S. (1989). Strategy Formulation: The Impact of National Culture. Organization Studies. 10 (2), 1989, pp. 157-176.

Scott, C. (2015). The Futures of Learning 2: What kind of learning for the 21st century? UNESCO Education Research and Foresight, Paris. [ERF Working Papers Series, No. 14].

Seawright, J. and J. Gerring. (2008). "Case-Selection Techniques in Case Study Research: a Menu of Qualitative and Quantitative Options." Political Research Quarterly 61(2):294–308.

Sianesi, B. and J. Van Reenen. (2003). The Returns to Education: Macroeconomics. Journal of Economic Surveys, Vol. 17, pp. 157-200, April 2003. Available from SSRN: http://ssrn.com/abstract=416649

Silliman, M. and H. Virtanen. (2018). Heterogeneity in the Returns to General and Vocational Education. Working Paper presented at the XXVII Meeting of the Economics of Education Association in Barcelona: June, 2018: http://2018.economicsofeducation.com/user/pdfsesiones/181.pdf?PHPSESSID=rllbdtnf38r5b2di9aos8dejo0

Smink, M., Hekkert, M.P. and S.O. Negro. (2013). Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies. Business Strategy and the Environment. 24. 10.1002/bse.1808.

Soete, L. (2006). Knowledge, Policy, and Innovation, in Louise Earl and Fred Gault, (eds.) National Innovation, Indicators and Policy, Cheltenham: Edward Elgar.

Spady, W.G. (1994). Outcome-based Education: Critical Issues and Answers (Arlington, V A, American Association of School Administrators).

Sunde, U. and T. Vischer. (2015). Human Capital and Growth: Specification Matters. Economica, 82: 368–390. doi:10.1111/ecca.12116

Szirmai, A. (2015). "Socio-Economic Development," Cambridge Books, Cambridge University Press, number 9781107624498, December.

Szirmai, A. and B. Verspagen. (2015). "Manufacturing and economic growth in developing countries, 1950 2005," Structural Change and Economic Dynamics, Elsevier, vol. 34(C), pages 46-59.

Temple, J. (2001). "Generalizations that aren't? Evidence on education and growth," European Economic Review, Elsevier, vol. 45(4-6), pages 905-918, May.

Tether, B., M., Consoli, and D. Gagliardi. (2005). A literature review on skills and innovation. How does successful innovation impact on the demand for skills and how do skills drive innovation? ESRC Centre on Innovation and Competition, University of Manchester, Manchester.

Toner, P. (2010). Innovation and Vocational Education, The Economic and Labour Relations Review, 2010, Vol. 21 No.2, 75-98

Torugsa, N. and A. Arundel. (2016). Complexity of Innovation in the public sector: A workgroup-level analysis of related factors and outcomes, Public Management Review, 18:3, 392-416, DOI: 10.1080/14719037.2014.984626

Trilling, B. and C. Fadel. (2012). 21st Century Skills: Learning for Life in Our Times. San Francisco: Jossey Bass.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (1950). World Survey of Education.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (1969). Statistical Yearbook.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (1970). Statistical Yearbook.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (1991). Statistical Yearbook.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (1999). Statistical Yearbook.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2013). Education Sector Technical Notes: Technical and Vocational Education and Training. June, 2013.

UNESCO (United Nations Educational, Scientific and Cultural Organization). Institute for Statistics http://data.uis.unesco.org/ (Accessed: May 2014).

UNESCO Institute for Statistics (UIS). http://data.uis.unesco.org/ Accessed October, 2015.

UNESCO, UIS. (2011). ISCED (International Standard Classification of Education). (2011). United Nations Educational, Scientific and Cultural Organization (UNESCO). (http://www.uis.unesco.org/Education/Documents/isced-2011-en.pdf).

UNESCO. (2016). International Association of Universities and UNESCO Information Centre on Higher Education (2016), International Handbook of Universities 2017, Palgrave Macmillan.

van Damme, D. (2015). Global higher education in need of more and better learning metrics. Why OECD's AHELO project might help to fill the gap. European Journal of Higher Education, 5(4), 425–436.

van der Velden, R. and B. Ineke. (2017). "Skill effort: A new theoretical perspective on the relation between skills, skill use, mismatches, and wages," ROA Research Memorandum 005, Maastricht University, Research Centre for Education and the Labour Market (ROA).

van Veen, T., Cathles, A., Ou, D., Sasso, S. and M. Setrana. (2018). Where do you come from, where do you go? Assessing skills gaps and labour market outcomes of young adults with different immigration backgrounds. CESifo Working Paper No. 7157 (July 2018).

Vandenbussche, J., Aghion, P. and C. Meghir. (2006). "Growth, distance to frontier and composition of human capital" Journal of Economic Growth 11: 97–127.

Verspagen, B., (1991). A New Empirical Approach to Catching Up and Falling Behind, Structural Change and Economic Dynamics, vol. 2, pp. 359-380.

Volante, L. (2016). "Preparing interview guidelines for qualitative analysis" Seminar Skills Session at UNU-MERIT.

Volante, L., Klinger, D., & Bilgili, Ö. (Eds.). (2018). Immigrant student achievement and education policy. Cross-cultural approaches. Berlin: Springer.

von Davier, M., Gonzalez, E. and R. Mislevy. (2009). What are plausible values and why are they useful? In: IERI Monograph Series: Issues and Methodologies in Large Scale Assessments, Vol. 2. Retrieved from IERI website: http://www.ierinstitute.org/IERI_Monograph_Volume_02_Chapter_01.pdf

Wamani, H., Tylleskär, T., Åstrøm, A.N., Tumwine, J., and S. Peterson. (2004). "Mothers' education but not fathers' education, household assets or land ownership is the best predictor of child health inequalities in rural Uganda." International Journal for Equity in Health." The official journal of the International Society for Equity in Health. 3:9. DOI: 10.1186/1475-9276-3-9.

WDI (World Development Indicators). The World Bank. http://data.worldbank.org/ (Accessed February, 2016)

WEF (World Economic Forum). (2016). The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. Global Challenge Insight Report. January, 2018.

White, S. and T. Glickman. (2007). Innovation in Higher Education:Implications for the Future. New Directions for Higher Education, no. 137, Spring 2007.

Woessmann, L. (2003). "Schooling Resources, Educational Institutions and Student Performance: the International Evidence". Oxford Bulletin of Economics and Statistics. 65 (2): 0305-9049.

Woessmann, L. (2016). "The importance of School Systems: Evidence from International Differences in Student Achievement". Journal of Economic Perspectives 30 (3): 3-32.

Appendix A.

Appendix to Chapter 2

Appendix A.1 ISCED 1997

This appendix summarizes the demarcation of program orientation (general, vocational, pre-vocational) and educational trajectories at different levels of schooling according to the ISCED 1997 classification.

ISCED 1997 level			
Level 0: Pre-primary education.	"Programmes at level 0, (pre-primary) defined as the initial stage of organized instruction are designed primarily to introduce very young children to a school-type environment, i.e. to provide a bridge between the home and a school-based atmosphere. Upon completion of these programmes, children continue their education at level 1 (primary education)." (Page 20).		
Level 1: Primary education or first stage of basic education.	"Level 1: Programmes at level 1 are normally designed on a unit or project basis [distinct from level 2 which begins to divide educational material by subject. Level 1 gives] students a sound basic education in reading, writing and mathematics along within elementary understanding of other subjects such as history, geography, natural science, social science, art and music. In some cases religious instruction is featured." (Page 22). Education is continued at level 2. (Page 18).		
	A: General	**B: Pre- Vocational / Technical**	**C: Vocational / Technical**
Level 2: Lower secondary education or second stage of basic education	"ISCED 2A: programmes designed for direct access to level 3 in a sequence which would ultimately lead to tertiary education, i.e. entrance to ISCED 3A or 3B;" (page 25).	"ISCED 2B: programmes designed for direct access to level 3C;" (page 25).	"ISCED 2C: programmes primarily designed for direct access to the labour market at the end of this level (sometimes referred to as 'terminal' programmes)." (Page 25).
Level 3: Upper secondary education	"ISCED 3A: programmes at level 3 designed to provide direct access to ISCED 5A" (page 29).	"ISCED 3B: programmes at level 3 designed to provide direct access to ISCED 5B" (page 29).	"ISCED 3C: programmes at level 3 not designed to lead directly to ISCED 5A or 5B. Therefore, these programmes lead directly to labour market, ISCED 4 programmes or other ISCED 3 programmes." (Page 29).
Level 4: Post-secondary non-tertiary education	"4A programmes that prepare for entry to ISCED 5" (page 32).	"4B programmes not giving access to level 5 (primarily designed for direct labour market entry)." (Page 32).	

ISCED 1997 level		
Level 5 – First Stage of Tertiary Education *(**not leading** directly to an advanced research qualification)*	"Level 5A: First stage of tertiary education: largely theoretically based programmes intended to provide qualifications for gaining entry into more advanced research programmes and professions with higher skills requirements." (Page 36).	Level 5B: First stage of tertiary education: typically shorter, more practical / technical / occupationally specific programmes leading to professional qualifications. (Pages 35-36).
Level 6: Second stage of tertiary education ***(leading** to an advanced research qualification).*	"This level is reserved for tertiary programmes which lead to the award of an advanced research qualification. The programmes are therefore devoted to advanced study and original research and are not based on course-work only." (Page 39).	

Source: Excerpted from UNESCO, ISCED 1997. Relevant page numbers are cited.

Appendix A.2 Notes on Data-entry Decisions

NOTES FROM DATA ENTRY FROM 1969 UNESCO Statistical Yearbook [Covering the years 1950-1967]

Table 2.10 'Education at the second level: general, vocational and teacher training Teachers and pupils

1. Data from Portuguese Guinea were entered under Guinea-Bissau.
2. Data from Antigua are entered under Antigua and Barbuda.
3. Data from St. Kitts-Nevis and Anguilla were entered under St. Kitts and Nevis.
4. Data from St. Vincent were entered under St. Vincent and the Grenadines.
5. Data from Malaysia were not entered and subsequently treated as missing, because under Malaysia data were listed for: Sabah, Sarawak and West Malaysia. Looking at the Map from the 1950's; it is not clear whether it is valid to combine them.
6. Data from Maldive Islands were entered under Maldives.
7. Data from Saudi Arabia from 1949 are entered under 1950.
8. Data from Southern Yemen People's Republic are combined with data from Yemen (for the years where both have data available [1965], since in the 1990's the two states merged into Yemen.
9. Data from Czechoslovakia were entered under Czech Republic.
10. Data from Federal Republic of Germany and Eastern Germany were combined. Data from West Berlin were not included. Data were missing for general secondary for 1950, 1955 and 1960 for Eastern Germany.
11. Data from United Kingdom England and Wales are combined with the data from United Kingdom Scotland and were entered under United Kingdom.

United Kingdom Scotland has no data for Vocational Education at the Second level, but the data were combined for the other categories anyway.

12. Data from Ireland and Northern Ireland were combined and entered under Ireland.
13. Data for Congo (Brazzaville) were entered under Congo, Republic of and data for Congo, Democratic Rep. of were entered under Congo, Dem. Rep.
14. Data for Ivory Coast were entered under Cote d`Ivoire.
15. Data for Mauritius and deps. were entered under Mauritius.
16. Data for United Republic of Tanzania were entered under Tanzania
17. Data from British Honduras were entered under Belize.
18. New Zealand and United States do not have data for secondary vocational education.
19. Data for Ukrainian S.S.R. were entered under Ukraine for 1965.
20. Data for the U.S.S.R. for 1950, 1955, 1960 and 1965 were entered under Russia (under the assumption, that while the exact numbers may not be correct, the ratio should be relatively accurate).

NOTES FROM DATA ENTRY FROM 1999 UNESCO Statistical Yearbook [Covering the years 1970-1997]

Table II.6 'Secondary Education: teaching staff and pupils in general, teacher training and vocational education

21. Data (both general and vocational) from Burkina Faso for 1993/94 were used for 1995.
22. Burundi changed its education structure in 1975.
23. Data (both general and vocational) from Cape Verde for 1991/92 were used for 1990 and data for 1993/94 were used for 1995.
24. Data (both general and vocational) from Comoros for 1991/92 were used for 1990 and data for 1993/94 were used for 1995.
25. Vocational data for Cote d`Ivoire for 1980, 1985, and 1995 are for public vocational or technical schools that are attached to the ministry.
26. Data (both general and vocational) from Equatorial Guinea for 1992/93 were used for 1990 and data for 1993/94 were used for 1995.
27. Data (both general and vocational) from Gabon for 1991/92 were used for 1990.
28. Ghana changed its education structure in 1975.
29. Data (both general and vocational) from Ghana for 1991/92 were used for 1990.

30. Guinea changed its education structure in 1985.
31. Kenya changed its education structure in 1985.
32. Data (both general and vocational) from Mauritius for 1996 were used for 1995.
33. El Salvador changed its education structure in 1975.
34. Data (both general and vocational) from El Salvador for 1991 were used for 1990.
35. Data (both general and vocational) from El Salvador for 1992/93 were used for 1995.
36. Data (both general and vocational) from Honduras for 1991 were used for 1990.
37. Data from Jamaica for 1975 represent only public vocational education.
38. Brazil changed its education structure in 1975.
39. Data (both general and vocational) from Colombia for 1991 were used for 1990 and data for 1996 were used for 1995.
40. Data (both general and vocational) from Ecuador for 1992/93 were used for 1990.
41. Suriname changed its education structure in 1980.
42. Data for Uruguay for 1980 do not include data for courses at U.T.U. (Universidad del trabajo del Uruguay).
43. Venezuela changed its education structure in 1980.
44. Data (both general and vocational) from Brunei Darussalam for 1991 were used for 1990.
45. Data (both general and vocational) from Cambodia for 1996/97 were used for 1995.
46. Data for Cyprus do not include commercial general education from 1985 onward.
47. Iran changed its education structure in 1977.
48. Data (both general and vocational) from Iran for 1992/93 were used for 1990.
49. Jordan changed its education structure in 1990.
50. Data (both general and vocational) from Kazakhstan for 1996/97 were used for 1995.
51. South Korea changed its data coverage starting in 1981.
52. Data (both general and vocational) from Kuwait for 1991/92 were used for 1990.
53. Laos changed its education structure in 1976.
54. Data (both general and vocational) from Laos for 1991/92 were used for 1990.
55. Data (both general and vocational) from Lebanon for 1991/92 were used for 1990.

56. Data (both general and vocational) from Macao for 1992/93 were used for 1995.
57. Data for Malaysia for 1995 refer to public education only.
58. Data (both general and vocational) from Maldives for 1992 were used for 1990.
59. Oman changed its education structure in 1975.
60. Singapore changed its data coverage starting in 1981.
61. Thailand changed its education structure in 1978.
62. Data (both general and vocational) from Yemen for 1996/97 were used for 1995.
63. Bulgaria changed its education structure in 1995.
64. In the Czech Republic, teacher training and vocational education are counted together.
65. Finland changed its data coverage in 1975.
66. In 1995 in Iceland teacher training and vocational education are counted together.
67. Data (both general and vocational) from Luxembourg for 1991/92 were used for 1990.
68. Portugal changed its education structure in 1980.
69. Romania changed its education structure in 1988.
70. Spain changed its education structure in 1995.
71. Sweden changed its data coverage in 1975.
72. Data for Switzerland for 1970-1995 are for public education only.
73. Data (both general and vocational) from Macedonia for 1992/93 were used for 1990.
74. Data (both general and vocational) from Fiji for 1991 were used for 1990.
75. Data from Sudan (pre-succession) were used for Sudan.

Appendix A.3 Illustrative Example, the Netherlands

Netherlands Census Data 1971

The year 1970/71 is used because, that was the last year for which census data were collected in the Netherlands.[59] This example is intended to elucidate (1) how UNESCO constructed the data found in their tables from the Netherlands Census data, and (2) how Barro and Lee constructed their data on the distribution of educational attainment from the data tables found in UNESCO Statistical Yearbooks. Matching Data from UNESCO with Netherlands Census Data

The data on Educational Attainment in the Netherlands in 1970 that appear in UNESCO's 1991 Statistical Yearbook[60],[61] are exactly as follows:

Table A.3.1 UNESCO Educational Attainment Data: Netherlands 1971, Population 25

Highest Level Attainted (%)					
No Schooling	First Level		Entered Second Level		Post-Secondary
	Incomplete	Complete	S-1	S-2	
-	47	------>	36.7	9.1	7.2

Source: UNESCO (1991).
Notes: S-1 = First Stage; S-2 = Second Stage; '------>' means that the figure to the immediate left includes the data for the column(s) in which this symbol appears. The data signify the proportion of the population that reached a particular level of schooling and do not make it possible to distinguish between complete and incomplete.

Table A.3.2 shows how the Netherlands census data reports the education levels attained for the population over the age of 25 in the Netherlands in 1971. The percentages in the grey column 'MF % of Pop 25+' are calculated for each level (in bold) and sub-level (in italics) and the sub-levels sum to the total of the level.62,63 At the Extended Lower

[59] Due to citizen resistance, 1971 was the last year for which census data were collected in the Netherlands: http://www.volkstellingen.nl/nl/onderzoek_literatuur/new_0/powerpoints/powerpoint_luuk_iassist2003/index.ppt.

[60] From Table A.4.1 'Percentage distribution of population 25 years of age and over, by educational attainment and sex' for the Netherlands in 1971.

[61] Although these data are from 1971, the UNESCO Statistical Yearbooks from 1970-1980 were checked at the Royal Library in the Hague and none of those yearbooks report these data; the 1991 yearbook in the UNU-MERIT library was the first accessible yearbook that reports the 1970 data from the Netherlands.

[62] This is true except for the 'Higher Level' for women - the sum of the sub-levels is off by 10, but these numbers are not used for the purposes of this paper. There were some other instances in the Netherlands census data where the sub-totals did not sum exactly to the totals that were recorded in the census tables, but there was never a difference that was greater than 20 people and most of the time the numbers were just off by 5.

[63] For example, for men, the 'Extended Lower Level' is the sum of the subsequent :. general education', agricultural education, technical, and other vocational.

Level and Secondary Level, there is a sub-level indicating general education and several sub-levels indicating vocational education. The black column 'Vocational' shows the sum of the sub-levels by each broad level (Extended Lower Level and Secondary Level) and provides an overall total at the secondary level in the bottom right corner. As noted, these calculations exclude the population that was listed in the census data as 'level unknown'. For reference, the full census tables for these Netherlands data can be found in Appendix A.4.

Table A.3.2 Education Levels for the Population 25+ in the Netherlands in 1971

Men		Women		MF (% of Pop 25+)	Vocational
Basic Level	**1,207,980**	**Basic Level**	**1,563,290**	**47.3%**	
Lower Level	**213,535**	**Lower Level**	**294,665**	**8.7%**	
Extended Lower Level	**903,890**	**Extended Lower Level**	**686,360**	**27.2%**	
general education	224,305	general education	286,460	8.7%	
agricultural education	98,735	domestic science	326,600	7.3%	
technical	553,840	other vocational	73,300	10.7%	18.44%
other vocational	27,010			0.5%	
Secondary Level	**271,515**	**Secondary Level**	**252,835**	**9.0%**	
general education	75,345	general education	64,240	2.4%	
agricultural education	22,495	domestic science	46,085	1.2%	
technical	74,380	other vocational	142,510	3.7%	6.6%
other vocational	99,295			1.7%	
Semi-higher level	**171,870**	**Semi-higher level**	**119,850**	**5.0%**	
non-university	155,830	non-university	115,185	4.6%	
university	16,040	university	4,665	0.4%	
Higher level	**101,830**	**Higher level**	**17,935**	**2.0%**	
non-university	21,910	non-university	4,710	0.5%	Total
university	79,920	university	13,215	1.6%	Secondary
Day-time attendance	**32,250**	**Day-time attendance**	**16,820**	**0.8%**	**Vocational**
Population 25+	2,902,870	Population 25+	2,951,755	100%	25.01%

Source: Own calculations based on 1971 Netherlands Census data: Volkstelling A5A annex woningtelling, 28 februari, 1971: Het genoten onderwijs en het volgen van onderwijs.
Notes: Calculations exclude the population listed in the census data with education 'Level unknown'.
MF stands for 'Male and Female'The sum of vocational education looks like it is off by 0.1%, but that is because rounding. For example, 'other vocational' is really 0.46%, but because of rounding, it is presented as 0.5%.

Table A.3.3 shows a reconstruction of how UNESCO (middle column) must have ascertained the distribution of educational attainment from the Netherlands census data. Table A.3.3 can be read from left to right and shows that the UNESCO distribution is a simplification of the census data, whereby:

- **UNESCO's 'Second Level 1'** combines the Netherlands census categories 'Lower Level' plus 'Extended Lower Level' + 'Day-time attendance';
- **UNESCO's 'Second Level 2'** *(representing upper secondary)* is almost an exact match with the Netherlands census category of 'Secondary Level'.
- **UNESCO's 'Post-Secondary'** is almost an exact match for the combination of the Netherlands census category 'Semi-higher level' and 'Higher level'.

Since we can rather easily interpret how UNESCO most probably determined the educational distribution it lends some credence to the supposition that if they had included vocational education in the attainment distribution, they would have followed a similar method. Since the vocational tracks are subsumed under the overall levels, we can also make an educated guess as to which levels they would have been attributed and we can assume that the percentages would have been calculated in the same manner (excluding the population under 25 and where education level is unknown). This educated guess is presented in the furthest right column '*Estimated* Vocational Secondary, Pop 25+' and matches the illustration of the calculations using the census data (recall the furthest right column (in grey) 'Vocational' in Table A.3.2). It is calculated by separating the percentage of the population at the Extended Lower Level and Secondary Level that were indicated by the census data to have attained vocational education at each respective level (i.e., not in the sub-level *'general education'* in Table A.3.2). Total secondary school is comprised of both lower secondary (Second Level S-1) and upper secondary (Second Level S-2).

Table A.3.3 Comparing Netherlands Census with UNESCO Data

UNESCO Distribution of Educational Attainment		Match UNESCO with NLD 1971 Census	Netherlands Census 1971		
Education Level	Pop 25 +		Education Level	Pop 25 +	*Estimated* Vocational Secondary, Pop 25+
Primary	47	≈ Basic Level	Basic Level	47.3	
Second Level S-1	36.7	= Lower Level + Extended Lower Level + Day-time attendance	Lower Level	8.7	18.44
			Extended Lower Level	27.2	
			Day-time attendance	0.8	
Second Level S-2	9.1	≈ Secondary Level	Secondary Level	9.0	6.57
Post- Secondary	7.2	≈ Semi-higher level + Higher level	Semi-higher level	5.0	
			Higher level	2.0	
Total	100		Total	100	Vocational = 25.01

Sources: UNESCO (1991) and own calculations based on 1971 Netherlands Census data[64] Volkstelling A5A annex woningtelling, 28 februari, 1971: Het genoten onderwijs en het volgen van onderwijs.
Notes: S-1 = First Stage; S-2 = Second Stage; 8.7 (NLD Lower Level) + 27.2 (NLD Extended Lower Level) + 0.8 (NLD Day-time attendance) = 36.7

Under these assumptions, the total attainment of vocational secondary education in 1971 in the Netherlands could be said to be 25 percent of the population over the age of 25. Since this type of education is a subset of total secondary education (which is the combination of lower, extended lower, day-time attendance and secondary) it represents a little more than half (or 55 percent) the total secondary education attainment. This proportion of attainment in Vocational secondary education in 1970/71 is fairly well aligned with the proportion of vocational to total secondary enrolment ratio for the Netherlands in 1965, which works out to be 51 percent.

This is the critical check, because it is ultimately the constructed Vocational enrolment ratio (51 percent) that will be applied to the secondary attainment and years of schooling data reported by Barro and Lee (based on UNESCO data), to determine the Vocational Secondary Attainment and Vocational Secondary Years of Schooling variables. So, it is important to know that our constructed vocational ratio comes close the actual vocational attainment data reported in the census. The next step is to check how Barro and Lee constructed their data from the tables in the UNESCO statistical yearbooks.

[64] http://www.volkstellingen.nl/nl/volkstelling/jaarview/1971/index.html

Matching Data from UNESCO with Attainment and Years of Schooling from Barro and Lee

The data observed in the Barro and Lee data set for educational attainment in the Netherlands in 1970[65] in the population 25 years of age and older are as follows:

Table A.3.4 Barro and Lee Educational Attainment Data: Netherlands 1970, Population 25+

Variable Name	Value	Unit
No Formal Education	2.86	Percent
Primary	44.14	Percent
Secondary	45.8	Percent
Tertiary Education	7.2	Percent
Years of Primary Schooling	5.71	Years
Years of Secondary Schooling	2.08	Years
Years of Tertiary Schooling	0.24	Years
Years of Schooling	8.03	Years

Source: Barro and Lee (2013).
Notes: The percentages reported in the 4 educational attainment categories (No Formal Education, Primary, Secondary and Tertiary Education) are a distribution and sum to 100. The years of primary, secondary and tertiary schooling are calculated based on the fraction of age group that attained that educational level multiplied by the duration of that level of school (correcting for completion and mortality rates). The sum of the relative contributions at each level is equal to the total years of schooling for that country for that year.

How do the numbers correspond to the UNESCO data? Table A.3.5 compares the two sources and finds almost an exact match between the two. The only difference between the two sources is that Barro and Lee report that 2.86 percent of the population in the Netherlands in 1970 had 'No schooling'.[66] This number for 'No schooling' does not match with the proportion of the population listed in the Netherlands census data as 'Level unknown', which was 16 percent for the entire population and ranged from 4 to 26 percent among the different age cohorts. The good news is that the sum of 'No schooling' and 'Primary' for Barro and Lee is an exact match with the data reported by UNESCO for 'First level' which was earlier determined to be almost an exact match with the Netherlands census data. This means that, having reconstructed the way in which UNESCO obtained this educational distribution from the underlying Netherlands

[65] They round to the nearest 5 year interval.

[66] This 2.86 percent is a bit puzzling, Barro and Lee (2013) state that they sometimes use literacy data as a basis for 'No schooling', but in the 1991 UNESCO Statistical Yearbook where the attainment data were found, there are no data for the Netherlands in the Illiteracy Table.

Census data from 1971, it will be possible to check whether the 1965 Vocational enrolment ratio imputed on the secondary educational attainment distribution data from Barro and Lee for 1970 is close to the actual vocational attainment distribution data found in the census data and thus facilitates checking the validity of the application of the ratio to other measures of schooling.

Table A.3.5 Comparing Barro and Lee and UNESCO: Distributions of Educational Attainment Data for the Netherlands, Population 25+

Barro and Lee (2013)		UNESCO (1991)		Exact Match?
Netherlands 1970		**Netherlands 1971**		
No Formal Education	2.86	No Schooling	-	No
Primary	44.14	First Level	47	No, but*
Secondary	45.8	Entered Second Level (S-1 + S-2)	36.7 + 9.1 = 45.8	Yes
Tertiary Education	7.2	Post-Secondary	7.2	Yes

Sources: UNESCO (1991) and Barro and Lee (2013).
Notes: *44.14 (B&L Primary) + 2.86 (B&L No Formal Education) = 47.

Given the reasonable match between the distribution of attainment for the Netherlands in the UNESCO and Barro and Lee data, it is possible to roughly reconstruct the components of each level of schooling that sums to the total variable 'Years of Schooling' which is perhaps the most frequently used Barro and Lee variable in empirical research.

Table A.3.6 walks us through the reconstruction. The left hand panel is exactly what we observe in the Barro and Lee data set as the distribution of educational attainment in the Netherlands in 1970. The right hand panel shows an approximate reconstruction of how the attainment data translate to each level's componential contribution to total years of schooling in the Barro and Lee data set. The simplified calculation is based on the methodology described by Barro and Lee (2013) and is result of multiplying the percentage of the population with at least a given educational attainment by the corresponding level's duration of schooling and then summing the three components (primary, secondary and higher) to reach and average number of years of schooling.

For primary and secondary levels the duration used in Table A.3.6 for the reconstructed calculation is based on information from a diagram that illustrates the duration of different levels of schooling in the Netherlands found in the UNESCO's world survey of education from 1950. A copy of the diagram is available upon request. For higher education, the standard duration of 4 years used by Barro and Lee (2013) is used in the reconstruction. The years of education in the reconstructed calculation are a relatively

close approximation of the Barro and Lee figure, but they are not identical, because Barro and Lee's numbers account for completion ratios and mortality rates (which, as mentioned earlier, differ (a) among countries and (b) with education levels and age).

A similar reconstruction was also done for 1960 for the Netherlands where it was possible to make use of different attainment distributions for 3 distinct age cohorts[67]. Again the final results are fairly similar to those of Barro and Lee, but it was not clear whether Barro and Lee made use of the additional cohort data in 1960. It is more likely that if they used that data, they used it to fill in missing data in subsequent periods. The data from the Netherlands census were separated by 5 year age cohorts and these data were also used to approximately reconstruct the Barro and Lee components and years of schooling. Close approximations were also reached, but only in the case of the tertiary component were the results a closer approximation than the ones presented in Table A.3.6.

These rough reconstructions are useful to check whether applying the imputation of the Vocational / Total Secondary enrolment ratio (from UNESCO) to the component of secondary schooling in the total years of schooling (Barro and Lee) is a valid approach.

Table A.3.6 Approximate Reconstruction of the Components of 'Years of Schooling', Population 25+: Educational Attainment Distribution Combined with Duration to Create Respective Components

Variable Name	B&L Value	Unit		B&L Value	Unit	Reconstructed Calculation
No Formal Edu.	2.86	Percent				
Primary	44.14	Percent	Translates to	5.71	Years of Primary Schooling	≈ 6* .97= 5.83
Secondary	45.8	Percent	Translates to	2.08	Years of Secondary Schooling	≈ 4* .53 = 2.12
Tertiary Education	7.2	Percent	Translates to	0.24	Years of Tertiary Schooling	≈ 4* .07 = 0.29
			Sums to	8.03	Years of Schooling	8.24 Yrs of Schooling

Sources: UNESCO and Barro and Lee (2013).
Notes: .97 is the sum of the percent of the population with primary or more educational attainment: .53 is the sum of the percent of the population with secondary or more educational attainment. The duration for Secondary was adjusted (Barro and Lee did something similar (2013, page 188)) for the different durations of lower and upper secondary school (~ 80 percent of secondary attainment was at the lower level which and ~ 20 percent of secondary attainment was at the upper level for an adjusted duration of 4 years (rounded up)).

[67] The 1971 UNESCO Statistical Yearbook reports educational attainment data for the overall population 25+ as well as 3 cohorts: 25-34; 35-64 and 65+. The reconstruction of the different education level's componential contribution to years of schooling works out to be roughly the same and actually the overall population 25+ yields the closest approximation to the numbers reported by Barro and Lee for 1960.

The Barro and Lee (B&L) secondary years of schooling component –which represents the portion that secondary attainment contributes to overall years of schooling - will be used to generate an approximate sub-component of years of vocational secondary schooling with two different approaches. The first approach (labelled M1 in Table A.3.7 and the country data in Appendix A.6) is to use the Vocational Secondary Enrolment ratio from the previous period (t-5) and apply it to the secondary component of years of schooling from Barro and Lee (in time t) in the same fashion as it was applied to the share of secondary attainment. The second approach (labelled M2 in Table A.3.7 and the country data in Appendix A.6) would be to multiply the share of secondary attainment attributed to vocational education (on the basis of the ratio from the preceding period) by the duration of the vocational programming. Given that the duration of the different vocational tracks varies and that it could have changed over the years, another method could be to do what Barro and Lee do for higher education and use a standard duration for all countries. As a starting point, the same duration of 3 years[68] for all countries for all time periods was used in the second approach.

From Table A.3.7, we can see that the ratio of Vocational / Total Secondary enrolments in 1965 in the Netherlands was 51 percent. This 51 percent[69] was then applied to the share of Secondary Attainment in the Netherlands in 1970 as reported by Barro and Lee (45.80) and results in an approximate figure of 23.4 percent of the population 25 years of age and older with vocational secondary attainment. This represents a difference of 1.6 percentage points between the actual vocational attainment figure from the census data (namely 25 percent, see Table A.3.2 and Table A.3.3). This seems like an acceptable difference, but there are a couple of assumptions and potential issues that should be noted. The first major assumption is that all of the calculations embedded in the Barro and Lee data for Secondary attainment (forward and backward extrapolations for years with missing data; calculations that correct for completion or mortality rates) will be carried forward into the data for 3 of the 4 Vocational Secondary Schooling Variables. To the extent that it is a reasonable assumption that the Vocational enrolment ratio will show up in the attainment data five years later, it is assumed that the vocational program is always less than 6 years long. This may not always be the case.

[68] For the Netherlands, the diagram from UNESCO's World Survey of Education in 1950 was used to determine whether this was a reasonable approximation of the average duration for vocational secondary programs. The calculated average duration was 3.6 years (see Appendix A.5).

[69] Recall that this is a difference of about 4 percentage points between the actual attainment calculated on the basis of the Netherlands census data in 1971 – which yielded 55 percent.

Table A.3.7 Applying the Vocational Enrolment Ratio to the Secondary Attainment for the Netherlands

Year	B&L Total Secondary Attainment	Ratio: Vocational / Total Secondary	Vocational Secondary Attainment	B&L Secondary Years of Schooling	Vocational Secondary Years of Schooling M1	Vocational Secondary Years of Schooling M2	B&L Years of Schooling	Highest Concentration of Educational Level
1950	8.21	0.57		0.39			6.03	Primary
1955	9.67	0.52	5.48	0.45	0.26	0.19	6.17	Primary
1960	11.1	0.50	5.80	0.50	0.26	0.20	6.22	Primary
1965	26.66	**0.51**	13.39	1.23	0.62	0.47	7.04	Primary
1970	**45.80**	0.41	**23.40**	2.08	**1.06**	**0.82**	8.03	Secondary
1975	50.87	0.40	20.76	2.65	1.08	0.73	8.64	Secondary
1980	55.46	0.40	22.06	3.15	1.25	0.77	9.25	Secondary
1985	60.56	0.50	24.52	3.65	1.48	0.86	9.91	Secondary
1990	62.05	0.51	31.22	3.95	1.99	1.09	10.34	Secondary
1995	62.3	0.48	31.91	4.14	2.12	1.12	10.63	Secondary
2000	62.14	0.34	29.82	4.38	2.10	1.04	10.98	Secondary
2005	60.38	0.51	20.35	4.44	1.50	0.71	10.98	Secondary
2010	60.71	0.47	31.23	4.69	2.41	1.09	11.60	Secondary

Sources: Own calculations based on UNESCO and Barro and Lee (2013).
Note: M1 Method based on actual duration, M2 based on a standard duration of three years

From Table A.3.7, we can see that the first approach[70] to calculating Vocational secondary schooling yields a contribution of 1.06 years of education per person and the second approach[71] yields 0.82 years; these figures both represent relatively small shares of the total years of schooling. We have decided not to divide primary schooling on the basis of vocational secondary enrolments. This means that even though primary school is almost always a requisite for entering secondary vocational schooling and thus the proportion of the population who attained vocational secondary schooling also includes a fraction of the population with primary schooling, the primary school data has been kept as a contribution to general years of schooling (not added to the contribution of vocational years of schooling).

[70] Multiplying the Vocational Enrolment ratio from 1965 by the total Secondary Schooling Component from Barro and Lee.

[71] Vocational Secondary Attainment multiplied by a standard duration of 3 years.

Table A.4.1. Population aged 14 and over by age, sex and educational level (sample 1 in 10 (x 10))

	Younger than 20 years	20-24 years	25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years	65 years and older	Total	Total 25+
Men													
Basic Level	42,510	71,985	72,035	92,425	106,040	114,550	123,160	118,045	129,700	121,775	330,250	1,322,460	1,207,980
Lower Level	49,205	70,095	48,950	32,945	25,845	25,240	20,565	17,730	14,860	11,425	15,975	332,840	213,535
Extended Lower Level	127,515	246,730	188,565	151,480	131,905	110,000	96,370	76,610	58,235	42,530	48,195	1,278,130	903,890
general education	23,020	60,345	42,890	30,180	28,380	29,280	25,615	21,335	15,110	13,485	18,030	307,680	224,305
agricultural education	6,350	14,810	15,870	16,930	15,645	12,950	11,190	8,360	7,310	4,350	6,130	119,895	98,735
technical	93,850	163,390	124,150	101,015	84,710	64,800	56,485	43,480	33,740	23,235	22,225	811,065	553,840
other vocational	4,295	8,185	5,655	3,355	3,165	2,965	3,085	3,435	2,075	1,465	1,810	39,490	27,010
Secondary Level	7,055	60,035	55,070	42,095	36,900	34,725	31,725	22,200	15,345	13,380	20,075	338,600	271,515
general education	2,810	16,455	11,695	8,320	8,530	9,330	9,705	7,785	5,425	5,390	9,165	94,615	75,345
agricultural education	880	5,645	4,945	4,050	3,480	2,775	2,710	1,550	1,150	790	1,045	29,020	22,495
technical	1,140	20,540	19,440	14,820	11,100	8,840	6,910	4,410	3,170	2,485	3,205	96,055	74,380
other vocational	2,225	17,390	18,990	14,905	13,790	13,780	12,400	8,455	5,600	4,715	6,660	118,915	99,295
Semi-higher level	165	17,970	30,920	27,100	24,700	20,450	17,725	14,015	11,710	10,060	15,190	190,005	171,870
non-university	165	17,785	29,835	25,480	22,875	18,465	15,545	12,005	10,010	8,755	12,860	173,780	155,830
university		185	1,080	1,620	1,825	1,985	2,180	2,010	1,700	1,305	2,335	16,225	16,040
Higher level		1,780	11,525	14,465	13,145	13,530	13,110	9,825	8,000	6,300	11,930	103,615	101,830
non-university		655	1,965	2,795	2,830	2,720	2,650	2,630	1,815	1,320	3,185	22,565	21,910
university		1,130	9,555	11,670	10,315	10,810	10,460	7,195	6,185	4,980	8,750	81,050	79,920
Level unknown	24,035	55,200	53,295	58,235	56,630	58,170	64,260	60,505	62,185	59,010	147,750	699,290	620,040
Day-time attendance	433,650	83,745	20,000	4,800	2,220	1,440	935	690	560	435	1,170	549,645	32,250
Total	684,135	607,540	480,325	423,570	397,380	378,105	367,850	319,625	300,585	264,915	590,540	4,814,585	3,522,895
							Population 25+ excluding the 'Level unknown' population						2,902,870

Table A.4.1. Population aged 14 and over by age, sex and educational level (sample 1 in 10 (x 10)), continued

	Younger than 20 years	20-24 years	25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years	65 years and older	Total	Total 25+
Women													
Basic Level	42,725	64,415	68,920	96,085	127,320	148,870	164,960	158,625	172,510	165,440	460,560	1,670,435	1,563,290
Lower Level	68,570	96,110	77,605	52,840	39,495	34,450	25,035	21,190	15,490	12,130	16,430	459,350	294,665
Extended Lower Level	144,390	215,770	159,625	126,380	96,215	82,040	73,770	51,840	37,355	26,320	32,820	1,046,540	686,365
general education	45,280	78,860	58,005	43,295	38,990	37,305	32,975	23,385	17,115	14,245	21,145	410,595	286,460
domestic science	80,250	110,005	84,470	70,415	46,295	36,515	32,815	22,540	15,580	9,170	8,800	516,875	326,600
other vocational	18,860	26,905	17,150	12,670	10,930	8,220	7,980	5,910	4,660	2,905	2,875	119,065	73,300
Secondary Level	21,375	74,750	52,775	40,150	33,340	28,915	26,625	20,455	15,780	13,165	21,625	348,960	252,830
general education	6,270	15,675	11,335	7,760	7,080	7,480	7,295	5,520	4,125	4,580	9,065	86,190	64,240
domestic science	10,220	24,985	14,185	8,230	6,130	5,115	5,015	3,490	2,020	990	910	81,295	46,085
other vocational	4,885	34,085	27,260	24,160	20,125	16,320	14,310	11,445	9,640	7,600	11,650	181,475	142,510
Semi-higher level	235	20,375	22,520	18,475	13,890	11,650	9,565	9,025	8,840	9,160	16,720	140,460	119,845
non-university	235	20,245	21,820	17,660	13,325	10,990	9,230	8,475	8,530	8,875	16,280	135,665	115,185
university		130	705	815	565	660	335	545	310	290	440	4,800	4,665
Higher level		505	2,630	2,715	2,445	2,085	1,640	1,300	1,480	1,250	2,395	18,440	17,940
non-university		350	895	735	540	385	405	225	455	195	875	5,060	4,710
university		150	1,735	1,975	1,900	1,700	1,235	1,075	1,025	1,055	1,515	13,380	13,215
Level unknown	31,280	57,235	53,545	54,665	61,085	71,305	78,025	72,880	74,430	75,355	201,725	831,540	743,015
Day-time attendance	341,635	41,015	6,085	2,325	2,020	1,455	1,200	935	840	610	1,350	399,470	16,820
Total	650,215	570,170	443,715	393,635	375,815	380,775	380,825	336,255	326,730	303,440	753,625	4,915,195	3,694,815
							Population 25+ excluding the 'Level unknown' population						2,951,755

Source: 1971 Netherlands Census data[72] Volkstelling A5A annex woningtelling, 28 februari, 1971: Het genoten onderwijs en het volgen van onderwijs. The last column 25+ is calculated by me, the rest of the table is the data I found from the Census.

[72] http://www.volkstellingen.nl/nl/volkstelling/jaarview/1971/index.html

Appendix A.5 Duration of Secondary Vocational Education in the Netherlands in 1950

Educational Pathway	Translation	Duration	Starts at Age
Kleuterschool	Infant school: pre-primary school	3	3
Gewoon lager onderwijs	Primary School	6	6
Klein-seminarium	Junior seminary: general secondary school of academic type providing initial training for intending Roman Catholic Priests	6	12
Gymnasium	Grammar school - general secondary school of academic type, with two streams, A (languages) and B(science)	6	12
Hogere burgerschool	Modern secondary school: general secondary school with two streams, A(languages) and B(science)	6	12
Middelbare school voor meisjes	intermediate school for girls general secondary school of non-academic type for girls	5	12
Uitgebreid lager onderwijs	Advanced elementary school: lower general secondary school	3	12
Voorgezet gewoon lager onderwijs	Continued elementary education	2	12
Uitgebreid lager nijverheidsonderwijs	Advanced elementary vocational training: vocational training school	3	15
Uitgebreid lager niverheidsonderwijs voor meisjes	Advanced elementary vocational training: vocational training school (for girls)	2	15
Kweekschool	Teacher training for primary teachers	5	15
Algemene landbouw of tuibouwschool	Vocational secondary school for agriculture or horticulture	3	15
Middlebaar technish onderwijs	Intermediate technical education: vocational secondary school	4	15
Kunst-, kunstnijnerheid- en bouwkunstonderricht	Instruction in arts and crafts: vocational school of fine arts and crafts	4	15
Zee en luctvaartschool	Navigation and navel and aircraft mechanics school: vocational training school	4	15
Opleiding voor ninerheisonderwijs	Training classes for intending teachers in vocational schools for boys	3	18
Opleiding voor nijerheidsonderwijs (meisjes)	Training classes for intending teachers in vocational schools (for girls)	3	16

Educational Pathway	Translation	Duration	Starts at Age
Lager technische	Lower technical day school: vocational training school	2	12
Avondnijverheidschool	Technical Evening School: Part-time vocational training for boys	5	12
Bedrijfsschool	Vocational training school usually attached to a factory	4	12
Zeevisserijschool en binnenvaartschool	Fishery and inland navigation school vocational training school	2	12
Huishoudschool	Vocational training school of home economics	4	12
Lagere land of tulnbouwschool	Part-time agriculture or horticulture school vocational training	4	12
Handelsonderwijs	Vocational training schools of commerce of various kinds	5	12
	Average duration of vocational	3.6	

Source: UNESCO's World Survey of Education, 1950.
Notes: The duration of the Educational pathways highlighted in grey were averaged. The vocational categories that started at the age of 15, but were described as 'Advanced Elementary' were not included in the average.

Appendix A.6 Vocational Secondary Schooling Variables Dataset

Vocational Secondary Schooling Variables for the Population aged 25 and over

The full set of vocational variables are included in the appendix of Cathles 2016 available for download here: http://www.merit.unu.edu/publications/working-papers/abstract/?id=5911

(Original Data Sources: UNESCO and Barro and Lee):

Appendix B.

Appendix to Chapter 3

Appendix B.1 Descriptive Statistics Table

This appendix presents the descriptive statistics for the data used throughout the chapter.

Table B.1.1 Full Descriptive Statistics Table

Dependent Variables		Mean	S.D.	Min	Max	Observations		Analysis
GDP per Worker PWT 6.3	overall	21538.11	25101.85	415.71	320639.30	No. of Obs.	1068	Barro and Lee & Pritchett
	between		22217.58	1314.63	131385.70	No. of Countries	121	
	within		12058.84	-45808.34	216714.50	T-bar	8.83	
GDP per Capita Maddison	overall	6149.34	6513.02	214.16	36985.71	No. of Obs.	1259	Barro and Lee & Pritchett
	between		5534.33	517.20	21491.60	No. of Countries	121	
	within		3314.86	-6057.43	22266.11	T-bar	10.41	
Growth Rate (5-year) of Per Capita GDP (Maddison)	overall	2.23	2.87	-17.41	13.58	No. of Obs.	818	Szirmai and Verspagen & Own Approach
	between		1.33	-0.26	5.65	No. of Countries	76	
	within		2.54	-14.92	13.5	T-bar	10.76	
GDP per Worker (Mark PWT 5)	overall	8465.14	8131.593	486.6133	38796.21	No. of Obs.	684	Pritchett
	between		8523.373	584.9958	38796.21	No. of Countries	120	
	within		2415.544	-747.4309	17240.45	T-bar	5.7	
TFP growth 1960-1995	x-section	0.002	0.003	-0.007	0.011	No. of Countries	89	Benhabib and Spiegel
TFP growth 1960-2010	x-section	0.002	0.002	-0.005	0.008	No. of Countries	89	

Capital Variables		Mean	S.D.	Min	Max	Observations		Analysis
Log Capital per Worker PWT 6.3	overall	3.07	1.65	-1.94	7.51	No. of Obs.	948	Barro and Lee & Pritchett
	between		1.55	-0.41	6.22	No. of Countries	120	
	within		0.51	-1.20	6.07	T-bar	7.90	
Log Capital per Worker PWT 8.0	overall	10.40	1.34	7.18	13.67	No. of Obs.	1126	Barro and Lee & Pritchett
	between		1.27	7.50	13.01	No. of Countries	121	
	within		0.43	8.62	12.20	T-bar	9.31	

Full Descriptive Statistics Table (*continued)*

Log Capital per Worker PWT 9.0	overall	10.92	1.34	7.18	13.70	No. of Obs.	1132	Barro and Lee, Pritchett & Own Approach
	between		1.28	7.47	13.14	No. of Countries	121	
	within		0.45	8.40	12.71	T-bar	9.36	
Education Variables		**Mean**	**S.D.**	**Min**	**Max**	**Observations**		**Analysis**
Years of Schooling (25+)	overall	5.47	3.31	0.01	13.42	No. of Obs.	1330	All
	between		2.81	0.63	11.09	No. of Countries	121	
	within		1.77	0.71	10.30	T-bar	10.99	
Years of Schooling minus Vocational (25+)	overall	5.24	3.01	0.12	11.82	No. of Obs.	1096	All
	between		2.70	0.54	11.15	No. of Countries	121	
	within		1.58	0.85	9.67	T-bar	9.06	
Vocational Secondary Schooling (25+)	overall	0.36	0.48	0.01	2.43	No. of Obs.	1096	All
	between		0.40	0.01	1.48	No. of Countries	121	
	within		0.25	-0.82	1.45	T-bar	9.06	
Ratio Vocational to Total Secondary (25+)	overall	0.19	0.17	0.01	0.93	No. of Obs.	1275	For Reference: Not used as a Variable in Regressions
	between		0.14	0.01	0.63	No. of Countries	121	
	within		0.10	-0.23	0.72	T-bar	10.54	
Years of Primary Schooling (25+)	overall	3.51	1.95	0.01	8.99	No. of Obs.	1330	Pritchett
	between		1.77	0.45	8.38	No. of Countries	121	
	within		0.85	1.31	6.44	T-bar	10.99	
Years of Secondary Schooling (25+)	overall	1.70	1.46	0.02	6.90	No. of Obs.	1326	Pritchett
	between		1.14	0.07	4.75	No. of Countries	121	
	within		0.92	-1.32	5.93	T-bar	10.96	

Full Descriptive Statistics Table (*continued)*

Education Variables (continued)		**Mean**	**S.D.**	**Min**	**Max**	**Observations**		**Analysis**
Years of Tertiary Schooling (25+)	overall	0.26	0.28	0.01	1.76	No. of Obs.	1281	Pritchett & Benhabib and Spiegel
	between		0.20	0.01	0.86	No. of Countries	121	
	within		0.19	-0.41	1.29	T-bar	10.59	
Years of Schooling (15+)	overall	5.88	3.16	0.04	13.02	No. of Obs.	1331	For Reference: Not used as a Variable in Regressions
	between		2.68	0.86	11.24	No. of Countries	121	
	within		1.69	1.45	10.14	T-bar	11	
Edu (15+) S&V dataset	overall	4.77	2.7	0.1	11.85	No. of Obs.	809	Szirmai and Verspagen
	between		2.42	1.01	10.09	No. of Countries	76	
	within		1.31	1.24	8.63	T-bar	10.64	
Years of Schooling (25+)	overall	3.96	2.73	0.04	12.14	No. of Obs.	607	Pritchett
B&L 1993 dataset	between		2.61	0.32	10.70	No. of Countries	111	
	within		0.75	1.55	6.20	T-bar	5.47	
Log of 'Educational Capital'	overall	1.51	0.43	1.00	3.18	No. of Obs.	607	Pritchett
	between		0.41	1.03	2.79	No. of Countries	111	
	within		0.13	1.08	2.02	T-bar	5.47	

Other Explanatory Variables		**Mean**	**S. D.**	**Min**	**Max**	**Observations**		**Analysis**
Oil Exporter (Dummy)	overall	0.12	0.32	0	1	No. of Obs.	1243	Barro and Lee & Own Approach
	between		0.28	0	1	No. of Countries	121	
	within		0.16	-0.79	1.03	T-bar	10.27	

Full Descriptive Statistics Table (*continued*)

Other Explanatory Variables (continued)		Mean	S. D.	Min	Max	Observations		Analysis
Relus	overall	31.28	33.14	0.43	306.22	No. of Obs.	1069	Own Approach
(GDP per Capita Relative to the U.S.)	between		30.80	2.49	178.67	No. of Countries	121	
G-K method PWT 6.3	within		11.36	-69.40	158.83	T-bar	8.83	
Manufacturing	overall	17.78	8.12	0	44.8	No. of Obs.	724	Szirmai and Verspagen
(Value-added Share at Current Prices)	between		6.26	5.53	30.66	No. of Countries	76	
	within		5.29	-4.26	45.58	T-bar	9.53	
Services	overall	48.86	12.33	0	86.5	No. of Obs.	721	Szirmai and Verspagen
(Value-added Share at Current Prices)	between		9.73	24.32	74.03	No. of Countries	76	
	within		8.24	-4.46	90.7	T-bar	9.49	
RELUS	overall	30.49	26.74	1.4	115.7	No. of Obs.	818	Szirmai and Verspagen
(GDP per Capita relative to the U.S.)	between		26	2.95	98.35	No. of Countries	76	
	within		7.36	-7.65	65.71	T-bar	10.76	
kgatemp (Dummy)	overall	0.28	0.45	0	1	No. of Obs.	1694	Szirmai and Verspagen
	between		0.45	0	1	No. of Countries	121	
	within		0	0.28	0.28	T-bar	14	
Openness	overall	69.31	50.66	5.05	446.06	No. of Obs.	1179	Szirmai and Verspagen
	between		46.57	13.91	350.29	No. of Countries	121	
	within		22.45	-32.82	228.33	T-bar	9.74	
Log of Population	overall	9.31	1.51	5.69	14.05	No. of Obs.	836	Szirmai and Verspagen
	between		1.48	5.87	13.67	No. of Countries	76	
	within		0.36	8.02	10.35	T-bar	11	
TFP ratio 1960 (Relative to the U.S.)	x-section	0.83	0.12	0.59	1.09	No. of Countries	89	Benhabib and Spiegel

Sources: Barro and Lee 2010 and 1993; Szirmai and Verspagen, 2015; Maddison 2009; Penn World Tables 9.0, 8.0 and 6.3; World Development Indicators; and Gallup et al. 1999.
Notes: Recall that 'kgatemp' is a dummy variable that takes a 1 if >50% of the land area is in the temperate zone and openness is in current prices and is expressed as a percent (exports minus imports as a percent of GDP). 'Relus' is the measure for the distance of the economy to the frontrunner of productivity and is the GDP per Capita relative the U.S. at the start of the period. 'Edu (15+) S&V dataset' is the years of schooling variable that was used by Szirmai and Verspagen and is described in more detail in Section 4.3. Log of the population is the log of population size at the start of the period.

Table B.2.1 Original Barro and Lee Results and Our 'Most Exact' Replication Results

Original Barro and Lee (2010) OLS and IV Regression Results (pg 38)					Replication of Barro and Lee (2010) OLS and IV Regression Results				
A. Rate-of-return to Schooling: Total Population, 15 years and above									
Dependent Variable: ln (Real GDP per worker)					Dependent Variable: ln (Real GDP per Worker PWT 6.3)				
	OLS		IV			OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed		Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
ln (capital stock per worker)	0.652	0.65	0.58	0.544	Log (ln) Capital per Worker PWT 6.3	0.54***	0.49***	0.38***	0.20***
	[27.3]***	[20.1]***	[18.3]***	[12.3]***		(0.05)	(0.07)	(0.04)	(0.06)
Ave. years of schooling	0.017	0.019	0.055	0.121	Average years of schooling 15+	0.04**	0.04	0.08***	0.00
	[1.77]*	[1.74]*	[3.26]***	[3.16]***		(0.02)	(0.03)	(0.02)	(0.03)
Oil Exporter Dummies Included	yes	yes	yes	yes	Oil Exporter Dummies Included	yes	yes	yes	yes
Time Dummies Included	yes	yes	yes	yes	Time Dummies Included	yes	yes	yes	yes
Constant	Included but not reported				Constant	7.59***	7.76***	8.09***	8.93***
						(0.11)	(0.20)	(0.12)	(0.22)
Observations	962	962	962	962	Observations	892	892	704	704
Number of countries	127	127	127	127	Countries	122	122	122	122
					R-sq. within	0.46	0.46	0.16	0.19
					R-sq. between	0.85	0.84	0.83	0.82
R-squared	0.87	0.61	0.86	0.55	R-sq. overall	0.83	0.82	0.81	0.79
B. Rate-of-return to Schooling by Region					**B. Rate-of-return to Schooling by Region**				
	(5)	(6)	(7)	(8)		(5)	(6)	(7)	(8)
ln (capital stock per worker)	0.625	0.596	0.56	0.492	Log (ln) Capital per Worker PWT 6.3	0.51***	0.42***	0.32***	0.11*
	[23.0]***	[15.1]***	[16.4]***	[8.55]***		(0.05)	(0.07)	(0.04)	(0.06)
Ave. years of schooling (15+)					Average Years of Schooling (15+)				
Advanced countries	0.031	0.047	0.066	0.133	Advanced Economies	0.07***	0.09***	0.12***	0.09***

Original Barro and Lee (2010) OLS and IV Regression Results (pg 38)					Replication of Barro and Lee (2010) OLS and IV Regression Results				
	[3.27]***	[3.90]***	[3.75]***	[3.39]***		(0.02)	(0.03)	(0.02)	(0.03)
East Asia	0.032	0.052	0.052	0.103	East Asia and the Pacific	0.08***	0.14***	0.11***	0.13**
	[2.52]**	[3.91]***	[2.43]**	[2.53]**		(0.02)	(0.04)	(0.03)	(0.05)
Europe and Central Asia	-0.012	0.008	0.015	0.085	Europe and Central Asia	0.02	0.10***	0.04	0.04
	[0.94]	[0.38]	[0.75]	[1.56]		(0.02)	(0.03)	(0.03)	(0.07)
Latin America	0	-0.001	0.034	0.065	Latin America and the Caribbean	0.02	0.02	0.04	-0.06
	[0.02]	[0.05]	[1.81]*	[1.82]*		(0.02)	(0.03)	(0.02)	(0.04)
North Africa and Middle East	0.008	-0.001	0.057	0.078	North Africa and Middle East	0.03	-0.01	0.07*	-0.01
	[0.57]	[0.04]	[2.91]***	[2.43]**		(0.03)	(0.05)	(0.04)	(0.05)
South Asia	-0.015	0.001	0.035	0.113	South Asia	0.01	0.07	0.09***	0.14***
	[0.57]	[0.05]	[1.09]	[1.97]**		(0.03)	(0.05)	(0.03)	(0.04)
Sub-Saharan Africa	0.006	0.004	0.038	0.066	Sub-Saharan Africa	0.01	0.01	-0.03	-0.07
	[0.51]	[0.27]	[1.76]*	[1.78]*		(0.03)	(0.04)	(0.03)	(0.05)
Oil Exporter Dummies Included	yes	yes	yes	yes	Oil Exporter Dummies Included	yes	yes	yes	yes
Time Dummies Included	yes	yes	yes	yes	Time Dummies Included	yes	yes	yes	yes
Constant	Included but not reported				Constant	7.69***	7.86***	8.30***	9.07***
						(0.12)	(0.24)	(0.12)	(0.24)
Observations	962	962	962	962	Observations	892	892	704	704
Number of countries	127	127	127	127	Countries	122	122	122	122
					R-sq. within	0.48	0.50	0.25	0.32
					R-sq. between	0.84	0.70	0.80	0.38
R-squared	0.87	0.62	0.87	0.58	R-sq. overall	0.82	0.70	0.78	0.39

Notes: In the left hand panel Barro and Lee report T statistics in parentheses. In the right hand panel, we report robust standard errors in parentheses. PWT stands for Penn World Tables. * p<0.10, ** p<0.05, *** p<0.01.

Appendix B.3 Additional Tables for the Szirmai and Verspagen (2015) Replication

Table B.3.1 Our 'Most Exact' Replication of Table 2 in Szirmai and Verspagen

	Dependent Variable = Growth of per capita GDP (Maddison 2009)			
	Random	Fixed	HT	BE
	(1)	(2)	(3)	(4)
Value added share of Manufacturing (% of GDP)	0.0489**	0.0578*	0.0370	0.0967*
	(0.02)	(0.03)	(0.02)	(0.05)
Value added share of Services (% of GDP)	0.0249	0.0020	0.0139	-0.0189
	(0.02)	(0.02)	(0.02)	(0.03)
GDP per capita relative to the US at the beginning of the 5 yr period	-0.0461***	-0.1035***	-0.0844***	-0.0306*
	(0.01)	(0.02)	(0.01)	(0.02)
Taken from Barro and Lee (avg years of schooling 15+)	0.3217***	0.0524	0.0741	0.2487
	(0.11)	(0.19)	(0.14)	(0.17)
Dummy variable =1 if more than 50% of the land is in the temperate zone	1.1100***	Omitted	3.2684**	0.4724
	(0.42)		(1.45)	(0.52)
Openness in Current Prices	0.0067	0.0104	0.0094*	0.0191**
	(0.01)	(0.01)	(0.01)	(0.01)
log population UN 2009 from the structural change dataset	0.0969	-2.5358***	-0.5383	0.3487*
	(0.17)	(0.86)	(0.35)	(0.19)
D1955-60	0.4037	1.3400***	0.8805*	-21.3633**
	(0.36)	(0.45)	(0.46)	(8.16)
D1960-65	0.5191	1.7699***	1.1013**	10.0150
	(0.34)	(0.47)	(0.47)	(9.08)
D1965-70	-0.0665	1.7611***	0.8110	-19.5978***
	(0.45)	(0.64)	(0.52)	(7.07)
D1975-80	-0.4739	1.7455**	0.5534	2.0976
	(0.53)	(0.79)	(0.54)	(9.31)
D1980-85	-2.7809***	-0.1266	-1.5585***	-8.9756
	(0.46)	(0.80)	(0.59)	(7.43)
D1985-90	-2.0662***	0.9658	-0.6857	-11.2206
	(0.46)	(0.85)	(0.64)	(7.19)
D1990-95	-2.1498***	1.1976	-0.6439	-7.1322
	(0.47)	(0.98)	(0.70)	(6.46)
D1995-00	-2.2119***	1.5917	-0.5241	9.3833
	(0.61)	(1.18)	(0.77)	(6.87)
D2000-05	-1.8757***	2.2129*	-0.0619	-22.1960***
	(0.59)	(1.20)	(0.81)	(6.48)
Constant	-0.4697	26.0982***	6.9249**	3.6039
	(1.71)	(7.73)	(3.38)	(5.68)
Observations	679	679	679	679
R-squared Overall	0.17	0.001		
R-squared Between	0.15	0.19		0.51
R-squared Within	0.17	0.02		

Source: Own elaboration based on data collected by Szirmai and Verspagen and primary sources described in Section 3 of this paper.

Appendix B.4 Additional Tables for the Pritchett (2001) Replication

Table B.4.1 Extension of the Pritchett Analysis: Split Education Capital Primary, Secondary (Non-vocational and Vocational) and Tertiary | Highest r to Tertiary

	Split Educational Capital into Primary, Secondary (Vocational and Non-Vocational) and Tertiary			
	GDP and K = PWT 6.3		GDP and K = PWT 9	
	(7a)	(8a)	(7b)	(8b)
Growth of 'Primary Capital' per Worker (r = 0.08)	-0.27**	-0.27*	-0.14**	-0.14
	(0.11)	(0.14)	(0.06)	(0.09)
Growth of 'Secondary Non-Vocational Capital' per Worker (r=0.12)	-0.02	-0.14	0.04	-0.04
	(0.09)	(0.10)	(0.04)	(0.06)
Growth of 'Secondary Vocational Capital' per Worker (r=0.12)	0.04	0.11*	0.02	0.04
	(0.07)	(0.06)	(0.04)	(0.04)
Growth of 'Tertiary Capital' per Worker (r = 0.16)	0.36***	0.24**	0.13*	0.03
	(0.13)	(0.10)	(0.08)	(0.09)
Growth in Capital* per Worker	0.32***	0.24***	0.60***	0.52***
	(0.07)	(0.06)	(0.06)	(0.08)
ln (initial GDP per Worker)		-0.005*		-0.005**
		(0.002)		(0.002)
Constant	-0.003	0.05*	-0.003	0.05**
	(0.01)	(0.03)	(0.004)	(0.02)
Countries	95	77	95	64
R-squared	0.47	0.48	0.75	0.74

Notes: Pritchett has t-statistics in parentheses and I have Standard errors in parentheses. *Pritchett calls Capital 'CUDIE' in his results table: Cumulated Depreciated Investment Effort. * p<0.10, ** p<0.05, *** p<0.01.

Appendix B.5 Introducing the Lagged Dependent Variable in the OLS FE effects setting

In general, introducing the lagged dependent variable (log of GDP per capita) in the OLS fixed effects levels regression seems to wash out the effects of the other variables. In column 1, while the education variables become negative and slightly significant, the coefficient on Capital per worker, which usually is robust and stable across almost any OLS FE specification, shrinks remarkably to 0.09 (although it is still statistically significant). The lagged dependent variable has a huge coefficient, which illustrates how it is dominating the regression. We are reminded that when exogenous variables are heavily trended themselves, the fact that a lagged dependent variable dominates the regression may be a statistical artifact, rather than any evidence of a causal relationship (Achen, 2001).

In column 2, when we introduce lags of the explanatory variables, the schooling variables, the coefficient on the contemporaneous effect of capital per worker is restored to a value within an expected range, and the coefficients on the schooling variables are insignificant. Column 3 drops the contemporaneous explanatory variables and includes only their lags. The result is that all the effects are washed out, even the effect of capital per worker.

Table B.5.1 Further Assessing Vocational Secondary Schooling: Introducing Lagged log GDP per Capita

	Panel A: LEVELS		
Dependent variable:	**Log GDP per capita 1960-2010**		
	OLS FE	OLS FE	OLS FE
	(1)	(2)	(3)
Non-vocational Years of Schooling	-0.01*	-0.01	
	(0.01)	(0.01)	
Vocational Secondary Schooling	-0.04*	0.01	
	(0.03)	(0.03)	
Lag (1 period) Non-vocational Years of Schooling		0.01	-0.01
		(0.02)	(0.01)
Lag (1 period) Vocational Secondary Schooling		-0.01	-0.04
		(0.03)	(0.03)
Log K per Worker PWT 9.0	0.09**	0.45***	
	(0.04)	(0.06)	
Lag (1 period) Log K per Worker PWT 9.0		-0.38***	-0.01
		(0.05)	(0.03)
Lag (1 period) Log GDP per capita	0.79***	0.77***	0.86***
	(0.04)	(0.03)	(0.03)
Oil exporter and time dummies included	y	y	y
Constant	0.85***	1.11***	1.40***
	(0.26)	(0.22)	(0.25)
Observations	840.00	774.00	814.00
Countries	105.00	105.00	105.00
R-sq.	0.88	0.90	0.88

Notes: Robust Standard errors in parentheses. * p<0.10 ** p<0.05 *** p<0.01

The results presented here are for the sake of comparison. Otherwise, applying OLS to dynamic models with issues of persistence and (potential) endogeneity is not advisable. That is why we focused our own empirical approach on GMM techniques.

Appendix C.

Appendix to Chapter 4

Appendix C.1 Describing Countries' Data Availability

Table C.1.1 Countries with sufficient UIS and PIAAC data

Country	UIS Investment Data	PIAAC Data
Belgium (Flanders)	**Yes**	**Yes**
Denmark	**Yes**	**Yes**
Finland	**Yes**	**Yes**
France	**Yes**	**Yes**
Ireland	**Yes**	**Yes**
Italy	**Yes**	**Yes**
Japan	**Yes**	**Yes**
Netherlands	**Yes**	**Yes**
Norway	**Yes**	**Yes**
Spain	**Yes**	**Yes**
Sweden	**Yes**	**Yes**
UK (England / N. Ireland)	**Yes**	**Yes**
Australia	Only after ~ 1993 (consistently)	Missing a STATA file for AUS
Austria	Yes	Missing AGE variable
Canada	Not sufficient Inv. Data	Missing AGE variable
Czech Republic	Only after ~ 1993 (consistently)	Yes
Estonia	Only after 1993	Missing ISCED classification
Germany	Not sufficient Inv. Data	Yes in the ZA_5845
Korea	Only after 1998	Yes
Poland	Only after ~ 2002 (consistently)	Yes
Slovak Republic	Only after 1992	Yes
United States	Only after ~ 1986	Missing AGE variable
Partners		
Cyprus	Missing Inv. Data	
Russian Federation	Missing Inv. Data	Yes

Sources: PIAAC (OECD, 2015) and data provided by UIS.

Appendix C.2 PIAAC Numeracy Assessment Tasks

An example of a question that has a difficulty of 228 (which is at the low end of Level 2), asks respondents to look at a picture of a gas tank gauge that has needle indicating that the tank is three quarters full and asks "The full tank holds 48 gallons, how many gallons remain in the tank?" Figure Appendix C.2.1 shows that, on average, people in the 12 OECD countries can answer that question, but not a question that asks them to detect a pattern and formula (as illustrated by the example question indicative of a difficulty level of 307).

Table C.2.1 Examples of PIAAC Questions and Associated Numeracy Scores

Score	Level	Task Description	Example	Photo
0-175	Below Level 1	Concrete, familiar contexts. Simple processes, counting, sorting, basic arithmetic.	How many water bottles?	
176-225	Level 1	Tasks usually require simple one-step or two-step processes involving basic arithmetic operations.	Respondent is shown a picture of Tea candles (100 candles) - it can be seen the candles are packed 5 rows of 5 candles each how many layers of candles are there?	
226-275	Level 2	Tasks tend to require the application of two or more steps or processes involving calculation with whole numbers and common decimals, percents and fractions.	The full tank holds 48 gallons, how many gallons remain in the tank? (Low end of Level 2 | 228)	
276-325	Level 3	Tasks in this level require the respondent to understand mathematical information which may be less explicit not always familiar, and represented in more complex ways.	Discern the pattern and the formula. (Difficulty: 307)	
326-375	Level 4	These tasks involve undertaking multiple steps and choosing relevant problem-solving strategies and processes.	Compound interest. Respondents are shown the advertisement and asked whether it is possible to double $1,000 and support the answer with relevant calculations.	**Advertisement:** Double the amount invested in 7 years based on a 10% fixed interest rate each year.
376-500	Level 5	Tasks in this level require a broad range of mathematical information that may be complex, abstract or embedded in unfamiliar contexts.	No example given.	

	Single Ticket Price	Season Ticket Price
Orchestra	10	45
Sporting Event	16	72
Movies	5	22.5
Concert	250	1125

Source: Everything except the last column (column 5) was excerpted from the OECD PIAAC Technical Report (OECD, 2013c).

Appendix C.3 Linking UIS Investment data with PIAAC

This appendix explains how investment data have been assigned to the highest levels of educational attainment on the basis of International Standard Classification of Education (ISCED) classification codes which are available in the PIAAC data. It gives two examples to illustrate exactly how Eq. 3 and Eq. 4 are applied to assign cumulative public investment. The OECD has already undertaken the effort to standardize the educational attainment across the countries participating in PIAAC and has classified the nominal years of schooling in each country according to the ISCED standards and recorded this in the variable 'Highest Level of Qualification' (HLQ) which we use to ascertain the amount of public investment, specifically from which streams of funding (either the primary, secondary or tertiary levels) that should be assigned to each individual.

For the sub-group in 'Uncompleted Secondary': according to the HLQ in the PIAAC data, the individual has attained ISCED 2, and is therefore assumed to have 3 years of secondary school. It is assumed that all individuals have completed a standard 6 years of primary education. This analysis excludes individuals who have not attained at least some secondary schooling.

For the sub-group in 'Completed Secondary': according to the HLQ in the PIAAC data, the individual has attained ISCED 3, and is therefore assumed to have 6 years of secondary school.

For the sub-group in 'Tertiary': according to the HLQ in the PIAAC data, the individual has attained ISCED 4 the following assignments have been made:

- If the individual has attained ISCED 4: 1 year of tertiary public expenditure (Tertiary 1),
- If the individual has attained ISECD 5a, Bachelor's: 3 years of tertiary public expenditure (Tertiary Bachelor's),
- If the individual has attained ISECD 5b: 2 years of tertiary public expenditure (Tertiary Vocational),
- If the individual has attained ISECD 5a, Master's: 4 years of tertiary public expenditure (Tertiary Masters),
- If the individual has attained ISECD 6: 6 years of tertiary public expenditure (Tertiary Doctorate).

All individuals who have attained at least ISCED 4 have been grouped together in one category called 'tertiary', but the assignment of public expenditure has been done on the basis of their individual levels of educational attainment (HLQ). The nominal years of schooling in each country that are associated with each ISCED level of schooling are compiled the Technical Report for the PIAAC database (OECD, 2013). A summary of the relevant information for the preliminary analysis is presented in Appendix C.5.[73]

Example 1: how public investment in Person$_i$ in Italy who was 43 years of age at the time of the PIAAC survey has been cumulated and assigned.

1) 2011 – 43 = 1968 (calculated year of birth)

2) 1968 + 6 = 1974 (assumed age at which Person$_i$ begins Primary School)

Table C.3.1 Example of how Public Expenditure is assigned

Year	Gov. Expenditure on Primary Education (LCU) (i.e., Lira)	Enrolment in Primary Education (i.e., in Italy)	Expenditure per Pupil for Primary Edu (i.e., in Italy)	GDP per capita, old LCU for EUR countries (i.e., Lira)	Public Expenditure per Pupil as % of GDP
1974	1,456,467,992,580	4,969,667	293,072	2,269,171	12.9
1975	1,656,310,022,140	4,927,452	336,139	2,583,585	13.0
1976	2,041,771,933,700	4,833,415	422,428	3,234,577	13.1
1977	m	4,735,301	m	3,913,702	13.4
1978	2,925,500,088,320	4,648,504	629,342	4,587,585	13.7
1979	3,801,362,923,520	4,562,441	833,186	5,595,832	14.9
				Sum Primary Person$_i$	81.0

Source: Data provided by UIS.
Notes: Our interpolation for 1977 is in red. 'm' stands for missing.

[73] As can be seen in Appendix C.5, there is variation between the number of years associated with certain levels of schooling (i.e., in Belgium (Flanders) 16 years of schooling are associated with a Master's degree, while in Denmark 17 years of schooling are generally required for a Master's degree). Therefore, when investments were imputed for individuals within countries, the number of years of investment for a particular level can vary according to national standards. Sometimes it is impossible to distinguish exactly how many years would be required to reach a particular level. We made the decision to assign a consistent number of years of public expenditure across all countries for the HLQ (Highest Level of Qualification).

3) Repeat for Secondary and Tertiary *(Depending on the Highest Level Qualification of Person$_i$). Assuming no breaks, skips or repeats.

4) Sum the expenditures over the person's education lifetime:
   - amount for primary (in this example 81.0)
   - plus amount for secondary
   - plus amount for tertiary (if tertiary is attained).

Example 2: is the person with the maximum investment in our sample. This person took the PIAAC assessment in Belgium, was 32 years old in 2011, and attained a doctorate degree. Public investment for this person is computed as follows:

1) Public Investment in Primary education - cumulated over the 6 years (1985-1990):
   222.5 = (37.7 from 1985 + 37.4 (exact calculation described) from 1986 + 40.7 from 1987+ 42.5 from 1988 + 35.5 from 1989 + 28.5 from 1990).
   Exact calculation: 1986 Primary Expenditure per student over GDP per Capita in Denmark. The Danish government invested 20,570,999,168 Krone (LCU) in primary education in 1986. There were 402,707 number of students enrolled in primary education. The education in primary per student in 1986 was: 51,082 Krone. Divided by the GDP per Capita (136,467 in current LCU – derived from the Euro conversion), is equal to a public investment per student over GDP per capita of 37.4.

2) Public Investment in Secondary education - cumulated over the 6 years (1991-1996):
   211.5 = (31.6 from 1991 + 34.8 from 1992 + 38.1 from 1993 + 34.8 from 1994 + 35.0 from 1995 + 37.2 from 1996)

3) Public Investment in Tertiary education, cumulated over the 6 years (1997-2002):
   408 = (59.9 from 1997 + 62.5 from 1998 + 65.9 from 1999 + 70.2 from 2000 + 75.6 from 2001 + 73.9 from 2002).

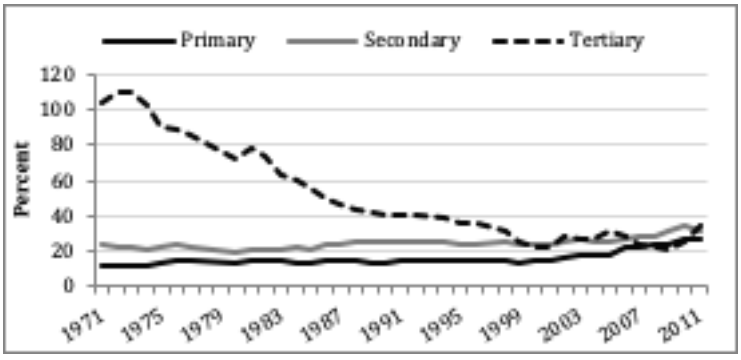
4) The total public investment for this person would be: 842 = (222.5 + 211.5 + 408).

Appendix C.4 Descriptive Analysis - Public Investment in Education

Figure C.4.1 portrays trends in public expenditure per student as a fraction of the country's GDP in the three levels of schooling for a subset of countries in the sample. The figure shows substantial variation between the different countries and within countries over time. Looking at the marked decrease in investment in tertiary education in the UK since the 1970s, it's possible that the older population in the UK who achieved the tertiary level of education, benefited from stronger public support than younger cohorts. In Denmark, funding for tertiary education has consistently remained a priority over the 40 year period. Italy and France show relatively low and flat levels of investment over the time period, with Italy's public investment per student tapering out at about 20 percent.

Figure C.4.1 Trends in Public Investment by Level of Education, Selected countries

UK: Government Expenditure as a % of GDP per Capita



Denmark: Government Expenditure as a % of GDP per Capita

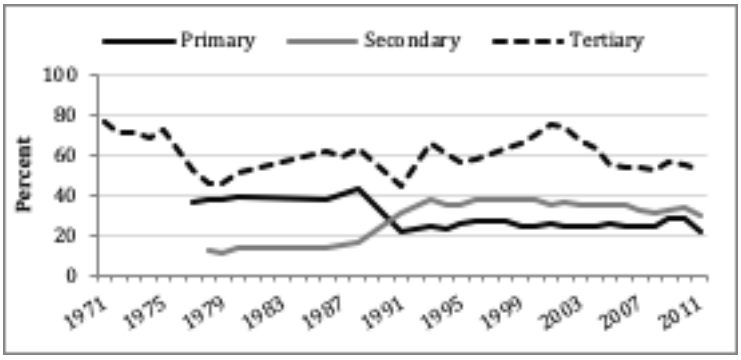
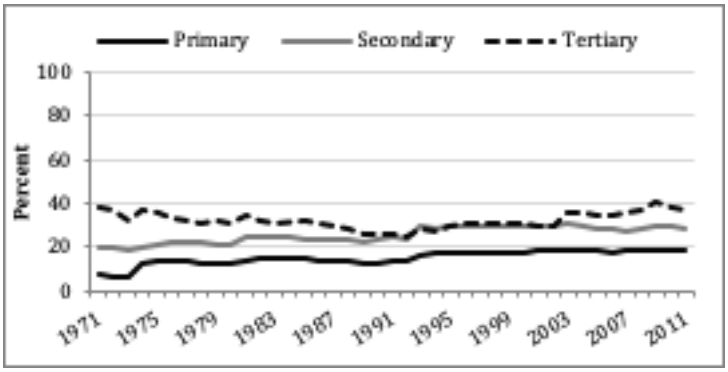
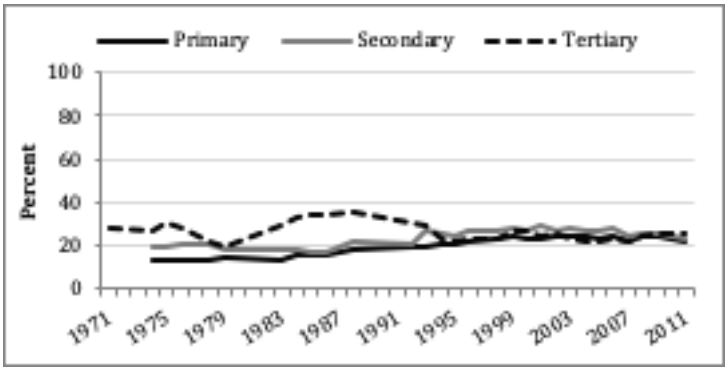


Figure C.4.1 Trends in Public Investment by Level of Education, Selected countries (continued)

France: Government Expenditure as a % of GDP per Capita



Italy: Government Expenditure as a % of GDP per Capita

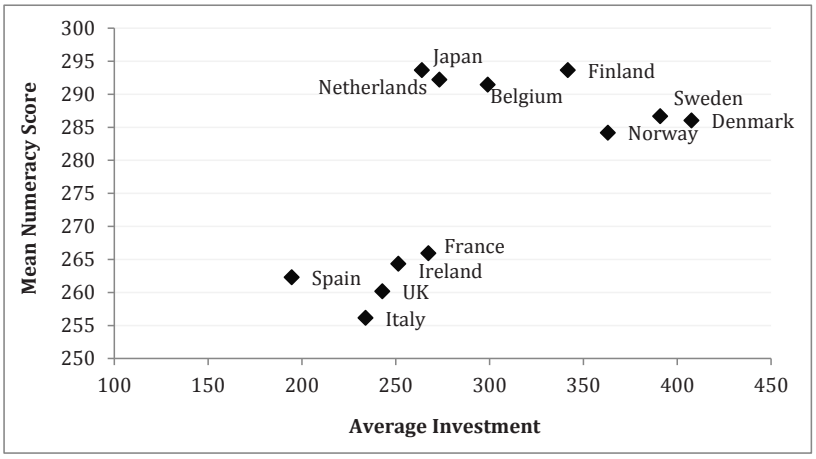


Source: Own elaboration based on data provided by UIS.

Appendix C.4 Descriptive Analysis - Public Investment in Education (continued)

Figure C.4.2 plots the mean numeracy score against the mean public investment for each country, regardless of education level. We see some clustering of countries with respect to numeracy scores. There are the countries clustered toward the lower-left; Italy, the UK, Ireland, Spain and France. These countries are the ones with a higher proportion of people with skills that are 'Level 1' and below dragging the overall mean numeracy score down in these countries. Considering the examples of numeracy tasks (see Appendix C.2) in PIAAC, level 1 is practically innumerate. The other cluster of countries; Norway, Sweden, Denmark, Belgium (Flanders), Finland, the Netherlands and Japan are clustered to the upper-right and these are the countries with a relatively higher proportion of people with skills that are 'Level 2' and above bringing the mean numeracy scores in those countries up. It is notable that there is very small proportion of people (for which we have data) with 'Level 5' numeracy skills in any of the countries. When we simply compare the mean numeracy with relative public effort some countries, such as France and the Netherlands are, on average, investing similar amounts (vis-à-vis) their respective GDPs, but the Netherlands appears to be getting better results in terms of the average numeracy of its adult population.

Figure C.4.2: Relationship between Mean Numeracy Score and Average Public Investment



Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.

Notes: The UK is England/N. Ireland for PIAAC numeracy and UIS investment; Belgium is actually Flanders (Belgium) for PIAAC numeracy, but not necessarily for UIS investment. The possible numeracy scores range from 0 to 500, but the scale shown on the axis for both numeracy scores and mean public investment has been truncated for visualization purposes. These numeracy scores were calculated using all plausible values and replicate weights, rather than using the first plausible value. In the case of the UK, there is an additional difference, because due to a coding issue with the data in the UK, mean scores and investments for individuals with ISCED level 6 (tertiary) are not included in this figure. These individuals are included in the analysis and tables in the main text.

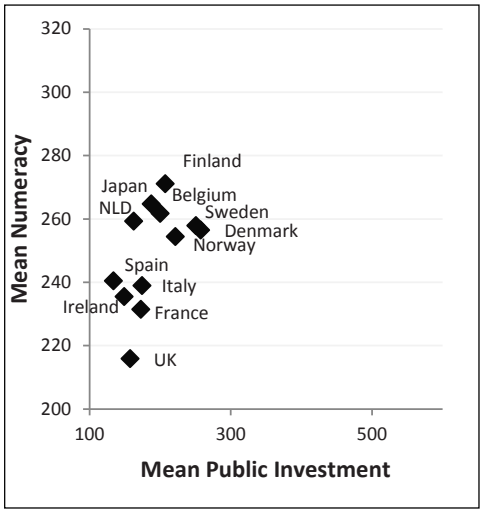
Appendix C.4 Descriptive Analysis - Public Investment in Education (continued)

Figure C.4.3 plots mean numeracy by our three educational attainment groups. As we would expect, the mean numeracy scores increase with the levels of educational attainment for all of the countries in this analysis. In France we see that the mean numeracy scores are relatively low at the uncompleted and completed secondary levels, the mean numeracy of those who have attained a tertiary education is closer to that of the countries with overall higher average numeracy scores.

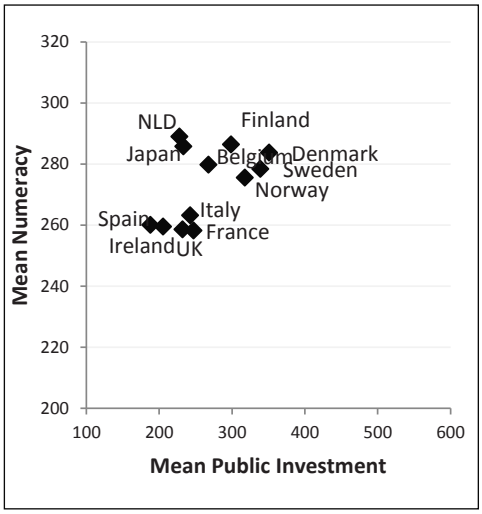
The relationship between mean public investment and the mean numeracy score seems to change as we move up the educational ladder. The variation among countries mean scores is highest at the lowest levels of educational attainment (uncompleted secondary), but the variation in relative public investments (relative to each country's GDP) is the smallest. At the secondary level the mean scores cluster together more; but some countries start to emerge as bigger investors. By the time we reach the tertiary level, some countries are clearly investing more, and for the most part, those that invest more seem to be getting better results.

Figure C.4.3: Mean Numeracy Score and Average Public Investment per Student by Education Level

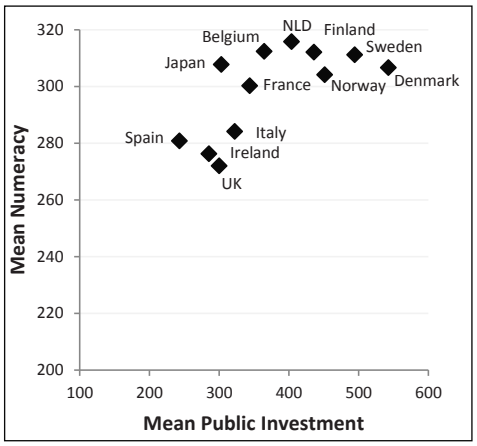
Uncompleted Secondary



Completed Secondary



Tertiary



Source: Own elaboration based on PIAAC (OECD, 2015) and data provided by UIS.
Notes: The UK is England/N. Ireland for PIAAC numeracy and UIS investment; Belgium is actually Flanders (Belgium) for PIAAC numeracy, but not necessarily for UIS investment. These numeracy scores were calculated using all plausible values and replicate weights, rather than using the first plausible value. In the case of the UK, there is an additional difference, because due to a coding issue with the data in the UK, mean scores and investments for individuals with ISCED level 6 (tertiary) are not included in the tertiary panel in this figure. These individuals are included in the analysis in the main text.

Appendix C.5 Describing Years Corresponding to Educational Category at the National Level

The following table shows the number of years that are associated with each level of ISCED educational attainment, by country.

Table C.5.1 Corresponding Years to Educational Categories in the Countries in our sample

		BELGIUM			DENMARK			FINLAND			FRANCE			IRELAND			ITALY		
ISCED Level	B_Q01a (PIAAC)	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV
No formal qualification or below ISCED 1	**1**										5						0		
ISCED 1	**2**	6			6			6			5			8			5		
ISCED 2	**3**	8	1	9	9	1	9	9	1	9	5,9*	1	9	11,12*	1	9	8	1	9
ISCED 3C Shorter than 2 years	**4**	n.a.			10		n.r.	n.a.			11		n.r	n.a.			9	2	12
ISCED 3C 2 Years or more	**5**	12	2	12	12	2	12	n.a.			14	2	14	n.a.			11	2	12
ISCED 3A-B	**6**	12	2	12	12	2	12	n.a.			13	2	13	n.a.			13	2	12
ISCED 3 (without distinction A-B-C 2y+)	**7**	12	2	12	12	2	12	11,12*	2	12	12	2	12	14	2	12	n.a.		
ISCED 4C	**8**	n.a.				3	13	n.a.			n.a.			15,18*	3	13	n.a.		
ISCED 4A-B	**9**	13	3	13	13	3	13	n.a.			n.a.			n.a.			n.a.		
ISCED 4 (without distinction A-B-C)	**10**	13	3	13	13	3	13	12	3	13	n.a.			n.a.			15	3	13
ISCED 5B	**11**	15	3	14	15	3	14	14	3	14	14	4	14	16,17*	3	14	16	3	14
ISCED 5A, bachelor's degree	**12**	15	3	15	15	3	15	16,15*	3	15	14,15*	5	15	18	3	15	18	3	15
ISCED 5A, master's degree	**13**	16	3	17	17	3	17	17	3	17	17**	6	17	19	3	17	19	3	17
ISCED 6	**14**	20	3	18	20	3	18	19,21*	3	18	20	7	18	21	3	18	21	3	18

Sources: OECD, 2013 and the PIAAC (OECD, 2015).

Notes: 'N_Yrs' stands for Nominal Years of School'; 'Edu_G' stands for the Educational Group to which individuals with this level of educational attainment have been assigned; 1 = Uncompleted Secondary, 2 = Secondary, and 3 = Tertiary; 'S_Yrs INV' stands for the standard years of investment that have been assigned to each of the individuals. In the case of Uncompleted Secondary, for example, 9 total years of public investment have been assigned; 6 from the primary stream of funding and 3 from the secondary stream of funding. 'n.a.' stands for not applicable; there were no corresponding school levels in that country. 'n.r.' stands for no response - no observations received that code for that country. 'n.s.' stands for not stated (in Appendix 5 of the technical report).

*in these cases, the same B_Q01a code could correspond to different years of schooling, but since the data were coded by PIAAC, it is impossible to know which observations had which years; the most standard (across other countries) x of years was chosen and used for imputing investment.

** For France, it is believed that 18 observations were miscoded in B_Q01a with '16', but tabulating B_Q01a for France revealed that they were labeled as 5A Bachelor's/Master's; these 18 observations were treated as Master's and received 17 years of imputed investment.

Table C.5.1 Corresponding Years to Educational Categories in the Countries in our sample (continued)

		JAPAN			NETHERLANDS			NORWAY			SPAIN			SWEDEN			UK (GBR)		
ISCED Level	B_Q01a (code)	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV	N_Yrs	EDU_ G	S_Yrs INV
No formal qualification or below ISCED 1	**1**													6					
ISCED 1	**2**	6			7			7			6			6			6		
ISCED 2	**3**	9	1	9	11	1	9	10	1	9	10	1	9	9	1	9	11	1	9
ISCED 3C Shorter than 2 years	**4**	10	2	12	n.a.			12	2	12	11	2	12	10	2	12	11	2	12
ISCED 3C 2 Years or more	**5**	12	2	12	13,14*	2	12	14	2	12	12	2	12	12	2	12	11	2	12
ISCED 3A-B	**6**	12	2	12	12,13,14 *	2	12	13	2	12	12	2	12	11	2	12	13,12*	2	12
ISCED 3 (without distinction A-B-C 2y+)	**7**	9	2	12	n.a.			n.a.			n.a.			12	2	12	n.a.		
ISCED 4C	**8**	n.a.			n.a.			15	3	13	n.a.			n.a.			n.a.		
ISCED 4A-B	**9**	n.a.			n.a.			14	3	13	14	3	13	n.a.			n.a.		
ISCED 4 (without distinction A-B-C)	**10**	13	3	13	n.a.			n.a.			n.a.			13	3	13	13	3	13
ISCED 5B	**11**	14	3	14	14	4	14	15	3	14	14	3	14	14	3	14	15	3	14
ISCED 5A, bachelor's degree	**12**	16	3	15	16	5	15	16	3	15	15	3	15	15	3	15	n.s.	3	15
ISCED 5A, master's degree	**13**	18,21*	3	17	17	6	17	18	3	17	17	3	17	16	3	16	n.s.	3	17
ISCED 6	**14**	21,9*	3	18	20	7	18	20	3	18	21	3	18	20	3	18	15,16,19*	3	16

Sources: OECD, 2013 and the PIAAC (OECD, 2015).

Notes: 'N_Yrs' stands for Nominal Years of School'; 'Edu_G' stands for the Educational Group to which individuals with this level of educational attainment have been assigned; 1 = Uncompleted Secondary, 2 = Secondary, and 3 = Tertiary; 'S_Yrs INV' stands for the standard years of investment that have been assigned to each of the individuals. In the case of Uncompleted Secondary, for example, 9 total years of public investment have been assigned; 6 from the primary stream of funding and 3 from the secondary stream of funding. 'n.a.' stands for not applicable; there were no corresponding school levels in that country. 'n.r.' stands for no response - no observations received that code for that country. 'n.s.' stands for not stated (in Appendix 5 of the technical report).

*in these cases, the same B_Q01a code could correspond to different years of schooling, but since the data were coded by PIAAC, it is impossible to know which observations had which years; the most standard (across other countries) x of years was chosen and used for imputing investment.

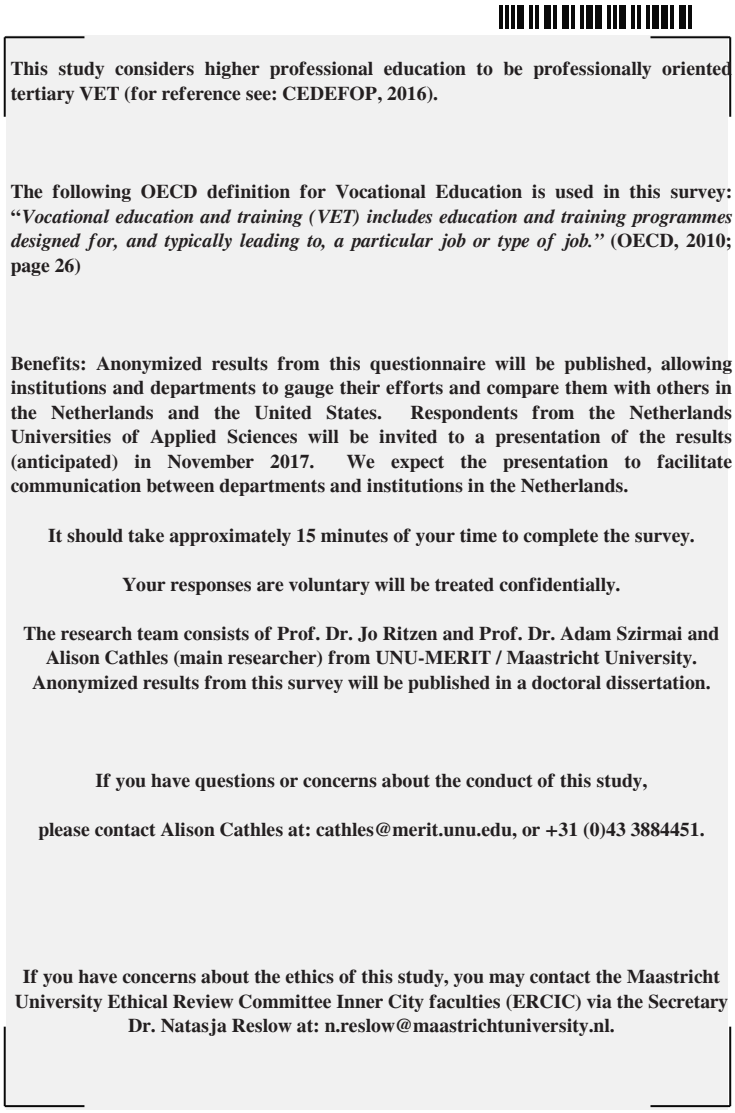
** For France, it is believed that 18 observations were miscoded in B_Q01a with '16', but tabulating B_Q01a for France revealed that they were labeled as 5A Bachelor's/Master's; these 18 observations were treated as Master's and received 17 years of imputed investment.

Appendix D

Appendix to Chapter 5

Appendix D.1: HBO Institutional Level Questionnaire

Double-click on the image to open the PDF file containing the full questionnaire.



This study considers higher professional education to be professionally oriented tertiary VET (for reference see: CEDEFOP, 2016).

The following OECD definition for Vocational Education is used in this survey: "*Vocational education and training (VET) includes education and training programmes designed for, and typically leading to, a particular job or type of job.*" (OECD, 2010; page 26)

Benefits: Anonymized results from this questionnaire will be published, allowing institutions and departments to gauge their efforts and compare them with others in the Netherlands and the United States. Respondents from the Netherlands Universities of Applied Sciences will be invited to a presentation of the results (anticipated) in November 2017. We expect the presentation to facilitate communication between departments and institutions in the Netherlands.

It should take approximately 15 minutes of your time to complete the survey.

Your responses are voluntary will be treated confidentially.

The research team consists of Prof. Dr. Jo Ritzen and Prof. Dr. Adam Szirmai and Alison Cathles (main researcher) from UNU-MERIT / Maastricht University. Anonymized results from this survey will be published in a doctoral dissertation.

If you have questions or concerns about the conduct of this study,

please contact Alison Cathles at: cathles@merit.unu.edu, or +31 (0)43 3884451.

If you have concerns about the ethics of this study, you may contact the Maastricht University Ethical Review Committee Inner City faculties (ERCIC) via the Secretary Dr. Natasja Reslow at: n.reslow@maastrichtuniversity.nl.

Appendix D.2: HBO locations in the Netherlands and CC locations in NYS

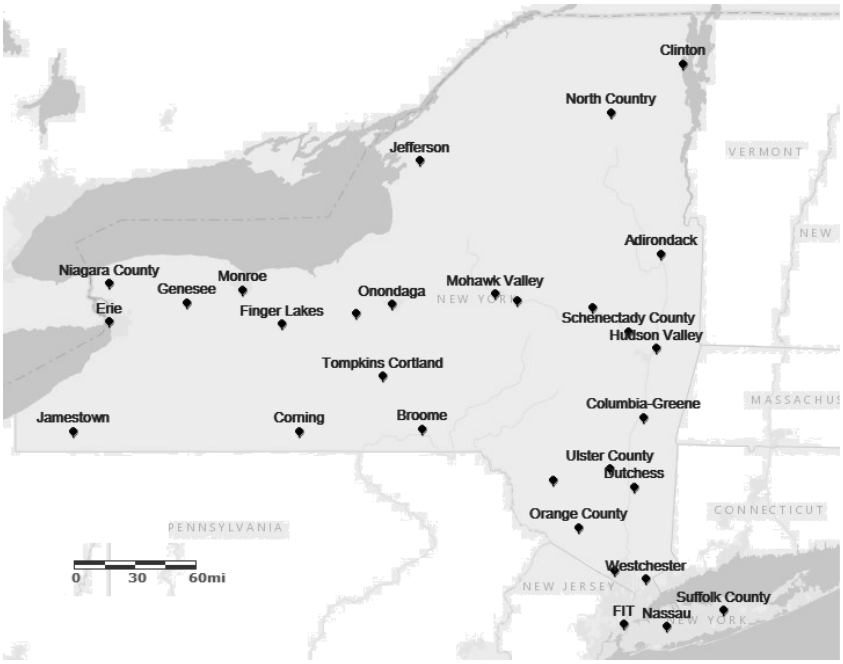
The regional spread of HBOs and Community Colleges is illustrated in Figure D.2.1. We do not conduct a regional analysis in our study, but that would an interesting avenue for further research.

Higher Professional Education Initiations (HBOs) in the Netherlands

*Please note that some institutions have more than one location. For example, Zuyd (easily visible in the South), has three locations, but it counts as one institution.

Appendix D.2 continued: HBO locations in the Netherlands and CC locations in NYS

Community Colleges in the SUNY System in New York State



Valorization Addendum

This addendum of valorization is in accordance with article 23.5 of the "Regulation governing the attainment of doctoral degrees at Maastricht University" decreed by resolution of the Board of Deans, dated 3 July 2013.

A good quality education is so important that UNESCO declared it a birthright.[74] One reason education is regarded as personally and societally beneficial is because it offers various pathways to develop a range of skills that will increase opportunities to succeed in the labor market. But media, think tanks, international organizations, policy makers and society are grappling with questions about how best to educate people for a changing workplace and whether discipline-specific, vocational or transversal skills are the most relevant.

Guidance for good practice is often sought by consulting what has (or has not) worked in the past. Macroeconomic literature highlights the absence of studies that distinguish between vocational and general education as a particularly policy relevant research gap. Without these types of studies, macroeconomic lessons cannot be gleaned from the past to help guide the future. Chapters 2 and 3 of this dissertation contribute to filling this gap and contribute to a deeper understanding of the economic relevance of vocational education in secondary school. Vocational education is definitionally specific to the workplace.

Policy makers can use the following results to concretely discuss the how vocational secondary schooling has affected economic growth over the past 60 years:

- First and foremost, vocational secondary schooling is consistently positively related to economic performance using a variety of metrics and analytical approaches. Therefore, vocational education should not be left out of the policy discussion. Despite re-entering the international public debate recently, the topic of vocational education was neglected in development for about 20 years and mistakenly left out of national innovation policy strategies in some advanced economies, such as Australia.

- Chapter 2 shows that at a global level, there has been a relative decline in vocational secondary schooling, but that there is a lot of variation between and within countries. National policy makers can use the data from Chapter 2 to assess the pattern in their own country and consider whether this has

[74] http://www.unesco.org/new/en/unesco-liaison-office-in-new-york/areas-of-action/education/right-to-education/

been a deliberate policy choice or the result of aggregate individual choices and whether this has coincided with national economic trends.

- The economic effect of vocational secondary schooling is captured better by GDP per capita than by GDP per worker. This suggests that the mechanism by which vocational secondary schooling affects GDP is primarily via increasing employment, smoothing the school to work transition, more than by increasing the efficiency or productivity of workers. Policy makers can use this information to design and sequence policy levers. For example, when unemployment levels are high, policy makers could consider directing more resources to vocational education pathways.

- Countries need to be closer to the technological frontier than previously theorized in order to take advantage of vocational secondary schooling for economic growth. This presents a policy puzzle that cannot be resolved with the research conducted in this thesis. It could be the quality of vocational secondary schooling is systematically higher in countries that are close to the technological frontier, or it could be that other external conditions associated with advanced stages of development need to be in place, before vocational secondary schooling to have a growth effect.

- Fortunately, the conclusions reached in Chapter 3 can be further vetted by other researchers, because the vocational secondary schooling data are made available in Chapter 2. A larger body of evidence will help policy makers distill whether differentials in the quality of vocational education drive its economic effect, or whether there are other factors at play. This information would aid decisions about when to invest in enhancing the quality of vocational programming.

The internationally comparable set of vocational secondary schooling data introduced and described in Chapter 2 are already available in the annex of a working paper (UNU-MERIT Working Paper Series #2016-002). These data will be made available via Dataverse in a user-friendly Stata file. The data have been used by Nobuya Haraguchi, Bruno Martorano, Marco Sanfilippo, Anirudh Shingal in 2018 to draft a paper on manufacturing growth accelerations in developing countries.[75] Factors that contribute to manufacturing growth accelerations in developing countries are clearly of interest to international policy makers. If it is shown that vocational secondary schooling plays a role, it provides policy makers with an evidence based understanding of how job-specific

[75] Their paper was recently submitted for a journal publication and was used for a UNIDO report.

secondary education is related to economic performance, in the long-run and during growth spurts.

The results in Chapter 3 are interesting for statistical agencies they were well received at the 35th International Association for Research in Income and Wealth (IARIW) conference held in Denmark in August, 2018. The IARIW association hosts conferences that are attended by statistical agencies around the world (i.e., Statistics Denmark, Statistics Sweden, Groningen Growth and Development Center at the University of Groningen, Bureau of Economic Analysis and Labor Statistics in the U.S., Eurostat, IMF, the OECD, and the Office for National Statistics UK) as well as representatives from academia from Russia, India, China and Japan, to mention a few. A primary objective of the IARIW is to collect, discuss, and disseminate new information about the definition and measurement of income, wealth, and related statistical measures. The acceptance of the paper underlying Chapter 3 at the 35th IARIW conference is indicative of interest in statistical forms of educational measurement that distinguish between vocational and general education pathways.

Chapter 4 shifts gears and investigates how public investments in different phases of schooling (primary, secondary and tertiary) relate to transversal numeracy skills in adulthood. Governments tend to prioritize education among the different public services under their purview. It is, for example, the fourth largest government expenditure in the EU (Eurostat, 2018)[76]. Methodologies and analysis regarding the optimal spread of expenditure to facilitate skill acquisition are clearly a matter of public interest and societal relevance that extends beyond academia. Policy makers can draw upon the following:

- Greater investments in primary school are important not only for higher numeracy scores later in life, but also for facilitating higher levels of educational attainment.

- In order to realize the full benefit of investments in primary, later stage investments in tertiary are also important.

- A well-designed investment strategy should take into account how the investments in different stages (primary, secondary, and tertiary) relate to each other. It is possible to calculate indicative thresholds where complementary investments become substitutes. This means that optimal investment goals in each stage could set so that the investments are brought up to (but not unnecessarily above) a certain threshold.

[76] Accessed November 2018 from: ttps://ec.europa.eu/eurostat/statistics-explained/index.php/Government_expenditure_by_function_–_COFOG

The insights from the results in Chapter 4 are highly relevant for policy makers when considering investment options available to them in different education stages, because the results show the interdependence of the investments matters for numeracy skills.

Early results from Chapter 4 were published as an IZA discussion paper (IZA DP No. 10565) and were presented at the Worldwide Universities Network (WUN) Economics Workshop held at Maastricht University in April 2016. The presentation resulted in my being selected to join a small diverse team of five people from four different continents. The team was asked by workshop organizers to submit a proposal for a small grant to work on a related global challenge. The WUN grant was awarded and subsequently resulted in a socially relevant published working paper about the role of school quality in closing skills gaps for young people with different immigrant backgrounds. The paper includes an assessment of STEM (Science Technology Engineering and Math) labor market outcomes. Involvement with WUN is not strictly about the value of the results from Chapter 4, but serves to illustrate how the public presentation of results from Chapter 4 piqued the interest of a broader community and led to desirable outcomes.

The first part of chapter 5 is a contemporary analysis about the job-education and skill match. It compares results from higher vocational and academic education pathways. The key lesson for policy makers is that the type of vocational education system matters. For example, whether the education system is non-vocational, school-based vocational, or has an apprenticeship vocational system, the best results in terms of job-education match and numeracy skill use at work are for people with higher vocational education in an apprenticeship vocational system. These results can be related back to the results from chapter 3 and the need to deepen the evidence base regarding which qualities of vocational education are linked with the best outcomes.

The future of work is a topic currently capturing the attention of all sectors (public, private and academic). Many argue that educational reform is needed to meet the needs of a workplace that is being reshaped by technology and digitalization. And although many people would agree with the following Chinese proverb: *"Do not confine your children to your own learning, for they were born in another time.",* there is little guidance for policy makers when it comes to innovation in education. While higher professional education in particular may be attempting to adapt its educational services to meet the needs of a changing labor market, the obstacles they face are not entirely clear. Firms have been surveyed about innovation and the obstacles to innovation for years. In the context of innovation in higher education, the significance of obstacles or challenges that

impede adaption, to the extent that these adaptations are crucial labor market success, will be borne by students, employers, and society when they enter the labor market.

Value-added in Chapter 5 comes from the development of a prototype survey that borrows from accumulated knowledge from innovation surveys and draws from a variety of existing survey instruments. The survey is explicitly designed to ask higher professional institutions about the challenges and opportunities they face when they attempt to adapt to meet the needs of the future workplace. The results of the survey point to very easily adoptable policy recommendations. For example, the community colleges in New York State (SUNY) say that they need more disaggregated data. At a time when LinkedIn is helping international organizations like the World Bank and the IDB identify skill mismatches (demand and supply) in Africa and Latin America, surely the SUNY system could partner with LinkedIN to gain access to better data. Universities of Applied Sciences in the Netherlands worry about upgrading the digital skills of their teachers. Policy makers in the Netherlands could look for ways to support teachers in upskilling. The survey itself could be further developed by organizations such as the OECD that are currently engaged in working on topics spanning innovation and labor market relevance of higher education.

UNU-MERIT/MGSoG Dissertation Series

2019

Alison Cathles
Educational Pathways and Skills: Past, Present, and Future
UNU-MERIT/MGSoG Dissertation Series № 223

Ibrahima Sory Kaba
Aggregate Fluctuations and Development: Essays on Macroeconomic Volatility and Economic Growth
UNU-MERIT/MGSoG Dissertation Series № 222

Charlotte Keijser
Firm Participation, Learning and Innovation in Heterogenous Value Chains of IT-enabled Services
UNU-MERIT/MGSoG Dissertation Series № 221

Salih Çevikarslan
Innovation Strategies and Their Implications for Technological Change and Market Outcomes: An Evolutionary Multi-Agent Based Modelling Approach
UNU-MERIT/MGSoG Dissertation Series № 220

Wondimagegn Mesfin Tesfaye
Essays on the Impacts of Climate-Smart Agricultural Innovations on Household Welfare
UNU-MERIT/MGSoG Dissertation Series № 219

Tatevik Poghosyan
How Board Networks Affect Firm Performance and Innovation Incentives in Transition Economies: The Case of Armenia
UNU-MERIT/MGSoG Dissertation Series № 218

Arip Muttaqien
Essays on Inequality and Polirization: Empirical Studies in Developing Asia
UNU-MERIT/MGSoG Dissertation Series № 217

2018

Katrin Marchand
Essays on Forced Migration and Labour Market Participation in Developing Countries
UNU-MERIT/MGSoG Dissertation Series № 216

Ortrun Merkle
The Myth of Gender Neutral Power: Corruption and Gender Norms
UNU-MERIT/MGSoG Dissertation Series № 215

Biljana Meshkovska
Life after Trafficking: (re)integration processes of women that have been trafficked for the purpose of sexual exploitation in Europe
UNU-MERIT/MGSoG Dissertation Series № 214

Vincenzo Vinci
The Relevance of Institutions and People's Preferences for Social Protection
UNU-MERIT/MGSoG Dissertation Series № 213

Silke Heuser
The Effectiveness of Environmental Policies on Reducing Deforestation in the Brazilian Amazon
UNU-MERIT/MGSoG Dissertation Series № 212

Jennifer Waidler
Social Assistance and Remittances and Their Role in the Fight Against Poverty
UNU-MERIT/MGSoG Dissertation Series № 211

Choolwe Muzyamba
The role of community mobilization in the promotion of maternal health of women living with HIV in Zambia
UNU-MERIT/MGSoG Dissertation Series № 210

Juan Carlos A. Castillo Sánchez
Assessing the Role of the Export Sector in Mexican Economic Development,1965-2014
UNU-MERIT/MGSoG Dissertation Series № 209

Tareq Abuelhaj
Food Security Policy Impact Analysis: The Econometrics of Cash and Food Assistance Cost Effectiveness
UNU-MERIT/MGSoG Dissertation Series № 208

Marta Férnandez de Arroyabe Arranz
Essays on M&AS and Innovation
UNU-MERIT/MGSoG Dissertation Series № 207

Clotilde Mahé
Essays on Migration and Occupational Choice
UNU-MERIT/MGSoG Dissertation Series № 206

Simone Sasso
Talent on the move. Essays on Human Capital, Graduate Mobility and Economic Development
UNU-MERIT/MGSoG Dissertation Series № 205

Khaled Walid Rajab
Strategic Planning under Fragility
UNU-MERIT/MGSoG Dissertation Series № 204

Mutinta Hambayi Nseluke
A Tall Order: Improving Child Linear Growth
UNU-MERIT/MGSoG Dissertation Series № 203

Elvis Korku Avenyo
Innovations and Firm Performance in sub-Saharan Africa: Empirical Analyses
UNU-MERIT/MGSoG Dissertation Series № 202

Ni Zhen
Employment Dynamics, Firm Performance and Innovation Persistence in the Context of Differentiated Innovation Types: Evidence from Luxembourg
UNU-MERIT/MGSoG Dissertation Series № 201

Caroline Wehner
Too Scared to Achieve: The Relation Between Neuroticism, Conscientiousness and Socioeconomic Outcomes
UNU-MERIT/MGSoG Dissertation Series № 200

Stefania Innocenti
On Institutional Persistence
UNU-MERIT/MGSoG Dissertation Series № 199

Hassen Abda Wako
Economic Globalization, Institutions and Development: Essays on Aid, Foreign Direct Investment and Trade
UNU-MERIT/MGSoG Dissertation Series № 198

2017

Hans-Erik Edsand
Winds of Change
UNU-MERIT/MGSoG Dissertation Series № 197

Ana Patricia Silva Vara
Redressing the Gender Gap
UNU-MERIT/MGSoG Dissertation Series № 196

Andrés Iván Mideros Mora
Essays on the Economic Effects of Non-contributory Social Protection
UNU-MERIT/MGSoG Dissertation Series № 195

Tobias Broich
New Actors in the Global Economy
UNU-MERIT/MGSoG Dissertation Series № 194

Bernard Nikaj
From No-government to E-government
UNU-MERIT/MGSoG Dissertation Series № 193

Ali Safarnejad
Prioritizing the HIV Response
UNU-MERIT/MGSoG Dissertation Series № 192

Clovis Freire
Diversification and Structural Economic Dynamics
UNU-MERIT/MGSoG Dissertation Series № 191

Michael Verba
Innovation and Knowledge Dynamics: Essays on the Knowledge Economy
UNU-MERIT/MGSoG Dissertation Series № 190

Pui Hang Wong
The Hearts and Minds in Conflict and Peace: The Economics of Counterinsurgency and the Psychology of Reconstruction
UNU-MERIT/MGSoG Dissertation Series № 189

Brenda Yamba
Schooling Despite All Odds: Evidence from Lesotho on Female Child Carers who Stayed in School
UNU-MERIT/MGSoG Dissertation Series № 188

Sheng Zhong
Moving towards An Energy Efficient Future: Essays on Energy Efficiency, Technology and Development
UNU-MERIT/MGSoG Dissertation Series № 187

Julieta Marotta
Access to Justice and Legal Empowerment of Victims of Domestic Violence through Legal Organizations in the City of Buenos Aires: A Qualitative Empirical Legal Study
UNU-MERIT/MGSoG Dissertation Series, № 186

Andrea Franco-Correa
On the Measurement of Multidimensional Poverty as a Policy Tool: Empirical Applications to Chile, Colombia, Ecuador and Peru
UNU-MERIT/MGSoG Dissertation Series, № 185

2016

Yesuf Awel
Insurance for Growth: Empirical Essays on Insurance Demand and Impacts in Africa
UNU-MERIT Dissertation Series, № 108

Tigist Mekonnen Melesse
Grow More Food using Fewer Resources: Agricultural Technology Adoption and Innovation Practices for Inclusive and Sustainable Development
UNU-MERIT Dissertation Series, № 107

Eleni Yitbarek
Getting Ahead or left Behind? Essays on Poverty Dynamics and Social Mobility in Africa
UNU-MERIT Dissertation Series, № 106

Thuy Dieu Nguyen
Firm-Level Theory and Evidence of Corruption
UNU-MERIT Dissertation Series, № 105

Raquel Tsukada Lehman
Essays on Household Production with Labor-Saving Technology
UNU-MERIT Dissertation Series, № 104

Eva Barteková
Multi-Problem Challenges for a Renewable Future: Empirical Studies on Competitive Disadvantages from Electricity Price Differentials and Mineral Supply Risk in an Open Economy
UNU-MERIT Dissertation Series, № 103

Jocelyn Olivari
Entrepreneurial Traits and Innovation: Evidence from Chile
UNU-MERIT Dissertation Series, № 102

Muhammad Shafique
Essays on the role of knowledge, R&D, and Technology-based Firms in the Evolution of Socio-techno-economic System
UNU-MERIT Dissertation Series, № 101

Serdar Türkeli
Governance of Innovation Policy: Empirical Studies on Applied Political Economy by Multi-Methods Analysis
UNU-MERIT Dissertation Series, № 100

Ayokunu Adedokun
Pathways to Sustainable Peace building in Divided Societies: Lessons and Experiences from Mozambique
MGSoG Dissertation Series, № 75

Luiz Rothier Bautzer
Organizing Concurrent Engineering through ICT Platforms Blueprinting Product Lifecycle Management Platforms across Disciplinary Agencies
MGSoG Dissertation Series, № 74

Natalia Popova
Migration in the Periphery of the European Union: Determinants of Successful and Sustainable Labour Market Integration of Return Migrants in Albania, Egypt, Moldova and Tunisia
MGSoG Dissertations Series, № 73

Richard A. Martina
Uncertainty and Resource Constraint in the Small Island Developing States: Essays in Entrepreneurial Cognition
MGSoG Dissertations Series, № 72

Cécile Cherrier
The Expansion of Basic Social Protection in Low-income Countries: An Analysis of Foreign Aid Actors' Role in the Emergence of Social Transfers in Sub-Saharan Africa
MGSoG Dissertations series, № 71

Paul Caldron
The Tacit Bargain in Short-Term Medical Missions: Why U.S. physicians go and what it costs
MGSoG Dissertation Series, № 70

Mahmut Kobal
Customs & Excellence: A Comparative Approach on Administrative and Regulatory Compliance Perspectives of the EU-Turkey Customs Union
MGSoG Dissertation Series, № 69

Craig Loschmann
Essays on Conflict-related Migration and Development in the Case of Afghanistan
MGSoG Dissertations Series, № 68

Andrea Milan
Rural Livelihoods, Location and Vulnerable Environments: Approaches to Migration in Mountain areas of Latin America
MGSoG Dissertation Series, № 67

Farida Lada
On Guarding the Welfare of Clinical Trial Subjects While Promoting Novel Drug Innovation
A Game Theoretical Approach
MGSoG Dissertation Series, № 66

2015

Hibret Belete Maemir
Dissecting Aggregate Productivity: International Integration and Growth with Heterogeneous Firms
UNU-MERIT Dissertation Series, № 96

Giorgio Triulzi
Looking for the Right Path: Technology Dynamics, Inventive Strategies and Catching-up in the Semiconductor Industry
UNU-MERIT Dissertation Series, № 95

Abdul Baseer Qazi
Knowledge flows and networks in the ICT sector: The case of Pakistan
UNU-MERIT Dissertation Series, № 94

Ajay Thutupalli
Technology Paradigm Shifts in Agriculture: Drivers of Sustainability and Catch up
UNU-MERIT Dissertation Series, № 93

Eduardo Urias
Improving access to HIV/AIDS treatment in Brazil: When are Compulsory Licenses effective in Price Negotiations?
UNU-MERIT Dissertation Series, № 92

Francesca Guadagno
Why have so few Countries Industrialised?
UNU-MERIT Dissertation Series, № 91

Daniel Opolot
The Evolution of Beliefs and Strategic Behaviour
UNU-MERIT Dissertation Series, № 90

Alejandro Lavopa
Structural Transformation and Economic Development: Can Development Traps be Avoided
UNU-MERIT Dissertation Series, № 89

Jinjin Zhao
Urban water management reform: The Case of China
UNU-MERIT Dissertation Series, № 88

Simona Vezzoli
Borders, Independence and Post-colonial Ties: the Role of the State in Caribbean Migration
MGSoG Dissertation Series, № 65

Silvia Consuelo Gómez Soler
Civil Conflict and Education: How Does Exposure to Civil Conflict Affect Human Capital Accumulation? Evidence from Standardized Exit Exams in Colombia
MGSoG Dissertation Series, № 64

Paula Nagler
Occupational Choice in the Developing World
MGSoG Dissertation Series, № 63

Jasmin Kientzel
Determinants of Professional Commitment to Environmental Sustainability
MGSoG Dissertation Series, № 62

Mehmet Güney Celbiş
Regional Policies: Convergence, Trade, and the Allocation of Public Capital
MGSoG Dissertation Series, № 61

Florian Henning
Living Up to Standard: Interoperability Governance and Standards Adoption in Government Information Networks
MGSoG Dissertation Series, № 60

Niels P. Groen
The Never-Ending Project Understanding E-Government Project Escalation
MGSoG Dissertation Series, № 59

Derek Copp
Teacher-Based Reactivity to Provincial Large-scale Assessment in Canada
MGSoG Dissertation Series, № 58

Michaella Vanore
Family-Member Migration and the Psychosocial Health Outcomes of Children in Moldova and Georgia
MGSoG Dissertation Series, № 57

Sonja Fransen
The Economic and Social Effects of Remittances and Return Migration in Conflict-Affected Areas: The Case of Burundi
MGSoG Dissertation Series, № 56

Ibrahim Khalil Conteh
The Impact of Floods on Primary School Education in Zambia
MGSoG Dissertation Series, № 55

Richard Bluhm
Growth Dynamics and Development Essays in Applied Econometrics and Political Economy
MGSoG Dissertation Series, № 54

Nevena P. Zhelyazkova
Work-Family Reconciliation and Use of Parental Leave in Luxembourg: Empirical Analysis of Administrative Records
MGSoG Dissertation Series, № 53

2014

Dirk Crass
The Impact of Brands on Innovation and Firm Performance: Empirical Evidence from Germany
UNU-MERIT Dissertation Series, № 87

Samyukta Bhupatiraju
The Geographic Dimensions of Growth and Development
UNU-MERIT Dissertation Series, № 86

François Lafond
TheEvolution of Knowledge Systems
UNU-MERIT Dissertation Series, № 85

Annalisa Primi
Promoting Innovation in Latin America: What Countries Have Learned (and What They Have Not) in Designing and Implementing Innovation and Intellectual Property Policies
UNU-MERIT Dissertation Series, № 84

Fatoumata Lamarana Diallo
Evaluation of Meal and Deworming Programs for Primary Schools in Rural Senegal
UNU-MERIT Dissertation Series, № 83

Sachin Kumar Badkas
Metachoice and Metadata: Innovating with Environmental Policy Analysis in Europe
MGSoG Dissertation Series, № 52

Irina S. Burlacu
An Evaluation of Tax-Benefit Systems Impact on the Welfare of Frontier Worker:
The Case of Luxembourg and Belgium
MGSoG Dissertation Series, № 51

Özge Bilgili
Simultaneity in Transnational Migration Research: Links Between Migrants' Host and Home Country Orientation
MGSoG Dissertation Series, № 50

Yulia Privalova Krieger
Reshaping the Big Agenda: Transnational Politics and Domestic ResistanceFinancial crisis and social protection reform in Bosnia and Herzegovina
MGSoG Dissertation Series, № 49

Marieke van Houte
Moving Back or Moving Forward? Return migration after Conflict
MGSoG Dissertation Series, № 48

Oxana Slobozhan
Global Governance in the Management of Natural Resources: The Case of the Extractive Industries Transparency Initiative (EITI)
MGSoG Dissertation Series, № 47

Luis Bernardo Mejia Guinand
The Changing Role of the Central Planning Offices in Latin America: A Comparative Historical Analysis Perspective (1950-2013)
MGSoG Dissertation Series, № 46

Cheng Boon Ong
Ethnic Segregation in Housing, Schools and Neighbourhoods in the Netherlands
MGSoG Dissertation Series, № 45

Luciana V. Cingolani
Bureaucracies for Development: Oxymoron or Reality? Studies on State Capacity in Challenging Governance Contexts
MGSoG Dissertation Series, № 44

Carlos Cadena Gaitán
Green Politics in Latin American Cities - Sustainable Transport Agendas
MGSoG Dissertation Series, № 43

Katie Kuschminder
Female Return Migration and Reintegration Strategies in Ethiopia
MGSoG Dissertation Series, № 42

Metka Hercog
Highly-Skilled Migration and New Destination Countries
MGSoG Dissertation Series, № 41

Margaret Agaba Rugadya
Can Remittances Influence the Tenure and Quality of Housing in Uganda?
MGSoG Dissertation Series, № 40

Ilire Agimi
New Governance Under Limited Statehood: The Case of Local Government Reform in Kosovo
MGSoG Dissertation Series, № 39

2013

Anant Kamath
Information Sharing through Informal Interaction in Low-Tech Clusters
UNU-MERIT Dissertation Series, № 82

Flavia Pereira de Carvalho
What we talk about when we talk about Brazilian Multinationals: An Investigation on Brazilian FDI, Economic Structure, Innovation and the Relationship between them
UNU-MERIT Dissertation Series, № 81

Jun Hou
Complementarity in Innovation and Development: A Cross-country Comparison
UNU-MERIT Dissertation Series, № 80

Rufin Baghana
Impacts of Government Incentives to R&D, Innovation and Productivity: A Microeconometric Analysis of the Québec Case
UNU-MERIT Dissertation Series, № 79

Lilia I. Stubrin
High-Tech Activities in Emerging Countries: A Network perspective on the Argentinean Biotech Activity
UNU-MERIT/MGSoG Dissertation Series, № 78

Kristine Farla
Empirical Studies on Institutions, Policies and Economic Development
MGSoG Dissertation Series, № 38

Marina Petrovic
Social Assistance and Activation in the Pursuit of Happiness: Shedding New Light on Old Policy Solutions to Social Exclusion
MGSoG Dissertation Series, № 37

Laura Torvinen
Assessing Governance Assessments: The Case of Mozambique: Governance Assessments in the Context of Aid Effectiveness Discourse
MGSoG Dissertation Series, № 36

Biniam Egu Bedasso
Institutional Change in the Long Shadow of Elite: Essays on Institutions, Human Capital and Ethnicity in Developing Countries
MGSoG Dissertation Series, № 35

Sepideh Yousefzadeh Faal Deghati
Childhoods Embargoed: Constructing and Reconstructing Multidimensional Child Poverty in Iran 1984-2009
MGSoG Dissertation Series, № 34

Robert Bauchmüller
Investing in Early Childhood Care and Education: The Impact of Quality on Inequality
MGSoG Dissertation Series, № 33

Martin Rehm
Unified Yet Separated: Empirical Study on the Impact of Hierarchical Positions within Communities of Learning
MGSoG Dissertation Series, № 32

2012

Abdul Waheed
Innovation Determinants and Innovation as a Determinant: Evidence from Developing Countries
UNU-MERIT Dissertation Series, № 77

Bilal Mirza
Energy Poverty and Rural Energy Markets in Pakistan
UNU-MERIT Dissertation Series, № 76

Benjamin Engelstätter
Enterprise Software and Video Games: An Empirical Analysis
UNU-MERIT Dissertation Series, № 75

Fulvia Farinelli
Natural Resources, Innovation and Export Growth: The Wine Industry in Chili and Argentina
UNU-MERIT Dissertation Series

Rodolfo Lauterbach
Innovation in Manufacturing: From Product Variety and Labor Productivity Growth to Economic Development in Chile
UNU-MERIT Dissertation Series

Kirsten Wiebe
Quantitative Assessment of Sustainable Development and Growth in Sub-Saharan Africa
UNU-MERIT Dissertation Series, № 74

Julio Miguel Rosa
Organizational Strategies, Firms' Performance and Spatial Spillovers: The Canadian Case in Research and Development.
UNU-MERIT Dissertation Series, № 73

Johannes Wilhelmus Marie Boels
Joseph Schumpeter, Honderd Jaar Economische Ontwikkeling: Een Historisch-theoretische Beschouwing.
UNU-MERIT Dissertation Series

Dorcas Mbuvi
Utility Reforms and Performance of the Urban Water Sector in Africa
MGSoG Dissertation Series, № 31

Lina Salanauskaite
Distributional Impacts of Public Policies: Essays in Ex-Ante and Ex-Post Evaluation
MGSoG Dissertation Series, № 30

Esther Schüring
To Condition or not – is that the Question?
An Analysis of the Effectiveness of Ex-Ante and Ex-Post Conditionality in Social Cash Transfer Programs
MGSoG Dissertation Series, № 29

Joe Abah
Strong Organisations in Weak States: Atypical Public Sector Performance in Dysfunctional Environments
MGSoG Dissertation Series, № 28

Zina Samih Nimeh
Social Citizenship Rights: Inequality and Exclusion
MGSoG Dissertation Series, № 27

2011

Daniel Vertesy
Interrupted Innovation: Emerging Economies in the Structure of the Global Aerospace Industry
UNU-MERIT Dissertation Series, № 72

Tina Saebi
Successfully Managing Alliance Portfolios: AnAlliance Capability View
UNU-MERIT Dissertation Series, № 71

Nora Engel
Tuberculosis in India: A Case of Innovation and Control
UNU-MERIT/MGSoG Dissertation Series, № 70

Evans Mupela
Connectivity and growth in Sub-Saharan Africa: The Role of Communication Satellites
UNU-MERIT Dissertation Series, № 69

Nantawan Kwanjai
Cross Cultural Intelligence amid Intricate Cultural Webs: A Tale of the UnDutchables in the Land of 1002 Smiles
UNU-MERIT Dissertation Series, № 68

Lina Sonne
Innovation in Finance to Finance Innovation: Supporting Pro-poor Entrepreneur-based Innovation
UNU-MERIT Dissertation Series, № 67

Lenka Eisenhamerová
Legitimacy of 'Humanitarian Military Intervention'
MGSoG Dissertation Series, № 26

Sonila Tomini
Informal Payments for Health Care Services in Albania
MGSoG Dissertation Series, № 25

Jinjing Li
Dynamic Microsimulation in Public Policy Evaluation
MGSoG Dissertation Series, № 24

Aziz Atamanov
Rural Nonfarm Employment and International Migration as Alternatives to Agricultural Employment: The Case of Kyrgyzstan
MGSoG Dissertation Series, № 23

Frieda Vandeninden
Poverty Alleviation: Aid and Social Pensions
MGSoG Dissertation Series, № 22

Juliana Nyasha Tirivayi
The Welfare Effects of Integrating AIDS Treatment with Food Transfers: Evidence from Zambia
MGSoG Dissertation Series, № 21

Agnieska Ewa Sowa
Who's Left Behind? Social Dimensions of Health Transition and Utilization of Medical Care in Poland
MGSoG Dissertation Series, № 20

Emmanaouil Sfakianakis
The Role of Private Actors in the Provision of Public Goods with Applications to Infrastructure and Financial Stability
MGSoG Dissertation Series, № 19

Siu Hing Lo
White Collars Green Sleeves: An Inter-organizational Comparison of Determinants of Energy-Related Behaviors among Office Workers
MGSoG Dissertation Series, № 18

Treena Wu
Constraints to Human Capital Investment in Developing Countries: Using the Asian Financial Crisis in Indonesia as a Natural Experiment
MGSoG Dissertation Series, № 17

Henry Espinoza Peña
Impact Evaluation of a Job-Training Programme for Disadvantaged Youths: The Case of Projoven
MGSoG Dissertation Series, № 16

2010

Fernando Santiago
Human Resources Management Practices and Learning for Innovation in Developing Countries: Pharmaceutical Firms in Mexico
UNU-MERIT Dissertation Series, № 66

Zakaria Babutsidze
Essays on Economies with Heterogeneous Interacting Consumers
UNU-MERIT Dissertation Series, № 65

Bertha Vallejo
Learning and Innovation Under Changing Market Conditions: The Auto Parts Industry in Mexico
UNU-MERIT Dissertation Series, № 64

Donatus Ayitey
Technical Change, Competitiveness and Poverty Reduction: A Study of the Ghanaian Apparel Industry
UNU-MERIT Dissertation Series, № 63

Sergey Filippov
Multinational Subsidiary Evolution: Corporate Change in New EU Member States
UNU-MERIT Dissertation Series, № 62

Asel Doranova
Technology Transfer and Learning under the Kyoto Regime: Exploring the Technological Impact of CDM Projects in Developing Countries
UNU-MERIT Dissertation Series, № 61

Florian Tomini
Between Family and Friend: Understanding the Interdependency of Private Transfers
MGSoG Dissertation Series, № 15

Michał Polalowski
The Institutional Transformation of Social Policy in East Central Europe: Poland and Hungary in Comparative and Historical Perspective
MGSoG Dissertation Series, № 14

Maha Ahmed
Defining, Measuring and Addressing Vulnerability: The Case of Post Conflict Environments
MGSoG Dissertation Series, № 13

Pascal Beckers
Local Space and Economic Success: The Role of Spatial Segregation of Migrants in the Netherlands
MGSoG Dissertation Series, № 12

Victor Cebotari
Conflicting Demands in Ethnically Diverse Societies: Ethno political Contention and Identity Values in Europe
MGSoG Dissertation Series, № 11

Dennis Gyllensporre
Competing and Complementary Perspectives on the EU as a Crisis Management Actor: An Examination of the Common Security and Defence Policy through the Lenses of Idealism and Realism
MGSoG Dissertation Series, № 10

Judit Vall Castello
Business Cycle and Policy Effects on Labour Market Transitions of Older and Disabled Workers in Spain
MGSoG Dissertation Series, № 9

Keetie Roelen
False Positives or Hidden Dimensions: The Definition and Measurement of Child Poverty
MGSoG Dissertation Series, № 8

Denisa Maria Sologon
Earning Dynamics in Europe
MGSoG Dissertation Series, № 7

Melissa Siegel
Money and Mobility: Migration and Remittances
MGSoG Dissertation Series, № 6

Jessica S. Hagen-Zanker
Modest Expectations: Causes and Effects of Migration on Migrant Households inSource Countries
MGSoG Dissertation Series, № 5

2009

Alexis Habiyaremye
From Primary Commodity Dependence to Diversification and Growth: Absorptive Capacity and Technological Catch Up in Botswana and Mauritius.
UNU-MERIT Dissertation Series, № 60

Yoseph Getachew
The Role of Public Capital in Economic Development
UNU-MERIT Dissertation Series, № 59

Sandra Leitner
Embodied Technological Change and Patterns of Investment in Austrian Manufacturing
UNU-MERIT Dissertation Series, № 58

Semih Akçomak
The Impact of Social Capital on Economic and Social Outcomes
UNU-MERIT Dissertation Series, № 57

Abraham Garcia
The Role of Demand in Technical Change
UNU-MERIT Dissertation Series, № 56

Saurabh Arora
Coherence in Socio-technical Systems: A Network Perspective on the Innovation Process
UNU-MERIT Dissertation Series, № 55

Mirtha R. Muniz Castillo
Human Development and Autonomy in Project Aid: Experiences from four bilateral projects in Nicaragua and El Salvador
MGSoG Dissertation Series, № 4

Christiane Arndt
Governance Indicators
MGSoG Dissertation Series, № 3

Britta Augsburg
Microfinance: Greater Good or Lesser Evil?
MGSoG Dissertation Series, № 2

2008

Rutger Daems
Medicines for the Developing World
UNU-MERIT Dissertation Series, № 54

Johannes Hanel
Assessing Induced Technology: Sombart's Understanding of Technical Change in the History of Economics
UNU-MERIT Dissertation Series, № 53

Rifka Weehuizen
Mental Capital: the Economic Significance of Mental Health
UNU-MERIT Dissertation Series, № 52

Danielle Cloodt
The Relationship between R&D Partnership Formation, Social Embeddedness and Innovative Performance
UNU-MERIT Dissertation Series, № 51

Sabine Fuss
Sustainable Energy Development under Uncertainty
UNU-MERIT Dissertation Series, № 50

Geranda Notten
Measuring and Managing Poverty Risks
MGSoG Dissertation Series, № 1

2007

Tobias Kronenberg
Reconciling Environmental Conservation with Economic Prosperity: The Feasibility of Double Dividends in the Short and Long Run
UNU-MERIT Dissertation Series, № 49

Viktoria Kravtsova
Assessing the Impact of Foreign Direct Investment in Transition Economies
UNU-MERIT Dissertation Series, № 48

Suhail Sultan
The Competitive Advantage of Small and Medium Sized Enterprises: The Case of Jordan's Natural Stone Industry
UNU-MERIT Dissertation Series, № 47

2006

Bulat Sanditov
Essays on Social Learning and Imitation
UNU-MERIT Dissertation Series, № 46

Mamata Parhi
Dynamics of New Technology Diffusion: A Study of the Indian Automotive Industry
UNU-MERIT Dissertation Series, № 45

Andreas Reinstaller
Social Structures and the Innovation Process: Their Role in the Demand of Firms and Consumers
UNU-MERIT Dissertation Series, № 44

Rose Kiggundu
Innovation systems and Development: The Journey of a Beleaguered Nile Perch Fishery in Uganda
UNU-MERIT Dissertation Series, № 43

Thomas Pogue
The Evolution of Research Collaboration in South African Gold Mining: 1886-1933
UNU-MERIT Dissertation Series, № 42

Geoffrey Gachino
Foreign Direct Investment, Spillovers and Innovation: The Case of Kenyan Manufacturing Industry
UNU-MERIT Dissertation Series, № 41

Önder Nomaler
Technological Change, International Trade and Growth: An Evolutionary, Multi-Agents-Based Modeling Approach
UNU-MERIT Dissertation Series, № 40

2005

Samia Satti Osman Mohamed-Nour
Change and Skill Development in the Arab Gulf Countries
UNU-MERIT Dissertation Series, № 39

Elad Harison
Intellectual Property Rights: Economics and Policy Analysis
UNU-MERIT Dissertation Series, № 38

Daniel Dalohoun
Learning to innovate: agricultural innovation and entrepreneurship: the case of Songhaï farmers in Benin
UNU-MERIT Dissertation Series, № 37

Müge Ozman
Networks, Organizations and Knowledge
UNU-MERIT Dissertation Series, № 36

Bas Straathof
Product Variety and Economic Growth: The Counteracting Effects of Scale and Idiosyncrasy
UNU-MERIT Dissertation Series, № 35

Wilfred Schoenmakers
Knowledge Flows between Multinational Companies: A Patent Data Analysis
UNU-MERIT Dissertation Series, № 34

Myriam Cloodt
Mergers and Acquisitions (M and As) in High-Tech Industries: Measuring the Post-M and A Innovative Performance of Companies
UNU-MERIT Dissertation Series, № 33

2004

Paola Criscuolo
R&D Internationalisation and Knowledge Transfer: Impact on MNEs and their Home Countries
UNU-MERIT Dissertation Series, № 32

Maarten Verkerk
Trust and Power on the Shop Floor
UNU-MERIT Dissertation Series, № 31

Gottfried Leibbrandt
Adoption, Harmonization and Succession of Network Technologies across Countries
UNU-MERIT Dissertation Series, № 30

Mark Sanders
Skill Biased Technical change: Its Origins, the Interaction with the Labour Market and Policy Implications
UNU-MERIT Dissertation Series, № 29

2003

Nadine Roijakkers
Inter-firm Cooperation in High-tech Industries: a Study of R&D Partnerships in Pharmaceutical Biotechnology
UNU-MERIT Dissertation Series, № 28

Viki Sonntag
Speed, Scale and Sustainability
UNU-MERIT Dissertation Series, № 27

Masaru Yarime
From End-of-Pipe Technology to Clean Technology
UNU-MERIT Dissertation Series, № 26

Stéphane Malo
The Combinatorial Chemistry Revolution: Sustaining a Superior Performance Position through Technological Learning
UNU-MERIT Dissertation Series, № 25

2002

Annelies Hogenbirk
Determinants of Inward Foreign Direct Investment: the Case of the Netherlands
UNU-MERIT Dissertation Series, № 24

Bastiaan Johan terWeel
The Computerization of the Labour Market
UNU-MERIT Dissertation Series

2001

John Adeoti
Technology Investment in Pollution Control in Sub-Saharan Africa: The Case of the Nigerian Manufacturing Industry
UNU-MERIT Dissertation Series, № 23

Edward Huizenga
Innovation Management: How Frontrunners Stay Ahead: An Empirical Study on Key Success Factors in the ICT sector
UNU-MERIT Dissertation Series, № 22

2000

Machiel van Dijk
Technological Change and the Dynamics of Industries: Theoretical Issues and Empirical evidence from Dutch Manufacturing
UNU-MERIT Dissertation Series, № 21

1999

Jan Cobbenhagen
Managing Innovation at the Company Level: A Study on Non-Sector-Specific Success Factors
UNU-MERIT Dissertation Series, № 20

Marjolein Caniëls
Regional Growth Differentials: The Impact of Locally Bounded Knowledge Spillovers
UNU-MERIT Dissertation Series, № 19

1998

Aldo Geuna
Resource Allocation and Knowledge production: Studies in the Economics of University Research
UNU-MERIT Dissertation Series, № 18

1996

Reinoud Joosten
Dynamics, Equilibria, and Values
UNU-MERIT Dissertation Series, № 17

Hugo Kruiniger
Investment, R&D, and the Financing Decisions of the Firm
UNU-MERIT Dissertation Series, № 16

1995

Hans van Meijl
Endogenous Technological Change: The Case of Information Technology, Theoretical Considerations and Empirical Results
UNU-MERIT Dissertation Series, № 15

René Kemp
Environmental Policy and Technical Change: A Comparison of the Technological Impact of Policy Instruments
UNU-MERIT Dissertation Series, № 14

Rohini Acharya
The Impact of New Technologies on Economic Growth and Trade: A Case Study of Biotechnology
UNU-MERIT Dissertation Series, № 13

Geert Duysters
The Evolution of Complex Industrial Systems: The Dynamics of Major IT Sectors
UNU-MERIT Dissertation Series, № 12

Marjan Groen
Technology, Work and Organisation: A Study of the Nursing Process in Intensive Care Units
UNU-MERIT Dissertation Series, № 11

1994

Huub Meijers
On the Diffusion of Technologies in a Vintage Framework: Theoretical Considerations and Empirical Results
UNU-MERIT Dissertation Series, № 10

Theon van Dijk
The Limits of Patent Protection: Essays on the Economics of Intellectual Property Rights
UNU-MERIT Dissertation Series, № 9

Hans Voordijk
Naar Integrale Logistiek in Bedrijfsketens: Ontwikkelingen in de Bouw
UNU-MERIT Dissertation Series, № 8

1993

Paul Diederen
Technological Progress in Enterprises and Diffusion of Innovation: Theoretical Reflections and Empirical Evidence
UNU-MERIT Dissertation Series, № 7

Ben Dankbaar
Economic Crisis and Institutional Change: The Crisis of Fordism from the Perspective of the Automobile Industry
UNU-MERIT Dissertation Series, № 6

Hanno Roberts
Accountability and Responsibility: The Influence of Organisation Design on Management Accounting
UNU-MERIT Dissertation Series, № 5

1992

Bart Verspagen
Uneven Growth between Interdependent Economies: An Evolutionary View on Technology Gaps, Trade and Growth
UNU-MERIT Dissertation Series, № 4

Sjoerd Romme
A Self-organization Perspective on Strategy Formation
UNU-MERIT Dissertation Series, № 3

1989

John Spangenberg
Economies of Scale, and Atmosphere in Research Organisations
UNU-MERIT Dissertation Series, № 2

1988

John Hagedoorn
Evolutionary and Heterodox Innovation Analysis: A Study of Industrial and Technological Development in Process Control and Information Technology
UNU-MERIT Dissertation Series, № 1