

**A Weather Eye on Employment and  
Education:  
Essays on Employment Polarization, Technology  
and Human Capital Formation**

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# Synopsis

This thesis is related to two widely discussed strands in economics literature: first, the relationship between technology and workforce and second, the impact of environmental factors on economic outcomes. With the rapid pace at which technology has evolved since the late 1990s, it is not surprising that several studies have investigated how the workforce composition has evolved (Katz and Murphy (1992), Acemoglu and Autor (2011), Goos et al. (2014)) and whether machines substitute workers or demand more of them (Acemoglu and Autor (2011), Autor and Salomons (2018), Aghion et al. (2020), Acemoglu and Restrepo (2020)), a hotly debated issue. At the same time there are numerous studies that look at how weather elements such as rainfall and temperature have affected economic outcomes like agricultural productivity, labour productivity, health and education (Jayachandran (2006), Colmer (2021), Somanathan et al. (2021), Park (2022)). These studies are particularly relevant in recent years as climate changes (such as global warming) have significantly increased in pace due to human activities like burning of fossil fuels. This thesis tries to provide an understanding of both these topics focusing in particular on the impact on employment and education.

The World War II saw a phase of rapid technological progress and, by 1970, microprocessors became widely available leading to computational tasks becoming

economically feasible to perform. This allowed firms to substitute workers with computer machines in certain tasks (Acemoglu and Autor (2011)). Autor et al. (2003) point out that machines displace workers from occupations which carry out tasks that are relatively easier to code into machines. Middle wage occupations like manufacturing and sales are easier to code into machines unlike low wage occupations like janitors and high wage occupations like doctors. As a result, *job polarization* has occurred in several advanced economies: employment has decreased for middle wage occupations but increased for low and high wage occupations (Autor et al. (2006), Goos et al. (2014)). The first chapter of the thesis focuses on this phenomenon in the context of two developing economies – India and Indonesia.

Skill upgrading in developing economies may not occur in the same manner as in advanced economies as demonstrated by Berman et al. (2005) in the context of India. Similarly, while analyzing employment changes across occupations, studies on developing economies seem to produce a wide range of results (Kupets (2016), Ariza and Raymond Bara (2020), World Bank (2020), Cortes and Morris (2021)). We hypothesize that the presence of non-regular workers, a salient feature of developing economies (ILO (2016)), may be affecting the job polarization analysis in the context of developing economies. Our study accounts for this aspect and examines whether employment polarization has occurred in the developing economies of India and Indonesia.

While the first chapter looks at the evolution of workforce through a macroeconomic lens, the second chapter examines how hiring decisions at the level of firms are affected due to technology investment in the context of Indian manufacturing firms. The relationship between technology and demand for workers is a highly debated issue: do machines have a cost-saving or productivity improving effect leading to an

increase in demand for workers, or a labour displacing effect leading to a decrease in demand for workers (Autor and Salomons (2018), Acemoglu et al. (2020))? What makes this question difficult to answer is that technology adoption is neither random nor exogenous since the decision to invest in technology is taken by firms. This has forced researchers to adopt quasi-experimental techniques in their analyses (Bessen et al. (2019), Aghion et al. (2020)). The second chapter of the thesis focuses on this question and exploits weather fluctuations (rainfall shocks) to provide a novel way to circumvent the endogeneity issue. This chapter also brings into focus how environmental factors like rainfall can affect economic outcomes like demand for industrial workers (Adhvaryu et al. (2013), Chaurey (2015)). We examine how hiring decisions of manufacturing firms are affected due to computer capital investments in the face of demand shocks.

The econometric method proposed in the second chapter (rainfall shocks leading to labour demand shocks) provides a natural segue to the next chapter of the thesis. This chapter falls under the broad research area of impact of climate on human capital formation. There have been studies that look at climate affecting economic outcomes indirectly, such as heat affecting crop yield which in turn affects human welfare (Heal and Park (2020)). However, recent studies have emerged focusing on the direct impact of heat on human physiology and cognitive performance, affecting health and labour productivity (Graff Zivin et al. (2020), Park (2022)). Global temperatures are rising, and are predicted to do so over the next century, making these studies increasingly important (Dell et al. (2012)). In the last chapter of the thesis I examine how temperature can affect human capital formation by studying the impact of exam time temperature on the high-stakes secondary exam scores of Indian school students.

The chapters are briefly described below where I discuss the research question, empirical strategy and the results of each study.

## **Evolving occupations or occupation-status? Employment polarization in the context of developing countries**

Several studies on developed economies have pointed out that the labour market has undergone *job polarization*: a phenomenon in which employment hollows out for occupations in the middle of the wage distribution along with a concurrent rise at the two ends of the wage distribution (Autor et al. (2006), Goos and Manning (2007), Acemoglu and Autor (2011), Goos et al. (2014)). The most cited reason for this phenomenon is technology replacing occupations concentrated in the middle of the wage distribution, as middle-wage occupations tend to consist of more routine tasks which are easier to automate (Autor et al. (2003), Acemoglu and Autor (2011)). This chapter analyzes the phenomenon of employment polarization in the context of two developing countries – India and Indonesia, using data from the NSS Employment and Unemployment Household surveys for India and Indonesia Family Life Surveys for Indonesia. Following the analyses carried out for developed countries, we find, surprisingly, no evidence of job polarization in India and Indonesia for the periods 1983-2004 and 1993-2000, respectively.

The absence of job polarization may be due to organizational and institutional factors specific to developing economies, which could be very different from that of developed economies. A salient feature of developing countries is the significant presence of a large number of non-regular workers (Shyam Sundar (2011), ILO

(2016), Rothenberg et al. (2016)), even leading to segmented labour markets within the same economy (Günther and Launov (2012)). To make our analysis reflect the labour market conditions of these developing countries, instead of documenting employment change across occupations, we consider *occupation-status* as the primary unit of analysis. For India we consider the worker statuses of regular, casual and self-employed, while for Indonesia the worker statuses are government, private and self-employed. Interestingly, we do find that employment decreases in the middle of the wage distribution across occupation-worker status categories while increases at the two ends of this distribution, a phenomenon we term as *occupation-status polarization*.

We establish that worker statuses are important not simply in terms of labour market conditions but also in terms of the skills required in an occupation. We apply a mixture model to our data to create heterogeneous skill groups among workers in India in 1983 and workers in Indonesia in 1993. The mixture model is a data-driven endogenous clustering technique that has the advantage of not specifying any cutoffs or terciles but requiring only the data to create heterogeneous classes (Günther and Launov (2012), Maitra (2016), Dell and Querubin (2018)). Following the job polarization literature, we use wages and years of schooling as indicators for skill, and create skill classes in the overall sample as well as within major occupation groups for India and Indonesia.

Finally we examine the association of worker statuses with these heterogeneous skill classes to establish that worker statuses are distinct skill groups within occupations. We find that, in both countries, workers with statuses of non-regular nature are relatively more likely to belong to lower skill classes and less likely to belong to higher skill classes within occupation groups. On the other hand, workers of regular

status are relatively more likely to belong to higher skill classes and less likely to belong to lower skill classes within occupation groups. Our results suggest that skills differ across worker statuses even within similar occupations. This provides support that occupation-status is more appropriate as a unit of analysis while documenting employment polarization in developing economies.

## **Do clouds have a silicon lining for firms? Contract hiring and computer investment: Evidence from rainfall shocks**

The role of technology in driving labour market changes has been well established in the literature (Tinbergen (1974, 1975), Katz and Murphy (1992), Autor et al. (2003), Acemoglu and Autor (2011)). But the literature provides mixed evidence on whether technology adoption leads to a rise or fall in employment. Firm-level studies have documented that technology adoption leads to both decreases in employment (Autor et al. (1998), Autor and Salomons (2018), Bessen et al. (2019), Acemoglu and Restrepo (2020)), as well as increases in employment (Van Reenen (1997), Blanchflower and Burgess (1998), Bessen (2019), Aghion et al. (2020)). In this chapter we look at how Indian manufacturing firms' contract worker hiring decisions are affected due to investment in computer capital in the face of demand shocks for the period 2000-2010. Documenting the relationship between technology and employment is a difficult exercise as technology investments are not random or exogenous shocks. Our study circumvents this issue by exploiting rainfall shocks as proxies for demand shocks to study how hiring decisions differ across firms with varied computer capital investments.

Following Adhvaryu et al. (2013) and Chaurey (2015), we use data on rainfall shocks as industrial labour demand shocks, as rainfall affects agricultural productivity and yield which in turn leads to higher income and spending for agricultural workers. This in turn results in an increase in demand for industrial goods, leading to an increase in industrial labour demand (Chaurey (2015)). As rainfall shocks are transitory demand shocks, we focus on contract workers as they are not protected by labour regulations like the Industrial Disputes Act, 1947 (IDA) that restrict firms from firing workers. Since rainfall shocks are exogenous demand shocks, identification comes from the interaction of a computer capital investment measure and exogenous demand shocks (Nizalova and Murtazashvili (2016)). For measuring computer capital investment, we create a computer capital share dummy for firms that have above-average computer capital expenditure.

We find that firms with above-average computer capital share tend to hire 2.32 fewer contract workers compared to firms with lower-than-average computer capital share, in response to positive transitory demand shocks. This differential hiring is 11.33% of the sample mean of contract employment. In line with Chaurey (2015), we find that the results are driven by rural firms as the mechanism of rainfall shocks proxying for demand shocks work through changes in income and spending in the agricultural sector. We also find that our results are mostly driven by contract workers who are employed in the main manufacturing processes in the firm and not in peripheral works such as maintenance and security. We conclude that firms investing in computer capital may be shifting towards labour-substituting technologies, and therefore do not need to hire as many workers during transitory demand shocks. Our results are robust to controlling for agricultural inputs, state specific laws, state-industry specific factors such as tariffs, and a host of alternative computer capital



investment measures such as the computer capital share of a firm, dummies for above-median computer capital share, industrial average computer capital share, industrial-year computer capital share, and a number of measures based on the US computer capital shares.

## **The Heat is on: Temperature and exam scores in India**

While there has been an extensive research on how rising temperatures have caused adverse effects on economic outcomes through indirect channels (such as rising sea levels affecting infrastructure), a relatively recent literature has emerged studying the direct impact of temperature on economic outcomes (Heal and Park (2020)). Several studies have analyzed how rising temperatures affect economic outcomes such as health and labour productivity (Deschênes and Greenstone (2011), Somanathan et al. (2021)). This chapter adds to this recent literature investigating the impact of temperature on human capital formation by studying how temperature affects exam scores (Cho (2017), Graff Zivin et al. (2018), Tien Manh (2019), Conte Keivabu et al. (2020), Graff Zivin et al. (2020), Park (2022)).

We use secondary board exam scores from the administrative data of the Central Board of Secondary Education (CBSE) for the period 2012-2015. In India, the secondary board exam is an important exam as the scores potentially affect academic stream choices in higher secondary education, which in turn affect college or university admissions and hence future career paths of students. Also, secondary exam scores are given non-trivial weightage during the admission process of colleges and universities in India.

Our unit of analysis is student-subject standardized exam scores. As a student takes more than one subject exam at their secondary level, this allows us to exploit variation in district temperature across subject exam days for each student (allowing us to control for student specific characteristics). Identification comes from the exogeneity in district temperatures during exam time.

We find that one degree Celsius rise in temperature leads to a fall in standardized scores by 0.003 standard deviations, or a one standard deviation increase in temperature leads to a decrease in exam score by 0.016 standard deviations. We also find that temperature has a non-linear impact on exam scores: the marginal impact of temperature on exam scores increases with temperature. We find further that students located in rural areas or of disadvantaged castes perform relatively better when exposed to high temperatures (compared to urban or general caste students, respectively). Rural and backward caste students may be accustomed to living in uncomfortable temperatures (as they may not be able to afford cooling equipment like air coolers or air conditioners). Hence, our results point to students performing relatively better when they have adapted to heat. In line with the heat adaptation literature, we also find that students in very hot districts (above the 80<sup>th</sup> percentile) perform relatively better than others (Cho (2017), Alberto et al. (2021)).

Finally, we provide evidence that temperature works through a physiological channel when affecting exam scores by examining whether the impact of temperature differs across male and female students. The literature provides evidence that physical differences between males and females can lead to thermoregulatory differences, with men being relatively more susceptible to thermal discomfort (Deschênes and Greenstone (2011), Mishra and Ramgopal (2013), Bai et al. (2014), Schweiker et al. (2018)). We find that male students perform relatively poorly compared to

female students when exposed to higher temperatures. We also establish the impact of heat on cognitive ability working differentially for quantitative vis-a-vis language subjects. Interestingly, the effect of heat on cognitive ability is further amplified by physical heat stress for male students. Our explanation, following the relevant medical and economics literature (Hocking et al. (2001), Deschênes and Greenstone (2011), Bai et al. (2014), Schweiker et al. (2018)), is that female and male students have very different physiological aspects that play a vital role in regulating thermal temperatures of the human body. Thus, our results point to the direction that the physiological channel is at work.

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