Investigating the Effects of ICT Use on R&D Productivity:

A Case Study on Optics and Photonics Research in the Philippines

Emerging Trends *in* APO Members

Asian Productivity Organization

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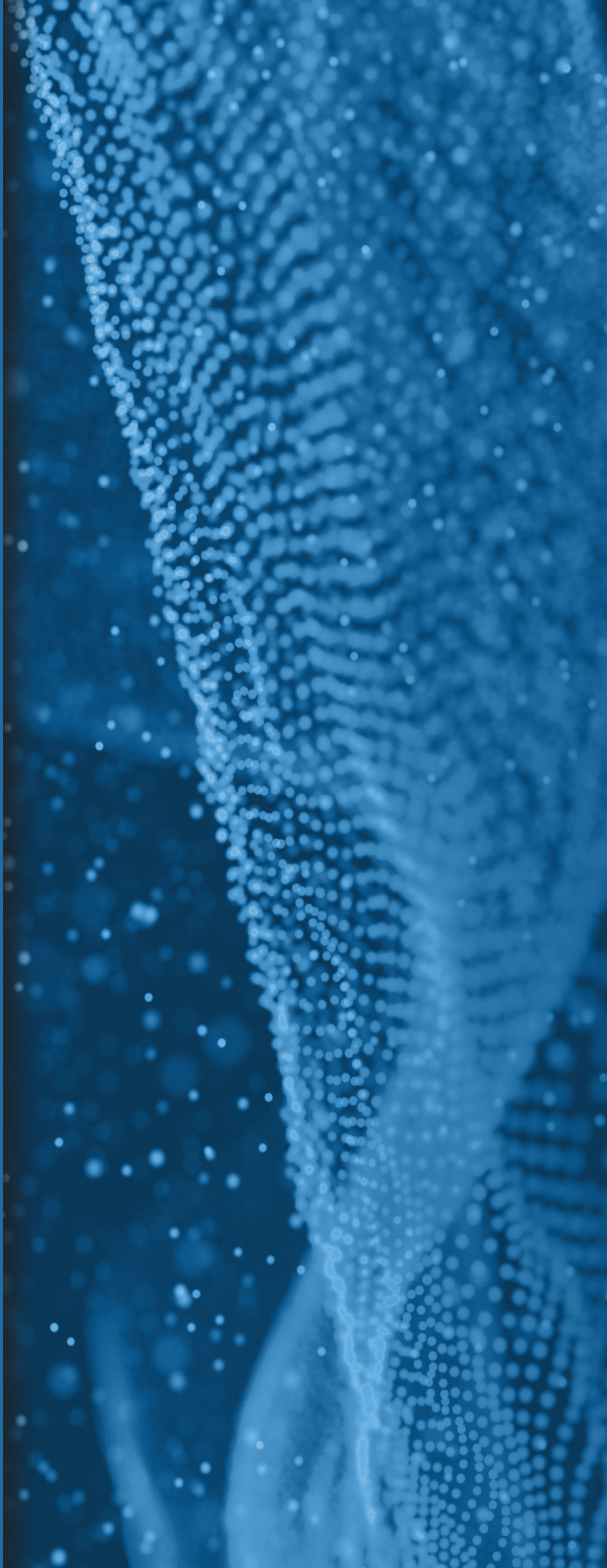
APO Members

Bangladesh, Cambodia, Republic of China, Fiji, Hong Kong, India, Indonesia, Islamic Republic of Iran, Japan, Republic of Korea, Lao PDR, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Turkiye, and Vietnam.



EMERGING TRENDS IN APO MEMBERS:

INVESTIGATING THE EFFECTS OF ICT USE ON R&D PRODUCTIVITY - A CASE STUDY ON OPTICS AND PHOTONICS RESEARCH IN THE PHILIPPINES

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THE PHILIPPINES

Dr. Benjamin B. Dingel served as the research expert and report author.

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1-24-1 Hongo, Bunkyo-ku
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www.apo-tokyo.org

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PREFACE

This publication on *Emerging Trends in APO Members* is aimed at enabling better navigation of the volatility, uncertainty, complexity, and ambiguity (VUCA) landscape. In today's turbulent, unpredictable world, the APO adopts a country-specific approach to understand and analyze emerging trends and driving forces that will have significant effects on member economies in terms of productivity and competitiveness. This series of reports introduces several emerging trends with the potential to disrupt and transform markets, governments, and society now and in the near future. It is hoped that through these publications analyzing those impactful trends, governments, policymakers, and ordinary citizens from all walks of life will be able to harness those driving forces while coping with critical uncertainties.

Recommended approaches and methods to address the challenges ahead include political, economic, social, technological, legal, and environmental perspectives. Being future-ready requires such a comprehensive approach to informed decision-making by governments, enterprises, and individuals in the fast-changing environment in the Asia-Pacific region. For the APO, it is all about early identification of issues and prospects, which requires strengthening its role as a think tank and regional adviser on productivity in the region.

The APO thanks all contributors to the report. We hope that it will benefit those seeking to improve productivity and quality of life brought about by emerging trends in a rapidly changing world.

INVESTIGATING THE EFFECTS OF ICT USE ON R&D PRODUCTIVITY: A CASE STUDY ON OPTICS AND PHOTONICS RESEARCH IN THE PHILIPPINES

Executive Summary

Information and communication technology (ICT) use in the workplace is an emerging trend due to the strong potential to boost productivity. However, evidence shows that ICTs also contribute to detrimental effects in the form of technostress, which in turn reduces productivity. Recognizing optics and photonics R&D as an emerging trend among APO member economies as well as its active reliance of ICT, this report presents the Philippine optics and photonics R&D sector as a case study to highlight both the benefits and risks of ICT use. Data for the case study was gathered through a survey questionnaire on technostress, interviews with members of the Philippine optics and photonics R&D sector, and an analysis of public data on a number of scientific publications from various laboratories. The findings show that ICT use improves the productivity of researchers in the Philippine optics and photonics sector by increasing access to information, streamlining data gathering and analysis, and creating opportunities for international collaboration. Although technostress is experienced by the case study subjects through information overload, addiction to ICT, and physical strain, strategies to manage these negative effects can be implemented at the individual level by moderating the amount of time spent using ICT. Policy that seeks to maximize productivity should therefore focus on expanding the benefits of ICT use rather than reducing its risks. Case studies, nationwide surveys, and meta-analyses could can help identify policies to maximize the productivity benefits of ICT use in optics and photonics R&D.

Introduction

ICT: An Emerging Trend in the Workplace

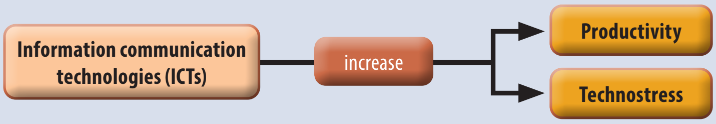
In the corporate climate of the 21st century, the increasing digitization of work is a trend that has redefined practices, processes, and standards across nearly every industry [1]. This shift is brought about by the development of ICTs, which involve various tools used to store, retrieve, transmit, and manipulate information [2]. Examples of ICTs include the internet, computers, and mobile devices. This emerging trend of ICT in the workplace has been identified as the main driver of productivity growth in the 21st century [3].

ICTs are also considered essential for achieving the UN's 2030 Agenda for Sustainable Development, spanning a variety of fields, such as digital healthcare, mobile payment methods, telecommunication systems, the Internet of Things (IoT), and artificial intelligence (AI) [4]. In both the United States of America (USA) and Japan, advancements in ICT products have reduced capital costs and lowered output prices across industries [5]. Additionally, ICTs enabled continuous productivity in various sectors amid the COVID-19 pandemic through the emergence of the work-from-home setup in which employees are no longer required to be physically present in a central place of work [6].

While a strong positive link has been established between ICT use and productivity, negative impacts on the workforce have also been observed. In 1984, Craig Brod coined the term technostress, which is defined as a modern disease of adaptation caused by the inability to cope with new computer technologies in a healthy way [7]. In simple language, technostress is stress induced by ICT use [8]. Following the identification of technostress as a potential risk of using ICTs, various psychophysiological symptoms associated with ICT use have been observed, including high levels of stress-sensitive hormones, poor concentration, and memory disorders [9]. Although ICT use has been demonstrated to increase productivity, there is empirical evidence suggesting that productivity is decreased at elevated levels of technostress [10]. Figure 1 shows the relationship between ICT use, productivity, and technostress.

FIGURE 1

RELATIONSHIP BETWEEN ICT USE, PRODUCTIVITY, AND TECHNOSTRESS



Optics and Photonics Research and Development (R&D): An Emerging Trend among APO Member Economies

Optics and photonics, defined as the science and application of light [11], are key drivers of productivity and serves as the foundation for technologies used in a variety of sectors [12]. As of 2022, optics and photonics R&D has a global market value of USD865 billion, with a compound annual growth rate (CAGR) of 6.8% from 2019 to 2022. This growth is projected to continue, reaching USD1.2 trillion by 2027 [13]. Table 1 highlights various application segments that contribute to the global photonics market share. With 11 different applications, varying from healthcare to telecommunications to agriculture and food, each occupying at least 1% of the total global market share, equivalent to over USD4 billion, optics and photonics play a significant role in enhancing productivity across various sectors.

TABLE 1

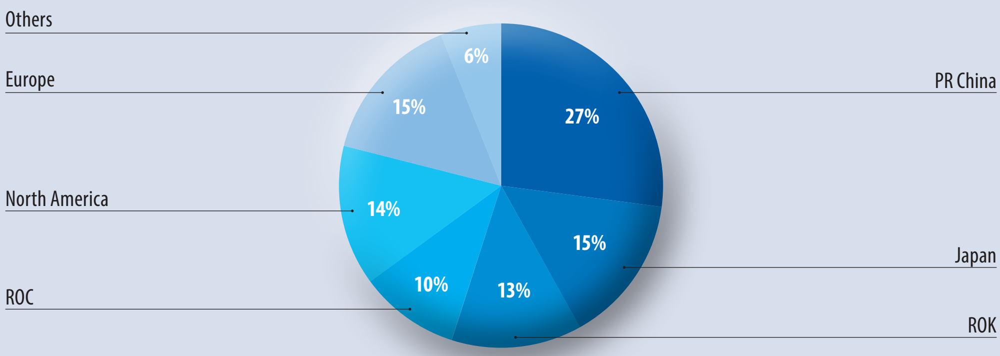
GLOBAL OPTICS AND PHOTONICS MARKET BY APPLICATION SEGMENT AS OF 2022 [13]

Application Segment	Market Share (USD 'billion)	Percentage (%)
Consumer and professionals	247.51	29
Environment, energy, and lighting	150.05	17
Components and materials	122.90	14
Healthcare	96.86	11
Industry	70.63	8
Mobility	57.45	7
Telecommunications	47.98	5
Defense and security	44.06	5
Instrumentation	15.99	2
Agriculture and food	6.36	1
Large instruments and space	4.81	1

Among members of the Asian Productivity Organization (APO), the optics and photonics R&D sector currently exists at two extremes. On one side, after the People's Republic of China (PR China), three APO member economies - Republic of China (ROC), Japan, and the Republic of Korea (ROK) - dominate the industry, accounting for nearly 40% of global photonics production. On the other side, the remaining 18 APO member economies occupy only 6% of the global share, as illustrated in Figure 2. While the optics and photonics R&D sector is highly productive in these three APO member economies, it is merely an emerging industry in the remaining 18.

FIGURE 2

GLOBAL PHOTONICS MARKET SHARE AS OF 2019 [14]



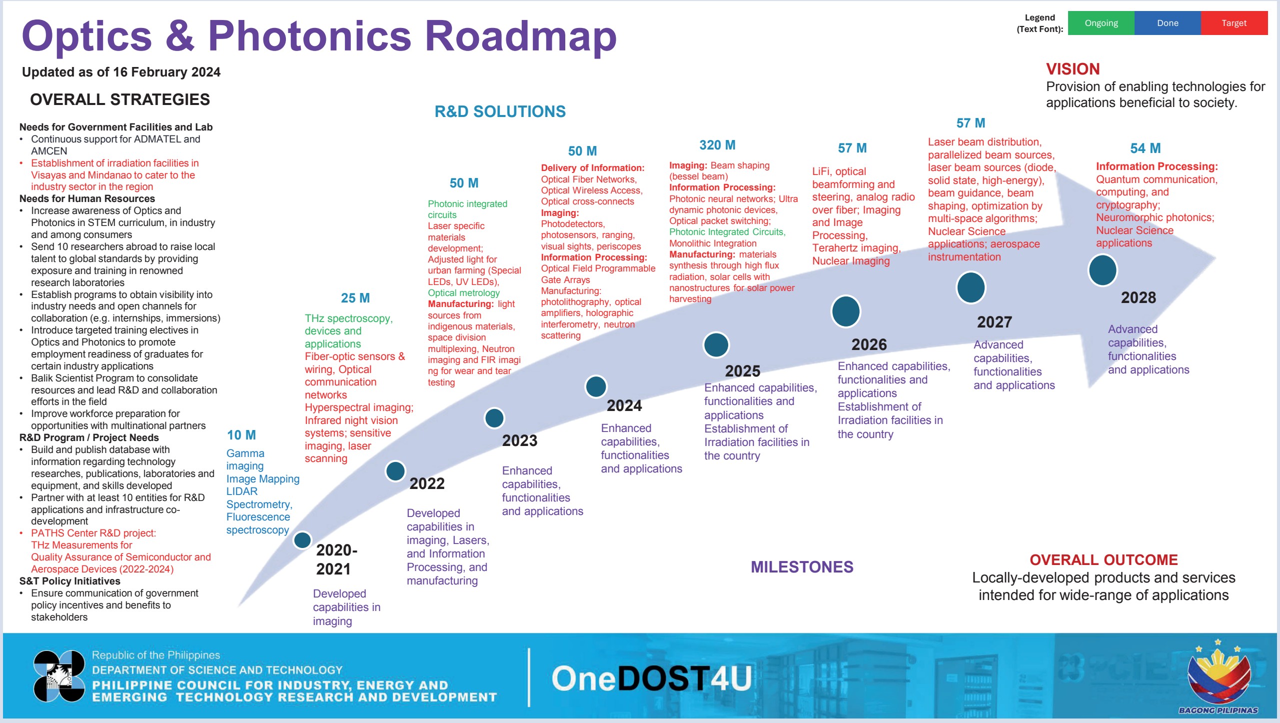
Trends on ICTs, Optics, and Photonics in the Philippines

The Philippine government has recognized both ICT use and development and optics and photonics R&D as key emerging trends. In 2016, the Department of Information and Communications Technology (DICT) was established through Republic Act no. 10844 to oversee a variety of projects aimed at leveraging ICTs for nation-building. These initiatives include the National Broadband Plan to deploy fiber optic cables and wireless technology to improve internet speed and affordability, the National Government Data Center to enhance government data security and government services delivery, and the establishment of Digital Transformation Centers to promote ICT literacy among Filipinos [15].

From 2021 to 2022, the Philippine digital economy increased by 11%, from USD33 billion to USD36.5 billion. On average, Filipinos spend 10 hours online daily, driven by long commute hours, working from home, and virtual schooling as significant contributors [16]. The nation is also committed to advancing optics and photonics R&D, as demonstrated by the release of the DOST-PCIEERD Optics & Photonics Roadmap, shown in Figure 3. PCIEERD is the Philippine Council for Industry, Energy, and Emerging Technology Research and Development, one of the three sectoral planning councils of the Department of Science and Technology (DOST). The roadmap is a government initiative that provides an overview of the sector's status and outlines development strategies. This roadmap highlights the importance of active collaboration between academia and industry to maximize productivity. However, while most research is currently conducted in universities, a collaborative ecosystem between industry and academia is still lacking. The roadmap emphasizes the need for the country to develop a holistic support system for effective R&D that integrates academia with industry.

FIGURE 3

DOST-PCIEERD OPTICS & PHOTONICS ROADMAP FOR 2020–28



Source: Reproduced with permission from DOST-PCIEERD [17].

The conclusions of the DOST-PCIEERD Optics & Photonics Roadmap is in alignment with the success stories of the ROC and Japan. When the ROC began its proactive endeavor into the sector in 2014, funding was initially focused on research activities carried out by universities. It wasn't until 2020 that attention shifted to the commercialization of innovation. ROC's experience and track record demonstrates that investing in university R&D before expanding into the commercial sector is an effective strategy. Japan's success, on the other hand, is attributed to its tripartite approach involving the government, industry, and academia [12]. With these two major players emphasizing the role of academia in the optics and photonics R&D sector, the Philippines is justified in following a similar path.

Goal of this Report

Recognizing the significant use of ICT and optics and photonics R&D as two distinct emerging trends, this report investigates the intersection of these trends by assessing the productivity-related benefits and risks of ICT use through a case study on the optics and photonics R&D sector in the Philippines. Case studies are an effective methodology for measuring the impacts of ICTs despite their limited scope as they can be utilized to explore causation, take advantage of both existing and new sources of data, and are generally very detailed. While their results are not generalizable beyond the limited context of the case study, they may indicate hypotheses for broader assessment in the future [18].

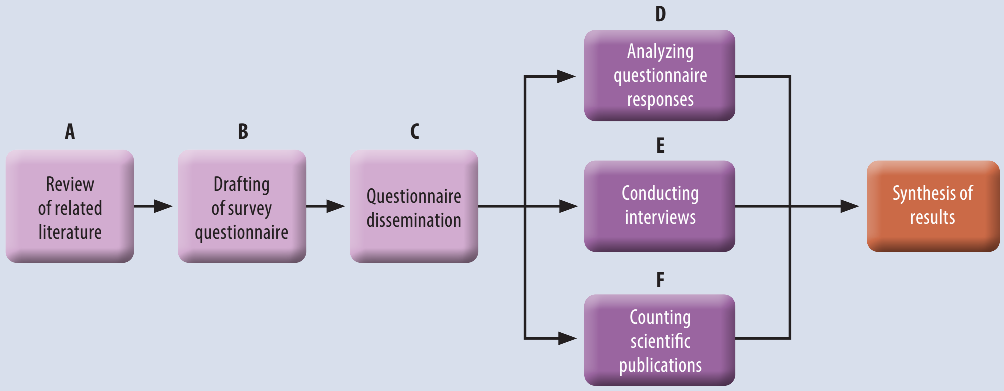
Given that the optics and photonics R&D sector is integral to the development of a wide variety of technologies, it is expected that ICTs are extensively utilized by members of this sector. Therefore, this specific sector serves as a relevant case study to generate insights into the effects of ICT use on both productivity and technostress. Additionally, the Philippine sector is particularly interesting, despite being an emerging field in the country, the national government has expressed its commitment to developing it through a dedicated roadmap [14]. Insights from this case can be used to inform international policy aimed at maximizing the productivity benefits of ICTs across APO member economies.

Methodology

In order to produce a report on the effects of ICT use on Philippine productivity in the optics and photonics R&D sector, a five-step methodology was employed, as shown in Figure 4.

FIGURE 4

REPORT METHODOLOGY FLOWCHART



Review of Related Literature

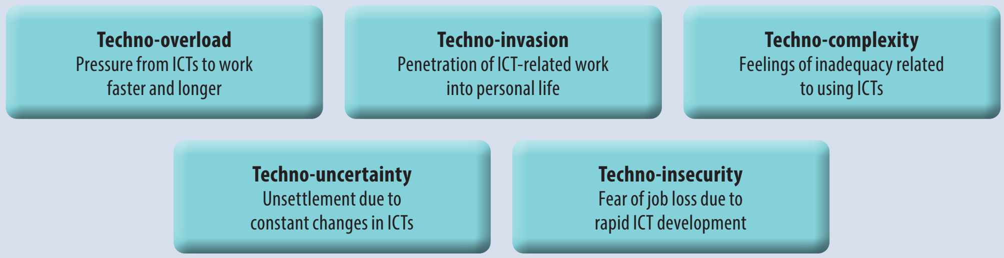
A review of related literature was conducted to understand the development of technostress as a concept and how it is assessed in the workplace. In 1984, technostress was defined as a modern disease of adaptation caused by the inability to cope with new computer technologies in a healthy way [7]. Over a decade later, in 1997, Rosen and Weil expanded that the scope of technostress was identified to be both psychological and physiological by defining technostress as any negative impact on attitudes, thoughts, behaviors, and physical health caused by technology [19]. In 2007, Tarafdar et al. further simplified Rosen and Weil's definition of technostress to "stress created by ICT use" [8].

To investigate how technostress is experienced in the workplace, a sample of workers is typically requested to rate how strongly they agree or disagree with a set of statements relating ICT use and work. A five-point Likert scale survey is commonly employed, where a rating of 1 indicates strong disagreement while a rating of 5 indicates strong agreement [20].

Although the definition of technostress acknowledges its scope as both psychological and physiological, survey assessments of technostress in the workplace typically focus on its psychological effects. Tarafdar et al. (2007) identified five key creators: techno-overload, techno-invasion, techno-complexity, techno-uncertainty, and techno-insecurity [8]. These five concepts are defined in Figure 5. Meanwhile, Pirkkalanien et al. identified that stress-inducing conditions, such as high ICT prevalence in the workplace, increased strain, often manifesting as feeling drained, tired, and burnt out [20]. Finally, to identify the link between technostress creators and work performance, Li and Wang developed a survey to link technostress creators with work performance by asking respondents whether ICTs increased their productivity, work convenience, and capacity for innovation [21].

FIGURE 5

TECHNOSTRESS-CREATING FACTORS [8]



Drafting of Survey Questionnaire

After reviewing various surveys utilized to measure technostress in related literature, a case study survey questionnaire was drafted with three sections. The first section outlined the objective of the case study - to assess the benefits and risks of ICT use on optics and photonics research in the Philippines - and sought informed consent from participants. The second section included 25 statements from the surveys employed by Tarafdar et al. [8], Nimrod [20], Pirkkalainen et al. [21], and Li and Wang [22], to which respondents were requested to respond using a five-point Likert scale. Finally, the third section collected demographic information, such as gender, generational cohort, education, daily ICT usage for work, and affiliated research organizations.

Questionnaire Dissemination

Google Forms was used as the survey platform, and the questionnaire was disseminated via email to acquaintances and colleagues of the report co-authors in the field of optics and photonics R&D field as well as an email blast to the National Research Council of the Philippines (NRCP).

Analyzing Questionnaire Responses

Survey results were analyzed using Microsoft Excel, where the mean and standard deviation (SD) for each of the 25 statements on ICT use were computed.

Conducting Interviews

Selected respondents were contacted via email for 30-minute Zoom interviews, in order to gain further insight into their survey responses. Although interview questions were tailored to each respondent's answers, common questions were also used in all interviews, as listed in Table 2.

TABLE 2

INTERVIEW QUESTIONS FOR ASSESSING ICT USAGE IN OPTICS AND PHOTONICS RESEARCH

Item No.	Questions
1	Could you outline your experience in doing optics and photonics research?
2	Could you outline what a typical day of work looks like for you?
3	Did you always find ICTs easy to use for doing optics/photonics research, or was there a time wherein you were struggling to use them?
4	What experiences have helped you learn to use ICTs effectively?
5	In a world where ICTs are highly prevalent, how do you maintain strong boundaries between work time and leisure time?
6	What opportunities have ICTs opened up for you as a researcher?
7	If you were to write a policy to improve ICT use for optics and photonics research and development in the Philippines, what would you propose?

Counting Scientific Publications

To gain an overview of the productivity of optics and photonics R&D in the Philippines, four different Philippine-based laboratories from four universities were examined. The number of publications was determined using public Google Scholar profiles and research group websites. For all four groups, both local and international publications were included.

Results and Discussion

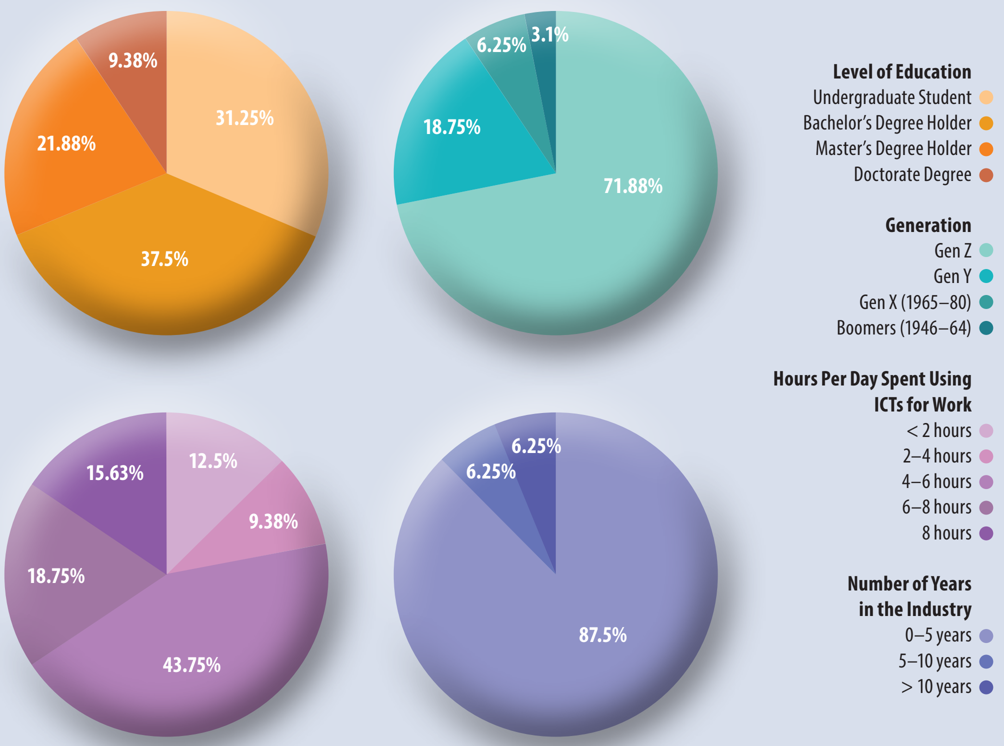
Survey Results

About the Respondents

The survey questionnaire received a total of 87 responses. However, some responses failed to indicate an affiliation with a research organization doing optics and photonics, leaving only 32 valid responses from individuals with experience in optics and photonics R&D in the Philippines. Thus only these were considered in the analysis. Most respondents were young researchers from Generation Z (71.9%) with less than five years of experience in the sector (87.5%). The majority of respondents have completed at least an undergraduate degree, 9.4% held a doctorate, 21.9% possessed a master's degree, and 37.5% held an undergraduate degree as their highest qualification. Without significant variation across gender, generational cohort, or educational attainment, 43.8% of respondents reported using ICTs for work 4–6 hours per day, 34.4% for over six hours, and 21.9% for less than four hours. These demographic observations are summarized in Figure 6.

FIGURE 6

DEMOGRAPHICS OF SURVEY RESPONDENTS



About the Responses

The results of the five-point Likert survey are shown in Table 3. The most consistent results are the statements in the fifth category: work performance. All five statements in this category received the same average rating of 4, which indicates that respondents agree with each statement. The respondents therefore generally agree that ICTs improve their work performance, enhancing quality of work, better output, greater convenience in doing work, greater capacity for innovation, and overall research improvement.

Similarly, in the techno-overload category, all five statements received an average rating of 3, which indicate neither agreement nor disagreement. This suggests that respondents generally do not feel pressured by ICTs to work faster or longer.

For techno-invasion, statements depicting blurred boundaries between work and home life were given an average rating of 4. However, statements suggesting that the blurring of boundaries posed a detrimental effect on home life, such as reduced family time, disruption of completing tasks for the home, and a general invasion of personal life received an average rating of 3. These results imply that ICT-related work indeed penetrates into the personal lives of the respondents, but it does not necessarily do so in a negative way.

In the techno-complexity category, statements describing ICTs as easy to use received an average rating of 4 but gave an average rating of 2 or 3 to statements that describe ICTs as difficult to use, suggesting that the respondents generally find ICTs easy to use for work.

For the final category of strain, statements expressing irritation or annoyance toward ICTs were given an average rating of 4 while those linking ICT use to drain, burnout, and discomfort obtained an average rating of 3.

TABLE 3

SURVEY QUESTIONS AND RESULTS ON ICT USAGE IN OPTICS AND PHOTONICS RESEARCH

Statement Categories	Mean (SD)*
1. Techno-overload	
I am pressured by ICT to work much faster	3 (1.10)
I am pressured by ICT to do more work than I can handle	3 (1.11)
I am pressured by ICT to work with very tight time schedules	3 (1.16)
I have a higher workload because of increased ICT complexity	3 (1.06)
ICT creates many more problems than I would otherwise experience	3 (1.28)
2. Techno-invasion	
I spend less time with my family due to ICTs	3 (1.18)
I have to be in touch with my work even during weekends and vacations due to ICTs	4 (1.30)
I feel my personal life is being invaded by ICTs	3 (1.37)
ICT use blurs boundaries between my work and home life	4 (1.22)
I do not get everything done at home because I find myself completing work due to ICTs	3 (1.05)
3. Techno-complexity	
I do not know enough about ICTs to handle my job satisfactorily	2 (1.22)
I need a long time to understand and use new ICTs	3 (1.15)
Learning to use ICTs is easy for me	4 (1.03)
ICTs are easy to use	4 (0.78)
It is easy to get the results that I desire from ICTs	4 (0.83)

Statement Categories	Mean (SD)*
4. Strain	
I feel drained from activities that require me to use ICT at work	3 (1.15)
I feel burned out from my ICT activities at work	3 (1.00)
I am irritated by the vast variety of ICTs that are utilized at my workplace	2 (1.13)
I am annoyed by the excessive use of ICTs at my workplace	2 (1.09)
I feel uncomfortable with the invasion of ICTs in all aspects of my work	3 (1.20)
5. Work Performance	
ICT use improves the quality of my work	4 (0.61)
ICTs help me accomplish more work than would otherwise be possible	4 (0.73)
ICTs allow me to perform my work duties with convenience	4 (0.68)
ICTs enable me to try out innovative ideas	4 (0.66)
ICT use has improved my research	4 (0.60)

**The mean is the average rating value while the SD is the standard deviation.*

About the Implications

Based on the data, it can be concluded that work-related ICT use does not cause the respondents to experience increased strain. Overall, these results are summarized in Table 4. By integrating the observations and implications from the five survey categories, it is suggested that ICT use is accelerating productivity in optics and photonics R&D in the Philippines.

TABLE 4

SUMMARY* OF SURVEY RESULTS ON ICT USAGE IN OPTICS AND PHOTONICS RESEARCH

Category	Observation	Implication
Techno-overload	Respondents gave a neutral rating to all statements	Respondents are not pressured by ICTs to work faster and longer
Techno-invasion	Respondents agreed with statements depicting blurred boundaries between work and home life, but felt neutral towards statements suggesting that ICTs interfere with home life	ICT-related work does penetrate into the personal lives of the respondents, but not in a detrimental way
Techno-complexity	Respondents agreed with statements describing ease when using ICTs, but disagreed with or felt neutral towards statements describing difficulty	Respondents feel capable and well-equipped to utilize ICTs for work
Strain	Respondents disagreed with statements expressing irritation or annoyance with ICTs, but felt neutral towards ICTs causing drain, burnout and discomfort	Respondents do not experience increased strain from using ICTs for work
Work performance	Respondents agreed with all statements relating ICT use to improved work performance.	Respondents perceive the effect of ICTs on their work performance as positive.

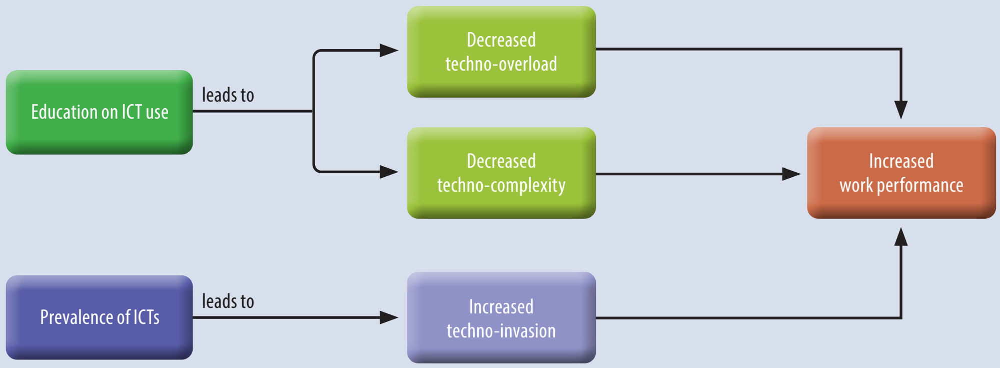
**A visual summary of the survey results is available in the appendix.*

This conclusion is supported by the survey results in the categories of techno-overload, techno-complexity, and techno-invasion. The lack of significant experiences of techno-overload and techno-complexity among respondents can likely be attributed to their educational background in science, technology, engineering, and mathematics (STEM), which has equipped them with the skills to use ICTs with ease and effectively. This is consistent with a meta-analysis study by Vargas-Montoya, Gimenez, and Fernandez-Gutierrez (2023). By analyzing data from 236,540 students attending 10,193 schools in 44 countries, they discovered that students from schools that integrate effective ICT use into their curriculum demonstrate better ICTs proficiency and improved academic performance compared to those from schools where ICT use is not emphasized [23]. Proper training and education on ICT use can therefore prevent feelings of pressure and being overwhelmed, typically associated with techno-overload and techno-complexity.

Furthermore, although survey respondents reported experiencing techno-invasion, they also agreed that ICT use improves their work performance. This suggests that techno-invasion may actually contribute to work performance by providing opportunities for researchers to carry out their work remotely, outside of normal workplace settings. With the availability of the internet, computers, and smartphones at home, researchers have the option to work from home, therefore getting more work done. The relationship between the survey results on techno-overload, techno-complexity, techno-invasion, and work performance is depicted in Figure 7.

FIGURE 7

IMPACT OF TECHNOSTRESS ON WORK PERFORMANCE



Interview Results

Compositions

To supplement the survey results and gain deeper insights into the risks and benefits of ICT use in optics and photonics R&D in the Philippines, five out of the 32 survey respondents were interviewed. All interviewees are based in the Philippines and conduct research work involving optics and photonics, though four out of five interviewees have experienced working in this field in other countries, such as the USA and Japan. Table 5 provides an overview of the five interviewees, detailing their generational cohort, educational attainment, years of experience in optics and photonics R&D, and the number of

TABLE 5

DEMOGRAPHIC PROFILE OF SURVEY RESPONDENTS

Interviewee	Generation	Education	Years in Field	Hours Spent per Day Using ICTs for Work
A	Baby Boomers (1946–1964)	Doctorate or higher	More than 15 years	More than 8 hours
B	Generation X (1965–1980)	Doctorate or higher	More than 15 years	4–6 hours
C	Generation Y (1981–1996)	Doctorate or higher	Between 5–10 years	2–4 hours
D	Generation Y (1981–1996)	Master's degree	Less than 5 years	4–6 hours
E	Generation Z (1997–2012)	Master's degree	Less than 5 years	4–6 hours

hours they spend using ICTs for work on a daily basis. Interviewees A–C in Table 5 are professors in the academe, handling a variety of day-to-day tasks, such as delivering lectures, mentoring students, holding laboratory meetings, and publishing scientific journal articles. In contrast, interviewees D and E are primarily researchers, focused on laboratory experimentation and data analysis.

The Benefits and Risks of ICTs

All interviewees utilize ICTs for their work in optics and photonics R&D, though to varying degrees. The many benefits of ICT use discussed by the five interviewees can be categorized into three categories: access to information, data gathering and analysis, and work flexibility. Conversely, the various risks associated with ICTs mentioned by the interviewees can also be grouped into three categories: information overload, ICT addiction, and physical strain. A summary of benefits and risks of ICT use discussed by the interviewees is presented in Table 6 while the details of these benefits are elaborated in the following discussion.

TABLE 6

BENEFITS AND RISKS OF ICT IN THE PHILIPPINE OPTICS AND PHOTONICS R&D SECTOR

Benefits of ICT Use	Risks of ICT Use
Access to information ICTs provide easy access to resources, such as scientific publications and video tutorials for conducting research	**Information overload** Some interviewees notice that their students often struggle to manage and organize this abundance
Data gathering and analysis ICTs have made data gathering and analysis more convenient through innovations in data logging, data display, programming, and artificial intelligence	**Addiction** Some interviewees use ICTs excessively, to the point that it interferes with other activities, such as their sleep and driving
Capacity for collaboration ICTs enable communication that transcends physical barriers, promoting international collaboration among researchers	**Physical strain** Some interviewees expressed experiencing physical symptoms attributed to excess ICT use, such as eye strain, headaches, and back pain

All interviewees identified access to information as a significant benefit of ICTs. Interviewee C emphasized how videos, vlogs, and webinars have been helpful in learning essential research skills, such as programming and computer-aided design. Meanwhile, Interviewee B highlighted the ease of information access enabled by ICTs by comparing journal access in the 1990s with the current situation. In the 1990s, if a student wanted to read an article by a specific professor, they would have to personally mail a request to the professor, who would then have to mail back a physical copy. Alternatively, the student could search for articles at a local library, but the available articles would be out of date, given that article acquisition took at least 6–12 months after publication. In the current climate, however, direct correspondence between an interested reader and a publication author can be done through websites, such as Google Scholar, ResearchGate, and ORCID.

ICTs have also directly facilitated the gathering and analysis of experimental data for the interviewees. Interviewee B described that monitoring an experimental setup has been made more convenient with the use of cameras and display monitors. Without these equipment, an experimental setup could only be observed from one angle at a time by a single researcher. However, with these tools, multiple angles can be monitored simultaneously. Similarly, Interviewee E expressed that the use of computers makes data logging and display convenient. Finally, Interviewee D pointed out that AI models, such as ChatGPT, have proven helpful in speeding up program writing and code debugging.

Collaboration as a benefit of ICT use was particularly emphasized by Interviewees A and C. Interviewee A discussed how video conferencing platforms, such as Zoom, have been essential for mentoring students and delivering lectures despite physical barriers, especially during the COVID-19 pandemic. Interviewee C outlined how ICTs enable researchers in developing countries to remotely control advanced machines located in developed countries through the use of TeamViewer. Both Interviewees

A and C also discussed the benefits of emails and messaging platforms, such as Messenger and Line for quick communication with fellow researchers and students.

One risk associated with ICT use discussed by some interviewees is information overload, which refers to the difficulty of filtering out relevant information from an abundance of data [24]. Although not specifically attributed to work in optics and photonics, Interviewee A described experiencing strain due to oversaturation of news. Meanwhile, as an active research mentor, Interviewee B has observed many students struggling to manage the overwhelming amount of scientific information currently available and expressing distress over their inability to organize it. However, Interviewee B does not view this as a problem to be resolved by reducing information availability but rather by training students in becoming scientists with the maturity to handle a wide scope of information.

A more pressing risk identified by some interviewees is the phenomenon of ICT addiction. Interviewee A uses ICTs for over 18 hours on a daily basis, for both work and nonwork purposes, getting only three to four hours of sleep at night. Moreover, Interviewee B finds it challenging to resist the temptation to read journal articles on a smartphone while driving in traffic. These anecdotal experiences are consistent with patterns found in published literature, where ICT addiction associated with an increased risk for poor sleep [25] as well as a higher likelihood of experiencing safety-critical traffic events [26].

Finally, Interviewees A and E mentioned headaches and eye strain as physical symptoms they attribute to ICT use. This observation is supported by related literature, which indicates that eye strain and headaches are among the most common negative health symptoms associated with ICT use [27].

Notably, Interviewees C and D claimed to be unaffected by the risks of ICT use. For Interviewee C, this may be attributed to using ICTs for only 2–4 hours per day. In contrast, Interviewee D takes proactive measures in maintaining boundaries between work and leisure. Interviewee D does not store any data on personal devices, reducing the temptation to do work outside of work hours. Additionally, Interviewee D devotes time to physical activities, such as jogging, hiking, and participating in marathons.

Related literature suggests that the risks of ICT use, namely addiction, physical strain, and information overload, are dependent on the amount of time spent using ICTs. Addiction and physical strain appear to increase with the amount of time spent using ICTs. Controlled use of digital technology have been identified as an effective psychotherapeutic intervention for treating technological addictions [28] while restricting the use of digital screens to under four hours per day and taking frequent breaks has been shown to reduce physical strain associated with digital technology [29]. In this case study, both Interviewees C and D restrict their ICT use and claim to not experience the associated risks, in contrast to Interviewees A, B, and E, suggesting that the experiences of the subjects of this case study are consistent with findings in related literature. Interestingly, however, information overload appears to decrease with the amount of time spent processing information. In fact, time pressure has been identified as a key factor for aggravating information overload as a source of stress [30]. Given this information, effective mitigation of the risks associated with ICT use should involve minimizing the amount of time spent using ICTs while maximizing the time spent processing the information gained from ICTs.

Assessment of Productivity

To gain an overview of research productivity, data was gathered on the publication output of four photonics research groups from different universities, and their publication trends over the past decade were analyzed. By examining the patterns across these groups, factors influencing their productivity, such as the potential role of ICT in collaboration efforts and the challenges of maintaining consistent publication rates, can be better understood. This analysis offers insights into the different patterns observed among these groups and may show some aspects of their research dynamics.

FIGURE 8

NUMBER OF ANNUAL PUBLICATIONS BY FOUR RESEARCH GROUPS BETWEEN 2013–24 [31]

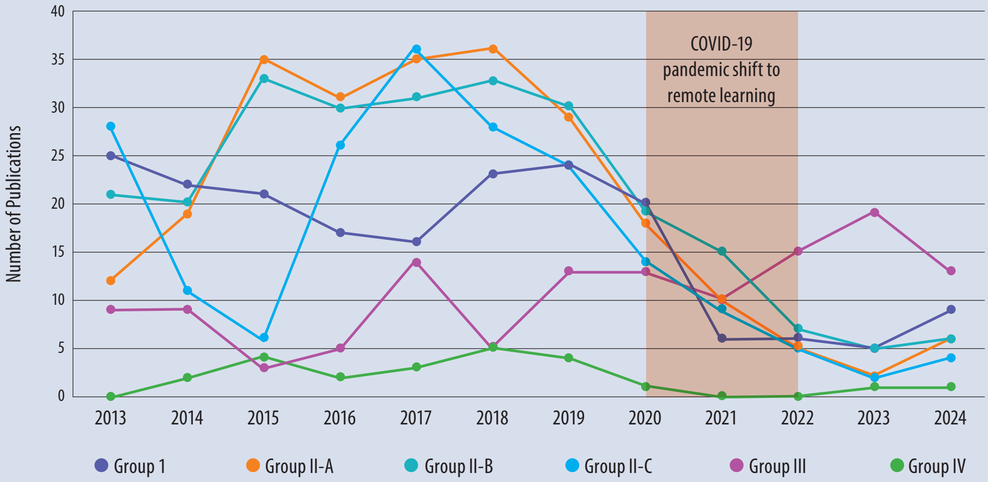


Figure 8 shows the publication trends of four research groups from different universities in the Philippines over the past decade. Groups I–IV share some similarities but primarily differ in their specializations in the field of optics and photonics. Group II, being larger, consists of three subgroups: Group II-A, Group II-B, and Group II-C. The publication numbers for each subgroup are plotted individually.

Looking at the plot, it is evident that Group I maintained consistent publication productivity until experiencing a noticeable decline during the pandemic years. All of Group II (Group II-A, Group II-B, and Group II-C) had experienced a surge in publications from 2016 to 2019, likely due to extensive collaborations with international partners, though they too faced a dip during the pandemic. Group IV followed a similar trend, with a decline during the pandemic years.

Group III, on the other hand, did not follow the same downward trend. One of the contributors, who was also interviewed, mentioned their prior heavy reliance on ICT for remote mentoring before the pandemic, which likely minimized the impact of the shift to remote mentoring on their publication trends.

In contrast, an interviewee from Group I discussed the challenges of not having in-person research meetings during the transition to remote learning and mentoring. This experience emphasized the importance of resuming face-to-face interactions with students and researchers now that things have returned to normal, leading them to prefer in-person meetings over online options.

In conclusion, the use of ICT was a significant factor in shaping the publication trends of these research groups. Group III's prior adoption of ICT for remote mentoring enabled them to sustain stable productivity while other groups, such as Group I, faced challenges due to the lack of in-person interactions, reinforcing their preference for face-to-face meetings. This contrast highlights the varying levels of adaptability among the groups and the impact of ICT on their research outputs.

Several other factors also likely influenced these trends, such as the reliance on hands-on experiments, emerging trends in the field of photonics, and increase grant support. However, the study is limited to the observations of the use of ICT based on insights gathered from interviews and surveys.

Conclusion

Recognizing that optics and photonics R&D is an emerging trend among APO member economies, and that it actively involves ICT use, this report presents the Philippine optics and photonics R&D sector as a case study subject to highlight the benefits and risks of ICT utilization. The investigation look into the positive impact, such as increased productivity, ease in sharing information, building networks, and utilizing online classes, alongside the negative effects, which include increased technostress, loss of work-life balance, techno-overload, and techno-complexity, resulting from the significant exposure and usage of ICT in the workplace among members of the Philippine optics and photonics R&D sector.

The methodology used is survey questionnaires, interviews, data gathering, and analysis from a total of 86 respondents. The overall result indicates the positive impact of ICT usage. There is little evidence of techno-overload and techno-complexity that impede productivity. This is likely due to the STEM education of the survey respondents.

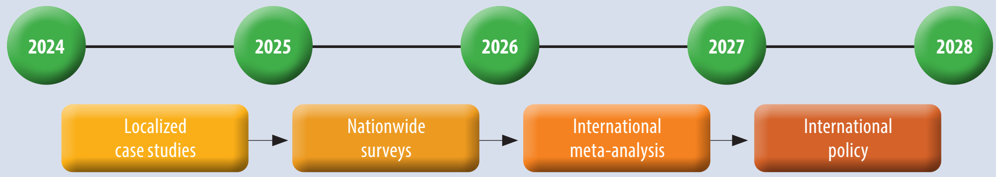
While the negative effects of ICTs can be minimized at the personal level, the benefits should be maximized at the policy level by enhancing further growth: (i) open-access technical journals and open-source software; (ii) sharing of library, equipment, and facilities among universities and industries; (iii) bolstering AI-based data gathering and programming incentives; (iv) promoting sustainable remote and online mentoring; and (v) increase support to enable experimentation by remote control from distant campuses or facilities.

Recommendations

Policies involving ICT use and R&D play a crucial role in boosting productivity, not only in the Philippine optics and photonics sector but also in various emerging R&D sectors across different APO member economies. Figure 9 illustrates a five-year roadmap for the development of international policy at improving ICT use in R&D, with four integral components: (i) localized case studies; (ii) nationwide surveys; (iii) international meta-analysis; and (iv) international policy.

FIGURE 9

ROADMAP IN DEVELOPING INTERNATIONAL ICT POLICY IN R&D



Case studies are research endeavors conducted on a small scale but are highly detailed and can incorporate a variety of qualitative and quantitative sources of data. Even though case study findings are bound by their contextual frameworks, they are useful for exploring causation within defined context and identifying topics that are worth assessing more broadly through quantitative means [18]. This report serves as an example of a case study, focusing on optics and photonics researchers in the Philippines as the subject. While definitive conclusions on the benefits and risks of ICT use are beyond the scope and nature of this report, it has successfully identified patterns among Philippine-based optics and photonics researchers, including:

- The importance of access to journal publications, laboratory equipment, and facilities for productivity
- The facilitation for international collaboration through ease of communication
- The significant role of education in maximizing ICT use

Additional case studies may be conducted in other APO member economies in order to illuminate further patterns within the sector.

The next step in the roadmap is to conduct nationwide surveys to confirm any patterns observed through case studies at the national level. Following comprehensive nationwide surveys across many APO member economies, a meta-analysis of these survey-based studies can be undertaken to identify common patterns among different members as well as important moderators for any differing results observed [32]. With the quantitative findings from the meta-analysis, international policy can be drafted to maximize the benefits of ICT use while minimizing its risks across diverse countries and cultures.

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APPENDIX

TABLE A1

STATEMENTS AND RESULTS FOR THE TECHNO-OVERLOAD CATEGORY

Statement Categories	Mean (SD)
1. Techno-overload	
1A. I am pressured by ICT to work much faster	3 (1.10)
1B. I am pressured by ICT to do more work than I can handle	3 (1.11)
1C. I am pressured by ICT to work with very tight time schedules	3 (1.16)
1D. I have a higher workload because of increased ICT complexity	3 (1.06)
1E. ICT creates many more problems than I would otherwise experience	3 (1.28)

FIGURE A1

SURVEY RESULTS ON DISTRIBUTION OF RESPONSES FOR TECHNO-OVERLOAD

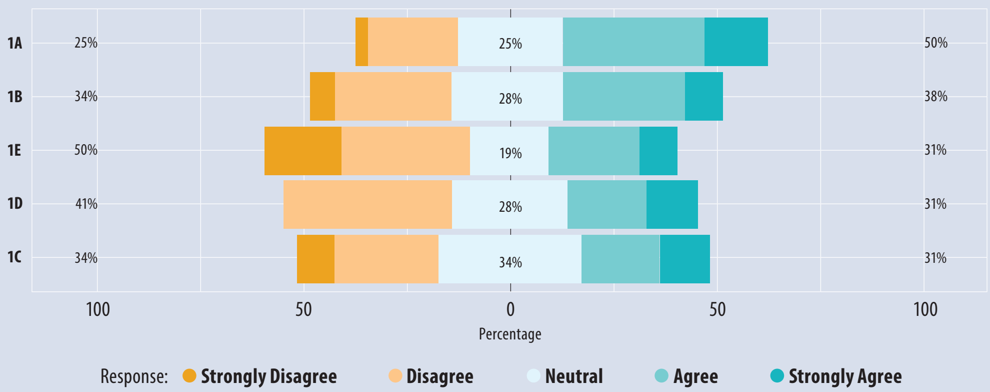

FIGURE A2

HEATMAP OF RESULTS SHOWING THE INTENSITY AND DISTRIBUTION OF RESPONSES

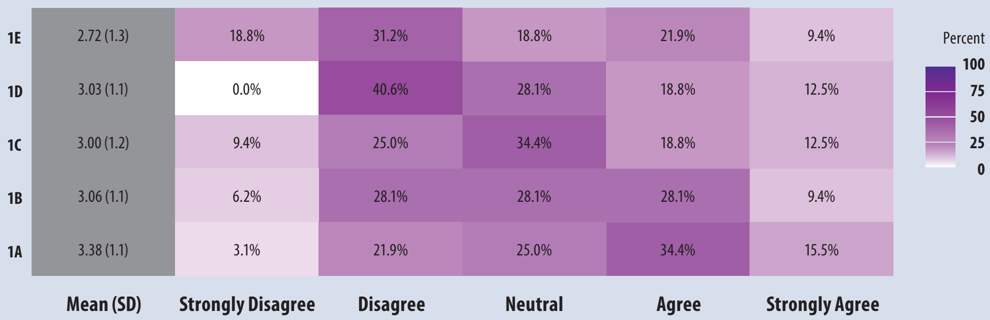

TABLE A2

STATEMENTS AND RESULTS FOR THE TECHNO-INVASION CATEGORY

Statement Categories	Mean (SD)
2. Techno-invasion	
2A. I spend less time with my family due to ICTs	3 (1.18)
2B. I have to be in touch with my work even during weekends and vacations due to ICTs	4 (1.30)
2C. I feel my personal life is being invaded by ICTs	3 (1.37)
2D. ICT use blurs boundaries between my work and home life	4 (1.22)
2E. I do not get everything done at home because I find myself completing work due to ICTs	3 (1.05)

FIGURE A3

SURVEY RESULTS ON DISTRIBUTION OF RESPONSES FOR TECHNO-INVASION

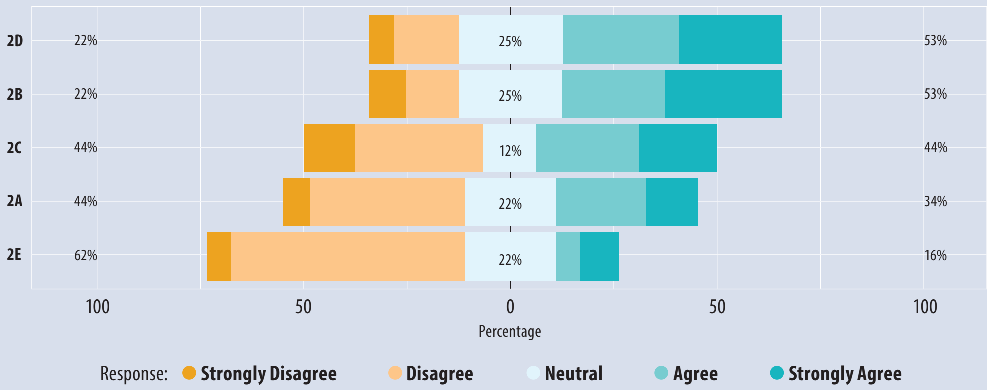

FIGURE A4

HEATMAP OF RESULTS SHOWING THE INTENSITY AND DISTRIBUTION OF RESPONSES

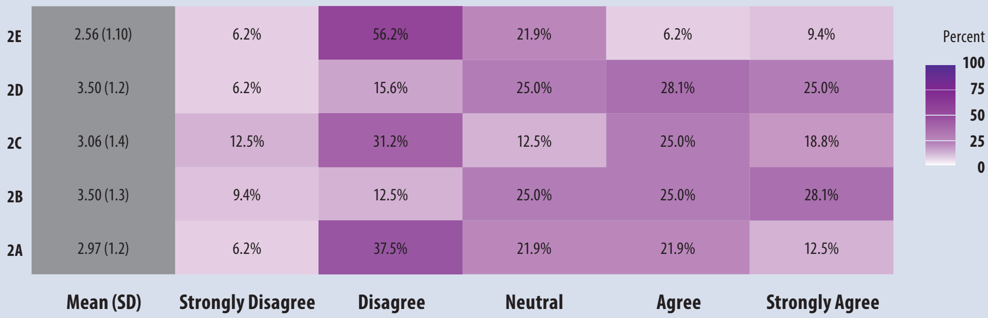

TABLE A3

STATEMENTS AND RESULTS FOR THE TECHNO-COMPLEXITY CATEGORY

Statement Categories	Mean (SD)
3. Techno-complexity	
3A. I do not know enough about ICTs to handle my job satisfactorily	2 (1.22)
3B. I need a long time to understand and use new ICTs	3 (1.15)
3C. Learning to use ICTs is easy for me	4 (1.03)
3D. ICTs are easy to use	4 (0.78)
3E. It is easy to get the results that I desire from ICTs	4 (0.83)

FIGURE A5

SURVEY RESULTS ON DISTRIBUTION OF RESPONSES FOR TECHNO-COMPLEXITY

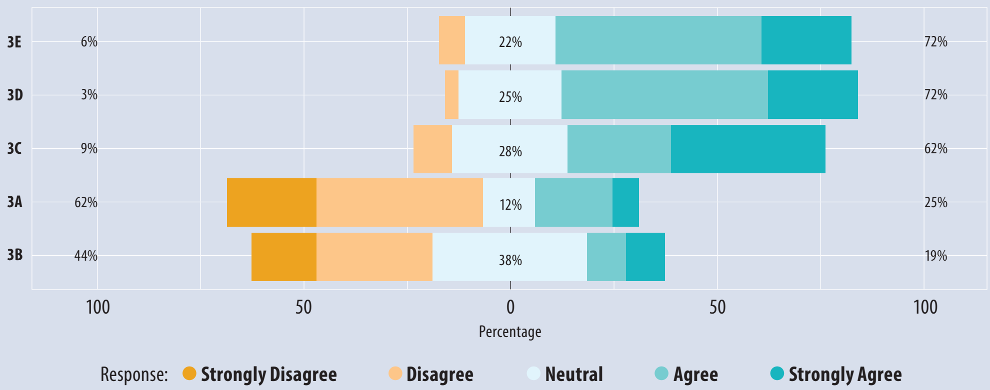

FIGURE A6

HEATMAP OF RESULTS SHOWING THE INTENSITY AND DISTRIBUTION OF RESPONSES

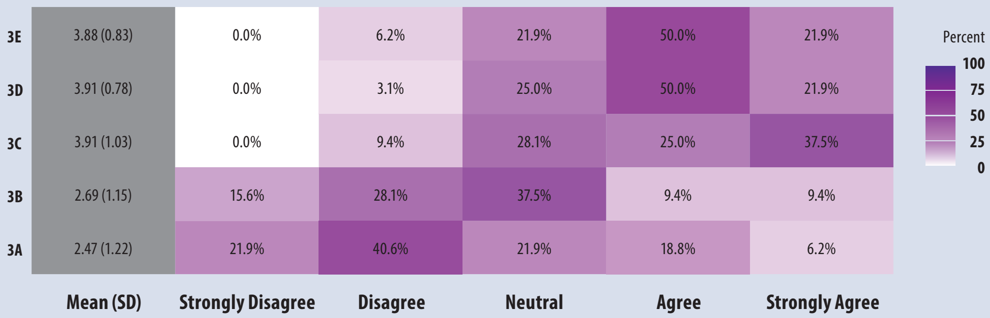

TABLE A4

STATEMENTS AND RESULTS FOR THE STRAIN CATEGORY

Statement Categories	Mean (SD)
4. Strain	
4A. I feel drained from activities that require me to use ICT at work	3 (1.15)
4B. I feel burned out from my ICT activities at work	3 (1.00)
4C. I am irritated by the vast variety of ICTs that are utilized at my workplace	2 (1.13)
4D. I am annoyed by the excessive use of ICTs at my workplace	2 (1.09)
4E. I feel uncomfortable with the invasion of ICTs in all aspects of my work	3 (1.20)

FIGURE A7

SURVEY RESULTS ON DISTRIBUTION OF RESPONSES FOR STRAIN

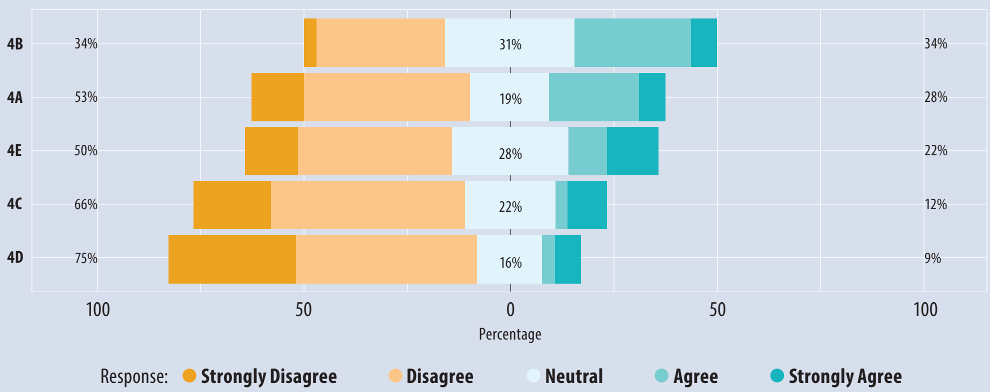

FIGURE A8

HEATMAP OF RESULTS SHOWING THE INTENSITY AND DISTRIBUTION OF RESPONSES

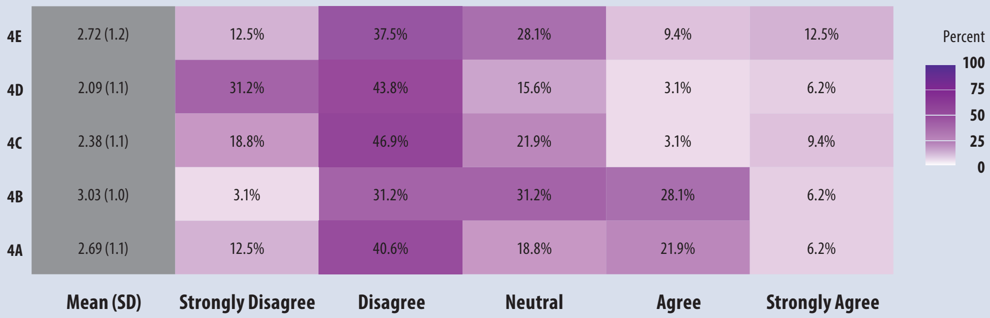

TABLE A5

STATEMENTS AND RESULTS FOR THE WORK PERFORMANCE CATEGORY

Statement Categories	Mean (SD)
5. Work Performance	
5A. ICT use improves the quality of my work	4 (0.61)
5B. ICTs help me accomplish more work than would otherwise be possible	4 (0.73)
5C. ICTs allow me to perform my work duties with convenience	4 (0.68)
5D. ICTs enable me to try out innovative ideas	4 (0.66)
5E. ICT use has improved my research	4 (0.60)

FIGURE A9

SURVEY RESULTS ON DISTRIBUTION OF RESPONSES FOR WORK PERFORMANCE

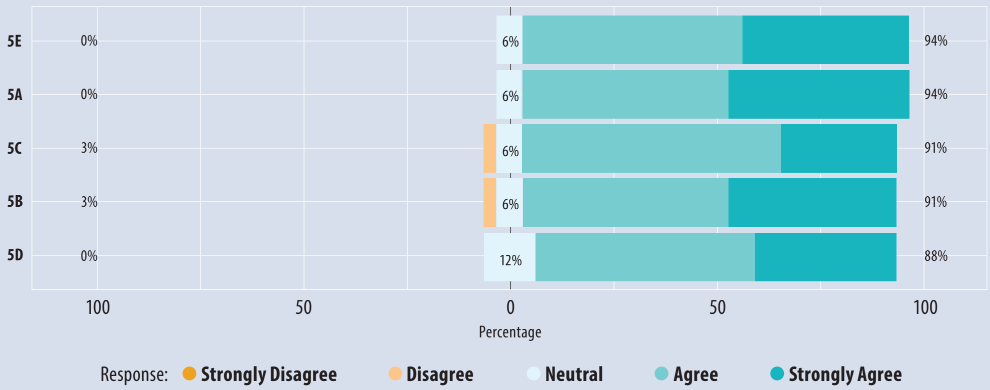

FIGURE A10

HEATMAP OF RESULTS SHOWING THE INTENSITY AND DISTRIBUTION OF RESPONSES

	Mean (SD)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5E	4.34 (0.60)	0.0%	0.0%	6.2%	53.1%	40.6%
5D	4.22 (0.66)	0.0%	0.0%	12.5%	53.1%	34.4%
5C	4.16 (0.68)	0.0%	3.1%	6.2%	62.5%	28.1%
5B	4.28 (0.73)	0.0%	3.1%	6.2%	50.0%	40.6%
5A	4.38 (0.61)	0.0%	0.0%	6.2%	50.0%	43.8%

Percent: 100, 75, 50, 25, 0

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ABBREVIATIONS AND ACRONYMS

AI	Artificial intelligence
APO	Asian Productivity Organization
DICT	Department of Information and Communications Technology
DOST	Department of Science and Technology
ICT	Information and Communication Technology
IoT	Internet of Things
NRCP	National Research Council of the Philippines
PCIEERD	Philippine Council for Industry, Energy, and Emerging Technology Research and Development
R&D	Research and development
ROC	Republic of China
SD	Standard deviation
STEM	Science, technology, engineering, and mathematics
UN	United Nations
USA	United States of America
USD	United States of America's currency "Dollar"

LIST OF RESEARCHERS

Dr. Benjamin B. Dingel
Research Fellow
Research on Optical Sciences, Engineering, and Systems (ROSES) Lab Group
Department of Physics
Ateneo de Manila University

Amante Joshua P. Dumalus Jr.
DOST Science Research Specialist II
Research on Optical Sciences, Engineering, and Systems (ROSES) Lab Group
Department of Physics
Ateneo de Manila University

Alessandra Ilsa L. Molo
Science Research Specialist I
Research on Optical Sciences, Engineering, and Systems (ROSES) Lab Group
Department of Physics
Ateneo de Manila University

Kryss C. Urbano
Science Research Specialist II, DOST-SEI CIP MS Graduate Fellow
Research on Optical Sciences, Engineering, and Systems (ROSES) Lab Group
Department of Physics
Ateneo de Manila University