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The Impact of the Coronacrisis on KIBS Sector

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Abstract

Knowledge-Intensive Business Services (KIBS) are problem-solvers for other organizations. The coronacrisis affects KIBS directly, but also means that their clients are confronting new problems. How are KIBS addressing these two sets of challenges? This paper draws upon material available in the trade and industry press, on official reports and statistics, and the early academic studies addressing these themes. We find that KIBS have been active (alongside other organizations) in providing a substantial range of services aimed at helping their clients (and others) deal with the various contingencies thrown up by the crisis. Not least among these are the need to conform to shifting regulatory frameworks and requirements for longer-term resilience. KIBS themselves have had to adapt their working practices considerably, to reduce face-to-face interaction with clients and within teams collaborating on projects. Adaptation is easier for those whose tasks are relatively standardized and codified, and it remains to be seen how far a shift to such activities - and away from the traditional office-based venues of activity – is retained, as firms recover from the crisis. KIBS are liable to play an important role in this recovery from the crisis and policymakers can mobilize their services. Some KIBS are liable to be critical for rendering economies more resilient in the face of future pandemics, and we argue that these firms are also important for confronting the mounting climate crisis.

Keywords: KIBS; coronavirus pandemics; coronacrisis; COVID-19; longer-term resilience

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KIBS and Crises

Knowledge-Intensive Business Services (KIBS) are critical components of modern economies, as has been argued in several essays in this journal and elsewhere. KIBS are private firms, applying expertise to the business problems of clients. Figure 1 provides an overview of the industrial sectors involved in traditional professional services (e.g., accountancy and legal services), technology and engineering-related services (including computer and information technology (IT) services, research and development (R&D), and testing services), and services with more of a creative/cultural focus (advertising, design, etc). They have grown rapidly in modern economies and become integrated into many supply chains and business strategies. The future of KIBS is of obvious interest to all analysts of long-term change in economies, employment, and knowledge dynamics. This essay considers how their future is liable to be affected by the *Coronacrisis*. We refer here to:

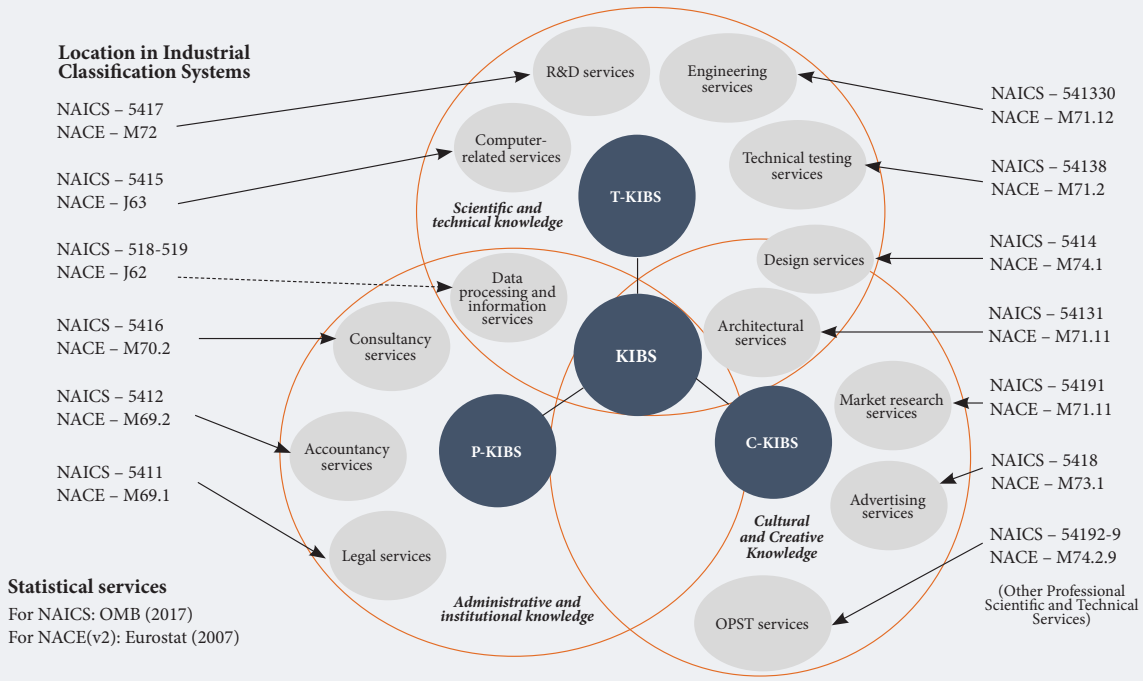
- the complex of events surrounding the immediate effects of the pandemic associated with the SARS-COV2 virus and the disease it causes, COVID-19;
- the major social and economic interventions undertaken by governments around the world in attempts to control and/or manage the pandemic; and
- the substantial and potentially long-lasting effects of the lockdowns and other measures that have been introduced.

Lessons from the Previous Crises

The world of course has experienced pandemics before the current coronacrisis, but the current situation is very different from that of a century ago. While the coronacrisis is widely seen as being more likely to resemble the Great Depression of the 1920s and 1930s in terms of massive and long-lasting economic impacts, KIBS, in general, were very small parts of national economies at that time. The impact of the coronacrisis on KIBS is thus without precedent in the history of pandemics. We can examine KIBS' response to more endogenous economic crises. The most recent major global economic crisis, the Great Recession, was triggered by the financial crisis of 2007-2008 at a time when KIBS had developed to a scale roughly similar to that we see today. The general picture seems to be that the impact of the Great Recession (henceforth GR) on KIBS was abrupt but short-lived. Figures 2a and 2b present trend data for the EU-15 economies. The growth or decline of employment and output in KIBS sectors and the whole economy is represented (each indicator is given the baseline of 100 in the year 2000).

Before the crisis, all KIBS employment grew more rapidly than the economy as a whole. With the onset of the crisis, employment decreases were relatively higher in several KIBS than in the whole economy (Advertising; Architecture and Engineering – hence A&E). However, most KIBS sectors recovered to practically pre-crisis employment growth rates by early 2010. Advertising, however, lacked the dynamism of other KIBS and if anything

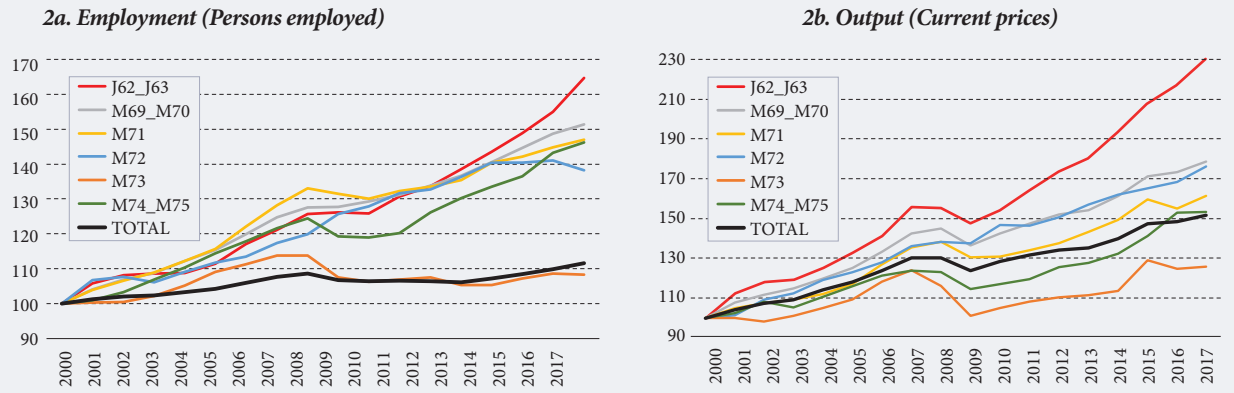
Figure 1. **Main Categories and Statistical Classifications of KIBS**



Note: The group of Data Processing and Information Services has been added to the standard list of KIBS since these are also mainly B2B services requiring considerable professional expertise. They are in any case often aggregated with Computer-related Services in published data presentations and downloads.

Source: authors.

Figure 2. EU-15 Trends



Notes: The sectors featured are: J62_J63 - Computer programming, consultancy, and information service activities; M69_M70 - Legal and accounting activities; activities of head offices; management consultancy activities; M71 - Architectural and engineering activities; technical testing and analysis; M72 - Scientific research and development; M73 - Advertising and market research; M74_M75 - Other professional, scientific and technical activities; veterinary activities. TOTAL refers to the whole economy.

Sources of data: Calculated from Eurostat

grew somewhat less than the total economy. In terms of output, R&D services show little sign of being impacted by the crisis. Other KIBS demonstrated a sharp downturn. Computer and information services display remarkably high growth and most KIBS remain above the economy as a whole. Broadly speaking, the patterns of KIBS growth in the EU-15 before the crisis have resumed after a brief hiatus. Arguably, A&E services display a slightly lowered pace of growth in employment and output terms after the crisis than before.[1] Details vary across different KIBS and countries but overall the experience of the GR suggests that these industries are, in large part, relatively resilient to an economic crisis.

Quantitatively, the coronacrisis's impacts upon GNP and employment look to be both more severe and of longer duration than the GR [OECD, 2020]. The coronacrisis also differs qualitatively from the 2007-2008 crisis, though in both cases service industries, traditionally seen as relatively less impacted by economic crises than other sectors, were badly hit. In the GR, financial services were at the center of the storm. In the coronacrisis, entertainment and hospitality services have sustained heavy losses.

The Coronacrisis

KIBS are affected – both directly themselves and indirectly through the problems that their clients face and bring to them – by three aspects of the Coronacrisis:

A. The *pandemic* itself: as it evolves, the patterns of illness and deaths arise. There may be temporary or permanent loss of colleagues, clients, and business partners leading to the loss of knowledge and a disruption of operations. Health and Social Care (HSC) services are impacted acutely, not only by the intermittent availability of human resources. Urgent needs arise for biomedical knowledge and services: shortages of equipment and materials are experienced as demand surges and supply chains falter.

B. The *policy responses* to the pandemic: efforts are made to understand and apply public policy instruments to "managing" the pandemic, for example by limiting the spread of the virus and by mobilizing health services and related institutions to treat sufferers. Table 1 outlines the main policy responses seen across advanced economies. These responses include identifying and isolating infected individuals, reducing social contacts that can allow pathogens to be transmitted, increasing standards of hygiene, safeguarding the vulnerable people with protective equipment, or other means, introducing large-scale test/track/trace systems, and so on.

C. The *persistent impacts* of the pandemic and the aforementioned policy responses on the wider economy together with further policy measures designed to offset the most negative impacts and, in some cases, promote new directions for social and economic development. Many businesses are liable to collapse or substantially reduce operations in the wake of the loss of income. Many will need to re-establish customer relationships and build new partnerships and supply chains while patterns of consumer demand are liable to change and business practices could be redesigned to allow for resilience in the face of future pandemics. Persistent impacts of similar sorts may be felt by KIBS themselves, of course – not least in their ability to engage in F2F (face-to-face) interactions with clients.

Figure 3 illustrates these three elements, from both the supply and demand side of KIBS. We shall first consider these elements in terms of how they affect the operations of KIBS and then examine how they impact demand from clients for the services provided by KIBS firms. As we note, considerable uncertainties surround the evolution of the pandemic itself (point A) and one result is uncertainty concerning the application of policy measures (point B). This means that the extent to which various restrictions may remain in place (inter-

[1] This is perhaps because the financial crisis was closely connected with dubious financing of property development and mortgages in the early years of the century.

mittently or otherwise) and the duration of this uncertainty is equally uncertain. The ongoing impacts of the coronacrisis on KIBS and other businesses itself could be more or less profound, and more or less extensive over time.

Demand for KIBS

One immediate impact of the coronacrisis is the reduction or even cessation of activity and income in many sectors. In many countries, several service industries that face difficulties in restructuring in the wake of the introduction of social distancing measures were forced to close or limit operations for extended periods– this often applied to hotels, restaurants, bars and clubs, and much of the retail and consumer services sector along with many cultural, recreational, and entertainment facilities. When "lockdowns" were instituted, the operations of construction, social services, swathes of Agriculture, Forestry and Fishing, and much manufacturing, were substantially curtailed. Much work in these primary and secondary sectors requires physical proximity between co-workers in farms, fisheries, factories, construction sites, and so on. Dramatic decreases in demand were experienced by many public transport sectors as both work and leisure travel diminished.[2] Contemporarily, the growth of online retail meant increased demand for delivery services and shifts in retail consumption, so the enterprises that shifted to new forms of commerce in a timely manner suffered less.

Other service industries are often less dependent upon particular locations and facilities; professional and administrative work can often be conducted in socially distanced ways, notably by working from home (WFH) supported by telecommunications infrastructure [Eurofound, 2020]. WFH (and other forms of remote working, together known as "teleworking" or "telecommuting") was forecast to become prominent by commentators from at least the 1980s [*Qvortup,* 1998], but developed much more slowly than projected – until taking off dramatically during the coronacrisis [Eurofound, 2020]. The rapid transition to large-scale WFH has proven a major challenge for those industries for whom this was a feasible way of maintaining their business activity – especially given that some of these industries are experiencing substantial changes in demand. However, there are many accounts of businesses deciding that WFH is quite effective and that they can save money currently consumed by expensive office facilities [Dimensional Research, 2020]. This may have substantial long-term impacts on city centers and the businesses serving them.

Financial and Related Problems

Due to the coronacrisis, many firms are likely to go out of business or pare down activities and discretionary expenditures (including on those KIBS inputs that are not deemed essential in the short-term). A survey of independent consultants found them experiencing drops in contracting for many of their services, with financial consultancy least affected and market research most impacted.[3] It may well also lead to more caution in the use of KIBS, with clients opting for familiar suppliers, well-known KIBS brands, which will typically mean the larger firms, or in some cases those firms with a strong local presence. This could also imply an avoidance of

Table 1. **Common Policy Measures in the Coronacrisis**

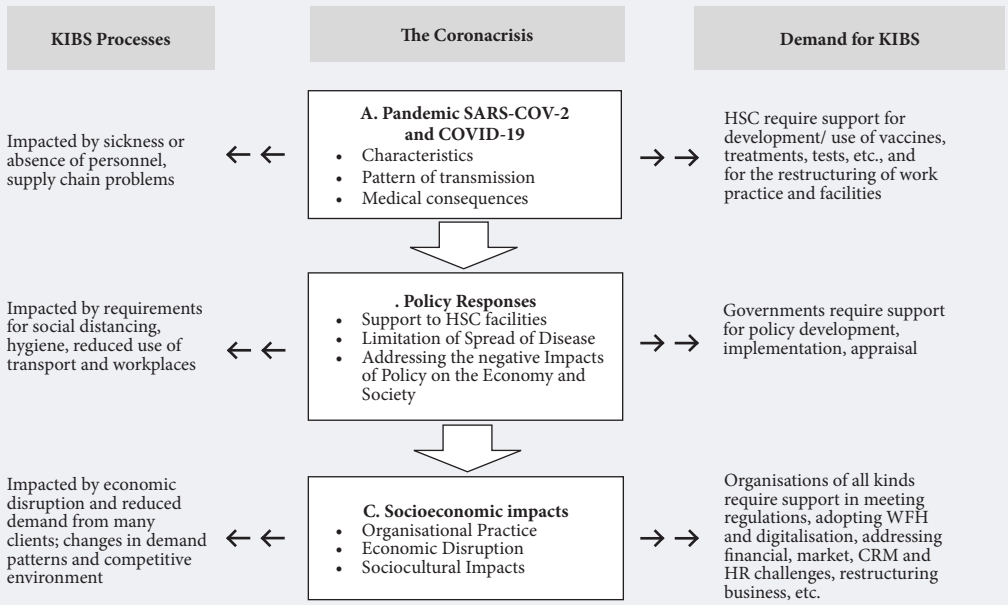
Aim	Contents
Limiting the spread of the virus and protecting those most vulnerable	• Advice, or enforcement of measures, that restrict the use of meeting places such as clubs, bars, restaurants, hotels, and non-essential shopping venues and public facilities such as libraries, museums, schools and colleges. This has obvious impacts on the conduct of many businesses, as well as on all levels of education. • More or less stringent enforcement of what became known as social distancing, requiring people to stay at home and businesses to shift work online, as far as possible; restricting travel to work for employees in non-essential industries. Again, many businesses are affected, including KIBS. • Restricting international movements, seeking to quarantine those arriving from other countries. • Recommending or enforcing the use of masks (especially in indoor public locations). • Introduction of testing systems, to identify cases, and tracking systems to locate contacts of those believed to be infected.
Strengthening and supporting frontline health and social care services	• Preventing available HSC resources from being overwhelmed by COVID-19. This includes building/redesigning of hospitals and efforts to develop and supply relevant equipment and medicines, and the provision of support for R&D that can feed into such efforts to support the capabilities of HSC services to cope with the pandemic. • Management of complex new procedures established to assist HSC in addressing the coronacrisis, and KIBS may have roles to play both in providing advice as to organizations and supporting this through the provision of staff. • As it becomes evident that COVID-19 can have long-term impacts upon physical and mental health, increased effort into establishing systems for helping to alleviate these effects is being demanded.
Supporting businesses, employees, and others affected by the pandemic and policy responses	• Impacts related to loss of business due to social distancing and, especially, enforced closure may be alleviated by various means such as loans, grants, etc. • Employees may be supported via, for example, furlough schemes (which aim to protect jobs), one-off payments, or welfare benefit systems. • More general requirements for compensatory measures to offset the loss of time in education and mental health and similar services to help deal with the emotional fall-out from the coronacrisis are liable to be significant elements of the long-term policy response.

Source: authors.

[2] https://www.itf-oecd.org/transport-face-pandemic (accessed 24.12.2020).

[3] The study was reported on 15 July 2020. Available at https://www.consultancy.uk/news/25094/covid-19s-impact-on-the-independent-consulting-market, accessed 24.12.2020. Over a thousand independent consultants in major countries (UK, US, France, Germany) had been surveyed; large decreases in business came from travel and leisure and the construction sectors, while lower decreases were reported from clients in pharmaceuticals, healthcare, chemicals, and agriculture.

Figure 3. **KIBS and the Coronacrisis**



Source: authors.

the risks associated with investing in more novel inputs. Clients will also seek to tackle their problems with internal resources and seek free advice.

Businesses will require assistance in dealing with the fallout from long-term market disruptions. This immediately means demand for support concerning bankruptcy, divestment, property sales, managing redundancy, and a host of related (and often tragic) problems from KIBS, finance and insurance firms, regulatory authorities, and industry associations. Many KIBS have been making free basic advice available, for instance through webpages and webinars, partly to help stave off a huge number of queries from desperate clients, partly to be good citizens supporting their business partners and ecosystems, and as a way of securing the loyalty of existing clients and recruiting custom for more customized and/or elaborate services. Specialized anti-coronacrisis solutions are also widely available from non-KIBS organizations such as charities, universities and business schools, and national and local government agencies, as well as from online communities (Figure 4).

KIBS use may be encouraged by governments, who may facilitate businesses' access to emergency support. A UK example, Recovery Advice for Business, offers free telephone-based advice to small and medium-sized businesses. Topics include accounting, advertising, HR, and legal affairs. Professional bodies and trade associations mobilized experts in their sectors to provide such free advice.[4] Financial support – such as various types of loans and grants of various types, including those associated with furlough schemes – has been provided to firms by some governments. Such resources are distributed with some safeguards aimed at ensuring that businesses will ensure adequate business plans, commitments concerning staff retention and operating conditions, and so on. KIBS providing accountancy and similar support are liable to confront demand from clients seeking to access such funds, as well as from those providing the funds.[5]

Pandemic Preparedness

It is far from clear how long the difficulties associated with the pandemic will persist; scenarios on this topic have proliferated. Though several vaccines have been developed rapidly and should be produced on sufficient scale to immunize much of the world's population within a few years, SARS COV2 appears able to mutate readily and may well reinfect people with immunity to earlier strains (as winter influenza and the common cold do). Other zoonotic infectious diseases are likely to emerge, with the intrusion of population growth and modern ways of life into natural environments. Thus, at least some the measures introduced to manage the pandemic may be applied continually, at least in some regions of the world. Even after substantial recurrences of COVID-19 are eliminated (if they are), some distancing and hygiene measures will probably remain in effect for a long time. Such measures may be instituted re-

[4] Cf. https://www.enterprisenation.com/freesupport/ (accessed 24.12.2020) and the Northern Ireland-focused https://www.nibusinessinfo.co.uk/content/coronavirus-business-support-organisations-offering-advice-and-guidance (accessed 24.12.2020).

[5] In a report entitled "Consultants hired to check Covid-19 rescue loans for fraud" (Available at https://www.consultancy.uk/news/25448/consultants-hired-to-check-covid-19-rescue-loans-for-fraud, accessed 24.12.2020), journalists reported that the state-owned British Business Bank was spending more than £1 million contracting auditors to detect cases of fraud in the distribution of coronacrisis rescue loans, as well as £20 million in fees to assist in setting up schemes such as Coronavirus Business Interruption, and Bounce Back, Loans.

Figure 4. **New Speciality Services in the Wake of the Coronacrisis**

Services may be offered to provide support with:	Relating to new demands concerning:
• Accounting • Accreditation • Auditing • Business Continuity • Customer Service • Evaluation • Event Planning • Facilities Design • Litigation • Logistics management • Marketing and PR • Opinion and attitudes research • Resilience and Recovery • Service blueprinting and design • Software/web service design • Training Etc.	• Cleaning buildings, furniture, equipment • Clothing and equipment for staff • Digital collaboration, interaction and communication • Health issues (customers / staff) • Hygiene • Information provision in different formats for (potential) customers, staff, visitors • Pandemic Readiness • Social and Physical Distancing • Testing of staff and visitors to facilities • User pathways through facilities • Work organisation Etc.

Source: compiled by the authors.

currently or on a longer-term basis. Businesses will be under pressure from governments, insurers, investors, business partners, employees, and/or consumers to have plans in place for rapid response to future threats. Even if SARS COV2 can be more or less controlled, the world is liable to confront future threats, associated with other emerging diseases, or more virulent varieties of familiar diseases. As policymakers, insurers, business leaders, and informed societies recognize these risks, improved capabilities to respond rapidly to outbreaks by introducing such measures are a likely consequence. Organizations of all sorts will similarly be under pressure to establish plans for ensuring continuity and survival should such measures come into play. This is liable to mean increased demand for risk management and business continuity services are among the KIBS that are active here. Advice may be provided concerning compliance with regulations; plans and designs may be drawn up to render establishments, events, buildings, and working arrangements more pandemic-proof, and to allow organizations to better manage social distancing measures in their internal operations, in interacting and communicating with customers, and so on. Some KIBS are specialists at providing early warnings of ominous developments and emerging risks (a field in which the insurance industry has long had an interest), but they are probably most effective when complementing and feeding into businesses' own systems for monitoring changes in their operating environments.[6]

Some KIBS professions, such as architecture, may need to substantially revise aspects of their curricula and practices to facilitate the use of appropriate design principles. Standardized advice and simple design rules may be sufficient where the issues are mainly about personal behavior (maintaining physical distance, hygiene, face-masking, rules about queuing, etc.) or the use of facilities (discouraging of hot-desking and shared utensils, regular cleaning of surfaces and keyboards, tighter control of cafes, etc.). Where working, transport, or other arrangements require much more restructuring, which may often be the case in, for example, factories, construction sites, and warehouses, more sophisticated designs may be required – probably stimulating the need for engineering and industrial design services, along with those parts of management consultancy focused on work organization, employee relations, and customer relationships.

Suppliers, Customers, and Employees

Further new demands are liable to arise from businesses associated with disruptions in supply chains – and international tensions were already rendering some established supply chain arrangements and trading patterns problematic. The difficulties occasioned by reliance upon long-distance travel and transport, and on overseas sourcing of what proved to be critical products, are liable to lead to a rethinking of global activities. 9/11 was widely seen as likely to reduce trends towards global just-in-time systems [*Sheffi,* 2001], but the current crisis is liable to produce much more fundamental changes. Services supporting international businesses may be hit by disruptions to international trade and a possible retraction of some transnational businesses from their global markets. But businesses confronting new patterns of international trade, possibly involving new value chains and lead markets, will require assistance from consultancy and marketing services, among others. The same is true for efforts to support national and regional economies - for example policies and demand for more locally-based production facilities – which may reflect aims of self-reliance for strategic goods and services, but also efforts to create employment opportunities, regional rebalancing, or more social objectives such as providing meaningful work in an era of high automation. Across all sectors, customers, clients, business partners, and other stakeholders are liable to require information as to what the disruption to services and supply chains is liable to mean, what their options are, what the other parties are liable to do. Strategy consultancy of various kinds is liable to encounter clients searching for solutions to both immediate and long-term dilemmas. Often these will involve more use of digital media (thus digital advertising has grown, even if advertising revenues in broadcast TV and print newspapers have declined).

Employees (and other stakeholders) may respond negatively to organizational failures to effect sufficient improvements in terms of social distancing, hygiene, and pandemic preparedness; or conversely, may resist

[6] Risk management has its own ISO standard: ISO 31000 (more details and links to risk assessment techniques are available at: https://www.iso.org/iso-31000-risk-management.html, accessed 24.12.2020). Overviews of the field include [*Power,* 2007; *Spedding, Rose,* 2007; *Andersen, Schroder,* 2010]. On success factors for risk management systems, see [*Yaraghi, Langhe,* 2011]. A discussion of risk and foresight in connection with vaccine development and deployment is presented in [*Özdemir et al.,* 2011], while [*Suk et al.,* 2008] describe how risk analysis was undertaken in a foresight exercise on infectious diseases.

changes that render work environments less comfortable, ergonomic, or convivial. Methods to support the psychological resilience of employees can be critical, such as internal counseling services and support groups, team-building and consultation activities, regular demonstration of management's attentiveness to staff concerns and welfare, and leadership that evidences empathy and supportiveness [*Kock et al.,* 2018]. Again, specialist KIBS provide advice in many of these areas.

Technology and Innovation

Though we have focused upon the damage inflicted by the coronacrisis, some businesses have been unaffected or even benefitted from the pandemic. Suppliers of medical equipment, sanitary products, and pharmaceuticals experienced high demand, along with suppliers of equipment and services supporting online communications and online services of many sorts – among them, retail, entertainment, and news services. The pandemic also accelerated the development of service robots for hospitals, office buildings, and other facilities. KIBS are frequently involved in R&D on artificial intelligence, navigation systems, robot controls, and user interfaces. Organizations experiencing increased demand often encounter new problems and may require KIBS support to manage expansion, develop strategies, work in new markets, locate and integrate new partners, staff, and technologies. IT consultancies will experience requests from clients as to the issues involved in digitalization. All organizations are being advised to instruct and train staff to avoid cybercriminals exploiting opportunities associated with the pandemic (not least, those associated with remote working).

More generally, however, the financial constraints on businesses are liable to create pressures on funding for innovation.[7] IT-related efforts have likely been diverted toward the sorts of digitalization that support WFH and customer relations. Longer-term and more ambitious efforts to introduce advanced systems using data analytics, AI, and other applications of new technology and associated approaches have had to be reduced and/or delayed. This will have had knock-on effects on those KIBS involved in advising on, designing, and implementing such systems, while there will be a redistribution of activities within the computer and IT services sector, toward more immediate support and away from the longer-term projects.

This may be reversed once new digital technologies have bedded in. As their use becomes more widespread and routine, so a learning process can be anticipated, much along the lines of Barras' "reverse product cycle" [Barras, 1986, 1990], with users discovering new ways of organizing work, business processes, and customer relationships, and developing new service offerings. There may then be increased interest in the more ambitious, and longer-term, IT-based innovations and this should be associated with a corresponding revival in demand for KIBS support.

KIBS Practice and the Coronacrisis

Overall Demand for KIBS

The discussion above drew attention to some areas where demand for services may grow, but the coronacrisis meant an immediate, substantial drop in the demand for many KIBS. Recent statistics on production and employment dynamics vividly illustrate this (Figures 5 and 6). All industries experienced sudden shocks and it is striking that computer and information services did not appear immune to this. Advertising, which had been impacted badly by the Great Recession, looks to have been particularly badly hit after it had just shown signs of steady growth. The coronacrisis led to many KIBS facing sharp decreases in demand for their services. Sometimes there is the evident postponement of requests, for example, legal services have had to put cases on hold and worry that a mounting backlog of business law cases will eventually need addressing. It is unclear what the consequences will be for the future of KIBS in structural terms – will we see numerous mergers and acquisitions? Will it be larger or smaller companies that are most able to save costs in the ways discussed above? Will there be a growth in KIBS microbusinesses as displaced employees set up their own firms?

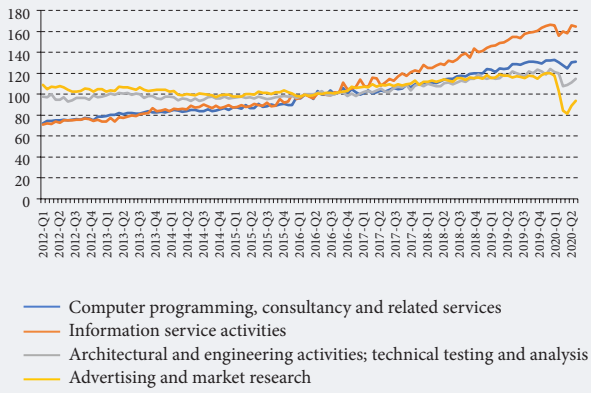
Changing Patterns of Demand

The earlier discussion of the impacts of the coronacrisis upon businesses provided some indications of which sectors are liable to be most affected and of the implications for demand for various KIBS inputs. Relative growth for services that support processes of digitalization, business continuity, and recovery - and dealing with business failure - is a predictable outcome, though such support can be delivered by organizations other than KIBS. Specialized KIBS provide consultancy, legal, and other forms of support for firms facing problems associated with the disruption of global supply chains [*Guan et al.,* 2020]. KIBS themselves may confront problems when they operate internationally, needing to forge new partnerships - some international operations are conducted through franchises, while joint ventures and strategic alliances are among the other common models of partnership [*Greenwood et al.,* 2020]. KIBS play roles in many global supply chains and these roles may well be impacted by the coronacrisis and its fallout. International trade tensions were already growing. These may render the use of overseas KIBS more difficult in some countries and supply chains.

Another aspect of demand change that predates the coronacrisis, but that it potentially accelerates, is the transition to more environmentally sustainable trajectories of economic development. Already some countries and intergovernmental organizations had been drawing up plans for "green growth", the decarbonization of their economies, and similar initiatives [*Capasso et al.,* 2019]. Early in 2020, the need for change was being underlined by Arctic warming, forest fires, and other striking weather-related events. The coronacrisis itself may have

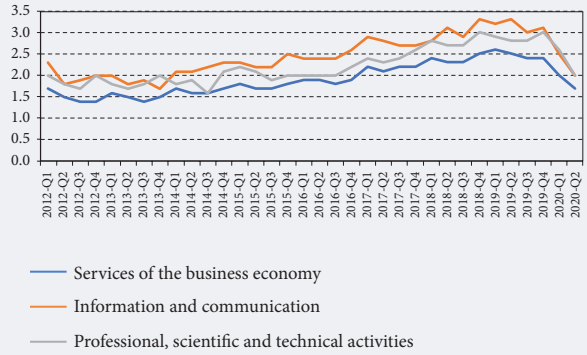
[7] Disruptions in the clinical testing industry – itself vital in the coronacrisis – are discussed by [*van Dorn,* 2020].

Figure 5. **Volume Index (2015=100) of production in services in EU (27 countries as in 2020)**



Note: Seasonally and calendar adjusted data
Source: Calculated based on Eurostat data

Figure 6. **Job vacancy rate in EU (27 countries as in 2020).**



Note: The job vacancy rate (JVR) is the number of job vacancies expressed as a percentage of the sum of the number of occupied posts and the number of job vacancies. Unadjusted data.
Source: Calculated based on Eurostat data.

reshaped public perceptions as to the desirability and feasibility of such a transition. The first impact relates to the dramatic demonstration, in many parts of the world, that governments are capable of responding to a crisis with substantial interventions into social and economic affairs. Awareness that such interventions can be politically feasible is claimed to have undermined the belief that the sorts of change required by the global climate crisis are utopian and impracticable.

The second impact relates to public sentiments, as people report greater awareness of the value of nature, of less air pollution, and of reduced pressures to consume and commute. A cross-national survey in 16 major countries (June 2020) found around three-quarters of people expect their government to make protection of the environment a priority in planning recovery from the coronacrisis, and report feeling "a strong responsibility to ensure their generation does not destroy the planet for the next generation" (agreement with this sentiment is close to or over 80% in all of the countries").[8]

Thus, we anticipate that despite the hardships induced by the coronacrisis, there will be significant efforts to establish new trajectories of change that create meaningful work and support more sustainable "green growth". For example, policies providing financial support to badly hit industries may tie such support to clear and verifiable undertakings about the substantial and continued reduction of wasteful and polluting activities. Incentives may direct R&D and innovation efforts toward greener technologies and the restoration of vital ecosystems. KIBS will find new roles in supporting these reorientations of business and innovative efforts [*Hartshorn, Wheeler,* 2002]. Indeed, numerous KIBS already do specialize in such areas – "green" marketing, design, R&D, and similar services.

Another way in which clients' demand may change was also mentioned – expectations that in times of stress many clients will be risk-averse and orient themselves toward more familiar and trusted KIBS. Some commentators see the current crisis as liable to be most severe for smaller KIBS firms, as they are for smaller firms in many sectors. Many small KIBS lack the established brands and reputations and long-term client relationships of larger firms – and may also struggle more with digitalization on account of less efficient IT systems and experience with digital ways of working. Of course, there are some smaller KIBS who are extremely proficient in these aspects, some being technology pioneers, some having extremely strong locality-based linkages.

KIBS Working Practices

In terms of disruptions associated with the pandemic, such as the absence of members of staff due to illness or social isolation, KIBS resemble other organizations with high proportions of skilled staff. While routine workers may be relatively easy to replace or substitute, the absence of the sorts of professionals employed by KIBS can create severe problems, since they may have unique knowledge, skills, and relationships with clients. This is liable to affect smaller firms most severely.

Nevertheless, many KIBS have had to lay off staff to survive the sharp reductions in revenue they experience – though others have sought to retain staff with reduced working hours and some efforts to reduce salaries, benefits, and/or pensions. Where there is little requirement for complex equipment and information systems, many displaced workers may well seek to set up as self-employed service providers. While studies of the current situation have yet to emerge, earlier research indicates that more highly educated and skilled individuals are more likely to become self-employed, though details vary considerably across countries [*Dawson et al.,* 2009; *Hatfield,* 2015].

[8] Available at: https://www.ipsos.com/ipsos-mori/en-uk/majority-people-expect-government-make-environment-priority-post-covid-19-recovery, accessed 24.12.2020.

The policy measures designed to battle the pandemic – restrictions on travel, requirements for social distancing, etc. – affect KIBS substantially in terms of communication. In some cases, the meetings with current clients and project partners, authorities, or public parties might well be accomplished digitally; while for much fieldwork it could be more problematic [*Poom et al.,* 2017]. Like other organizations, many KIBS shifted much of their activity to enable employees' WFH.[9] As stricter lockdown measures relax, KIBS, like other organizations, have to make decisions concerning whether/when/how to return to office-based activities. In many cases, this will not be a simple return to long-established practices. When office-based work is resumed – which may ultimately be on a smaller scale than heretofore – the issues of design of premises and work processes confronted by KIBS will resemble those of other service industries. Some KIBS' technical activities involve tools and equipment that cannot be readily moved away from company premises, normally requiring employees to work on the premises, and in physical proximity with each other. Thus, many engineering, R&D, biomedical, and industrial testing services will require a redesign of work processes and restructuring of facilities to reduce the physical closeness of individuals, the introduction of ultra-hygienic practices, and where economically feasible, the use of robotics.

Remote working was already becoming fairly common as an occasional practice before the coronacrisis. In Canadian KIBS, about 20% of workers in 2016 usually worked most of their time at home compared to 4.7% in education and 1.6% in public administration. Moreover, there is quite a strong trend for the share of such workers to increase - from 1996 to 2006 from 15.1% to 19.0%, respectively. The share of KIBS workers attending the "usual" workplace decreased from 75.5% in 1996 to 72.0% in 2006 and 70.7% in 2016. In addition, 1.6% of KIBS workers in 2016 worked from abroad [*Shearmur,* 2020]. In the EU-27, the top two sectors for teleworking by 2018 were IT and communications services followed by other KIBS, education, and publishing/broadcasting. Over 30% of their workforce "usually or sometimes" teleworked [*Sostero et al.,* 2020]. The picture is somewhat affected by whether we are looking at self-employed people versus employees. The figure for IT and other communication services (and also education) is dominated by employees, while for other KIBS it is much more balanced between self-employed people and employees. The overall figures of the share of employees involved regularly or with some frequency in WFH were: 35% of employees in IT and other communication services; 32% in education; 25% in publishing activities; and 26% in other KIBS. The prevalence of telework varies tremendously around the EU, of course, with Northern Europe being most intensive users.

Larger firms are more prone to adopting teleworking than SMEs – though we might expect the self-employed/microbusinesses to deviate from this pattern. Estimating the proportion of workers in various occupations and sectors whose work could effectively be conducted via WFH, Sostero et al. conclude that this will be the case for over two-thirds of Europe's KIBS workers [*Sostero et al.,* 2020]. But this estimate is based mainly on physical handling tasks. Some social interactions are also problematic without F2F contact, and we can now cite occupational data (from April 2020) on who had begun to telework during the early months of the pandemic in Europe. Managerial and professional workers were most likely to do so (more than 50%) followed by associate professionals and clerical workers (around 40%).[10] Many KIBS have relocated work from offices to their employees' homes, supported by the use of computers and communications, Virtual Private Networks, and databases as well as videoconferencing and webinars.

Along with other businesses, KIBS may have been reluctant to fully embrace remote working because of perceived risks – cybersecurity threats (leakage of confidential information, hacking into corporate systems); lack of efficiency among employees; problems with teamwork; and so on. But as they learn about the scope of these systems and where there are benefits, we would anticipate motivation for ongoing change in KIBS firms' internal organization and interactions with clients. In particular, it can be anticipated that the savings of expenses and effort associated with office rents and maintenance costs, and high levels of travel, will dampen enthusiasm for a reversion to traditional practices. We may also anticipate a "reverse product cycle"-type process, as discussed for businesses in general, in which new services are introduced to take advantage of the new capabilities that have been acquired.

Office expenses are substantial for KIBS. While about half of the total costs of Russian KIBS in 2015 involved personnel, the second largest source of expenses was on offices and related services (utilities, etc.). These constituted about 16% of the total expenditures in Russian KIBS ranging from less than 14% for web and digital services to 18% for marketing and related services. Smaller shares were allocated for equipment, advertising, and other items [*Belousova, Chichkanov,* 2016]. This is why accountants frequently target offices as the first item of fixed overhead costs to reduce when making savings. Some companies prefer to forward the released funds to personnel development.

Learning about extending digital working practices has meant, for many KIBS firms, acquiring a deeper understanding of cybersecurity problems and solutions to mitigate the risks resulting from "work anywhere" operating models. Cloud computing reduces the need for localized physical storage, providing on-demand files and data, but also requires enhanced security. Likewise, experience has been gained of business, project management, and performance management solutions that can be applied to assigning ongoing business tasks (from accounting to HR) with adequate time management and delegation of duties. Communication among employees needs to find new platforms that can help maintain motivation and enable the sharing of ideas.

However, the fact that some elements of KIBS can be more or less effectively handled digitally does not mean

[9] For data on the shift to teleworking across Europe see [Eurofound, 2020; *Sostero et al.,* 2020].

[10] https://www.consulting.us/news/3966/four-ways-to-embrace-remote-work-during-covid-19-crisis, access date 24.12.2021.

that we should anticipate a comprehensive and long-lasting transition to these approaches. Many KIBS have traditionally relied on substantial face-to-face (F2F) exchanges with clients. More routine and standardized KIBS – preparing accounts and basic legal briefs for small firms, tailoring standard databases and web designs for such clients, for example – may be effectively conducted online. These are the service activities that have already often been offshored.

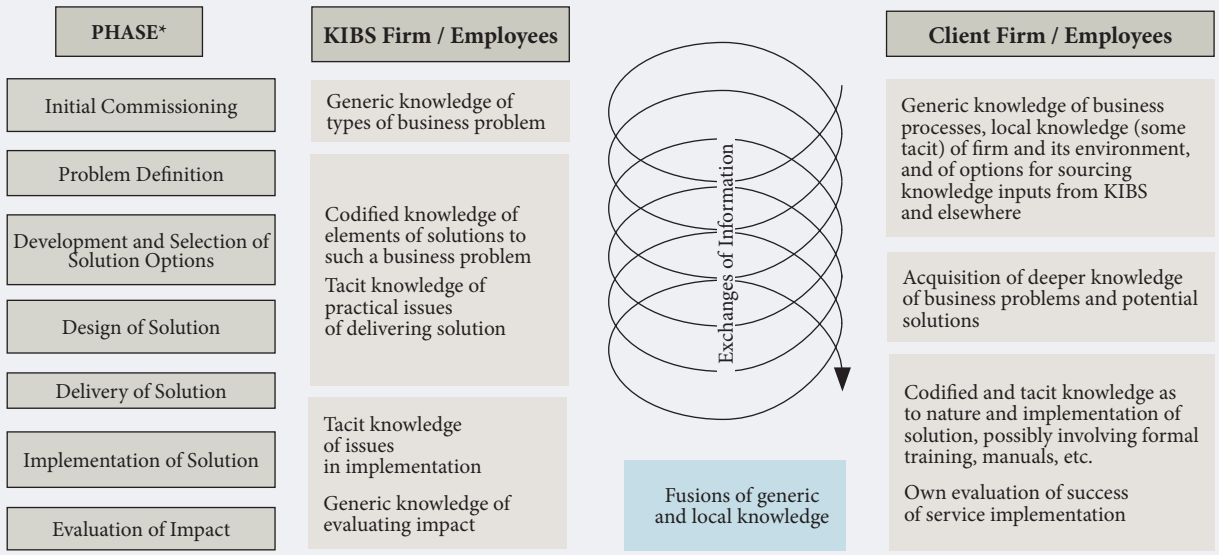
KIBS produce their services through a set of steps, often organized into projects, from initial problem definition to solution provision (and beyond, sometimes, to the evaluation of the success of the service – for example, advertising companies may research the impact of the campaigns they have mounted) (see Figure 7). Interactions between KIBS and clients are most intense in the earlier and later stages of the service process [Lehrer et al., 2012]. Interaction is needed to establish mutual agreements as to the nature of the client's business problem, the resourcing and type of solution possible, the specifics of the defined solution, the implementation of the solution, and the evaluation of its outcomes. It often involves the exchange of documents, but also typically requires substantial F2F contact at particular moments in the service process. The main exceptions are where the service is a fairly routine and standardized one, such as accountancy and audit for small businesses, repetitive types of technical testing, and such legal services as drawing up standard contracts.

In some cases, there can be more F2F contact with third parties than with the actual client. For example, market research may involve interactions with members of the public; legal services may require interactions with those in the courts. In addition, "front office" staff are liable to have more client contact than "back office" staff, by definition they are more customer-facing. KIBS representatives who facilitate the exchange of resources and knowledge typically rely more on F2F contacts. While those employees who perform more independent tasks like knowledge creation rely more upon technology-enabled communication – as, in contrast, do those dedicated to more standard tasks (e.g., creating presentations) [*Breidbach, Maglio,* 2016].

Much of the activity involved in client relations and teamwork can be largely conducted using online communications and databases. Those firms that already had much of their technical knowledge base stored electronically will have found this transition easier to undertake. But such media are limited when it comes to communicating body language cues, facilitating informal interactions (often the site of creative and informative exchanges), and establishing the close relationships that are required for effective KIBS operations. F2F encounters have enabled the alignment of knowledge between individuals through the mutual use of tools such as whiteboards. There are various efforts to replicate such tools in online environments, along with other aids for computer-supported collaboration.

Online communications are rarely designed to support such more informal exchanges even when systems enable break-out groups and private messaging alongside the main discussion. Furthermore, there are real limitations in current electronic communications, even when using high-definition images. KIBS practitioners interviewed by Growe [*Growe,* 2019] also highlight the critical roles of non-verbal communication and body language for the development of trusting relationships with their clients. Client-facing professionals often need to be aware – especially during the problem-definition phase – of nuances, lacunae, signs of unease or embarrassment, evidence of friction, and/or relations of power among members of the client team. Attention to such signals can be very important in defining the nature of the problem and the types of solutions likely

Figure 7. **KIBS-Client Interactions**



* There may be fewer or more phases, and phases may be reiterated.

Source: authors basing on [*Miles,* 2012].

to be effectively implemented by the client. Thus, F2F interactions support knowledge exchange and facilitate the building of trust and "chemistry" between partners, whether team members or clients [*Growe,* 2019].

Whether F2F interactions remain restricted after the coronacrisis, innovation efforts will likely continue to be aimed at narrowing the gap between F2F and digital interactions. Such developments are liable to be of use to firms other than KIBS, and some have already been pioneered in high-tech industries (and the military). We anticipate the development of:

- **Team building** procedures that can operate effectively in digital space. Often structured as games of one sort or another, these typically involve little additional technology, but involve guidelines and often require facilitation.
- Tools that provide many of the **dialogue-enhancing** functions currently associated with whiteboards and flip charts. Their designs may resemble these familiar instruments or take on quite novel forms. As well as enabling collaboration in creating, modifying, and selecting within texts, lists, illustrations, and 3D designs, such tools can enable voting, ranking, and other ways of getting a sense of areas of agreement and contention.
- Virtual Reality (VR), augmented reality, and telepresence systems may allow for a greater **sense of mutual presence** in the service interactions. VR goggles and headsets allow some degree of the visual experience of a 3D environment in which meetings take place. Currently, the virtual bodies (avatars) that participants don in Second Life-type environments are minimally related to their actual postures and movements, and are presented in flat 2D displays, though 3D visualization is becoming affordable. Even in these limited systems, participants can peel off from the main meeting into more secluded environs and use tools to enhance dialogue. The rapid development of videogames and simulations demonstrates the scope for implementing far more realistic, novel and immersive virtual environments [*Ekstrom,* 2017].
- **Haptic systems** include devices that enable people to "shake hands", sign documents, work together on and touch not only drawings but also virtual 3D objects (which might then be realized through 3D printers). Abilities to "feel" things and people may be provided by special gloves, for example [*Culbertson et al.,* 2018, *Pacchierotti et al.,* 2017; *Sreelakshmi, Subash,* 2017].
- New types and ways of applying and verifying digital **personae**, building on the avatars and agents that are currently in use. Both practice and literature on these topics are growing exponentially and in diverse directions [*Aljaroodi et al.,* 2019].

The sorts of professional systems that allow for telepresence, full-body imaging, and realistic haptic contact are liable to be well out of the price range for many smaller KIBS though innovation in cheaper consumer products may change this. The ongoing development of KIBS' products, as well as their processes, is bound to expand as new ways of working and interacting open up prospects for new services.

KIBS Offerings

Given their lesser dependence on F2F interchanges, those KIBS producing more routine and standardized services are likely to face less pressure to rapidly adopt the sorts of approaches discussed above. However, any firm is liable to find competitors gaining market share through appearing to be using more up-to-date tools. Pressures to adopt new approaches may be pervasive unless an organization is seeking to stress its adherence to traditional methods.

KIBS who have emphasized highly customized services may seek to shift their offerings to ones that require less F2F contact. One option is akin to "mass customization" – providing a menu of optional modules which the client is encouraged to choose between [*Cabigiosu et al.,* 2015]. Another is a form of "personalization", where a common core of activities is modified only with respect to more client-specific details – the data entered into a tax return or the names, images, and product details on a client's website, for example. Clients may be provided with tools whereby they can personalize the outcome via a form of "self-service", for example, by completing a template or series of questionnaires, whereby an informational service output – a database, a tax return, a web page, etc. – can be generated to specifications. Such increasingly standardized services may be actually preferred by some clients, who may find self-service cheaper and more convenient than direct contact with consultants.

Those KIBS most agile at adapting to new ways of working will be more likely to survive the downturn of demand associated with the coronacrisis. We can anticipate ongoing efforts to ensure that more vital knowledge is electronically available to employees and that they are trained in accessing and applying such resources, though it will also be important to ensure the security of confidential information. As suggested above, over time, a Barras-type "reverse product cycle" phenomenon could be visible – KIBS would learn from their forced rapid digitalization and ultimately be able to create new services based on this learning. It would be wise to draw on the experience of their staff, both as concerns teamworking and project management, as well as experience with customer (and wider network) relationships.

Conclusions: Implications for the Future of KIBS

The discussion above has outlined a range of prominent impacts and responses, though it can be by no means comprehensive. Further work would be necessary to discuss, for example, the developments in emerging economies (where KIBS are often playing important roles), or such issues as the new patterns of localization of clients and the KIBS servicing them and the likely responses these may evoke from city planners and other policymakers. For example, some established KIBS are liable to consolidate and build upon the innovative services they rapidly introduced, developing speciality offerings in these areas. New specialized entrants are also likely to play a role here, too.

KIBS are liable to face challenges from firms in other sectors. For example, office cleaning, transport, and

other more operational business service firms are experiencing new constraints and demands, and some of these are offering new services connected with their specialties. We can expect some of these to append related consultancy and management services to their offerings.[11] Some may move away from operational services altogether to focus on strategy, design, and other management services. Services similar to those offered by KIBS may also be supplied, at least partially, by other parties. For example, government agencies, industry associations, HEIs, and others have been providing advice and support to organizations hit by the coronacrisis. Furthermore, some established KIBS may face new types of "competition" as increasing numbers of potential clients may turn to online resources for help with some of their business problems [*Susskind, Susskind,* 2015]. Some free resources are provided in the freemium form would be disruptive innovators offering (usually pared-down) alternatives to conventional KIBS. This could well accelerate disruptive trends in areas such as fintech, lawtech, and crowdsourcing initiatives in areas like design and research.

This essay has focused on the impacts of a sudden crisis upon KIBS. The crisis is far from a "black swan" event – epidemiologists and public health bodies have long been warning about the likelihood of a major pandemic. This differs from the more endogenous roots of the Great Depression and Great Recession crises that were much more to do with the relationship between economic and political institutions. KIBS seem to have recovered along with the rest of the global economy after the GR, but the Great Depression persisted until a major war upset lives and livelihoods even more. The coronacrisis has already had deep impacts upon many economies and persistent effects are likely – not least in the social sphere, where many young people find their expectations as to education and careers upturned.

While we have outlined numerous challenges that KIBS are confronting and will continue to face into the foreseeable future, we have also demonstrated that these firms are often extremely active in seeking to help their clients deal with the problems that they too are facing. KIBS play important roles in helping provide solutions to business problems in "normal" times and their role in recovery is very likely to be vital.

However, recovery is unlikely to mean returning to the old "normal". A flock of ominous black swans are approaching in connection with another much-heralded crisis: the climate crisis, again this has much to do with the relationship between our economies and the biosphere. KIBS should be able to play significant roles in the transition of our economies to more environmentally sustainable trajectories of economic development. Organizations of all sorts are liable to confront problems associated with efforts to ameliorate the crisis and avert its worsening. Hopefully we will see the problem-solving capabilities of KIBS brought to bear - sufficiently rapidly and extensively - in helping to develop, disseminate, and implement solutions. If not, they could be overwhelmed by demands to deal with a multitude of business problems that will be engendered by further substantial global warming. Policymakers have evident responsibilities to establish incentives and regulatory frameworks that rise to the challenge. Such frameworks would encourage clients to look for greener solutions to their business problems and to define their problems in terms of the growing crisis (and not, for example, as a matter of PR and "greenwashing"). KIBS practices will then focus increasingly on the development, dissemination, and application of knowledge relevant to confronting the climate crisis..

While much specialist work in public health and risk appraisal did engage with the likelihood of future pandemics, this was rarely cited in major foresight exercises.[12] On reflection, given how the coronacrisis was greeted as a surprise by most commentators, it might be argued that all foresight exercises, on whatever theme, should have carried the warning that sooner or later this risk could considerably disrupt affairs. Beyond specialist work, little attention was paid to the logistical and other challenges a pandemic could engender in health services and across wide swathes of most economies. Pandemic preparedness was insufficient (with the probable exception of a few East Asian countries). Neither foresight and risk appraisal practitioners, nor the public health and epidemiological teams who had led specialist appraisals of pandemic contingencies, had managed to get their concerns taken sufficiently seriously by politicians and policymakers. More effective channels of communication need to be established concerning impending crises and risks, in general. This, of course, is old news for climate change researchers, who have struggled for years to raise the alarm and reshape policy agendas.

Crises involve cascades of problems (and responses), generating further problems (and responses), often with unexpected features. In the coronacrisis, it was not just the disease that displayed such features: the failures of political leadership, public attitudes, bottlenecks in supply chains, and the availability of skilled workers, all came into play. It is necessary to explore multiple scenarios when considering major risks and to not shirk from contemplating some real wild cards. Looking back at the GR, Gordon Brown (then UK prime minister) declared: "…it was not enough just to do day-to-day crisis management, or even to be one step ahead of events; the real challenge is to anticipate the next problem but one."[13] To achieve this, and act upon it, calls for real foresight and leadership.

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[11] Such a process is known as "KIBSification" [*Brax et al.,* 2008], and described without this label in [*Djellal,* 2002].

[12] One exception is the UK Foresight Programme, which ran a striking projection on "Detection and Identification of Infectious Diseases" (published in 2006, available at https://bityl.co/4uGx; see also [*Suk et al.,* 2008]; the recent Russia 2030 study drew attention to the danger of pandemics and the scope for new approaches to vaccine development [*Gokhberg,* 2016].

[13] https://www.theguardian.com/commentisfree/2020/sep/15/britain-crisis-recovery-coronavirus-gordon-brown, accessed 24.12.2020.

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The Spread of Gig Economy: Trends and Effects

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Abstract

The development of online communication platforms has given rise to the phenomenon of the gig economy. A new economic model that embraces a variety of forms of short-term employment is rapidly spreading around the world, becoming an everyday reality and transforming the labor market. The article analyzes the factors influencing the dynamics of this process and its main effects. Testing the main hypothesis showed that the development of technological infrastructure, despite its importance, does not fully explain the unevenness of the penetration of the gig economy and the variations in its impact upon different sectors, professions, and skill levels.

Gig economy drivers are subject to further study, but already now we can state the need for targeted measures to adapt the economy to the new model, including retraining or creating alternative employment opportunities for "traditional" workers giving up jobs in favor of gig-employed ones.

Keywords: gig economy; technology index; income distribution; digital platforms; labor markets; corporate strategies

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Following the 2008 global financial crisis and the resultant rise in unemployment, many professionals and skilled workers began performing short-term jobs to earn their livelihood. This phenomenon was described as the 'gig economy', a metaphor drawn from the music industry where artists performed gigs.[1] The spread of gig work was initially driven by skilled IT professionals who began using online digital platforms to search for such opportunities. Gig work is emerging as a livelihood option for job seeking students, retirees, low- and high-skilled workers. Working with US employment data, Collins et al. [*Collins et al.,* 2019] find virtually all expansion of the gig workforce since 2011 has come from online platform work. The expansion of the gig phenomenon has attracted the interest of researchers. Different descriptions have been offered towards for a clearer understanding of this phenomenon. There are various definitions that do not always coincide with practical approaches when it comes to the gig economy. Scholars also note the definitional difficulties associated with the platform economy – a term which is close to gig economy [*Frenken, Schor,* 2019].

Based on the existing literature, we draw upon the major characteristics of the gig economy, comment on its implications for labor productivity, employment growth, income distribution, and corporate strategies. Then we discuss the legal implications of the rise of the gig economy in India. Also, we examine the hypothesis that Information and Communications Technology (ICT) infrastructure plays a positive role in the spread of gig work by constructing a Technology Index (TI) encompassing mobile, internet, broadband connectivity, and electricity connections. Finally, based on our results we conclude with some policy recommendations.

The report by the World Bank [World Bank, 2015] categorizes the gig economy into three types of outsourcing activities such as Microwork, Freelancing, and Business Process Outsourcing. Meanwhile, drawing from the empiricist tradition the term 'gig economy' exhibits a few other characteristics. First is that gig work tends to be on-demand and short-term [*Berg,* 2016; *Van Doorn,* 2017]. It is priced by pre-defined outcomes and depending upon how much one earns, gig work is also referred to as the 1099 economy[2] [*Kalleberg, Dunn,* 2016].

There are no clear definitions for "short term" and "short-term contract". Gig workers may work for one year or more, under serially renewed fixed-term contracts, and yet fall under the classification of short-term contracts [*Connelly, Gallagher,* 2006].

A characteristic feature of the gig economy is that it is platform-enabled [*Kenney, Zysman,* 2016]. The gig economy uses technology platforms as conduits to connect the workers to the hirers, and the owners of assets to the customers. The first category is the transaction happening using a labor platform and the second is the transaction happening through a capital platform [*Farrell, Greig,* 2016].

Examples of labor market platforms are Uber, Task Rabbit, Swiggy, Zomato, among others. As the work is job-specific, workers using these platforms have the flexibility to work for more than one contractor. A food delivery person can work for both Swiggy and Zomato, and yet can drive Uber during some other time. Similarly, the aggregators may provide more than one type of service. For example, Uber which is generally known as a taxi service aggregator also has Uber Eats which is a food delivery and online take-out service app. The examples for capital market platforms are service providers such as Airbnb, which serves house owners in renting out temporarily free living space. Similar is the case with car rental service platforms such as Zipcar and Hertz.

The next characteristic is about scalability and the absence of entry barriers. The platform-enabled gig economy can accommodate a large number of buyers and sellers. The cost of entering a platform-enabled market is minimal. According to [*Drahokoupil, Fabo,* 2016], digital platforms have lowered the transaction cost of labor outsourcing and temporary access to goods and services. The gig economy has helped to reduce information asymmetry associated with job search costs [*Zhao,* 1999]. In India, for example, before the advent of the digital world, job seekers regularly waited in line – sometimes all day – to register at national employment exchanges for their job search. At present, digital platforms allow the job seekers to conduct most of the search and inquiry processes online. Finally, the gig economy usually operates on the basis of 'standardized' outcomes. As the job performed is outcome-based, the risks associated with moral hazard or asymmetric information are mitigated. For instance, in the case of a long-term contract, persons once hired cannot be fired without serving a notice period or trade unions agreeing to such a decision. The onus of risk associated with employee's output falls upon the employers. In the gig economy driven by task-based jobs, problems associated with information asymmetry and/or moral hazard generally do not arise. The rating systems on platforms for task-based services also ensure that only the most standardized and efficient suppliers get rewarded in the long-run.

Given these aforementioned characteristics and based on the work arrangement that the gig economy has to offer, it is spreading fast. According to US Bureau

[1] The Cambridge dictionary defines 'gig' as 'a single performance by a musician or a group of musicians'. See: https://dictionary.cambridge.org/dictionary/english/gig; accessed on 23 July 2020.

[2] Named by the title of the 1099-MISC tax form, which any American company is required to issue for a freelance employee whose income exceeds USD600.

of Labor Statistics, there are 1.6 million gig economy workers working for services such as Uber, TaskRabbit, and others.[3] Worldwide, major demand for gig work arises from Information Technology (IT), IT-enabled services, e-commerce, retail, hospitality, and the fast-moving consumer goods (FMCG) sector, wherein sudden and short-duration workers at the lateral levels are very much in demand [AfDB et al., 2018]. In 2015, some of the in-demand jobs dealt with internet marketing, blogs, and e-commerce jobs. There were about 26,000 open jobs paying hourly rates between $16 and $22 on average [World Bank, 2015]. The digital platforms are creating additional job opportunities for employees working in the traditional brick-and-mortar economy. Collins et al. [*Collins et al.,* 2019] find that in the US, the share of the workforce with income from gig work has grown by 1.9 percentage points of the workforce between 2000 and 2016. In the overall gig economy, about 60% of the workforce also have a full-time salaried income over the course of year.

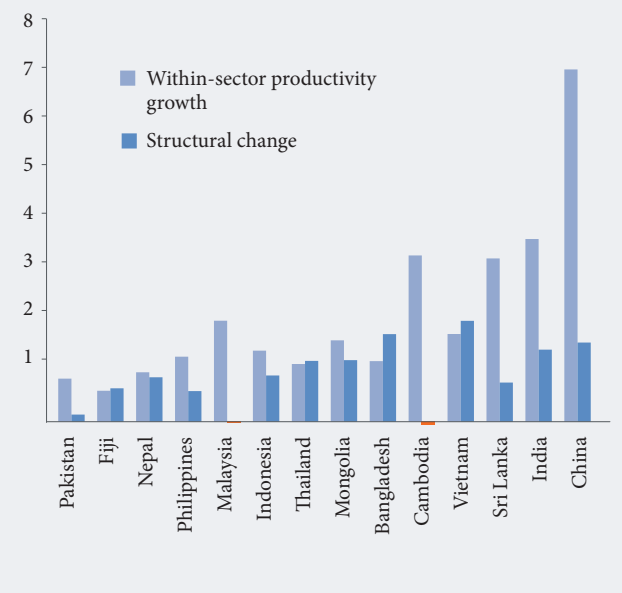
The Impact of Gig Economy

The rise of technology, cheap labor, and entrepreneurial spirit is aiding the growth of the gig economy. The platforms enable workers to connect across geographical boundaries. Consequently, the outcomes are raising productivity and optimizing employment and income distribution. In this section, we consider these dimensions in detail.

Productivity and Specialization

The rise of the gig economy is likely to increase overall productivity due to the increase in labor force participation rates and improved access to lower-wage workers from abroad, leading to more specialization and standardization of work. For instance, over the last few decades, Europe has been witnessing an ageing society and a fall in labor productivity. With falling birth rates and an ageing population, it is difficult to increase productivity through traditional labor force participation methods. The population growth rates in many Eurozone countries have fallen below the required replacement rate threshold of 2.1. For instance, the net population growth rates are 1.38 for Greece, 1.39 for Spain, 1.41 for Italy, and 1.94 for the UK. It is estimated that for Spain and Greece, the over-65-year-old population will increase from around 17% to 25% by 2030 [*Banik,* 2019]. An ageing society with strong trade unions finds it difficult to increase worker productivity [*Sherk,* 2009].[4] However, this is likely to change with the spread of gig work which increases productivity by increasing labor participation through digital platforms. Rather than hiring one generalist to complete all tasks, companies can designate tasks to various

Figure 1. **Source of Labor Productivity Growth** (%)



Source: [AfDB et al., 2018].

freelancers specializing in that area. Workers are also more accountable as performance standards dictate future incomes. Connected global labor markets will lead to a rise in economic productivity even in countries in Europe which now have a shortage in the supply of labor. Workers from labor-abundant developing countries are likely to gain. Owing to the standardized rules, in a gig world, low-salaried service workers from developing countries can now earn more by engaging in similar job profiles in established economies. There are no entry barriers and all that is needed is access to mobile/internet and electricity connections. The rise in labor productivity, as well as an increase in per-capita income can happen not only because of presence in gig work but also from the structural transformation brought in through technological innovation [*Bassanini, Scarpetta,* 2002]. (Figure 1)

Employment and Labor Participation

Labor participation in a gig world comes from a variety of sources. The lower-income individuals are more likely to participate on labor platforms than higher-income counterparts [*Farrell, Greig,* 2016]. As of 2016, 0.6% of the people in the lowest income quintile earned income from labor platforms such as Upwork and Uber, whereas the remaining 0.4% is dependent on capital platforms like Airbnb. This lower income group is also more persistent in using the labor platform: 56% of the participants in the lowest in-

[3] See: https://usafacts.org/articles/what-gig-economy/#:~:text=the%20United%20States%3F-,According%20to%20the%20Bureau%20of%20Labor%20Statistics%2C%20there%20are%201.6,1%25%20of%20the%20US%20workforce; accessed 27 July 2020.

[4] An ageing country is one with 10% or more of its population above 60 years of age. See [Sherk, 2009].

come bracket continued accessing the platform within 12 months compared to 47% of middle-income participants, and 40% from the highest income quintile. There are no barriers based on caste, religion, gender, and location. Women comprise more than a third of the 15,000 users of the digital platform Souktel in the West Bank and Gaza region, but only 19% of the entire labor force in the same area.[5] In the US, before the advent of Airbnb, African American rental hosts were getting 12% less rent than their white American counterparts for the same type of house in the same location [*Edelman, Luca,* 2014].[6] Spatial location of workers whether urban, rural, or small towns does not matter. Online labor markets such as Freelancer and Upwork are likely to substitute for physical labor migration and hence the uptake in working opportunities on digital platforms. The gig jobs have a spill-over effect not only on labor markets [World Bank, 2015; *Gomez-Herrera et al.,* 2017]. For example, after the introduction of taxi services by Uber and Ola, taxi fares were reduced in major cities in India [*Pandya et al.,* 2017]. The gig economy has other societal benefits such as a reduction in motor vehicle accidents and traffic congestion [*Greenwood, Wattal,* 2017] and the improvement of air quality [*Tran, Sokas,* 2017].

Income Distribution

The benefits from the advent of the gig economy as a complex and ambiguous phenomenon are not uniformly distributed. Full-time employment in the gig economy may lead to lower-income and economic vulnerability for lower-skilled workers in developed countries [*Bergman, Jean,* 2016]. As the workers from less developed countries get connected to the potential recruiters in developed regions, their wage rates are likely to increase at a faster rate. Similarly, a low-skilled worker from the developed country is likely to lose out in the presence of global competition. Things may get more difficult for these unskilled laborers in the presence of technological innovation. This leads to a skewed income distribution globally. For example, a rise in wage inequality in Germany results from firms paying more to their highly skilled workers in comparison to the others [*Card et al.,* 2013]. As the availability of highly skilled and talented workers are limited, wage premium increases. In the US, the reason for wage inequality has to do with more competitive firms tending to keep their highly skilled laborers as full-time workers, by paying a wage premium. The low-skilled work is outsourced, both in the US, as well as in other developed countries including Sweden, Japan, and the United Kingdom, typically as gig work. An International Labor Organization report suggests that gig workers are making less than the government-mandated minimum wage rate [ILO, 2018]. About two-thirds of the US workers using the Amazon platform made less than the federal minimum wage rate of $7.25 an hour and only 7% of Germans on the Click worker platform made the statutory minimum wage of 8.84 Euros ($10.40) an hour.[7] Virtual "sweatshops" created by technology platforms are largely unregulated with no floor on minimum wage rates. The workers do not have access to other fringe benefits such as health insurance, sick leave, working hours, the continuation of contracts, and settlement of disputes [*Chandy,* 2017]. Currently platform services are coming under increasing pressure to adhere to the rules that are applicable to traditional service providers in those fields. The city of Seattle has passed a law permitting Uber and Lyft drivers to unionize and the drivers receive unemployment benefits.[8] In a court ruling against a garment manufacturer in India, the Supreme Court of India passed a judgment stating that female contractual laborers who are working from home doing piece work would be considered "employees" of the company who has engaged them to do work [*Kumar,* 2019].

Another possible source of unequal income distribution arises from ownership of capital platforms. Although platform software has become ubiquitous, the market valuation of companies such as Uber, Airbnb, Facebook, and Amazon, put together, may in fact be higher than the GDP of many low-income countries. The drivers hired by Uber in the US were embroiled in a long-drawn legal battle, arguing they should be treated as employees and not as an independent contractors, with a better non-pecuniary benefit [*Lobel,* 2016]. For instance, although drivers using the Uber platform are paid by the job and have control over their work hours and geographical preference for operation, Uber set the passenger pay-rate and displaced the drivers falling below a minimum rating point. Drivers filed a class-action suit during 2013, with Uber finally agreeing to pay $20 million to settle the case in 2019.[9]

Exogenous shocks, such as COVID-19, can also change distribution of income. In a survey conducted by APPJOBS, comprising of 1,400 workers from 58 different countries, the study finds the sectors which benefitted from the pandemic includes delivery, consulting, freelancing, and online surveys. Whereas the in-person sectors, such as house sitting, babysitting, driving, and hospitality (hotel and tourism) industries, were negatively impacted [AppJobs, 2020].

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[5] https://blogs.worldbank.org/developmenttalk/narrowing-gender-gaps-through-online-job-matching-how-does-souktel-do-it, accessed 19.02.2021

[6] However, the organized labour market comes with a tag of equal opportunity employer, wherein the employer agrees not to discriminate against employee or job applicants because of race, national origin, and gender. See [Edelman, Luca, 2014].

[7] https://www.bloomberg.com/view/articles/2017-01-19/europe-stands-up-for-gig-economy-workers. Accessed 21 April 2020.

[8] See: https://www.nytimes.com/2015/12/15/technology/seattle-clears-the-way-for-uber-drivers-to-form-a-union.html; accessed 20 April 2020

[9] See: https://techcrunch.com/2019/03/12/uber-agrees-to-pay-drivers-20-million-to-settle-independent-contractor-lawsuit/; accessed 19 June 2020

The Impact of the Gig Economy on the Organizational Environments

The largest impact of the gig economy occurs in the areas of corporate strategies and performance management. In the traditional organizational forms, whether hierarchical, matrix, or network, the work is broken down into discrete units and allocated to workers in logical sequences of assembly-type dependency structures to ensure a swift, even flow [*Schmenner, Swink,* 1998]. However, the real-life organizations experience sub-optimal performance due to structural imperfections, incomplete specifications of work elements, coordination delays, and ambiguity experienced by the human element. Organizations compensate for such imperfections by building buffers of extra manpower and skills by calibrating the processes of worker selection and allocation. The dynamic of work expansion or contraction leads to the uneven absorption of such extra manpower adding to the coordination problems. In practice, therefore, the work environment of most organizations is plagued by overstaffing and understaffing at different stages of work cycles. The net effect of such a dynamic is a patchwork of idle time within the organizational environments. The idle time occurs both during the switchover between the tasks as well as endogenously within the tasks due to workers pacing their work differently under different conditions [*Gevers et al.,* 2006, 2015; *Brodsky, Amabile,* 2018]. Such idle time in an unevenly overstaffed organization is of serious concern to the management teams, who often employ various methods to plan work to maximize throughput.

The advent of the gig economy and availability of gig workers or freelancers represents an opportunity for managers to package work differently and assign it to gig workers through online platforms. While such assignments take the form of short-term engagements, they are different from outsourcing which generally consists of semi-permanent arrangements of non-core activities performed through business-to-business contracts and are paid on the basis of defined inputs or outcomes. Gig work on the other hand involves the element of choice on part of the gig worker, short-term contracts, and payment on the basis of pre-defined outcomes and typically are covered by person-to-person or by business-to-person contracts. For instance, the consulting firms working on complex contracts require specific subject matter experts. Such experts are rarely employed with anyone on a full-time basis; instead, the firms obtain them through gig channels. Thus, the gig work can consist of high expertise as well as commodity services such as canteen work, security, courier, transportation, and so on. Such a broad scope poses both challenges as well as opportunities for the operating management, who must develop the organizational capability to plan, decouple, and define the work packages, participate on the digital platform to select the gig workers, assign the work, and control the performance. Such a capability remains weak within the traditional organizations. This implies that organizations wishing to leverage the benefits of the gig economy must develop the processes to codify the work packages and the matching skills to be sourced from the gig platforms. Evidently, the organizations investing in such capabilities benefit from greater flexibility, scalability, and agility.

Another aspect of the gig economy is its retarding effect on the career and skill development of the gig worker [*Kost et al.,* 2020]. As the organizations adapt their processes to integrate gig work, the skill profiles of their full-time employees must change from generalists to specialists skilled in controlling the outsourced work and managing the arms-length relationships with the gig workers. Traditional organizations structure the roles of their employees in accordance with the principles of division of labor, repetitive tasks, and hierarchical control. Integrating gig work implies considerable changes in the managerial and interpersonal skills of the full-time employees, and corresponding changes in the processes of selection, fitment, training, and performance management [*Meijerink, Keegan,* 2019].

Finally, it should be quite evident that the applicability of gig work will be non-uniform within the value chains. Areas such as new product development, product strategy, or branding maybe less amenable to platform-type gig outsourcing, compared to the relatively standardized and non-critical areas such as employee benefits, payroll, transportation, warehousing, website development, and so on. Traditional organizations following a 'one size fits all' design philosophy will find it challenging to switch to more flexible and agile designs for themselves, as they must overcome the hurdles posed by generating the consensus and the action within the existing person-organization fits.

The Gig Economy in India

India has recently witnessed a rapid rise in the gig economy in the recent years as evidenced by the mounting anecdotal evidence. India has emerged as the fifth largest country in the world for flexi-staffing behind the US, China, Brazil, and Japan, and had about 3 million gig workers in 2018. It estimates that this figure will rise to 6 million by end of 2021.[10] It lists Banking, Financial Services, Insurance, Information Technology, and Retail as the major sectors absorbing the gig work. The growth of gig work is increasingly driven by large corporate companies who have begun to leverage independent consultants and freelancers to drive high-priority strategic projects and test new

[10] https://www.businessinsider.in/6-million-indians-will-be-in-the-gig-economy-within-two-years-thats-nearly-twice-the-current-size/article-show/69854133.cms; accessed 21.07.2020

product or service models [FlexingIt, 2019]. There has been a sharp growth in the registration of freelancers on the job portals, with 73% of the freelancers indicating that they do not intend to return to 9-to-5 full-time jobs [AppJobs, 2020]. While the emergence of the gig phenomenon is too recent to be comprehensively surveyed or studied by the researchers, the media articles suggest that the growth in the gig economy is driven by strong positive trends on both demand and supply sides.

From a demand perspective, gig work involves parcelling out short pieces of work with predefined outcomes by engaging workers on a non-permanent basis and paying them on the basis of the achievement of the outcomes. Thus, the ability to spin off work packages is critical for meeting demand for gig work. Most of the gig work until 2015 came from start-ups and small early-stage entrepreneurs. The recent entry of large corporate organizations trying to systemically reengineer the work processes imparts sustainability and robustness to the demand. Such reengineering involves the partitioning of all work into routine and non-routine categories, the careful reassessment of the work processes, and the development of managerial systems for engaging/outsourcing gig labor. Examples of routine work include processes related to ongoing functions such as production, sales, inventory management, and preventive plant maintenance. These activities require steady manpower to be engaged on a full-time employment basis. On the other hand, special projects or sporadic, one-time work do not require permanent manpower. Examples of such non-routine activities include the design of new products or services, market surveys and analysis, software development, process consultancy, occasional breakdown of specialized machinery, infrastructure or layout changes, and so on. In general, the organizations find it economical to engage the gig labor either because they do not possess the required expertise for such activities or do not have the economic justification for engaging such expertise on a full-time basis or the tasks being assigned for gig work are deemed sufficiently non-critical and low-valued [*Howcroft et al.,* 2019].

Coming to the supply side of the labor economy, India historically has had a large workforce in the unorganized (also called informal) sectors. The informal sector employs more than 90% of the labor and contributes 50% to the GDP of the country [Government of India, 2012]. Agriculture and Forestry, Fishing, Trade, Hospitality, Community, Social and Personal Services, Real Estate and Construction, and Manufacturing are the leading sectors for absorbing unorganized labor. According to 2015 data, nearly 85% of the workforce were engaged without job contracts or contracts of less than one year [Government of India, 2014]. Given the large size of India's unorganized economy, it is no surprise that it has continued to draw attention from diverse interests from stakeholders such as policymakers, legislators, economists, lawyers, and tax authorities and has generated extensive studies. While specific surveys and studies about the gig economy remain sparse, available reports indicate that it is fairly sizeable and is experiencing rapid growth. It is believed that workers in an unorganized economy have a low-level or no qualification. Extant literature on the gig economy however cites choice and flexibility as key qualifying attributes to be a gig worker [*Rosenblat*, 2016]. Initially, gig workers were characterized as highly skilled professionals doing multiple short assignments as a way of earning their livelihoods.[11] Since then, several authors have retained the attributes of diversity and skills and added the positive mediating effect of technology platforms on the gig phenomenon [*Lepanjuuri et al.,* 2018; *Gleim et al.,* 2019; *Wood et al.,* 2019]. We argue that choice, flexibility, and intermediation by technology platforms are the key attributes of gig work. Consequently, those parts of the informal economy which lack the elements of voluntary choice and platform intermediation must be excluded from the gig phenomenon.

Since its independence, India's public policies have had a strong socialist orientation, and this has been reflected in its labor laws. Present-day India has well-invested structures of labor laws for the protection of the workers from unfair and exploitative practices of employers. These laws were enacted in the times when industrial manufacturing was the dominant part of the formal economy, and the service sector was miniscule in size. With the passage of time, the manufacturing sector has contracted from 40% to less than 20%, while services have grown to more than 50% of the country's GDP. However, the labor laws have not kept pace with the changing times and face criticism from several quarters that they are excessively restrictive and their pro-labor orientation is choking investments as well as growth in organized employment. Taking consideration of such criticism, the government has tried to bring in reforms of the labor laws, however this remains a work in progress, with experts claiming these attempts to be at best anaemic.[12] The issue of informal sector workers is lost in the political crosswinds of change. All regulatory frameworks apply to the organized sector workers, leaving the very large number of informal sector workers unprotected against adverse practices by the employers.

TThe rapid rise of the gig economy is occurring in a legal landscape that has no regulation whatsoever and this exacerbates the issue of worker rights, protections, and social security. In 2018, the drivers of the ride-hailing services in India went on a strike protesting the

[11] https://www.fastcompany.com/1222400/thriving-gig-economy, accessed 20.02.2020.

[12] https://www.financialexpress.com/economy/covi19-labour-reforms-still-a-perennial-hot-potato-in-india/1991526/; accessed 26.07.2020

[13] https://www.reuters.com/article/us-uber-ola-strike/uber-ola-drivers-strike-in-india-demanding-higher-fares-idUSKCN1MW1WZ; accessed 26.07.2020

compensation structures of Ola and Uber – two firms operating the intermediating technology platforms.[13] In a paper on this issue, Surie [*Surie,* 2018] analyzes the nature of the engagement of these gig workers and argues for regulatory frameworks and bodies noting the potential for the exploitation of these workers.

The rapid rise of technology platforms and the gig economy has amplified the inequities of the labor situation. Unequal access to the internet and gender disparity in labor participation rates imply that several sections of the population have not been able to benefit from the gains of modern technologies. First, despite the rapid penetration of mobile telephony in India, the rural populations have generally not moved on from 2G telephony and thus lack good quality or high-speed access to the internet. This severely restricts their ability to engage in complex transactions. Second, the female population has not been able to participate in the gig economy, owing to multiple factors such as poorer literacy rates and technology illiteracy, familial responsibilities, and gender-determined social constraints. The issues of social security, workplace harassment, and contract enforcement transcend all segments of gig workers. A paper by the Indian think tank Observer Research Foundation notes dispute redressal, ombudsman of platforms, protection against workplace harassment, emergency button for physical safety, social security, and contractual protection as key areas for regulatory interventions [*Kasliwal,* 2020].

In summary, the growth of the gig economy in India holds considerable potential to address the endemic problem of employment generation and provides an impetus to the stalled process of reforms in India's labor laws. However, the promise of the gig phenomenon is unlikely to be delivered without enacting the necessary regulatory structures and legal frameworks.

Model Development and Analysis

Hypothesis Development

We developed a model to relate the size of the gig economy in terms of the contextual macroeconomic variables. The platform-based economy is creating new value by monetizing economic resources such as assets and labor. We anticipate the availability of mobile, internet and broadband connectivity, and electricity connections to aid the gig labor economy. Accordingly, we propose the following hypothesis:

H1: The number of gig workers is positively influenced by the availability of internet, mobile, broadband subscriptions, and electricity connections.

Further, we posit that workers in the low-skill categories face high search costs for work and continued uncertainty in accessing opportunities. The emergence of technology platforms will induce such workers to join the gig economy by leveraging the technology infrastructure. We therefore hypothesize that the supply of gig workers would be higher when per-capita income levels are lower. Accordingly, we put forward the following hypothesis:

H2: Rising per capita income negatively influences the number of gig workers.

Dependent Variable

The dependent variable is the number of gig workers in the country. ILOSTAT published by the International Labor Organization (ILO) provides employment data by occupation and gender, segregated by different occupation categories.[14] ILO estimates of employment by occupation categorize skills on four levels from level 1 (Low skilled) to level 4 (Professionals). ILOSTAT data suffers from several limitations. First, it reports data from conventional labor markets such as manufacturing and construction and does not cover gig workers. Second, a large proportion of professional workers such as university professors, doctors, and engineers are part of the organized labor markets and do not participate in the gig economy. Hence the ILOSTAT understates the estimates of professionals doing gig work. Third, ILO defines employment as worker employed for at least one hour in a week or a day [*Hussmanns,* 2007]. Such a measure fails to capture any collateral wage-earning work. For instance, if a worker employed full-time performs additional job(s), then such additional work is not counted in the employment statistics. Fourth, it is difficult to capture the value of gig work in areas such as product development, design, and marketing in published macro-economic data [*Corrado, Hulten,* 2010]. In general, the published macroeconomic data does not capture the online gig workers, even though such workers are large in number, especially in the developing countries.

To overcome these limitations, we use the Online Labor Index (OLI).[15] This dataset offers gig economy-equivalent of the conventional labor market statistics. OLI tracks workers using labor market platforms across countries and occupations posted on major online gig platforms in near real time and provides the counts of workers engaged in gig labor. OLI is based on data by accessing websites through collection technologies such as application programming interface, scraping, or downloading the data from the digital platforms [*Kässi, Lehdonvirta,* 2018]. It uses data from unique visitor counts on leading gig platforms from Alexa[16] and surveys of the top-five gig platforms: Upwork.com, Freelancer.com, Peopleperhour.com, Mturk.com,

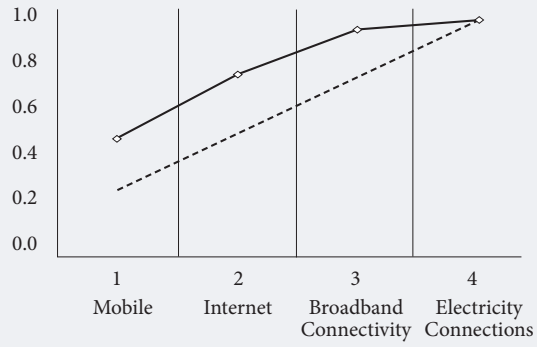
[14] ILOSTAT: https://www.ilo.org/ilostat/faces/wcnav_defaultSelection;ILOSTATCOOKIE=CgBvIYKcLYPs-arXRjMILEuDcsbDiGtTJeGhbnE-zyGkRf4ST-SD1!595095360?_afrLoop=1828381741967760&_afrWindowMode=0&_afrWindowId=null; accessed on 14 May 2020

[15] Published by the Oxford Internet Institute. See: https://ilabour.oii.ox.ac.uk/online-labour-index/ accessed on 26 June 2020.

[16] Alexa's site popularity traffic rankings are based on the anonymous usage patterns of one of the largest and most global samples of internet users available in the world. See: https://aws.amazon.com/alexa-top-sites/; accessed on 02 January 2021

[17] Our data set is based on OLI surveys conducted in July 2016 and again in February 2017.

Figure 2. **Cumulative Proportions of Eigen Values**



Source: compiled by the authors.

and Guru.com.[17] It includes the following occupation classes: Professional services (such as accounting, consulting, legal, etc.), clerical and data entry, creative and multimedia (such as animation, logo design, etc.), sales and marketing support, software development and technology, and writing and translation. The OLI database is more exhaustive with many countries in the sample, and to our knowledge is the first database to give a comprehensive estimate of the number of gig workers.

Explanatory Variables

For explanatory variables, we propose ICT components namely: mobile telephony, internet access, broadband connectivity, and electricity connection. Other studies also point to the pivotal role of ICT in the gig economy [*De Stefano,* 2016; *Aubert-Tarbey et al.,* 2018]. For instance, a joint study by the Foundation for European Progressive Studies and UNI Europa reports that 42% of the respondents had used online platforms to find services, including taxi drivers, builders, graphic designers, and accountants.[18]

To rule out the multicollinearity objections, we constructed a new variable, TI, by merging these four ICT variables. We take TI as an explanatory variable. Drawing from an earlier discussion in this paper, we expect the gig economy to positively affect the incomes of the gig workers. Gomez-Herrera et al. [*Gomez-Herrera et al.,* 2017] find that workers from low-income countries are likely to participate in jobs offered by the high-income countries.[19] Accordingly, we include log of per-capita income as an explanatory variable.

The data on mobile, internet and broadband connectivity, electricity connections, and per-capita income is taken from World Development Indicators [World Bank, 2017], detailing data about 139 countries.[20]

Model

We follow Ordinary Least Squares method to estimate the following equation:

$$OLI_i = \alpha + \beta T_i + \gamma PC_i,$$

Where, OLI refers to the online labor index, TI is the technology index, and PC refers to log of per-capita income. Subscript *i* refers to the country.

Results and Analysis

Using Principal Component Analysis [*Mardia et al.,* 1979], we construct TI as vector X ($X = X_1, X_2, \ldots, X_4$) where, X_1 = mobile, X_2 = internet, X_3 = broadband subscription, and X_4 = electricity connections. Before constructing TI, we standardize the data to ensure unit-free comparability among the data. The first principal component shows maximal variance of 1.94 and accounts for 48.5% variation among all regressors (Figure 2). It assigns weights of 0.65, 0.35, 0.66, and 0.05 to X_1, X_2, X_3, and X_4 respectively. The high weights of broadband and internet connectivity indicate their relatively high relative importance within the technology infrastructure, while connectivity to mobile telephony and to electricity have moderate and low importance, respectively. The second principal component with a variance of 1.09 however accounts for only 27.3% of the total variation. We therefore retain TI with its weights as the variable for the regression. For each country, we then compute TI using the software package EViews 11.

Table 1 reports the findings from the regression analysis. The results support the hypothesis that technology infrastructure is significantly and positively related to the number of gig workers. The significant negative per capita income suggests that workers from low-income countries are induced to participate in the gig economy. The employers and the firms contracting out gig work are predominantly located in high-income countries, while the gig work can be outsourced to low-

Table 1. **Gig Worker Index (Base Regression)**

Variable	Coefficient
Constant	0.036** (0.017)
Technology Index	0.008* (0.002)
Per capita Income	-0.003*** (0.001)
R-squared	0.14
Adjusted R-squared	0.13
No. of Observations	139

Note: Robust Standard Errors in Parenthesis; *p<0.01, **p<0.05, ***p<0.1.
Source: authors.

[18] http://englishbulletin.adapt.it/wp-content/uploads/2016/02/crowd-working-surveypdf1.pdf accessed on 26 June 2020

[19] Per-capita income follows log-normal distribution, with a vast majority of people earning low incomes.

[20] The World Bank classifies countries into three groups: low income, middle income, and high income. As of 1 July 2018, low-income economies are defined as those with a gross national income (GNI) per-capita of $995 or less in 2017; lower middle-income economies are those with a GNI per capita between $996 and $3,895; upper middle-income economies are those between $3,896 and $12,055; high-income economies are those with a GNI per capita of $12,055 or more. For data source, see: https://databank.worldbank.org/data/download/WDI_excel.zip accessed on 26 June 2020.

income countries [*Gomez-Herrera et al.,* 2017; *Song et al.,* 2019]. Within a particular country, as the evidence from the US suggests, high-skilled workers who already have traditional jobs are less likely to alter their behavior to search for gig work [*Collins et al.,* 2019].

For robustness checks of the results, we perform sensitivity analysis [*Levine, Renelt,* 1992] by including additional explanatory variables to our base regression model: Manufacturing value-added to GDP and Service value-added to GDP. The results from the augmented regression show that the coefficients of manufacturing value-added to GDP and service value-added to GDP are insignificant.

Conclusion

The gig economy complements the traditional brick-and-mortar economy by creating markets to exploit spaces that have remained inaccessible. The paper explores the drivers of the gig economy phenomenon and discusses its implications for labor productivity, employment, income distribution, and corporate strategies. As a case in point, we propose the hypothesis that the economics and the availability of ICT infrastructure moderate the supply of gig labor. We find that ICT infrastructure plays a pivotal role in the spread of the gig economy.

Given its ability to connect workers across the national boundaries, we find that such transnational reach does not lead to wage equalization. Rather, we find evidence of rising income disparity across low-skilled and highly skilled gig labor, indicating that the phenomenon impacts the different skill groups differently. At its intersection points with the traditional economy, businesses in sectors such as transportation, health, education, personal services, and the gig economy have caused displacement of brick-and-mortar workers. Given our finding about the unequal benefits of the gig economy across activities and skill classes, the policymakers should evaluate appropriate regulatory or tax interventions. The policymakers also need to design interventions to address the needs of such displaced workers through retraining or through alternative employment opportunities.

A few limitations of our work can be readily acknowledged. First, while we find that technology infrastructure plays a significant positive role in the gig economy, there are empirical reports about the uneven spread of the phenomenon. It is necessary to go beyond the infrastructure and examine whether societal variables especially related to the ability to access and use such technology infrastructure exist. Second, the demand for gig work is influenced by governmental policies related to unemployment benefits. Cross-sectional analysis falls short of studying the policy impacts and will require longitudinal studies. Third, the differential absorption of technology infrastructure across occupations and age groups will require further studies to elicit the workings of the phenomenon. Finally, further research is necessary to understand how the skill levels of workers affect their participation in the gig economy.

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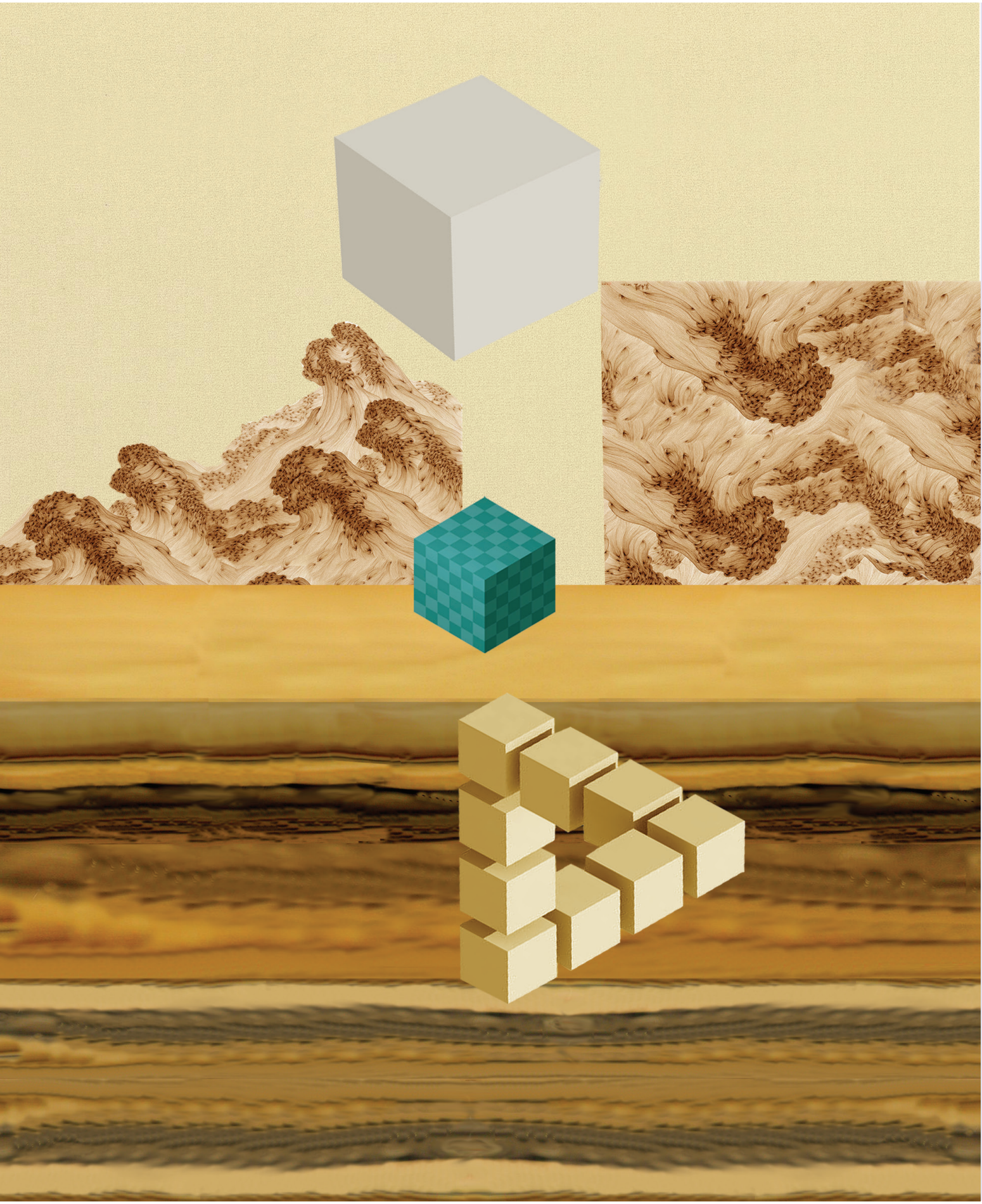

The Impact of R&D Expenditure upon the Efficiency of M&A Deals with Hi-Tech Companies

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Abstract

The motives behind merger and acquisitions (M&A) are often linked to the opportunities to obtain knowledge and technologies in order to enhance the competitive advantages of companies. In particular, the acquisition of digital technologies through mergers and acquisitions with ICT companies is especially relevant. However, the efficiency of such deals is often low and calls into question the implementation of digitalization strategies of companies. In this study we employ an approach for assessing the efficiency of M&A deals with ICT companies by using the DEA method. Applying regression analysis, it was found that the high level of research and development expenses of the acquirers can negatively impact the efficiency of the M&A deals with ICT companies.

Keywords: mergers and acquisitions (M&A); ICT sector; research and development (R&D); gross domestic expenditure on R&D; DEA; digital technologies

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Investing in research and development (R&D) can accelerate economic growth and improve business performance [*Griliches*, 1958, 1979; *Mansfield*, 1988; *Hall*, 1996; *Koellinger*, 2008]. A 10% increase in relevant domestic expenditures on average leads to a 1.6% increase in economic productivity [*Bravo-Ortega*, *Marin*, 2011]. One of the ways to accelerate companies' R&D and innovation development is through mergers and acquisitions (M&A) intended to acquire necessary competencies to create and apply technological or other innovations [*Hitt et al.*, 1991]. This strategy is seen as a long-term growth tool. Its choice is determined by the need to strengthen the research base and build up technological potential [*Capron, Hulland*, 1999; *Haleblian et al.*, 2009, *Sirmon et al.*, 2011].

Various aspects of the effect of "technological" mergers and acquisitions became the subject of empirical research. A number of studies (e.g. [*Ahuja, Katila*, 2001]) assess the impact of such deals upon the innovation or technological performance of buyer companies. Contrary to theoretical assumptions, empirical analysis not infrequently reveals the neutral [*Prabhu et al.*, 2005] or negative [*Ravenscraft, Scherer*, 1987; *Hitt et al.*, 1991, 1996] effect of M&A deals on companies' innovative development. Possible factors include the following:

- the negative impact of companies' merger on the processes associated with R&D [*Jemison, Haspeslagh*, 1991; *Ranft, Lord*, 2002];
- loss of key employees during the transition period [*Ernst, Vitt*, 2000; *Ranft, Lord*, 2000];
- organizational imbalances and low technological compatibility between the involved parties [*Chakrabarti et al.*, 1994; *Hagedoorn, Duysters*, 2002; *Cloodt et al.*, 2006].

Technological consistency between the parties contributes to M&A effectiveness [*Cloodt et al.*, 2006]. The closer the parties' technological arsenals match one other, the easier it is for the buyer company to adapt and use the acquired assets [*Cohen, Levinthal*, 1990; *Lane, Lubatkin*, 1998]. In high-tech sectors including information and communication technologies (ICT), the development, creation, and application of new solutions involve a high level of uncertainty [*Wagner*, 2011]. M&A strategies aimed at leveling the associated risks for the company are typically based on finding necessary technologies and knowledge externally [*Desyllas, Hughes*, 2008; *Ortega-Argilés et al.*, 2010]. Acquiring a player with unique technological competencies helps to accelerate development by integrating new knowledge [*Hitt et al.*, 1996]. In the age of digitization such strategies may be more effective than buying assets from other sectors of the economy.

The existing empirical studies on the effectiveness of "technological" M&A deals mostly involve applying regression analysis to assess buyers' financial performance after the transaction has been completed [*DeYoung et al.*, 2009]. Assessing how the company's technological indicators affect M&A results requires eliminating the impact of various specific factors, which, given the limited functionality of regression techniques and a lack of data, is fraught with certain difficulties.

In our study the effects of M&A are measured based on the basis input parameters of such deals with ICT companies using Data Envelopment Analysis (DEA).

The DEA technique, first presented in [*Charnes et al.*, 1978], is widely applied as a way to measure the relative effectiveness of M&A deals [*Worthington,* 2001; *Bogetoft, Wang,* 2005; *Liu et al.,* 2007; *Lozano, Villa,* 2010; *Peyrache,* 2013; *Wanke et al.,* 2017]. Compared to traditional performance metrics, it can take into account several input and output parameters to analyze non-linear functional dependencies between the data and is suitable for various sectors of the economy [*Emrouznejad, Yang*, 2018]. DEA allows one to proactively assess the impact of potential acquisition targets' various characteristics upon the buyer's capacities in the event the deal actually going through.

Methodology of the Study

We define ICT companies in line with the Bloomberg Industry Classification (BICS) which attributes companies to particular sectors on the basis of their main revenue-generating business segments [*Phillips, Ormsby*, 2016]. Our study covers segments such as semiconductors and semiconductor equipment; software and related services; communication services; and technological equipment. A number of parameters which describe the technological development of ICT companies whose activities depend on intangible assets (enabling them to develop, produce, and apply innovations) were considered. The motivation for M&A is often assessed using models in which one of the objectives of merging businesses is to acquire intangible assets [*Cassiman et al.*, 2005; *Phillips, Zhdanov*, 2013; *Jovanovic, Rousseau*, 2008]. Sectoral differences allow one to identify the effect of using such assets [*Brown et al.*, 2009], in particular to measure their role in promoting companies' internal R&D investments [*Eisfeldt, Papanikolaou*, 2014; *Peters, Taylor*, 2017].

Risk-avoiding firms in countries with low gross domestic expenditures on R&D (GERD) tend to have a conservative attitude toward investing in R&D, preferring more reliable strategies. In countries with a relatively low level of technological development, companies have to look for competencies they lack abroad [*Belderbos et al.*, 2014]. Jurisdictions with a high level of GERD promote companies' innovation

activities by offering knowledge flows, skilled labor, and opportunities to conduct R&D jointly with other organizations [*Iwasa, Odagiri*, 2004; *Griffith et al.*, 2006; *Audretsch, Belitski*, 2020]. At the same time companies in countries with a low level of GERD face information asymmetry combined with limited access to capital markets [*Alam et al.*, 2019]. Thus, the level of GERD in a country becomes a factor determining the effectiveness of M&A deals [*Xie et al.*, 2017]. M&A deals with ICT companies in jurisdictions with a relatively high value for this indicator are more likely to provide access to advanced technological knowledge and have a positive impact upon the buyer company. It should also be borne in mind that, as already noted, the level of technological development and innovation is industry-specific [*Hagedoorn, Cloodt*, 2003]. In high-tech sectors, R&D expenditures are a key development driver [*Duysters, Hagedoorn*, 2001], so buyer companies are primarily interested in strengthening their own research potential with the acquired players' R&D results [*Benou, Madura*, 2005]. The resulting synergy increases the overall cost-effectiveness of R&D and helps the buyer company to grow. However, it is not at all easy to ensure that M&A motivated by target companies' high R&D expenditures are feasible, since such investments are associated with a high degree of uncertainty. Furthermore, empirical research does not confirm that R&D expenditures always positively affect firms' overall performance [*Chan et al.*, 2001; *Hung et al.*, 2006]; sometimes a substitution effect is noted, when the R&D carried out by the acquired company do not bring the expected benefits to the buyer [*Hitt et al.*, 1991; *Bloningen, Taylor*, 2000; *Cassiman et al.*, 2005].

Capital expenditures (CAPEX) serve as an indirect measure of companies' technological development [*Healy et al.*, 1992], strengthening their performance and competitiveness by upgrading their technological assets [*Andrade, Stafford*, 2004]. Investment intensity is an indirect indicator of innovation activity [*Stoneman, Kwon*, 1996].

In our study the effects of "technological" M&A are assessed using the DEA method taking into account input parameters describing the technological activities of target companies. Table 1 presents the variables used in our calculations: technological characteristics of the acquired firms in the year before the transaction, including R&D cost intensity, intangible assets, and capital investments. The ratio of companies' market and book values (which reflects their growth potential and attractiveness to investors) was also considered as an input variable. Two characteristics of buyer companies associated with changes in their value were used as output parameters, namely revenue growth and return on assets a year after the deal was completed [*Kohers, Kohers*, 2000].

The DEA model solves the maximization problem:

$Output_i / Input_i \rightarrow max = DEA_i$ (1),

with

$Output_i < Input_i$ and $Output_n < Input_n$ (2),

where:

$Output_i$ and $Input_i$ are input and output variables for company *I*;

n is the number of input and output variables.

To assess how the buyer company's R&D and other indicators affect the deal results using the DEA method, a beta regression model was applied [*Ferrari, Cribari-Neto*, 2010]:

$$g(\mu_i) = \beta 0 + \beta 1 R\&Dint_{i,a} + \beta 2 Ln(Intangibles_{i,a}) + \beta 3 CAPEXint_{i,a} + \beta 4 GERD_{i,a} + \varepsilon_i, \quad (3)$$

where:

$R\&Dint_{i,a}$, is R&D expenditures-to-revenue ratio of the buyer company *i* before the deal;

$Ln(Intangibles_{i,a})$ is logarithm of intangible assets of the buyer company *i* before the deal;

$CAPEXint_{i,a}$, is capital investments-to-revenue ratio of the buyer company *i* before the deal;

Table 1. **Input and Output Parameters**

Variable	Variable description
Input parameters (estimated values for target companies a year before the deal)	
$Ln(Intangibles_{i,t})$	Logarithm of the i-th company's intangible assets
$R\&Dint_{i,t}$	R&D costs-to-revenue ratio of the i-th company
$CAPEXint_{i,t}$	Capital expenditures-to-revenue ratio of the i-th company
$MtB_{i,t}$	Market and book value ratio of the i-th company
Output parameters (estimated values for buyer companies a year after the deal)	
$Ln(RevGrowth)_{i,a}$	Logarithm of the i-th company revenue growth
$ROA_{i,a}$	Return on i-th company's assets

Source: composed by the authors.

Table 2. **Examples of M&A Deals in the Technology Sector**

Buyer company	Buyer company's home country	Target company	Target company's home country	Deal date
Nokia Oyj	Finland	Alcatel Lucent SAS	France	15.04.2015
Diodes Inc	US	BCD Semiconductor Manufacturing Ltd	China	26.12.2012
Delta Electronics Inc	Taiwan	Eltek AS	Norway	15.12.2014
Informatica LLC	US	Heiler Software GmbH	Germany	01.10.2012
AT&T Inc	US	Superclick Inc	Canada	26.09.2011
Schneider Electric SE	France	Telvent GIT SA	US	01.06.2011
Nuri Telecom Co Ltd	South Korea	Apivio Systems Inc	Canada	17.01.2017
Everbridge Inc	US	Unified Messaging Systems AS	Norway	14.02.2018

Source: composed by the authors.

$GERD_{i,a}$, is GERD as share of GDP of the home country of the buyer company *i* before the deal.

Sample Description

The sample of M&A deals in the technology sector was based on the BICS index, meeting the following criteria:

- Date of the deal announcement: between January 1, 2010 to January 1, 2019.
- Deal status: completed, announced, pending completion.
- Target company belongs to at least one of the BICS technology sectors: Communication Services (10) (except the first-level micro-sector "Media and Entertainment") or Technology (18).
- Both companies (buyer and target) are public joint stock companies quoted on a stock exchange.

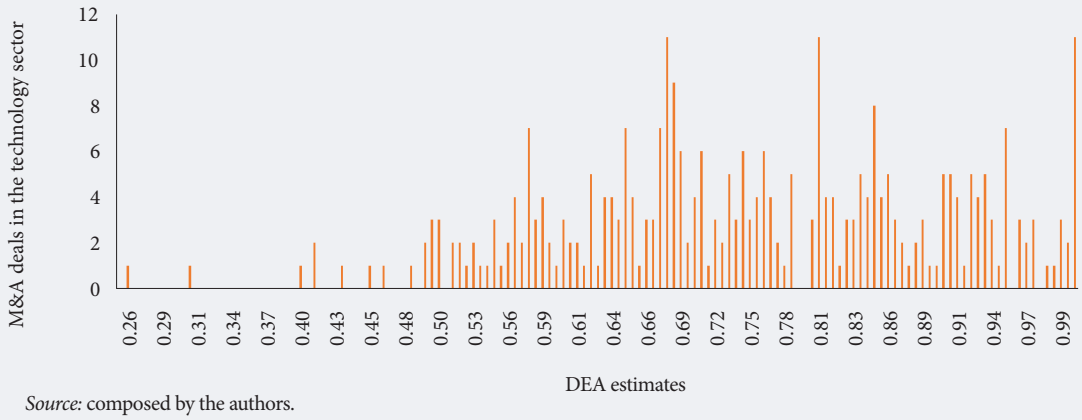
After applying these criteria, 322 deals were included in the sample (examples and descriptions are presented in Table 2).

Table 3. **Descriptive Statistics of DEA Parameters and Beta Regression Determinants**

Variable	Average	Standard deviation	Median
Input DEA parameters			
$R\&Dint_{i,t}$	0.1026	0.1303	0.0492
$CAPEXint_{i,t}$	0.0547	0.0951	0.0233
$Ln(Intangibles_{i,t})$	0.2284	0.7647	0.0149
$MtB_{i,t}$	3.0072	14.4005	1.9241
Output DEA parameters			
$Ln(RevGrowth)_{i,a}$	0.9573	4.2157	0.6357
$ROA_{i,a}$	2.3858	10.2538	3.8342
Independent beta regression variables			
$R\&Dint_{i,a}$	0.1088	0.2466	0.0339
$GERD_{i,a}$	2.3362	1.0495	2.7136
$CAPEXint_{i,a}$	0.0583	0.0705	0.0312
$Ln(Intangibles_{i,a})$	0.9434	1.8086	0.5011

Source: composed by the authors.

Figure 1. **Distribution of DEA Estimates**



Source: composed by the authors.

Table 4. Beta Regression Results

Dependent variable	DEA estimates			
	Coefficients	Standard error	t-value	p-value
Intercept	1.6179	0.1851	8.741	0.000***
$R\&Dint_{i,a}$	-0.7445	0.4525	-1.645	0.100*
$GERD_{i,a}$	-0.0942	0.0391	-2.408	0.016**
$CAPEXint_{i,a}$	-3.4135	0.4393	-7.769	0.000***
$Ln(Intangibles_{i,a})$	-0.0111	0.0186	-0.596	0.551
Number of observations: 322				

Note: This table shows the post-M&A beta regression results. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Source: composed by the authors.

The sample's descriptive statistics (Table 3) show that the target companies in M&A deals tend to make relatively low investments in intangible assets compared to buyers. The share of intangible assets varies significantly between the deal parties. Their average R&D cost intensity figures are similar, but the standard deviation is higher for buyers. The average GERD-to-GDP ratio in buyer companies' home countries is relatively high, at about 2.3% of GDP.

Results

The DEA estimate distribution is shown in Figure 1. The values range from 0 to 1, with relatively less effective deals in the sample located closer to 0 and relatively more effective ones closer to 1.

To test R&D expenditures' contribution to the relative effectiveness of M&A, a beta regression analysis of buyer companies' technological characteristics was conducted. The results are presented in Table 4. Their significance is at 10%.

High R&D expenditures of buyer companies negatively affect M&A results. A possible explanation is that firms which actively conduct R&D on their own tend to use technologies obtained through mergers less effectively, while the knowledge acquired as a result of the deal replaces the existing one. The GERD-to-GDP ratio of the buyer's home country also negatively affects M&A results. Therefore, the less technologically developed a country is, the more sense M&A deals with ICT companies make for firms registered there.

The regression results (Table 4) indicate that target companies' intangible assets do not make a positive impact upon the buyer's relative productivity after the deal is concluded (the coefficient sign is in the negative, low value zone). This suggests that after an M&A deal, buyers who invest a lot in intangible assets find it more difficult to efficiently handle the acquired company's technology. Finally, buyer companies' capital investment intensity is significant and negatively affects their post-M&A performance.

Conclusion

Data Envelopment Analysis and a beta regression model were applied in this study to assess the effects of M&A deals with ICT companies. The results show that the effectiveness of such transactions is negatively dependent upon the level of R&D expenditures, by the buyer company and in its home country alike. This may be a consequence of the technology substitution effect [*King et al.*, 2008] discovered in a number of studies in relation to ICT sector players. The effectiveness of applying digital technologies obtained from a target company depends upon the buyer's motivation to acquire new knowledge this way. There is a possibility that, if the buyer company actively conducts R&D, the newly acquired technologies will turn out to be incompatible with its own unique developments. Accordingly, companies with a developed R&D base may have problems finding a player on the market acquiring whom would lead to a tangible increase in their competitiveness. The conclusions formulated in this paper can help not only with making investment decisions, but also with developing digitization strategies which involve acquiring technology and knowledge through the M&A mechanism.

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Perception of New Technologies: Constructing an Innovation Openness Index

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Abstract

Rapid technological progress is one of the basic processes in the modern world. It is an integral part both in the field of labor and employment and in leisure and recreation. The request for an accelerated implementation of digital technologies in the economy and social sphere, which is inherent in one of the national development goals of the Russian Federation, makes this topic more important. In the presence of technological challenges, people have to adapt to constantly emerging innovations. Meanwhile the perception of innovations together with other individual characteristics and socioeconomic traits of different social groups could be considered determinants of openness to technological innovations. Based on this assumption, the authors of this article set the following objectives: they evaluate the openness of the population to innovation (through the construction of the index), examine the perception of innovation (by identifying factors of the perception of new technologies), and test the relationship between openness to innovation and the perception of new technologies. The multi-domain index of openness to innovation combines assessments of individual attitude, acceptance, and trust in innovations related to various spheres of the population's life. The perception of innovation is revealed through the F. Davis Technology Acceptance Model and includes: perceived ease of use of new technologies; the perceived usefulness of new technologies; perceived security and reliability of new technologies; and perceived elitist features of the new technologies. This study demonstrates that openness to innovation depends upon the perception of new technologies and that this is differentiated among population groups.

Keywords: innovation; perception of innovation; openness to innovation; technology acceptance model; multidimensional index; technological progress

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In the modern world, ideas are constantly being generated to create new, and modernize existing technological devices designed to improve living standards and increase labor productivity. However, such devices are adopted in different ways: some people eagerly wait for the release of the next new gadget, while others get stressed even by relatively simple, commonly used technologies. One way or another people increasingly have to use technological innovations, voluntarily or they are forced by the circumstances, for example, due to the digitization of various sectors or because their employer strives to optimize the duration and content of work processes. An ageing population and increasingly diverse work histories (among other things due to increased retirement age) that reflect the potential need to change profession, take an integrated retraining course, and master new technological devices, add to the urgency of the problem of coping with innovations. As a result, the ability to master innovations becomes a key to adapting to new realities.

In an attempt to assess the Russian public's openness to innovations, their perception of new technological devices was analyzed. This data will help to gauge the readiness of Russian society for the new era – the "sixth technological paradigm" – which is increasingly referred to in political statements and expert discussions [*Grinin, Korotayev*, 2015] as digitization and the "smart economy" [*Ansong, Boateng*, 2019; *Negrea et al*., 2019; *Nepelski*, 2019].

Our study aims to assess Russians' attitudes toward technological progress, compile profiles of more advanced groups, and identify the determinants of openness to innovations.

To accomplish these objectives, a specialized three-domain index was constructed using an originally developed methodology, which allows one to measure the public's openness to innovations. Further, the perception of new technological devices was studied through factor analysis; and finally, its relationship with openness to innovations was tested in the context of demographic and socioeconomic characteristics. Thus, this study accomplishes both methodological and analytical objectives to reveal specific features of the public perception of innovations.

A Review of International Practices

Numerous experts have studied attitudes toward innovations. Countries at different stages of economic development were analyzed with different access to cutting-edge technological solutions. A number of studies offer cross-country analyses of innovation potential and the current development level. For example, according to the World Bank, R&D expenditures as a share of GDP in Russia is almost two times higher than in India, but four times lower than in Korea.[1] In the Global Innovation Index Russia ranks 47th of 131, while Switzerland, Sweden, and the United States are the top three [Cornell University et al., 2020]. Various studies compare the actual level of and the potential for innovation-based development in two or more countries based on relevant macro-data [*Polterovich*, 2009].

However, it would not be possible to comprehensively compare the public perception of innovations across countries due to the very limited range of cross-national surveys and insufficient availability of microdata. The Eurobarometer survey which has been carried out in EU countries since the 1970s should be mentioned here. It periodically includes modules designed to assess attitudes toward science and innovation. The poll results indicate growing public attention to advanced technological solutions, with the Scandinavian countries taking the lead. The Eurobarometer reflects different socio-demographic groups' perception of innovations' impact upon various aspects of life [European Commission, 2014]. However, since Russia does not regularly participate in these polls, we have no data to compare its domestic situation with that of other countries.[2] According to the available data for 2006, Russians' opinions on new technologies' impact upon life are quite pessimistic: in terms of the share of positive assessments, Russia is close to the bottom, lagging behind European countries, the US, and Canada [*Shuvalova*, 2007]. Nevertheless, after 15 years, the situation seems to be changing, which is evidenced by the data obtained in the framework of the 2019 survey "Monitoring innovation activities of innovation process participants"[3] by the HSE Institute for Statistical Studies and Economics of Knowledge. According to this survey, Russians and residents of EU countries assess the prospects for applying new technologies at work similarly, welcoming robotization but fearing job cuts in the future.

Under these circumstances, the only way to compare Russia with other countries is using indicators measuring the public's access to the internet and their computer skills. The country ranks seventh in the world by the number of internet users and Russian is one of the ten languages most commonly used on the internet.[4] In 2016 the number of fixed broadband internet subscribers in Russia exceeded

[1] https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS, accessed on 27.01.2021.

[2] The "Eurobarometer in Russia" project has been regularly implemented by the Centre for Sociological Research of the Russian Presidential Academy of National Economy and Public Administration since 2012. However, the survey does not include comparable questions relevant for the topic of this study. For more, see: https://www.ranepa.ru/nauka-i-konsalting/strategii-i-doklady/evrobarometr/evrobarometr/, accessed on 15.12.2020.

[3] https://issek.hse.ru/news/311950906.html, accessed on 18.02.2021.

[4] https://www.internetworldstats.com/stats4.htm, accessed on 27.01.2021.

20% of the population,[5] which is comparable with Italy and China, but significantly lower than in France or Korea (where this figure is close to 40%) [*Bobylev, Grigoriev,* 2018]. At the same time, as the HSE ISSEK data suggest, Russians access the internet to make purchases and use banking services less often. However, the most recent factor affecting the development of the public's digital skills has been the COVID-19 pandemic. In the context of lockdown and the shift to remote employment and education, Russians began to more actively use various software and applications in everyday life[6] including for self-education and the development of human capital.[7]

However, if in terms of digital skills, Russians generally tend to lag behind Europeans in terms of online social interaction (from making video calls via various applications to communicating on social networks) they are ahead of the European averages.[8] Russia is above average in terms of the innovation potential indicators available for comparison. Accordingly, we analyzed the perception of new technologies by Russians and developed a methodological tool which subsequently, when comparable international survey data becomes available, can be applied for cross-country comparisons.

Innovations as the Object of Social Research

Innovation became the focus of scientific interest for the first time in the classic work by Joseph Schumpeter "The Theory of Economic Development" [*Schumpeter,* 1934]. Initially it was of a purely economic nature. For a long time the concept of "innovation" was applied exclusively to production processes in the context of advancing them, and was considered only as a means of doing so.

Later definitions focused on other aspects. In particular, Peter Drucker proposed a broader approach which saw "innovation" not just as a technical concept but one combining economic and social dimensions, due to the creation of value added and consumer properties [*Drucker*, 1985]. In Boris Santo's work, innovation is seen as a result of economic development, a process of designing better technologies to obtain advantages [*Santo*, 1994].

In the 1990s, innovations were already understood not only as improved products, but also as more advanced production processes. Subsequently the focus has shifted to other areas of studying and applying innovation, including the social sphere,[9] work organization and management, media, and municipal policy. Finally, innovation was recognized as a multidisciplinary process which goes beyond the scope of organizations, countries, or scientific disciplines [*Gault, von Hippel*, 2009].

There are structuralist and process-oriented approaches to analyzing innovation.

In the first case innovation is seen as an element introduced into society at various stages of the life cycle, which remains unchanged [*Swan et al.*, 1999]. An example is the concept of diffusion of innovations which defines this process as extended over time, with the duration of innovations' dissemination in society (or in another system) determined by the time it takes various individuals to decide to adopt them [*Rogers*, 2003]. Since not everyone accepts innovations equally and at the same time, a user classification was introduced based on technology adoption time.

Five groups were identified: innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and finally, laggards (16%). Each next group accepts an innovation only after it was adopted by its predecessors: its members need more time to accept the innovation since they are unwilling to take risks. As a rule, to gain the critical mass required for public acceptance, the new product must be adopted by at least 50% of the population.

The second approach, a process-oriented one, grants innovations a greater dynamism believing their evolution is affected by various social, political, economic, and other factors. New ideas are generated, discussed, and communicated, and their subsequent application depends upon the organizational context [*Swan et al.*, 1999].

The process approach is based on the OECD and Eurostat practices which define innovations as "new or improved products or processes (or their combinations) which are significantly different from previous analogues, available to potential users (in the case of a product) or applied in practice (in the case of a process)" [OECD, Eurostat, 2018]. Openness to innovations is discussed not only in a narrow practical context, but also in wider cultural and historical ones. In the 20th century, totalitarian regimes tended to significantly restrict individuals' aspirations to freely produce and adopt innovations,[10] which

[5] On the whole, three-quarters of Russian households currently have internet access (https://issek.hse.ru/news/316247475.html, accessed on 18.02.2021.)

[6] https://issek.hse.ru/news/438496284.html, accessed on 18.02.2021.

[7] https://issek.hse.ru/news/376501875.html, accessed on 18.02.2021.

[8] https://issek.hse.ru/news/377859466.html, accessed on 27.01.2021.

[9] Social innovation is becoming a separate subject of innovation studies and also has many different interpretations.

[10] The problem of transgression and its consequences is generally relevant in the context of discussing the emergence and dissemination of innovations. However, the risks are especially high for those who create and adopt innovations in authoritarian and totalitarian regimes, where innovation activity can lead not only to losing one's reputation in the community, but also to expulsion from it. [*Wegner*, 2019].

among other things affected the mentality of a dominant part of the Russian public and determined the specific features governing the perception of innovations in the country.

The Technology Acceptance Model

The methodological basis of our work is provided by the Technology Acceptance Model (TAM) [*Davis*, 1989], which allows one to assess users' willingness to apply computer technology at work. The model is based on the assumption that the adoption and further application of a new information system depends on its perception by the user. The primary aspects of perception are perceived usefulness and perceived ease of use.

These variables explain the differences in users' intentions. Perceived usefulness shows the level of an individual's confidence that using the innovation will increase their productivity, while perceived ease of use - that adopting the innovation will not require a significant effort [*Davis*, 1989]. Subsequently the TAM model was applied to assess the adoption of not only computer technologies, but also various information systems (including in education, banking, financial services, and e-commerce), and the use of various mobile applications. In some cases, this model is supplemented with variables such as social influence and trust. It was assumed that social pressure in the form of subjective norms affects the intention to use particular technologies, since individuals can choose a behavior to match the expectations of their peers. It has been demonstrated that subjective norms significantly affect the ability to predict the intention to use a particular technology [*Venkatesh, Davis*, 2000]. By synthesizing various approaches, a unified theory of technology acceptance and use was proposed, according to which users' behavior is determined by their self-assessment of their own productivity (through perceived usefulness), possible effort (through perceived ease of use), social influence, and working conditions [*Venkatesh et al.*, 2003]. Since many new technologies, especially in the field of e-commerce or electronic financial services, put consumers in a situation of risk and uncertainty, there is also the question of trust in them.

Accordingly, a number of researchers incorporated into the technology acceptance model the trust variable, which affects individuals' intention to adopt innovations [*Gefen et al.*, 2003] since it is trust that largely determines users' willingness to participate in monetary exchanges and the dissemination of personal data via online networks [*Hoffman et al.*, 1999].

A number of studies were focused on the cultural component because the perception of technologies and their further application is not just the result of rational decision-making but is largely determined by cultural and country-specific characteristics [*Im et al.*, 2011]. National markets, the degree of technology penetration, and relevant government policies differ. The perception of innovative processes has intercultural aspects. This affects the public's ability to accept innovations in various areas. International differences in the perception of ease of use and usefulness were assessed on the basis of the cultural dimensions theory [*Hofstede*, 1984] and these parameters' contribution to the intention to adopt the technology depending on the national cultural context was compared. For example, an earlier study compared the results of applying the TAM model in Japan, Switzerland, and the US. The authors found that users' willingness to adopt technologies (email was used as an example) could be predicted in the United States and Switzerland, but not in Japan [*Straub et. al.*, 1997]. International comparison is not a specific objective of this study, but a reference to the importance of taking into account cultural aspects that emphasizes the fact that social factors must be kept in mind when the perception of innovations and openness to them are measured.[11]

For the purposes of this paper, we assume that the perception of innovations, along with other individual features and characteristics of socioeconomic groups can be a factor affecting the openness to new technological solutions, and thus promote their adoption. The study is structured into three sections as follows:

- assessing openness to innovations (using a specially constructed index);
- analyzing the perception of innovations (by identifying factors affecting perception of new technological devices);
- testing the correlation between openness to innovations and the perception of new gadgets.

Openness is understood as the individual inclination to adopt innovations in various areas of life, expressed through the attitude toward, acceptance of, and trust in them. The perception of innovations comprises subjective personal judgments concerning their characteristics.

Empirical and Methodological Basis of the Study

The survey "Public perception of socio-economic changes in modern Russia" conducted in February 2017 (VNSEI) provides sufficient data for a comprehensive study of openness to innovations. This

[11] A brief overview of international differences in technology acceptance is presented in [*Im et al.*, 2011], along with an assessment of the differences in applying an improved version of the TAM for US and Korean users of internet banking technologies and digital players.

national representative survey is based on a unique sample built using a multimodal method: data was collected via face-to-face interviews and an online survey.[12] The total number of respondents was 5,087 (2,548 and 2,539, respectively); the sample was representative in terms of the social structure of the population.[13]

The survey included modules measuring the application of new technologies and innovations in various areas of life and questions to determine the attitude towards new technological devices based on the TAM. To assess the openness to innovations, the index method for measuring the living standard and quality of life was used [*Hallerod*, 1994; *Willitts*, 2006; *Decancq, Lugo*, 2013]. The constructed multidomain indicator allows one to receive an integrated assessment from each respondent (Formulas 1 and 2).

$$I_n = \frac{\sum a_i x_i}{\sum a_i} \times 100\,, \qquad (1)$$

where:

I_n is the innovation index component (domain index);

x_i are domain components (1 - individual is inclined to use innovations, 0 - not inclined);

a_i is domain component weight (share of individuals not inclined to use innovations);

i is the number of domain components.

$$I = \sum b_n I_n\,, \qquad (2)$$

where:

I is the innovation index;

I_n are innovation index components (domain indices);

b_n is the component (domain) weight calculated using univariate analysis;

n is the number of components (domains).

Individual perception of innovations was measured by identifying the factors affecting attitudes toward them using a set of questions about 17 variables (factor analysis conducted using the principal component analysis method), based on the TAM model.[14] Employees' willingness to use computer technologies and information systems at work was analyzed in education, banking, finance, and other sectors. The impact of new technology perception factors on the openness to innovations was tested using the linear regression method where the index is the dependent variable and a set of independent variables includes personality traits, demographic, and socioeconomic characteristics.

On the basis of the available data sources, it was established from the start that statements 1-4 describe perceived ease of use, statements 5-8 perceived usefulness, statements 9-12 safety and reliability, and statements 13-17 the social dimension of using new technologies.

Openness to Innovations

The survey results allow one to consider the public's openness to technological innovations in three dimensions:

- attitude toward applying cutting-edge technologies and discoveries in various fields;
- appeal of innovative products and services to respondents;
- type of help (from a technological device or a human) people would prefer to receive in various situations.

In other words, three structural aspects of the public's openness to innovations were studied: attitude, acceptance, and trust. For each of them a separate index domain was constructed (using Formula 1), while in combination (compiled according to Formula 2) they provide an integrated measure of individuals' openness to innovations or personal index values. Below we will describe the variables applied to construct each domain in more detail.

Attitude toward Innovations

This component is measured using questions about individuals' assessment of using cutting-edge technologies (software, new devices, scientific discoveries, etc.) in various areas.

On the whole, public perception turns out to be rather positive: the average scores exceed 4 on a five-point scale where "1" means completely negative and "5" means a completely positive attitude (Figure 1). Medical innovations have the highest approval rate: almost 50% of the respondents expressed a completely positive attitude. Approximately the same share supported technological development and innovations in agricultural production. The lowest approval rate was found for innovations in education: 43%, but even here the overall reaction is positive: in total, 76% of the public rather, or completely support the changes in this area.

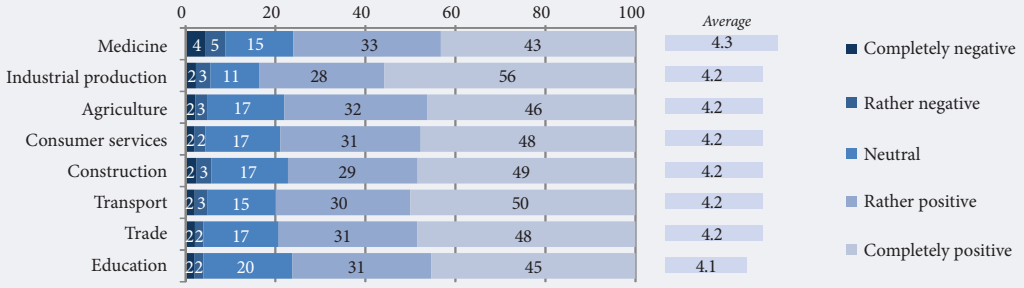
To summarize the data on the attitude toward using innovations in different areas into a single domain index (which is supposed to provide an integrated measure of the index component), the consistency of its components must be tested. The Cronbach's

[12] According to ESOMAR, a multimodal approach ensures the greater validity of the results compared to purely face-to-face or online interviews [*Cooke et al.,* 2008]. Combining these two techniques allows one to cover hard-to-reach regions and target groups, in the first case by conducting door-to-door personal interviews and in the second via online surveys which require certain population groups (age, region, settlement type, lifestyle, and income) to have adequate internet access.

[13] Sampling error does not exceed 1.5% with a confidence level of 0.95.

[14] Over the course of the pilot application of the toolkit, the respondents' interpretation of the statements was tested for subsequent adjustment.

Figure 1. **Public Attitude toward the Application of Innovations, by Area (%)**



Source: composed by the authors.

alpha scale reliability coefficient was used for this purpose. [15]

First, each of the variables was converted into a binary form: assigned the value "1" if the respondent was rather or completely positive about applying innovations in a certain area, and "0" if the answer was different. In our case, eight elements were grouped into a single domain with a high Cronbach's alpha value (0.919) and testing the domain index value for change by eliminating individual items gave grounds to leave them all in the index (Table 1).

The weight of the domain index components was determined by the share of the population negatively disposed towards innovations, i.e., it corresponds to the sum of segments where the responses varied between "completely negative" and "rather negative". Thus, according to the chosen methodological approach (e.g., similar to [*Hallerod*, 1994]), the smaller the share of the public who positively perceive innovations in a certain domain, the higher this component's contribution is to the final index for the respondents with a positive attitude toward innovations.

Acceptance of Innovations

The next index component, acceptance of innovations, is based on a set of questions about the appeal of innovative solutions (various goods and services), the answers to which range between "1" (not attractive to the respondent at all) and "4" (very attractive). Innovative food products have the lowest level of public trust: almost 60% of the respondents said such products have no appeal to them and only 8% found them very attractive (Figure 2). This is the only product group whose average rating on the aforementioned scale from 1 to 4 was in the rejection zone (below 2.5, the middle of the scale).

More than 40% of the respondents would not accept clothes and shoes made of radically novel materials and only 15% find such products attractive. Innovations in education also cause concern. A total of 37% of the public have no enthusiasm for digital educational programs and e-learning courses, while 17% seem to find such forms of education very attractive. More than 60% of Russians welcome innovative smartphone applications to one degree or another, and 20% completely approve of them. The respondents have shown significant openness toward cutting-edge medical procedures and operations: the acceptance rate reached almost 70%. At the top of the rating (with an 80% approval rate) were the latest household appliances and electronic devices.

To sum up, Russians are least likely to trust innovative products and services designed to meet basic personal needs (food, clothing), but are more open to technologies replacing other people's input (such as medical and consumer services). Innovations are also more readily accepted in areas where the technological race has been going on for a relatively long time (e.g., household appliances and electronics); conversely, in the domains where radical technological innovations emerge less frequently (e.g., education), people tend to be less enthusiastic about them.

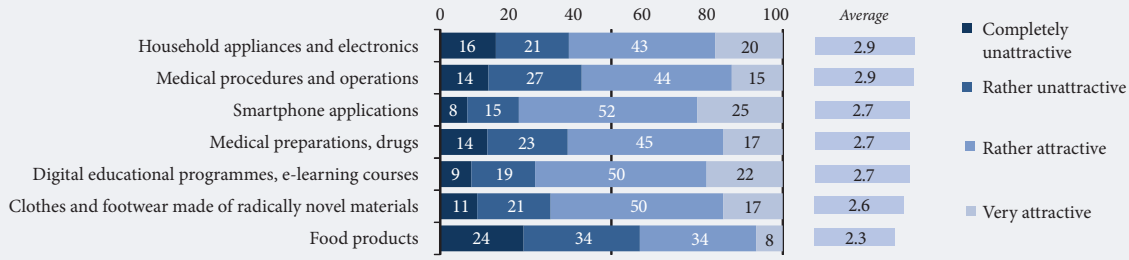
Table 1. **Consistency of the "Attitude toward Innovations" Domain Components and their Weight in the Domain Index**

Application area	Cronbach's alpha after excluding the item	Share of negative attitude (index weight, %)
Education	0.917	23.2
Medicine	0.910	16.0
Transport	0.909	21.1
Construction	0.906	20.5
Agriculture	0.908	22.2
Industrial production	0.905	19.9
Consumer services	0.906	20.1
Trade	0.910	22.7

Source: composed by the authors.

[15] Analyzing scale reliability using the Cronbach alpha model implies testing the correlation between the rank of each variable in the group describing a certain feature and the sum of the ranks of the remaining variables [*Taber*, 2018].

Figure 2. **Appeal of Innovative Products and Services (%)**



Note: These results are consistent with the data collected over the course of the project "Monitoring innovative behaviour of the population: the public's involvement in innovative practices" implemented by the HSE Institute for Statistical Studies and Economics of Knowledge. For more details see: https://www.hse.ru/monitoring/innpeople/news/page2.html, accessed on 15.12.2020.

Source: composed by the authors.

The domain index "Acceptance of innovations" measures attractiveness of innovations in all of the above product and service groups. This solution was verified by scale reliability analysis: with a high Cronbach's alpha (0.813), the index item exclusion test confirmed its components' consistency (Table 2). The components' weight was determined by the share of the population who did not accept innovations in each product and service group (i.e., the sum of segments where the answers ranged from "Rather ..." to "Completely unattractive").

Trust in Innovations

In the survey of public trust in technological innovations an alternative way of measuring was used (without using a scale). At this stage of the study, the respondents were offered a choice of alternatives: various life situations where one could ask another person for help or use a technological device instead.

Table 2. **Consistency of the "Acceptance of Innovations" Domain Components and their Weight in the Domain Index**

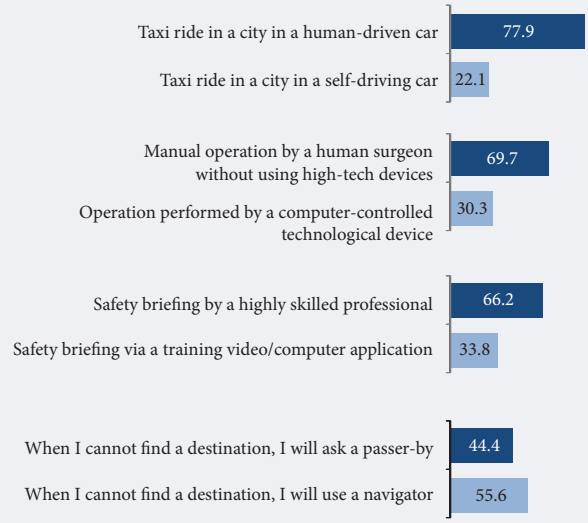
Application area	Cronbach's alpha after excluding the item	Share of negative attitude (index weight, %)
Food products	0.810	58.3
Medical preparations	0.780	32.2
Medical procedures	0.786	27.7
Education	0.786	37.2
Household appliances	0.784	22.9
Clothes and footwear	0.788	41.3
Digital applications	0.786	37.5

Source: composed by the authors.

The questionnaire captured the choices in four different contexts (Figure 3).

The public expressed the lowest amount of trust in unmanned vehicles, which is confirmed by data from other studies.[16] About 78% of the respondents would prefer a driver over a fully automated vehicle. Due to their relatively low prevalence, self-driving cars are still perceived as an element of futuristic dystopias and largely remain unavailable to the general public. Transport is still a source of increased danger to life,[17] so technologies which have not been used for long are perceived with distrust – even despite the extremely low assessment of public transport drivers' skills, in particular taxi drivers.[18]

Figure 3. **Respondents' Inclination to Trust a Stranger or a Technological Device (%)**



Source: composed by the authors.

[16] https://issek.hse.ru/news/202368869.html, accessed on 18.12.2020.

[17] https://wciom.ru/analytical-reviews/analiticheskii-obzor/bezopasnost-na-transporte-monitoring-1, accessed on 15.12.2020.

[18] For example, according to a study by the Romir holding, 54% of the capital's residents are concerned about the illegal status of carriers, 48% say taxi drivers do not know the city, and 35% pointed out to the poor state of the vehicle fleet. Plus, 35% of Russians noted a deterioration in driving culture (http://romir.ru/studies/taksi-vam-shashechki-ili-ehat, accessed on 15.12.2020).

Another source of potential risk to life is surgery. Respondents continue to trust doctors more than autonomous computers. If surgery becomes necessary, almost 70% of the respondents would prefer a human surgeon over a robot, despite the low overall trust in doctors.[19] A similar choice seems to be preferable when undergoing a safety briefing. Although a computer application or a video present information more clearly, demonstrate various situations, follow a strict instructional sequence, and guarantee a concise presentation, the public is more inclined to trust professionals. If there is a choice, only 34% of the respondents would opt to receive safety instructions without human involvement. Technological innovations which do not involve a risk to life and health seem to inspire greater trust (this is also confirmed by data from other studies, e.g. [*Voinilov, Polyakova*, 2016]). When it comes to finding a destination, most people would rather use a navigator (56%) than ask another person for directions (44%).

Apart from the relatively greater or lesser threat to safety, differences in the level of trust can also be explained by the degree of a technical device's autonomy from human control while it renders services. Unmanned vehicles imply fully automated decision-making in an ever-changing environment. Surgical interventions are most likely conducted after diagnostics performed by a specialist, according to the scheme they have chosen. A briefing is essentially a delivery of human-selected information. And navigation, although it is carried out in constantly changing conditions, leaves decisions for the user of the device.

The trust domain is based on quite different indicators measuring openness to innovations, so the Cronbach's alpha in this case is not as high as in previous ones (0.438). However, the analysis of consistency dynamics after excluding individual domain items shows that the Cronbach's alpha cannot be increased this way. In the absence of other ways to incorporate trust in the index when processing data, this domain can be based on four variables (Table 3).

Table 3. **Consistency of the "Trust in Innovations" Domain Components and their Weight in the Domain Index**

Application area	Cronbach's alpha after excluding the item	Share of negative attitude (index weight, %)
Transport	0.361	77.9
Medical operations	0.406	69.7
Navigation	0.405	44.4
Instructional briefings	0.294	66.2

Source: composed by the authors.

The Overall Openness to Innovation Index

When domains are combined into the overall index, the need to check their consistency becomes irrelevant due to the heterogeneous nature of the measured phenomena. The issue of differentiating the domain weights within the indicator comes to the fore. In this case we determined the weights using a univariate model: a technique suggested in a number of studies with similar methodological objectives [*Jacobs, Smith*, 2004; *Popova, Pishnyak*, 2017]. The weights of the index domains were established using factor analysis (maximum likelihood model) (Table 4). The "decision-making" component makes the largest contribution to the overall indicator, followed by "attitude toward innovations" and "trust in innovations".

The index values range between 0 and 100 and the average for the total population is 60.4, due to a shift towards higher values. This indicates the public's openness to innovations, but this in itself is not informative. The index method is better suited for comparing different groups, i.e., for use as a comparative analysis tool. Subsequently the index was used as a dependent variable in regression analysis to identify the determinants of public openness to innovations.

The differentiation of index values is considered from various perspectives, to demonstrate the tool's suitability in this context. As shown in Figure 4, residents of large cities tend to be more receptive to innovative solutions, while small towns and villages demonstrate rigidity. High index values are typical for population groups with a higher education and sufficient income.

Perception of New Technologies

Russians' attitudes toward adopting innovative technologies were measured using a set of 17 statements based on the TAM model. Most of the respondents agreed with the proposed statements or reacted to them neutrally (Figure 5). Average scores on a five-point scale for all statements except "*Only well-to-do*

Table 4. **Domain Weights of the Openness to Innovations Index**

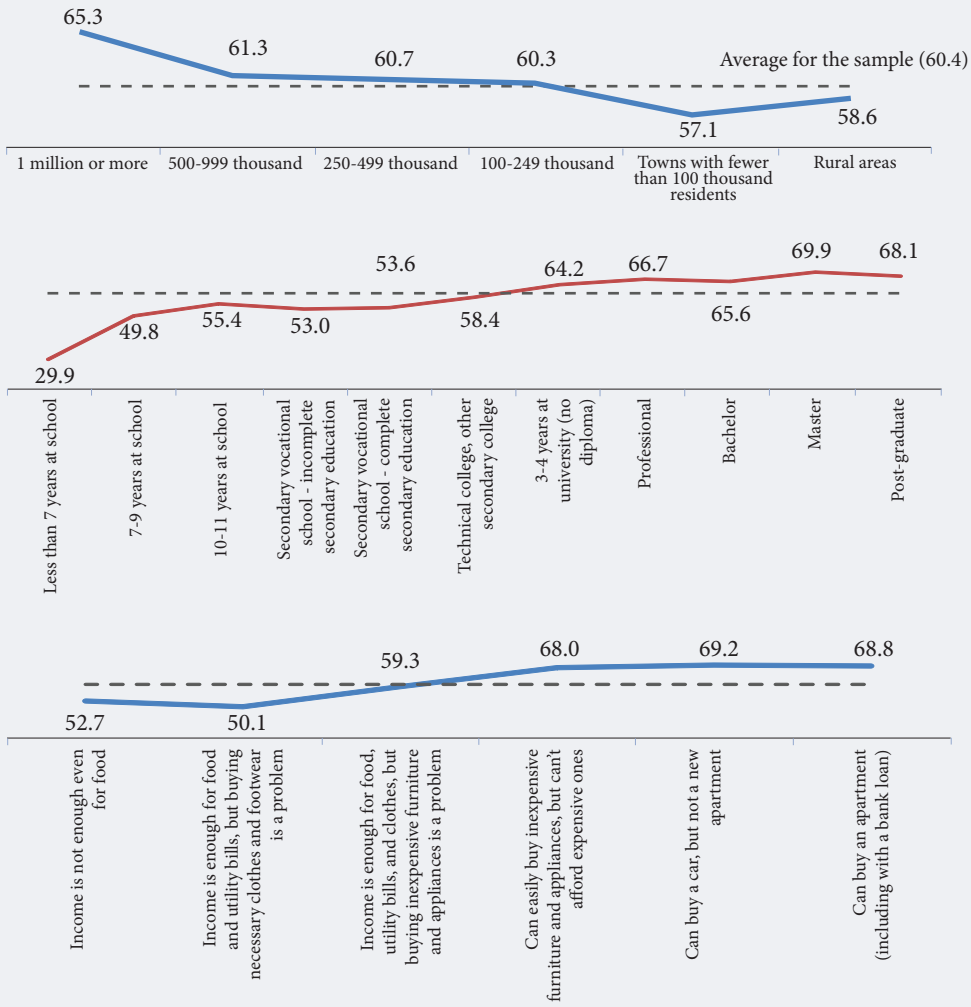
Domain	Factor load coefficients* (weight in the index)
Attitude towards innovations	0.237
Acceptance of innovations	0.632
Trust in innovations	0.131

* Based on the results of univariate analysis conducted using the maximum likelihood method. Variance explained - 49%.

Source: composed by the authors.

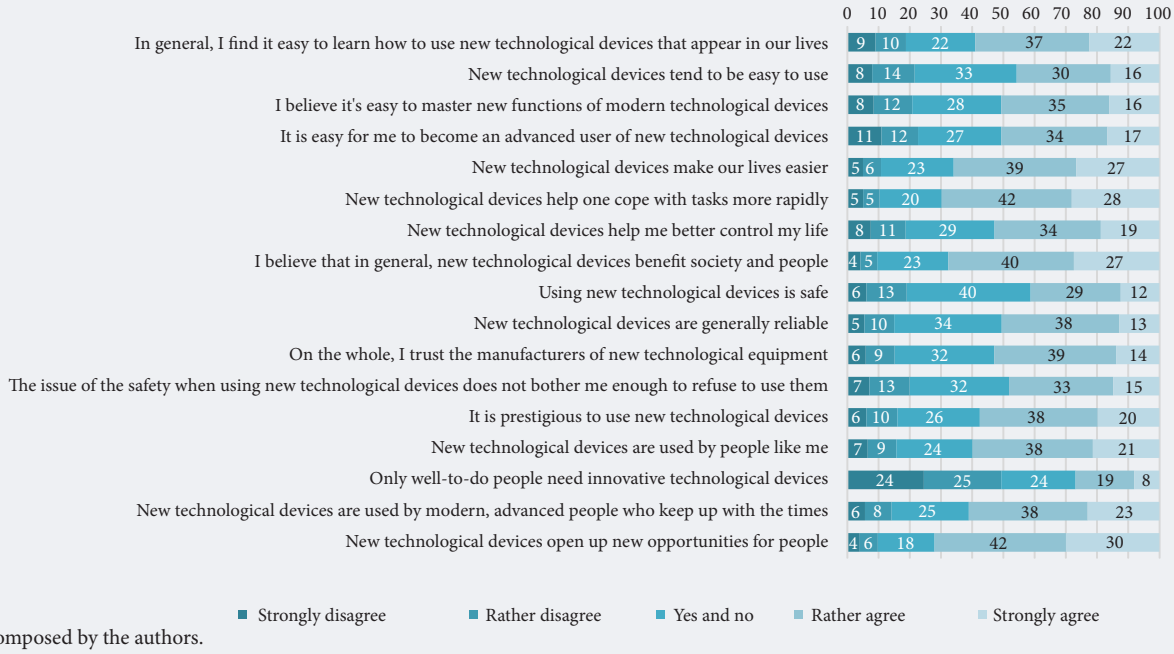
[19] According to the Levada Centre, only 18% of Russians completely trust doctors (http://www.levada.ru/2017/03/06/zdorove-i-doverie/, accessed on 15.12.2020).

Figure 4. **Average Openness to Innovation Index Values for Various Population Groups**



Source: composed by the authors.

Figure 5. **Public Attitudes toward Innovative Technical Devices (%)**



Source: composed by the authors.

Table 5. **Key Features of the Factor Analysis Model (rotated component matrix)**

Statement	Component			
	1	2	3	4
It is easy for me to become an advanced user of new technological devices	0.836			
I believe it is easy to master new functions of modern technological devices	0.818			
In general, I find it easy to learn how to use new technological devices that appear in our lives	0.809			
New technological devices tend to be easy to use	0.720			
New technological devices are used by people like me	0.530			
New technological devices are used by modern, advanced people who keep up with the times		0.719		
New technological devices open up new opportunities for people		0.705		
It is prestigious to use new technological devices		0.679		
New technological devices help one cope with tasks faster		0.656		
New technological devices make our lives easier		0.646		
I believe that in general, new technological devices benefit society and people		0.625		
New technological devices help me control my life better		0.516		
Using new technological devices is safe			0.747	
On the whole, I trust the manufacturers of new technological equipment			0.727	
New technological devices are generally reliable			0.713	
The issue of the safety of using new technological devices does not bother me enough to refuse to use them			0.604	
Only well-to-do people need innovative technological devices				0.928

Extraction technique: Principal Component Analysis. Rotation method: Varimax with Kaiser normalization.
a. Rotation converged in five iterations.
Source: composed by the authors.

people need new technological devices" exceeded 3.3. The statement about the usefulness of new technologies got the highest approval rate. [20]

Nearly 70% of the respondents agreed, to varying degrees, with the statements that new technologies:

- open up new opportunities for people (72%);
- help one to deal with various tasks faster (70%);
- benefit society and people (68%).

The statement about only wealthy people needing new technologies turned out to be the most controversial one: almost half of the respondents did not agree with it (49%) and every fourth replied neutrally. Doubts were also raised about safety: 40% took a neutral attitude and 19% a negative one.

Based on the results of the factor analysis conducted using the principal components method (Table 5), four perception attitudes were identified:[21]

- ease of use (statements 1-4, 14);
- usefulness (statements 5-8, 13, 16, 17);
- safety and reliability (statements 9-12);
- exclusivity (new technologies as an attribute of wealthy people) (statement 15).

The respondents' attitudes identified using the above statements somewhat differ from the initial assumption, but confirm the relevance of the chosen model.[22] Moreover, the selected factors open up prospects for further analysis of the social foundations of innovations, i.e., the strength of personal opinion about one's abilities and the possibilities for applying new technologies in social interaction. Ease of use also includes a self-identification component ("*New technological devices are used by people like me*"), while perceived usefulness among other things implies there is prestige in using new technologies: belonging to a group of people keeping pace with the times. Mastering innovations seems to be easy, especially in a supportive environment, while being able to use them and reap the benefits makes one feel advanced.

Perception of technological innovations is affected by the social status and environment, and depends upon various demographic and socioeconomic characteristics, which can be demonstrated by calculating weights and average factor values for each respondent. A positive value indicates a stronger attitude and indirectly suggests which population groups can act as agents of innovation-driven changes.

To establish the differences in attitudes toward new technologies between various socio-demographic groups, weights and average factor values were cal-

[20] In this study, innovative and new technologies/technological tools/devices are used as synonyms.

[21] The number of factors was determined in line with the original methodology of the study and explains 67% of the variance.

[22] The Cronbach's alpha scale reliability test yielded a good result amounting to 0.884 for the first attitude, 0.878 for the second, and 0.800 for the third one. In each case the changes in the Cronbach's alpha after eliminating any of the individual items suggest that these combinations do not require modifications.

culated for each respondent. A slight discrepancy in the gender perception of technological innovations was discovered: for men ease of use comes first, and for women – new devices' usefulness. No gender-related specifics were revealed in assessments of safety and reliability, or in status perception of technologies (Figure 6).

With age, the perception of new technologies changes. Young people over 16 years of age show a high level of perceived ease of use and a stronger belief that technology is an attribute of wealthy people than other respondents expressed.

After 40, the assessment of new technologies' ease of use decreases and after 60 mastering something from scratch turns out to be the hardest part. At the same time, starting from the age of 40 comes the highest awareness of new technologies' usefulness, while people over 50 (like the young ones aged 16-19) are more inclined to believe them to be safe and reliable. The question of whether this is due to trust based on acquired skills and knowledge, or, conversely, to blind faith combined with a lack of information and experience, requires additional study (Figure 7).

The level of respondents' education, as expected, affects their perception of innovations' ease of use. Only for people with higher education, the average factor loadings of perceived ease of use are clearly positive. For the rest, they fall in the negative value zone, increasing with a decrease in the level of education. Technology is seen as a wealthy people's attribute primarily by those whose education level is below secondary vocational. For holders of secondary vocational diplomas, this factor is not pronounced, while for university graduates, it has a negative median load, i.e., members of this group do not share this attitude at all (Figure 8).

The level of income can also affect people's attitude toward technologies, since the high costs at the market launch stage limits devices' availability to the general public. The poorest population groups who lack funds for food, or for clothes and shoes, tend to be negative about innovations; more than anyone else they are convinced that only the rich have demand for them. Perceived ease of use, safety, reliability and usefulness also have negative loads (but only among those who do not have enough money even for food).

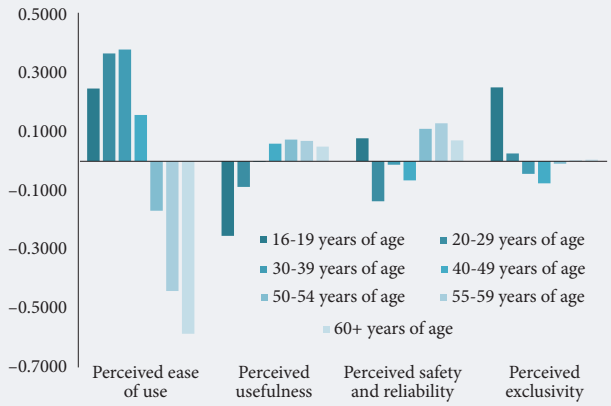
The perceived ease of use clearly depends upon the level of income: the average values increase as the respondents' assessments of their financial situation improves. As income rises, so does the strength of beliefs about innovative technological devices' safety and reliability. In the top income group, this factor's average values are negative, i.e., its members do not perceive innovations as safe and reliable (Figure 9). Perhaps this caution is due to being aware that any innovation has its limitations and that more wealthy people face increased risks of fraud.

Figure 6. **New Technology Perception Factors by Gender***

* Here and in the subsequent figures, the factors for which significant differences in mean values were discovered (at the level of 95%) are underlined.

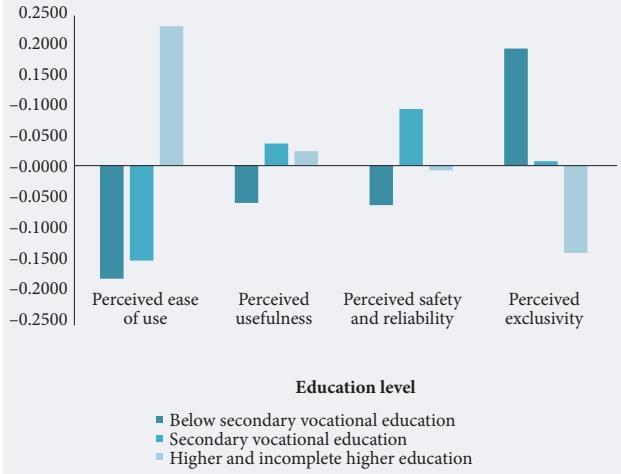
Source: composed by the authors.

Figure 7. **New Technology Perception Factors by Age**



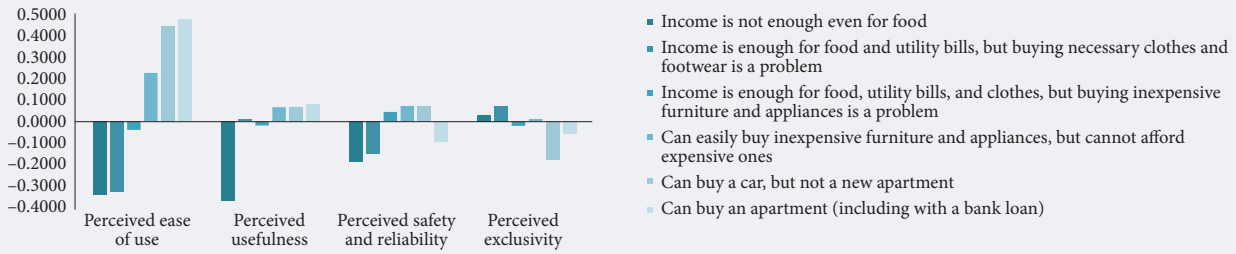
Source: composed by the authors.

Figure 8. **New Technology Perception Factors by Qualification**



Source: composed by the authors.

Figure 9. **New Technology Perception Factors by Personal Assessment of Income Level**



Source: composed by the authors.

In terms of place of residence, residents of megacities were the likeliest to agree with all of the proposed statements, in particular that technology is an attribute of wealth (probably due to the high-income differentiation in large cities). A similar attitude was also noted in small towns (fewer than 100 thousand residents).

Ease of use was perceived as high mostly in cities with up to 100 thousand residents; in small towns and villages the average values were negative, i.e., people who live there are less likely to believe mastering innovations is easy.

In small cities (up to 249 thousand), residents tend not to recognize the benefits of innovations. In rural areas, people are aware of their usefulness, but consider them difficult to use and unsafe (Figure 10).

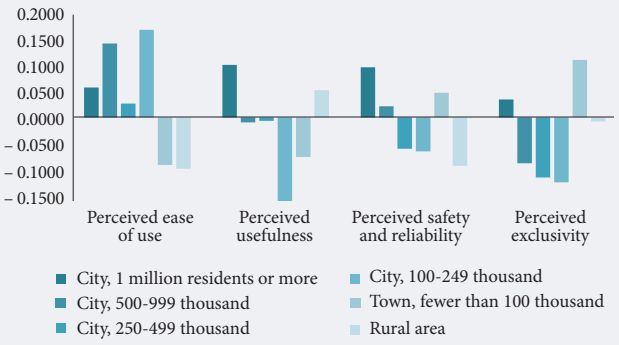
The internet as a radical innovation has changed the perception of new technologies, making it easier to access information about them. Assessing the level of internet usage via laptop and desktop computers, smartphones, and tablets[23] revealed significant differences between the perception of ease of use and exclusivity. Internet users predictably have an easier attitude toward technologies, while those who make do without online access tend to consider them an exclusive attribute of people with high income or status (Figure 11).

Determinants of Openness to Innovations

The relationship between the perception of innovations and openness to them was analyzed using the index determinants in the form of a regression model. The choice of the model and the dependent variable format were based on the innovation diffusion concept [*Rogers*, 2003] according to which "innovators", "early adopters", and "early majority" together account for 50% in any society. Their acceptance of an innovation serves as a kind of signal to everyone else: the innovation is useful and interesting, and worth adopting.

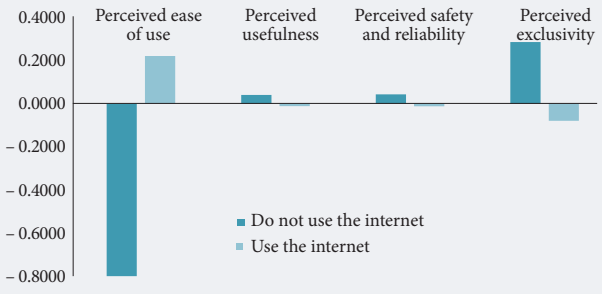
Assuming that the distribution of the Openness to Innovations Index values makes it possible to approximately define the above groups, the latter comprise the individuals for whom the index value exceeds the median[24] (i.e., 50% of the population). In other words, innovators are associated with the

Figure 10. **New Technology Perception Factors by Place of Residence**



Source: composed by the authors.

Figure 11. **New Technology Perception Factors by Internet Access Patterns**



Source: composed by the authors.

[23] It was assumed that the respondent actively uses the internet if answering the questions about how often they use it via a laptop/desktop computer and/or a tablet/smartphone, they chose the option "several times a month or more".

groups highly open to innovations identified using the index method and they ensure that innovations are adopted by the majority of the public. A binary logistic model in its general form presented in Formula 3 seems to provide optimal basis for regression analysis to identify the determinants of innovators' position:

$$p = \frac{1}{1+e^{-z}}, \quad (3)$$

where:

$Z = b_1X_1 + b_{22} + \ldots + b_n x X_n + a;$

X are independent variables' values;

b are coefficients calculated using binary logistic regression; and

a is a constant.

If P < 0.5 it can be assumed the event will not occur, otherwise it will.

The dependent variable takes the value "1" if the index value for the individual exceeds the median and "0" if it does not.

At the first stage the following independent variables were tested:

- factors affecting the perception of new technologies' ease of use, usefulness, safety and reliability, and exclusivity;
- gender;
- age;
- education;
- employment;

Table 6. **Regression Model Summary**

Step	–2 Log-likelihood	Cox and Snell R-square	Nagelkerke's R square
1	6182.242[a]	0.157	0.209

a. The assessment was terminated at iteration 4 since the parameter estimates changed by less than 0.001.

Source: composed by the authors.

Table 7. **Regression Classification**

			Predicted		
			Index value above median		Percentage of correct ones
			0	1	
Step 1	Index value above median	0	1656	862	65.8
		1	755	1814	70.6
	Total percentage				68.2

Note: Cut-off value — 0.500

Source: composed by the authors.

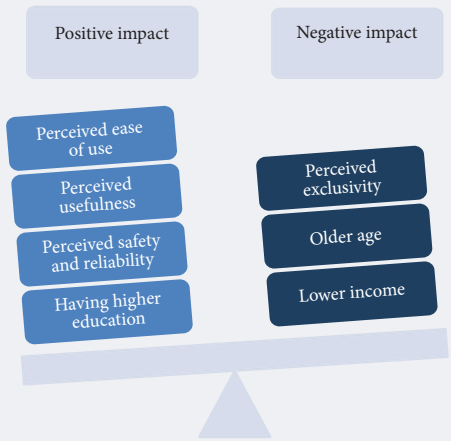
Table 8. **Regression Model Statistics**

	B	Root mean square error	Wald	Degree of freedom	Significance	Exp (B)
New technology perception factors						
Ease of use	0.482	0.037	170.224	1	0.000	1.619
Usefulness	0.532	0.034	242.711	1	0.000	1.702
Safety and reliability	0.416	0.033	160.231	1	0.000	1.517
Exclusiveness	–0.066	0.032	4.209	1	0.040	0.937
Age						
Number of full years	–0.014	0.002	35.169	1	0.000	0.986
Education						
Have higher education	0.326	0.064	26.090	1	0.000	1.385
Income						
Compared to those who do not have enough money even for food:						
Income is enough for food and utility bills, but buying necessary clothes and footwear is a problem	0.192	0.190	1.013	1	0.314	1.211
Income is enough for food, utility bills, and clothes, but buying inexpensive furniture and appliances is a problem	0.397	0.181	4.813	1	0.028	1.487
Could easily buy inexpensive furniture and appliances, but could not afford expensive ones	0.807	0.182	19.744	1	0.000	2.241
Could buy a car, but not a new apartment	0.731	0.207	12.485	1	0.000	2.078
Could buy an apartment (including with a bank loan)	0.946	0.288	10.748	1	0.001	2.574
Constant	–0.209	0.198	1.114	1	0.291	0.811

Source: composed by the authors.

[24] Median value divides the distribution into two equal parts.

Figure 12. **Determinants of High Openness to Innovations**



Source: composed by the authors.

- place of residence (settlement type);
- number of household members;
- having children under 16 years of age;
- income.

Testing various combinations of variables and the aggregation options for categorical variables' codes did not reveal a meaningful relationship between certain independent variables on the list and being an innovator. These characteristics include gender, place of residence, number of household members, and having children under 16. Therefore, at the second stage, the five above variables were excluded from the model. The remaining set allowed the authors to build a regression with a prediction accuracy of 70% (a detailed description of the final model is given in Tables 6–8).

Three of the four perception factors (ease of use, usefulness, safety and reliability), higher education, and level of income are positively associated with a high degree of openness to innovations. The correlation with the fourth factor (perceived exclusivity of innovative technologies) is negative. Summarizing the mathematical model results with certain assumptions, it can be stated that the easier to master, the more useful, safe, and reliable an individual finds innovations, the more likely he/she is to be open to them. Conversely, if technology is perceived as a luxury, in most cases the respondent should not be expected to be an innovator. At the same time, with a decrease in income[25] and increase in age[26] the chances of being among those for whom the index value is below the median increase. Having higher education, on the contrary, speaks rather in favor of being open to innovations (Figure 12).

Conclusion

TThe accelerating pace of technological development poses new challenges. Adaptability to innovations, including technological ones, is directly related to improved living standards and increased human capital. Accordingly, openness to innovations commands the growing interest of researchers.

Our study proposes the Openness to Innovations Index based on a multidomain methodological principle for an integrated analysis of public opinion. Innovations in various areas (from medicine and education to transport and manufacturing) are assessed using three components: individual attitude, acceptance, and trust, which are aggregated into an overall indicator. To assess the impact of the perception of innovations on the intention to use them, the later versions of the TAM model were applied, designed to test technologies' adaptation to various areas of life. The respondents' attitudes toward technological innovations are viewed through the prism of perceived ease of use, usefulness, safety, reliability, and exclusivity.

These factors' strength varies between different socioeconomic population groups and determines the latter's role in the innovation process. Ease of use is often noted by men, young people, educated, and well-to-do residents of large cities. Usefulness is primarily important for women, people over 40 years old with secondary vocational or higher education, above average income groups, and residents of megacities. Safety and reliability are of primary importance for people over 50 with secondary vocational education and average income. Finally, young people under 20, people with education below secondary vocational (mainly due to their age), low income, and residents of large and small cities alike tend to see new technologies as an exclusive attribute.

Assessing these factors' impact upon the public's openness to innovations, a positive relationship with the perceived ease of use, usefulness, safety, and reliability of technological innovations was revealed. Having a higher education also increases the

[25] No significant difference was observed only between the population group with income not sufficient even to buy enough food, and those who can afford food and pay utility bills, but not new clothes and shoes. (Table 8).

[26] The analysis does not include adolescents under 18 years of age. This finding applies to older population groups.

likelihood of an innovator attitude, while perceived exclusivity, on the contrary, decreases it. Finally, people tend to become less enthusiastic about innovations as their age increases and income decreases. Accordingly, young, educated, and successful people who are not afraid of new technologies most often act as agents of innovation.

Further research could address the issue of whether openness to innovations in the long term guarantees better life prospects, advantages on the labor market, and an overall increase in income and quality of life compared to other individuals in the world of ever-changing technology.

This paper is based on materials produced in the scope of the project "Analysing socio-economic inequality and redistribution policy, assessing the standard and quality of life for various social groups, and studying factors of healthy, active longevity" implemented in the framework of the HSE Basic Research Programme in 2018. The study also uses the results of the project "Poverty, inequality, and social mobility in present-day Russia: an interdisciplinary analysis" implemented in the framework of the HSE Basic Research Programme in 2020.

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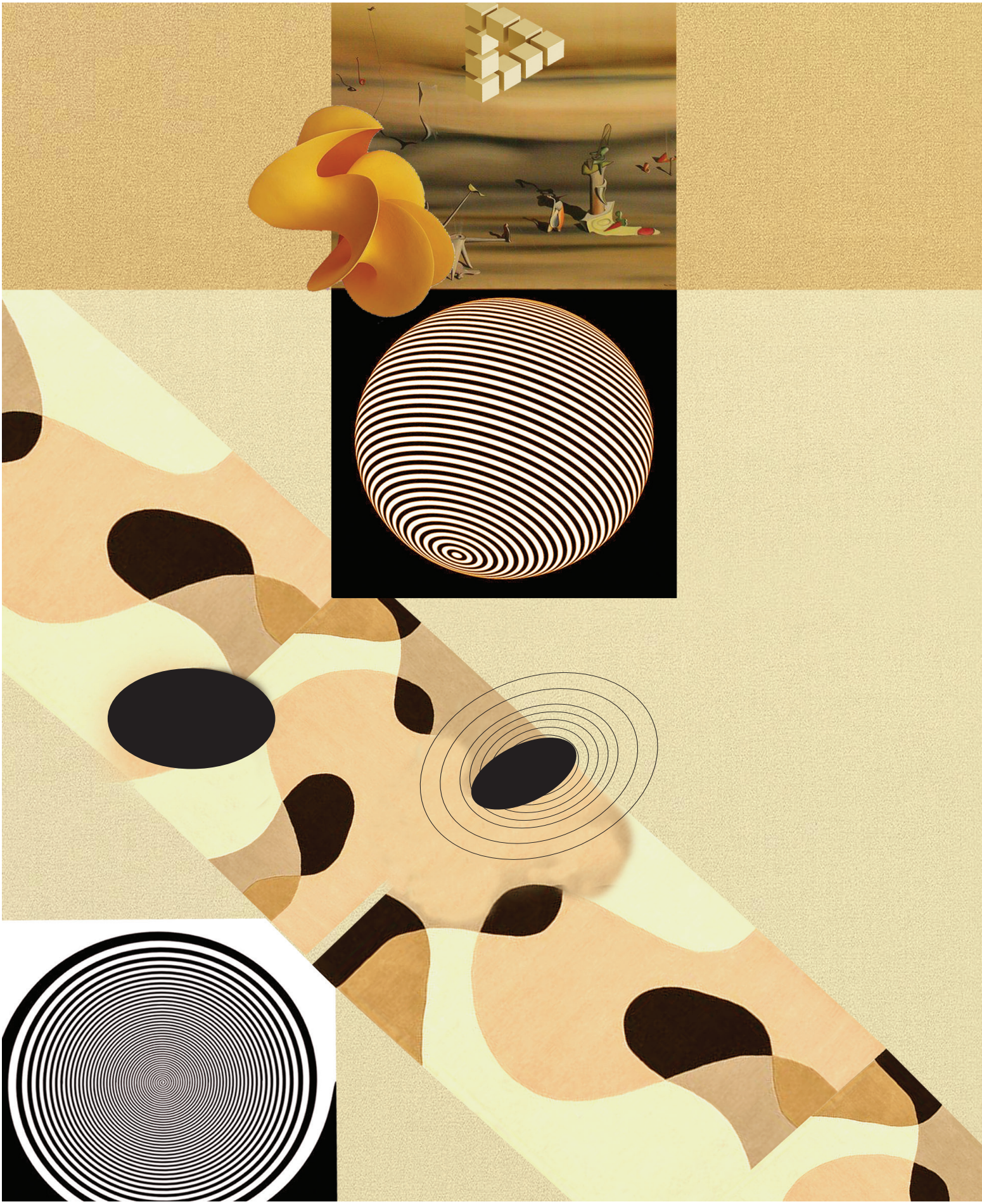

Early Career Researchers between Predatory Publishing and Academic Excellence: The Views and Behaviours of the Millennials

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Abstract

The paper draws on evidence of predatory publishing obtained from the four-year-long Harbingers research study of changing scholarly communication attitudes and behavior of early career researchers (ECRs). The project featured longitudinal interviews for its first three years with 116 ECRs researching science and social sciences who came from China, France, Malaysia, Poland, Spain, the UK, and US. The interview data provided the building blocks for a questionnaire survey in the fourth year, which obtained 1,600 responses from a global audience, which included arts and humanities ECRs and those from Russia. These studies investigated predatory publishing as part of general questioning about scholarly communications. The main findings from the interview study were: 1) ECRs generally do not publish in predatory journals; 2) they only allude to them lightly and mainly in the context of open access publishing; and 3) they no longer equate all open access publishing with predatory journals. The questionnaire found that, as in the case of the interviews, complaints that open access represents low quality publishing are diminishing, however, this positivity has been partly offset by increased concerns about the dangers of predatory journals.

Keywords: early career researchers; predatory journals; publication strategies; Harbingers study; scholarly communication

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Introduction and Aims

The Harbingers four-year long study (2016-2019), initially funded by the Publishing Research Consortium, dealt in considerable detail with ECRs' scholarly communication attitudes and behaviors (more than 24 scholarly activities were investigated) and whether these were changing. The first three years involved repeat interviews with nearly 120 ECRs from seven countries and the fourth year featured a questionnaire study which sought to confirm the results of the qualitative data obtained and to follow up on some of the original findings. Much of the findings have been widely published (see reference list) and summaries of the interview and questionnaire stages can, respectively, be found in [*Nicholas et al.,* 2019, 2020].

What we have not done to date though, is to publish what we discovered about predatory publishing and ECRs, and given the considerable rise in predatory journals over the period of the Harbingers study and the amount of research produced about them, literally hundreds of papers published, we wish to contribute our findings to the body of knowledge. We are doing this especially due to the special methodological approach taken, thus: 1) it is the result of studying ECRs in depth, and often personally, for four years; 2) we largely avoided direct questioning about what is a very sensitive and delicate subject, preferring in the interviews to approach the topic broadly or indirectly via discussions about related scholarly activities, such as open access and ethics, and largely through open ended questions in the case of the survey.

Literature Review

Predatory, questionable, illegitimate, dark, or deceptive publishing are the terms used to refer to fake and scam journals' accepting manuscripts for fees without sufficient quality control, while pretending the very opposite [*Frandsen,* 2017]. 'Predatory publishing' has become the term most often associated with the phenomenon [*Cobey et al.,* 2018], although as Eriksson & Helgesson argue, it "unhelpfully bundles misconduct with poor quality" [*Eriksson, Helgesson,* 2018]. According to Cabells journal blacklist[1], which screens journals against more than sixty behavioral indicators, the number of predatory journals is currently over 13,000, a considerable increase from the 8,000 or so found in 2014 [*Shen, Björk,* 2015]. Plainly then, predatory publishing, representing as it does the penetration of the 'fake news' mentality into the scholarly world, the debasing of scholarly research, a threat to the open science agenda, and the polluting of the scientific record, poses a real challenge to the integrity of science, its credibility, and trustworthiness [*Ojala et al.,* 2020; *Shaghaei et al.,* 2018]. Unsurprisingly, therefore, publishing in a predatory journal is said to render a piece of scholarly work unusable, unfit for citation, indeed, illegitimate, and stigmatized to an extent that puts at risk the reputation of its author [*Roberts,* 2016], while along the way also besmirching the very jewel in the scholarly communications crown that journals undoubtedly are.

With predatory publishing, thus, clearly running counter to the values widely held to be the very foundations of the scholarly enterprise, there are compelling deterrents against researchers' straying from the straight and narrow in their publishing practices. However, in an environment that sees research productivity as a major yardstick by which the reputation of scholarly success is measured [*Blankstein, Wolff-Eisenberg,* 2019; *Harley et al.,* 2016; *Herman, Nicholas,* 2019; *Nicholas et al.,* 2015a, 2015b; *Nicholas et al.,* 2017; *van Dalen, Henkens,* 2012; *Grimes et al.,* 2018; *Memon,* 2019], the aforementioned growth in the number of predatory journals, indeed, as we are about to see, with the evidence on the ground, seem to indicate that predatory publishing may be condemned in theory, but accommodated in practice.

Under these circumstances, predatory publishing may be even more of a challenge to young researchers (millennials[2]): just making their way, they have to publish to progress, so that the enticements of getting published easily in predatory journals may speak to them even more strongly, especially as, being as yet unversed in the ways of academe, they may be ignorant of the real nature and possible repercussions of the practice. This is of crucial importance, for, as Harbingers research has shown, ECRs'[3] stance toward developing trends in scholarly undertakings promises to lead the way in shaping its future character, indeed, this may very well be instrumental in bringing about an overhaul of the scholarly communications system [*Nicholas et al.,* 2019, 2020]. After all, they are millennials and attempting to re-arrange the world in line with their values and behaviors.

Indeed, young and inexperienced researchers from developing countries typically have been found to have published in predatory journals [*Frandsen,* 2017; *Nobes, Harris,* 2019; *Shen, Björk,* 2015; *Truth,* 2012; *Xia et al.,* 2015], with the situation in Africa shown to be particularly challenging [*Nwagwu,* 2015]. According to [*Kurt,* 2018] "predatory publishers have become another way in which people in the developing world are victimized."

[1] https://www2-cabells-com.ezproxy.haifa.ac.il/about-predatory

[2] The term 'millennials', also known as "Generation Y", refers to the cohort of people born or experiencing their formative years just before the turn of the millennium. In its broadest sense millennials are people born between the early 1980s and late 1990s (FEPS – Foundation for European Progressive Studies and ThinkYoung, 2018).

[3] Researchers who are generally not older than 35, who either have received their doctorate and are currently in a research position or have been in research positions but are currently doing a doctorate. In neither case are they researchers in established or tenured positions.

However, it is not that simple, for there is also ample evidence to suggest that developing countries and the young and inexperienced are not alone in publishing in predatory journals. In fact, many researchers, regardless of their career experience, geographic location, and disciplinary affiliation, seems to be involved [*Perlin et al.,* 2018]. Thus, predatory publishing is not only an issue in developing countries [*Eykens et al.,* 2019; *Moher et al.,* 2017], specifically with regard to tourism and hospitality [*Alrawadieh,* 2018]. Indeed, according to the findings of the latter, the socioeconomic and geographical dispersion of the problem may be quite wide: in a sample of 1,907 papers in more than 200 journals, thought likely to be predatory, more than half had authors from high- and upper-middle-income countries as defined by the World Bank. By the same token, the results of an investigation into the extent of predatory publishing in Germany showed that 5,000 researchers from German universities, institutes, and federal agencies, including prominent university professors, even a Nobel laureate, have frequently published articles in worthless online scientific journals belonging to pseudo-scientific publishers, often paying exorbitant fees for the privilege [NDR, 2018; Offord, 2018]. In Italy, too, about 5% of the 46,000 researchers seeking promotion have been found to publish in potential or probable predatory journals on Beall's list[4] [*Bagues et al.,* 2017]. This is perhaps not as surprising as it seems at first glance, experienced researchers from the developed world, as represented by the faculty of the University of South Denmark [*Shaghaei et al.,* 2018], publish in predatory journals, too, and mainly for the same reasons as researchers from developing countries do: lack of awareness, speed and ease of the publication process, and a chance to get work that has been rejected elsewhere published.

The findings by other researchers [*Alrawadieh,* 2018; *Eykens et al.,* 2019] also confirm that senior authors are visibly present on the predatory publishing scene, which, as the latter put it, render the assumption that predatory publications are authored mainly by inexperienced authors 'highly doubtful'. For example, experienced researchers in the Brazilian academic system were the ones more likely to publish in predatory journals [*Perlin et al.,* 2018]. For a sample of papers in the field of economics it is shown that more experienced scholars do publish in predatory journals [*Wallace, Perri,* 2018]. In fact, even the knowledge and influence of predatory journals seems to vary with seniority/experience, as a survey among Austrian dermatologists showed: it was the scientifically active and older participants who were more likely to be familiar with predatory journals [*Richtig et al.,* 2019].

Previous research has shown that predatory publishing is prevalent and is undertaken by junior and senior researchers and those from all parts of the world. However, we need to treat these studies with care. This is because the response rate in these studies is notoriously low (and unrepresentative), a phenomenon that holds true when people are invited to take part in a survey, and arguably even more so when they are asked to agree to be interviewed (see, for example, [*Cobey et al.,* 2019; *Demir,* 2018; *Shaghaei et al.,* 2018; *Shehata, Elgllab,* 2018]). The findings in these studies tend to be non-generalizable, too, pertaining as they typically do only to the idiosyncratic circumstances of researchers at a single research institute [*Pyne,* 2017; *Shaghaei et al.,* 2018], and/or in a limited geographical area [*Bagues et al.,* 2017; *Demir,* 2018; *Mouton, Valentine,* 2017; *Omobowale et al.,* 2014; *Perlin et al.,* 2018; *Shehata, Elgllab,* 2018], and/or a specific discipline or knowledge area [*Cobey et al.,* 2019; *Wallace, Perri,* 2018].

Methodology

The first leg of the study, conducted during the period 2016-2018, consisted of a longitudinal, in-depth (60-90 minute long) semi-structured interview study, which sought to map the changes in the scholarly communication attitudes and behaviors of 116 science and social science ECRs from China, France, Malaysia, Poland, Spain, the UK, and US in order to establish the extent to which early career researchers are the harbingers of change in the scholarly communications system. The make-up of the samples can be seen in Table 1.

Interviews were repeated each year for three years and contained more than 60 questions on two dozen scholarly activities and issues, such as social media, ethics, discovery, open access, publishing, and author practices. Changes were calibrated.[5] There were no direct questions about predatory publishing, instead data was: 1) volunteered during questions on open access publishing, publishing practices, and ethics; 2) prompted where an answer merited it; 3) collected by inspecting the CVs of each ECR furnished each year and papers published were cross-checked with Beall's list of predatory journals and publishers (now defunct) to detect predatory publishing.

The qualitative data obtained served to lay the ground for the second, quantitative questionnaire leg of the study (2019). The overarching aim of the questionnaire was to validate the key interview data found (that predatory publishing is associated in the minds of ECRs with open access), update it, and extend the study to a larger, global (including Russia which is also a case study) and a more diverse popu-

[4] Now defunct, see https://beallslist.net/

[5] The full list and coding sheet can be found at http://ciber-research.eu/download/20160916-Harbingers-research_instruments.pdf.

lation, including the arts and humanities.[6] The questionnaire reached a population of 1,600 participants worldwide, including Russia, which was not covered by the interview stage. The make-up of the sample can be seen in Table 1.

The questionnaire featured a comprehensive range of questions on scholarly activities, although not as many as covered by the interviews due to time constraints, but it did contain closed and open questions on open access publishing and predatory journals.

As already mentioned, neither in the first, qualitative stage of the study, nor in its second, quantitative stage, were there 'full on' questions about predatory journals for a variety of reasons, among which the methodological problems of probing sensitive issues figured highly. As the studies that examined the incentives and reasons for predatory publishing in the past few years amply prove, the sensitive nature of the topic gives rise to characteristic methodological problems, which we wish to circumvent. Indeed, a common denominator of these studies seems to be their limited scope, stemming from the difficulties of recruiting subjects, be they interviewees or survey respondents. This is unsurprising, of course, for the researchers approached were queried as to their own predatory publishing experience, so that even when anonymity is promised to be guaranteed, people are understandably reluctant to admit that they were either naive enough or unethical enough to publish in a predatory journal.

With respect to the repeat interviews, given the sensitivity of the topic, we explored the topic indirectly and in the context as we could not be sure that we would receive informed or truthful answers to questions directly about predatory publishing – after all, not many ECRs, due to their precarious position, would willingly and freely admit to a behavior that, according to [*Frandsen,* 2019] falls into one of two categories: naïve or deliberately unethical. Therefore, the topic came up as part and parcel of the responses to questions on publishing policies, open access publishing, ethics, and reputation. So this approach meant that the topic was mentioned in the context of reporting on a scholarly activity, rather than resulting from direct and, possibly, leading questions. The questionnaire was informed by the interview data produced, more direct and voluminous quantitative information which was obtained via questions about open access publishing which we had learned from the interviews and this was where predatory journals cropped up.

able 1. **Composition of Interview and Questionnaire Populations**

Distribution	Interviews (%)	Questionnaire (%)
Age		
30 and under	31	39
Over 30	69	61
Gender		
Female	42	48
Male	58	52
Subject		
Arts and Humanities	0	9
Sciences (physical, biological, medical, mathematical, computing and agricultural)	76	57
Social sciences	24	34
Geographical		
Africa	0	4
Asia	22	17
Australia/Oceania	0	5
Europe	54	30
Middle East	0	6
North America	24	33
South & Central America	0	5
Numbers	116	1600

Source: authors.

Findings

The longitudinal interview leg of the study

The interview schedule was extremely wide ranging. There were questions about scholarly communications where the topic could have been raised in a broader context especially in connection with open access publishing (e.g., What do you think are the advantages and disadvantages of OA publishing from the point of view of the author? Do you think OA publishing advances science and research, or are you worried that it will dilute the quality of publications, or do you agree/disagree with both propositions?). Ethics was also a topic where predatory journals could have been mentioned (e.g., Do you have a clear understanding of what is generally regarded as ethical and unethical in research and/or publishing practices or are you uncertain about what is meant by these terms? Are you aware of any unethical publishing/citing behavior among your peers or among those higher in the academic structure?).

In the majority of cases, predatory publishing and journals were only occasionally mentioned, and this might be explained largely by the fact that our ECRs did not publish in them (we inspected their CVs every year to double-check this and only one did). When predatory journals were mentioned, it was mostly in connection with questions about the pros and cons of open access publishing, which is not surprising because open access clearly opened the door for predatory publishing. As the project progressed from 2016 to 2018 it became obvious that ECRs, and especially the scientists among them, were becoming more informed about what open access is and how it could benefit them. They wit-

[6] Methodological details of the second leg of the study can be found in [Nicholas et al., 2019] and the questionnaire at http://ciber-research.eu/download/ECR-questionnaire-for-website-20191129.pdf).

nessed government attempts to encourage open access publishing, so it was no longer the bogey man that it once was. Indeed, as a consequence, fears that open access journals were in fact predatory lessened, although such concerns never went completely away.

This was true for every country, but most markedly so in the case of Chinese and Malaysian ECRs, who, by 2018, had a very clear understanding of what open access (OA) is. Thus, they exhibited a more neutral and objective attitude toward OA journals, whereas in 2016, unknowledgeable, they regarded most OA journals to be of low quality and predatory. However, despite their increasingly warm sentiments towards OA, in practice not all Chinese ECRs chose this model of publishing, partly because of lingering reputational/predatory concerns, but also, ironically, because they were just more aware of predatory journals, thanks to such sources as Beall's list and the fact that many were of a Chinese origin. Spanish ECRs also told us that they felt more comfortable about publishing in OA journals, as they now knew that they are not always predatory.

Of the seven countries covered, Malaysian ECRs raised the topic of predatory journals most frequently. The topic came up came up in two areas of questioning. The first was open access publishing. Science ECRs made it clear that they did not publish in OA journals or publishers that are listed on Beall's list, for instance, hijacked journals and journals that have misleading metrics since they only went for Web of Science (WoS) indexed journals. '*As long as it is OA is fine, as long as the journal is ISI* (Web of Science)*, reputable and the university will pay the article processing fees but you need to make sure that it is not listed in Beall's list. Not predatory*'. '*The ultimate goal of making the results of research freely available around the world is one that is worth fighting for. And has the tendency to increase downloads and citations. But OA is not perfect predatory journals remain a problem*'. A knowledgeable Malaysian ECR also lamented the fact that there have been quite a number of predatory journals which are indexed in Scopus and WoS, but listed on Beall's. The second topic area was ethical behavior. In this respect, Malaysians also talked about the consequences of unethical behavior in publishing (detailed in [*Abrizah et al.,* 2019]), with a couple of ECRs mentioning publishers being predatory because they did not provide thorough peer review or honest marketing material. Suspicions in Malaysia were being raised by increased reporting about journals being hijacked, more retraction occurrences, and new types of publication violations were emerging – fake reviews and fake acceptance letters [*Abrizah et al.,* 2019].

By way of contrast, US and UK ECRs provided few comments on predatory journals, indeed, they showed very little interest in ethical matters generally. No doubt they did so believing their scholarly houses were in order. Still, when prompted for a definition of what constitutes unethical behavior, US ECRs mentioned a host of practices: copying others' work and paying someone to do ghost writing; publishing things that are not true; not accurately portraying data; stealing people's ideas or gazumping someone based on presentation; using data more than once in different papers; and anything else that could deceive others. However, interestingly, they did not directly mention publishing in predatory journals, probably, because they have little familiarity with the practice, so it may never occur to them.

What also keeps ECRs on the scholarly straight and narrow (and away from predatory journals) is the prescriptive/recommended journal lists, which many governments and ministries produce to ensure that rewards – financial and reputational – are only given to those that publish in top Impact Factor (IF) journals. The Polish list, which minutely records nearly 30,000 journals, is a case in point. Polish researchers obtain a minimum of 20 points if they publish in a prescribed journal, otherwise it is just five points. Indeed, no Polish ECRs published in predatory journals.[7] Malaysian and Spanish ECRs are similarly constrained in their publishing choices.

In consequence, then, on the basis of the interview data, the strong conclusion that can be made is that (our) ECRs do not publish in predatory journals or care greatly about them. This can be ascribed to the fact that many were employed by top research universities, had experienced mentors, and published as part of groups of more senior researchers who kept them in line. Thus, French ECRs (who, incidentally, refer to predatory journals as 'charlatan' or 'Indian' journals – the latter because most of the "SPAM" they receive comes from Indian journals) spoke for all ECRs when they told us that they were always publishing their articles with their Principal Investigator and other members of the lab, and their main concern was to publish in the right journals (not necessarily with the highest IF) for reputation's sake.

So, there is no support here for the contention that millennials are not attracted to predatory publishing. Presumably, then, most of our ECRs did not meet criteria specified in [*Frandsen,* 2019] that there are two different types of authors who take up the option: the uninformed and the unethical. ECRs at top universities and on top research teams, as the Harbingers ones were, are clearly surrounded by high-

[7] Ministry of Science and Higher Education in Poland, Constitution for Science (2019) Komunikat Ministra Nauki i Szkolnictwa Wyższego z dnia 18 grudnia 2019 r. w sprawie wykazu czasopism naukowych i recenzowanych materiałów z konferencji międzynarodowych. http://www.bip.nauka.gov.pl/inne2/komunikat-ministra-nauki-i-szkolnictwa-wyzszego-z-dnia-18-grudnia-2019-r-w-sprawie-wykazu-czasopism-naukowych-i-recenzowanych-materialow-z-konferencji-miedzynarodowych.html

flying, knowledgeable, and experienced colleagues, so they are neither likely to fall prey to unscrupulous publishers nor come up with such low-quality research that their only option is publishing it in scam journals.

The questionnaire leg of the study

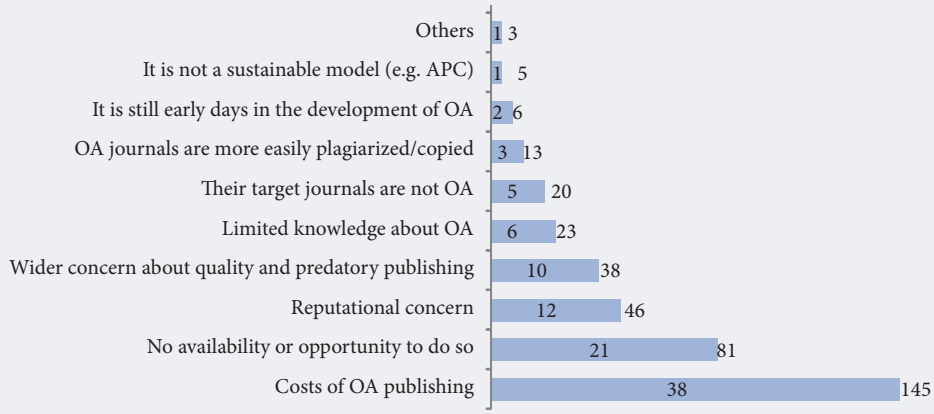
In the questionnaire, as with the interviews, we asked a range of questions about scholarly communications with respect to reading, citing, publishing, authorship, information use and seeking behavior, publishing, peer review, open access publishing, and data and metrics. However, we did not ask a question directly or devote a whole question to predatory journals for the aforementioned reasons. Instead, informed by the interview stage of the connection in ECRs' minds between predatory journals and OA, we adopted a dual approach. First, to ask open-ended questions of those who said they did not publish in OA journals, in order to find out why they did not do so, to see, among other things, whether predatory journals were a factor in this. Second, to ask a closed question on what they thought were the disadvantages of publishing in OA journals, where predatory journals are included on a list of eight reasons why they might not publish in OA. The full list of reasons is provided in Figure 1.

The open-ended responses were coded manually by two different researchers respectively at the same time and then the coding sheets were exchanged and cross-checked by researchers at the primary coding stage after the coding frame and guide were set. This process was repeated in the secondary coding stage. During the whole process, representative responses were quoted and marked for further analysis. The results showed that just 10% of ECRs felt that they would not publish in OA formats because of predatory or related quality concerns (Table 1). This seems in keeping with the interview findings that OA journals and predatory journals were being de-coupled in their minds. This result needs to be taken in the context of earlier questions in the survey, which found that most ECRs thought there were more and better reasons for publishing OA than not doing so, so just 380 out of 1,600 ECRs answered the question.

As in the case of the interviews, Chinese ECRs featured strongly among those that did not trust OA journals and (despite three years later) still grouped them together with predatory journals. They thought they were low quality, lacking credibility, and just generally doubtful. In the words of one ECR: *OA journals are unreliable and trustless; they are predatory journals which send me call for paper emails frequently. They usually don't have citations when published.* In a number of cases Chinese researchers did not even use the word predatory, although what they were talking about clearly had all the hallmarks of such journals. It was almost as though they could not mention their name because they were so despised. However, in contrast, Xu et al. [*Xu et al.,* 2020] found in a questionnaire study of mostly young Chinese researchers that perceptions towards OA publishing were more positive, with most respondents no longer thinking that OA journals published poor quality content or were predatory journals. One possible explanation for the different take on this might be that around a quarter of their respondents were recruited via MDPI, an OA publisher platform, and therefore were likely to be more familiar with OA and have more experience in publishing in OA journals. It could also be down to the fact that respondents were heavily skewed towards engineering and technology and more informed about what open access was and how it could benefit them. This brings us to the difficulties of doing studies in this area and how careful we should be about coming to hard conclusions.

The closed-question approach to predatory journals saw them embedded in a question about the disad-

Figure 1. **Main Reason(s) for Not Publishing OA (open-ended question) (N = 380)**



Note: Numbers in the bars are % and numbers at the end of bars are frequency.

Source: authors.

vantages of publishing in open access outlets (Figure 1) and we sought to test the hypothesis derived from the interview data that there were thought to be too many predatory journals going by the number of emails received. Mean values for these questions are in green and were calculated based on the numeric values of the scale item with not at all being 1 and to a great extent being 5.

As the open-ended question showed that while the cost of publishing and author processing charges (APCs) are the main concern (M=3.97) with respect to OA publishing, not so far behind is the belief that there are too many predatory OA journals (M=3.69), with nearly two-thirds of ECRs (62%) feeling this was somewhat or to a great extent the case. There was an open-ended option also to this question and six ECRs used the facility to leave comments. They provided further evidence of the concerns regarding predatory journals, saying, for instance, that it is hard for newcomers to work out which journals were predatory given the amount of emails they receive from OA journals. While although few in number, the fact that ECRs took the time to express their concern shows the importance they accorded to the predatory problem.

Examining the differences between the case study countries, ECRs from the US believed most (M=4.1) that the disadvantage of OA is that there are too many predatory journals among them whilst those from France think so to the least extent (M= 3.7). The main significant differences are between the US and France and the US and Poland. US concern was not obvious from the interviews, but then the issue was not pressed so strongly. It may be down to a feeling of general insecurity and, of course, the largest blacklist of journals in the world (Cabells International, see above) is American and sells well there, so, there is evidently some concern in these parts.

To put all this into a broader scholarly context: when presented with a number of advantages of OA publishing, which were thought to be especially beneficial to ECRs for the building of their reputations, it is increased visibility and bigger/wider audiences that proved to be the strongest OA draws. When it came to disadvantages, costs proved to be the biggest one and this was followed closely by the belief that OA journals were tarred with a predatory brush – quite a telling combination. Women tended to be generally more positive about the merits of OA than their male counterparts, although there were no statistical differences between the genders in terms of their views on predatory journals.

Discussion and Conclusions

From the longitudinal interview study and the accompanying CVs furnished by ECRs, we found that all bar one of our ECRs over the three years had not published in predatory journals. Yes, the pressure to publish was there for most, but not all, however they rarely published in journals they did not know or which were not known to mentors and in many cases these scholars published with their mentors (and when they did so it was not in predatory journals). This was not what we expected because, as we have heard, the literature catalogues numerous instances of young researchers and their older colleagues publishing in predatory journals [*Frandsen,* 2017]. This is thought to be largely the case because these ECRs came from good universities in developed countries and publish largely as part of groups, where they are mentored and advised. They expressed strong views on having to toe the traditional line to satisfy their principal investigators, co-authors, and mentors. Whether they would have done so without this form of control is something we do not know and will investigate further. Certainly, their precarious job status meant that it would benefit them to publish articles quickly and painlessly, but they also had to play by the accepted scholarly rules. Thus, even if, as millennials, they believe passionately in openness,

able 2. **Disadvantages of Open Access Publishing (N ≈ 1346)**

	Not at all		Very little		A little		Somewhat		To a great extent		don't know		total
	N	%	N	%	N	%	N	%	N	%	N	%	
Perceived poor quality of OA journals	199	14	208	15	378	27	404	29	204	15	65	5	1393
Perceived lower prestige/status of OA journals	189	14	225	16	335	24	399	29	240	17	64	5	1388
Costs of OA publishing	79	6	99	7	218	16	325	24	615	46	121	9	1336
Risks from a career advancing and reputational point of view	286	21	275	20	317	24	299	22	167	12	105	8	1344
Possibility that OA journals are more easily plagiarized	316	23	261	19	300	22	310	23	163	12	102	8	1350
Too many predatory journals	97	8	116	9	276	22	378	30	400	32	189	15	1267

Source: authors.

able 3. **ECRs Who Said that the Disadvantage of OA Journals is that Too Many Are Predatory**

Country case studies	Mean	N	Standard Deviation
China	3.7	217	1.0
France	3.4	139	1.4
Poland	3.5	123	1.4
Russia	3.6	86	1.0
Malaysia	3.9	91	1.0
USA	4.1	78	1.2
UK	3.6	70	1.3
Spain	3.9	66	1.2
Total	3.7	870	1.2

Note: $p < 0.005$, $F = 3.7$, $df = 7$

Source: authors.

sharing, and transparency, this does not extend to publishing in predatory journals.

ECRs not only avoided publishing in predatory journals, they also largely avoided talking about the subject altogether, only occasionally and lightly alluding to it in the interviews and, then, mainly with regard to one scholarly aspect – open access publishing and how it was blemished by predatory journals. However, this was a fear that diminished over the course of the life of the project.

The results of the survey, which sought to 'test' the main interview finding that predatory journals were associated with open access publishing on a bigger and wider population, tell us that it does not mean that the topic is widely disregarded or of little interest. Indeed, ECRs raised concerns voluntarily in open-ended questions when questioned about OA publishing. From this, it is clear, that while complaints that OA constitutes low quality publishing might be diminishing, this has been partly offset by growing concerns about the increasing numbers of predatory journals and fake research. Concerns were greatest in the US and lowest in France, but this has to be set in context, which is that just 10% of ECRs felt that they would not publish OA because of predatory or related quality concerns.

So, what does all this tell us? Well, first of all, there is the 'shock of the new' that needs to be taken into account. Thus, while at the beginning of the study much open access publishing was suspect, perceived as predatory, with time (four years) it has become far more acceptable. Predatory publishing, however, has not.

The value of our findings lies in the fact that this is an extremely important area where evidence is thin on the ground and often contradictory, especially as to whether it is young or mature researchers who are the guilty ones. In this study we avoided a direct, potentially intimidating approach to the topic wherever possible; we pulled rather than pushed and, as a consequence, hopefully, have provided an original and fresh view on the topic. You cannot help but come to the conclusion that predatory publishing is little practiced and an irritant rather than a significant threat to the integrity, credibility, and trustworthiness for early career researchers.

Finally, the study's limitations are, firstly, that because of our indirect approach to the topic, researchers were not forced to admit or say anything. They could keep their own counsel in other words. This, however, is countered by the fact that we did not lead them to say anything or force them to lie and the interviews and questionnaire data are very much in line as are the CVs. There is triangulation in other words. There is a second limitation and that is that we only covered relatively wealthy and developed countries. It might well be different in Africa, for instance.

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GREEN ECONOMY

Macro Study of Global Electric Vehicle Expansion

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Abstract

This study analyzes the diffusion of battery electric vehicles (BEV) in the world and evaluates vehicle charging stations based on the European Union (EU) scenario. Initially, the global BEV sales data from 2005 to 2018 were fitted with the two most frequently used econometric logistics and Bass diffusion models. Further, the study identifies the different stage adopters, forecasts the consumption of BEVs, and examines the velocity and acceleration of BEV diffusion. Finally, future charging stations are examined to meet the BEV sales demand. The results suggest that the adoption of BEVs demonstrates a better fit on the Bass model where the global BEV market is estimated to grow from 5,318,850 units in 2019 to 39,996,720 units by 2030, and with the reference of the EU countries' adoption scenario, the global charging stations will be increased from 2,084,000 units in 2019 to 9,999,000 units by 2030.

Keywords: business; innovation; diffusion; potential market; electric vehicle

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Electric Vehicle (EV) technology is one of the most rapidly growing innovations. The development of the technology and its introduction to the market is a continuous process. The adoption process is not permanent and stable and is subject to analysis through innovation diffusion research. In the diffusion process, a fraction of potential users are the first users who adopt the product and they play a decisive role in triggering the diffusion process [*Mahajan et al.,* 1990]. Relative advantage, compatibility, trialability, observability, and complexity are the essential characteristics of diffusion. The diffusion of innovation follows five different stages as innovators, early adopters, early majority, late majority, and laggards [*Rogers,* 1983]. Different stages of innovation diffusion and corresponding market share are summarized in Figure 1.

Over the last decade, green vehicle technology has grown in popularity among policymakers, consumers, and automobile manufacturers. An outstanding curiosity in every stakeholders' mind is how the electric vehicle will be adopted by consumers. Analyzing the adoption pattern and different stages of diffusion provide benefits for green vehicle industrial stakeholders. The vehicle manufacturers and their distributors' strategic plans would involve less uncertainty. Electric utilities can be better planned for the additional demand brought by electric vehicles (EVs). Policymakers can predict the impact upon government incentives and set national environmental targets [*Mahmoudzadeh Andwari et al.,* 2017]. In recent years, EVs have been one of the most innovative products in the automotive industry [*Al-Alawi, Bradley,* 2013].

EVs consist of BEVs and plug-in hybrid EVs (PHEVs) [*Daziano, Chiew,* 2012; *Nezamoddini, Wang,* 2016; *Rezvani et al.,* 2015]. The overall sales of EVs are steadily rising [*Hertzke et al.,* 2018]. This paper compares the widely used Bass and logistic econometric diffusion model parameters of battery electric vehicle (BEV), suggests the different stages of adopters, and forecasts the future consumption of BEVs until 2030. Further, we analyze the diffusion speed and acceleration of BEV adoption using the Bass function and the average BEV charging points from the reference of present European Union (EU) adoption.

Background

EVs are a feasible and sustainable solution for the future of technology in the automobile industry, which can reduce the current dependence on fossil fuels and greenhouse gas (GHS) emissions [*Adnan et al.,* 2017; *Liao et al.,* 2017]. EVs have a long history after Joseph Henry first introduced the DC-powered motor in 1830, professor Stratingh built the small model electric car in the Dutch town of Groningen in 1835. Moses Farmer first introduced the two-passenger EV in 1847. EVs were not viable because they did not have rechargeable electric cells (batteries) at that time. Frenchmen Gaston Plante and Camille Faure respectively designed (1865) and improved (1881) the storage capacity, then the new era for EVs began [*Bansal,* 2017] but commercially, the EV called Toyota Prius was first introduced worldwide in 2000 [*Dijk et al.,* 2013].

Diffusion studies were introduced in the 1960s [*Arndt,* 1967; *Bass,* 1969; *Mahajan et al.,* 1990; *Vinet, Zhedanov,* 2010]. Then a number of researchers had contributed to the study of diffusion. Diffusion modeling is a useful tool for understanding growth and to estimating future demand [*Rao, Kishore,* 2010]. The diffusion of innovation follows an S-curve pattern [*Fisher, Pry,* 1971]. This study conducts a macro study of the diffusion of EVs with two S-shaped growth Bass and logistic models.

Various factors such as the rapid reduction in the cost of batteries, a rise in gasoline prices, customer's awareness, government policies, operation cost, and others cause the rapid diffusion of greener and cleaner EVs [Åhman, 2006; *Liu et al.,* 2013; *Rezvani et al.,* 2015; *Scrosati et al.,* 2015; *Wansart, Schnieder,* 2010]. However, due to range anxiety, long charging time, and insufficient and inconvenient charging infrastructure, the adoption of EVs remains challenging [*Shen et al.,* 2019]. EVs are the best alternative for ecological reasons. The substitution of the conventional vehicle will be possible if EVs can subvert social and spatial inequalities and if the price of the vehicle can be controlled [*Ortar, Ryghaug,* 2019]. There are limited research studies that considered EV adoption and diffusion, but comparing and fitting with econometric diffusion models, estimating diffusion speed and acceleration, and forecasting using their diffusion parameters have not yet been studied. This paper aims to address those gaps considering the total BEV adopters from 2005 to 2018 with data extracted from a BNK securities (2019) report. The details of BEV adoption by the country that reported based on their previous releases and IEA data [IEA, 2019] by BNK securities in 2019 are presented in Table 1.

Theoretical Models

In this study, information diffusion epidemic contagion- logistic and mixed contagion- Bass diffusion models [*Frank,* 2004] are considered to analyze the diffusion of global BEVs. A brief explanation of the models is presented in this section.

Bass Model

A useful model for examining adoption patterns and forecasting the demand for new technology is the

Bass diffusion model [*Zhu, Du,* 2018]. The mathematical expression of the S-shaped Bass diffusion model [*Bass,* 1969] when each adopter buys only one unit of new product and market potential does not change over time is presented below:

$$N(t) = m\left[\frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}}\right] \quad (1)$$

where is the coefficient of innovation, is the coefficient of imitation, t is the time, is the total number of ultimate (potential) adopters by time t, and $N(t)$ is the cumulative numbers of adopters by time t. The coefficients p and q both are time-dependent variables.

Logistic Model

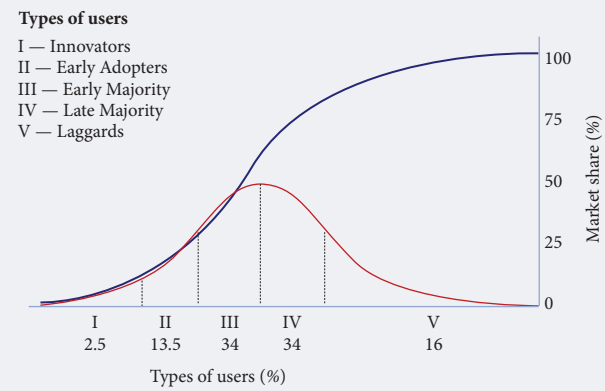
In this study, we used the Griliches logistic model [*Griliches,* 1957] that also follows an S-shaped sigmoid function. The cumulative adopters $N(t)$ of the innovation in logistic growth is expressed as in equation 2.

$$N(t) = \frac{m}{1+e^{-(a+bt)}} \quad (2)$$

where m is the potential adopters, a is the location or timing variable, b is the growth rate in the number of users relative to the proportion of agents who have not yet adopted the EV and t is time.

The logistic function performs symmetrically about its inflection point so that the maximum diffusion growth rate ($mb/4$) is reached when half of the maximum number of adopters ($N(t) = mb/4$) has adopted the new technology.

Figure 1. **Stages of Innovation Diffusion**



Source: [*Rogers,* 1983].

Empirical Analysis

Firstly, we estimated the diffusion parameters of Bass and logistic models using the NLS tool in R-studio. The details of the parameters are presented in Table 2. While fitting the Bass and logistic model with the global BEV adopters with data from 2005 to 2018, the residual standard errors are 24.18 and 24.84, respectively. We have chosen the Bass model as the best-fitted model for BEV adoption. According to the Bass growth, the potential adopters of BEV are 4.07E+04 and the coefficients of innovation and imitation are 2.52E-05 and 0.538 respectively, and adoption due to imitation is highly significant with a 99.9% confidence interval.

Table 1. **BEV Adoption by Country (in thousands)**

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Australia							0.05	0.22	0.41	0.78	1.54	2.21	3.42	5.22
Brazil										0.06	0.12	0.25	0.32	0.4
Canada							0.22	0.84	2.48	5.31	9.69	14.91	23.62	46.28
Chile							0.01	0.01	0.02	0.02	0.03	0.05	0.17	0.28
China					0.48	1.57	6.32	15.96	30.57	79.48	226.19	483.19	951.19	1767.06
Finland							0.06	0.11	0.17	0.36	0.61	0.84	1.35	2.12
France	0.01	0.01	0.01	0.01	0.12	0.3	2.93	8.6	17.38	27.94	45.21	66.97	92.95	124.01
Germany	0.02	0.02	0.02	0.09	0.1	0.25	1.65	3.86	9.18	17.52	29.6	40.92	59.09	95.15
India				0.37	0.53	0.88	1.33	2.76	2.95	3.35	4.35	4.8	7	10.3
Japan					1.08	3.52	16.13	29.6	44.35	60.46	70.93	86.39	104.49	131.02
Korea						0.06	0.34	0.85	1.45	2.76	5.67	10.77	24.07	53.71
Mexico								0.09	0.1	0.15	0.24	0.5	0.73	0.93
Netherlands				0.01	0.15	0.27	1.12	1.91	4.16	6.83	9.37	13.11	21.12	46.18
New Zealand						0.01	0.03	0.05	0.08	0.19	0.49	1.65	4.58	8.94
Norway			0.01	0.26	0.4	0.79	2.63	6.81	15.01	33.1	58.88	83.1	116.13	162.27
Portugal						0.72	0.91	0.96	1.1	1.29	1.97	2.78	4.67	9.1
South Africa									0.03	0.05	0.17	0.27	0.33	0.4
Sweden							0.18	0.45	0.88	2.12	5.08	8.03	12.39	19.54
Thailand		0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.28
United Kingdom	0.22	0.55	1	1.22	1.4	1.65	2.87	4.57	7.25	14.06	20.95	31.46	45.01	60.75
United States	1.12	1.12	1.12	2.58	2.58	3.77	13.52	28.17	75.86	139.28	210.33	297.06	401.55	640.37
Others	0.53	0.53	0.53	0.61	0.64	0.78	3.23	7.09	12.04	20.59	35.43	49.05	71.51	106.48
Total	1.89	2.23	2.69	5.15	7.48	14.59	53.53	112.92	225.5	415.74	736.9	1198.37	1945.78	3290.80

Source: [BNK Securities, 2019].

Table 2. **Comparison of Diffusion Parameters**

Parameters	Bass	Logistic
m	4.07E+07	3.61E+07
a(p)	2.52E-05	–9.898***
b(q)	0.538***	0.543***
Residual standard error	24.18	24.84

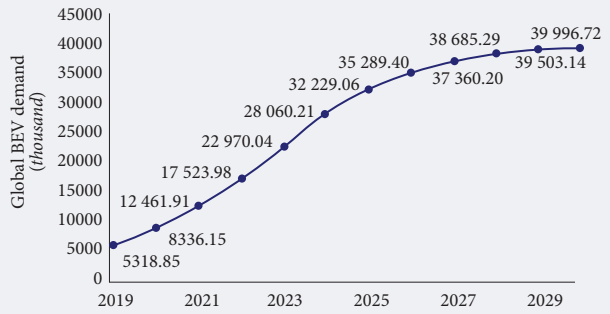
*** Significance at the 0.001 level.
Source: author's calculation.

Bass growth with the estimated parameters and the actual adopters of BEV [BNK securities, 2019] are plotted in Figure 2. We can see the Bass fit performers through the unique pattern with the actual adoption of BEV from 2005 to 2019. Similarly, future demand from 2019 to 2030, using the Bass growth parameters obtained in Table 1 is presented in Figure 3. The global BEV market is estimated to grow from 5,318,850 in 2019 to 39,996,720 units by 2030.

The first derivative of the Bass model (equation 1) with respect to time performs as the number of new adopters in a time unit. The dimension of speed is also measured in units per time, i.e., adopters per year. Similarly, the second derivative represents the adoption per square of time, which has the same unit as acceleration. The diffusion acceleration indicates the change in the number of new adopters in the period of time. The BEV adoption speed and diffusion acceleration are further calculated to analyze market fluctuations. The diffusion speed and acceleration, approximated by the first and second difference of BEV using the Bass diffusion function of the period from 2005 to 2030, are plotted in Figure 4.

The maximum diffusion velocity of BEV will be 5,387,248 adopters per year in 2023, and the maximum acceleration will be about 1,134,116 diffusion speed per year in 2020. After 2023, the acceleration of the diffusion will be negative and growing as time passes.

Figure 3. **Global BEV Demand 2019-2030**

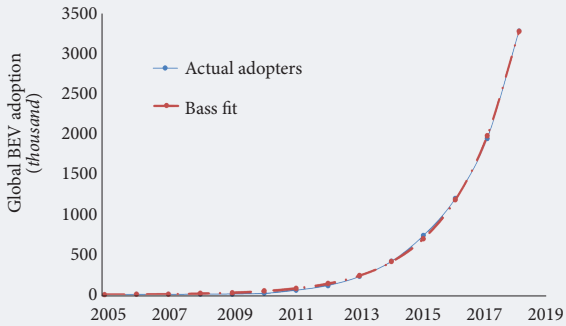


Source: compiled by the author.

Different Stages of BEV Diffusion

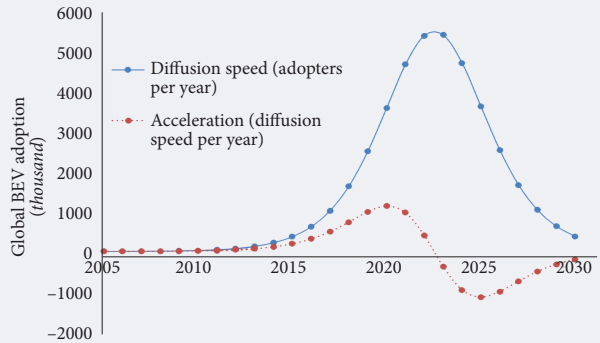
In 2000, the EVs were commercialized and subsequently BEV sales reached about 1,890 units in 2005 and 3,290,800 in 2018. As the different milestones in EV development influence the innovators and early majority, including with imitation effects, BEV technologies are highly and rapidly adopted in the world. Adopters are categorized as innovators, early minority, early majority, late majority, and laggards. The first 2.5% of the adopters are the innovators, the next 13.5% are the early adopters, the next 34% are the early majority, the late majority adopters are the next 34%, and the remaining 16% are the laggards as shown in Figure 1 [*Vinet, Zhedanov,* 2010]. Considering the maximum potential number of BEV adopters are about 40,710,000, the timeframes for the different stages can now be calculated. Innovators were the first 1,017,750 adopters, with

Figure 2. **The Fit of the Actual Adopters and the Bass Model**



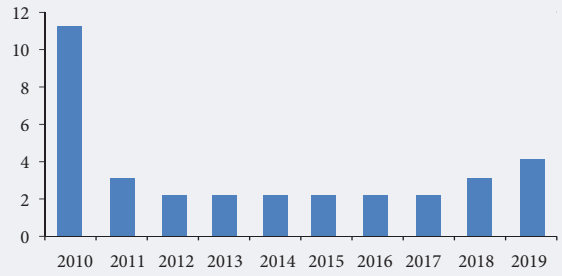
Source: compiled by the author.

Figure 4. **Diffusion Speed and Acceleration of Global BEV Adoption**



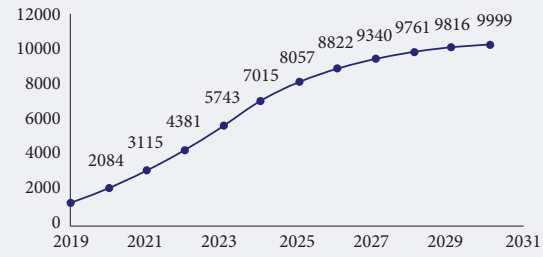
Source: compiled by the author.

Figure 5. **BEV per Charging Point**



Source: compiled by the author.

Figure 6. **The Demand for Public BEV Charging Points** (*thousands points*)



Source: compiled by the author.

this milestone passed in 2016. The next 5,495,850 users who were and will be added from 2016 to 2020 belong to the early adopters. By reaching the milestone of 20.36 million users in 2023, the participation of the early majority accounts for increasing users. Additionally, the increase in the number of BEV users from 20.36 to 34.2 million in the period 2023–2026 demonstrates the adoption as the late majority. The remaining, those who will adopt after 2026, can be regarded as the laggards.

Demand Forecasting for BEV Charging Points: Evidence From the EU

In the EU, the average BEVs per public charging point from the reference data observed from 2010 to 2019 is 3.3.[1] The details of BEVs per charging point in the EU is plotted in Figure 5. In this study, to forecast the demand for BEV charging stations, we have assumed there are four vehicles per charging station based on the scenario of EU countries in 2019.

Further, we forecast future global demand of BEVs based on the Bass diffusion growth model as explained above in section four and the public charging stations scenario in the EU. The detailed demand forecast for global BEV charging stations from 2019 to 2030 is presented in Figure 6.

When four vehicles per charging station and the global BEV adoption follow the Bass growth model, then there will about 10 million public charging stations in the world by the end of 2030.

Conclusion

This article studies the adoption and diffusion of BEVs in the world. The global BEV adoption data for 2005-2018 was fitted in the Bass and logistic models using the NLS tool in R-studio. The results show that the Bass model fits the data better than the logistic model. The final potential users of BEVs will be 40.7 million units. In the global scenario, early BEV adopters are active at present. We have forecasted the demand of the global BEV market using the Bass growth model, which is estimated to grow from 5,318,850 in 2019 to 39,996,720 units by 2030. Further, we estimated global demand for public charging stations for BEVs, using data for EU countries as a reference, which predicted that number of such station would rise from 2,084,000 in 2019 to 9,999,000 units by 2030.

For the optimal supply of energy sources, expected socioeconomic changes and future demand for energy must be considered in a timely manner [*Filippov,* 2018]. Loisel et al. [*Loisel et al.,* 2014] studied electricity demand of BEVs with the highly and slightly decarbonized scenarios and estimated that the total BEVs between 1,107,575 and 4,820,539 units would consume 2,400 MWh in the morning peak hour and 2,700 MWh during evening peak hour in 2030 in Germany. It should be noted that there is an extremely energy-intensive process during the manufacturing of the electric vehicle [*Milovidov,* 2019]. Without considering such energy consumption, the current study estimates future global demand for BEV charging stations based on the average adoption trends in the EU. The study can be a discussion document for researchers, policy designers, and green energy vehicle stakeholders to design their future research, policies, and sustainable infrastructures. The current study examined the speed and acceleration of BEV adoption on the global market, which the authors did not find in previous research. Such a time-dependent diffusion speed and acceleration study can pave the next path for electric vehicle market research.

However, there are some limitations to this study. First, there are many other diffusion models, but we

[1] https://www.eafo.eu/electric-vehicle-charging-infrastructure, accessed 15.11.2020.

adopted just Bass and logistic models to examine the diffusion pattern. Second, various factors affect diffusion, which are not considered in this study. Third, we have not made conclusions about the global situation surrounding velocity and acceleration in this study. They are estimated with first and second differentiation of the Bass model. Fourth, the global BEV public charging points may vary within different countries, but this study examined the public charging stations based on the present scenario of the EU.

Future work can address the limitations of the present study, including by analyzing and validating the factors affecting BEV diffusion globally as well as on country basis in order to examine the electricity required to meet future EV demand and in order to estimate impact upon the environment due to increasing EVs. This study focuses on global BEV diffusion. A similar study could also be conducted for individual countries and an estimation of their diffusion driving factors and BEV-related policy formulation studies could be considered in future research.

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Strategies for Green Economy in China

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Abstract

The transition to a "green" economic model is a complex strategic task that requires a combination of two previously incompatible development vectors: maintaining dynamic economic growth and preserving the natural environment on a long-term basis. No country has yet been able to cope with such complexity, nevertheless, the active search for a new balanced model continues, with the development of appropriate strategies. China is among the countries moving in this direction.

The article analyzes the influence of social, economic, and environmental factors upon the prospects for the development of a green economy and the preservation of natural areas in China. The dynamics of changes in the ecological situation from 1970 to 2018 is investigated. The authors propose a methodology for assessing the state of the environment based on demographic dynamics, economic indicators, and the level of technological development. Over the past 50 years, China has experienced intensive industrial development as a result of which the degradation of valuable natural assets is increasing in most regions. At the same time, efforts are being made in a number of provinces to remedy the situation through the formulation of new policies, the first results of which have been already visible. The government has established a new environmental legislation designed to scale the green practices of the pioneering regions throughout the country, including the trend toward the de-urbanization of individual megacities and others. The implementation of this strategy will be facilitated by the expansion of interdisciplinary scientific research, the development of complex technological solutions, and development programs that simultaneously take into account various factors.

Keywords: green economy; innovation strategies; sustainability; China wilderness areas; Kaya equation; wilderness area ratio (RWA); protected wilderness area ratio (PWA)

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Nowadays it is a common knowledge that "green" is a sustainable and sensitive economy that creates more useful instruments for humanity without causing ecological damage [*Costanza,* 1989; *Daly,* 2007]. German scientist Hugo Wilhelm Conwentz (1855-1922) and his follower Ivan Borodin were the first who at the end of 19th – beginning of 20th century started developing a nature conservation methodology, based on cultural and moral principles [*Williams,* 1996]. In recent times, all economic studies on the subject have aimed at finding answers to the questions emphasized in "The Limits to Growth" [*Meadows et al.,* 1972; *Hall et al.,* 2014]. There is a challenge to find a way to create a sustainable community and an improved quality of life without causing damage to nature. Preserving the natural productivity of ecosystems at the geopolitical level belongs to the concept of natural capital, although, we have not seen the ideas of sustainable development brought together with real actions by business and governments, individuals, and corporations in the economic sector [*Ward et al.,* 2016]. The UN included wilderness ecosystems as priority for conservation[1].

In recent years, mainly since the 12th five-year plan period, the enhanced measures including legislation, policy, regulatory, and economic means have been applied by the Chinese government in dealing with environmental problems. China's 12th five-year plan explicitly defined plans for the ultimate control of wilderness territory defenses and the optimization intensity of energy and water conservation [*Tang et al.,* 2018]. However, the synergy between wilderness conservation, energy efficiency, and economic growth has rarely been taken into consideration [*Xi,* 2020]. China's national policies promote high levels of economic growth, transforming China into a "world factory" since its opening and reform, but at a high cost in terms of sustainable energy and ecological protection. China faces a dilemma in upgrading its economy, energy system, and environmental security [*Tang et al.,* 2015]. Given this situation and concerning the demand of the government at different levels for environmental policy tools, the environmental policy research projects encompassing a wide range of subjects are carried out in China, especially those concerning nature conservation. China, as a seriously changed territory in terms of wilderness, needs to develop new complex models for the evaluation of how growth influences nature protection [*Bocharnikov,* 2019]. Indeed, the main problem is to increase data availability concerning wilderness areas [*Frelich, Reich,* 2009; *Kuiters et al.,* 2013]. Globally, the existing protected areas and Aichi Target 11 are not enough to slow the downward trends for biodiversity [*Cao et al.,* 2019]. Targets must be set for protected areas and the protected areas system should be further expanded [*Mittermeier et al.*, 2003].

Wilderness protection is increasingly important in the era of the Sixth Extinction and the Anthropocene [*Sandbrook,* 2015]. Cao Yue et al. in their research emphasized that wilderness areas have great value, however, China has not yet conducted an actual wilderness resources inventory [*Cao et al.,* 2019]. The concept of wilderness is lacking any accepted definition [*Nash,* 2014]. Thus, some research studies associated economic growth and urbanization with devastated lands and tried to find methods to define green urbanization processes [*Shi et al.,* 2016]. For example, there is a study for Portugal that uses special indicators to evaluate the diversity, rareness, and vulnerability of species in the National Park Peneda-Geres [*Ceauşu et al.,* 2015]. Steblyanskaya and Bragina examined how the largest companies could lead financial growth and pay attention to the energy, social, and ecological factors leading to sustainability and positive impacts for nature conservation [*Steblyanskaya et al.,* 2019]. In the same way, biophysical economics tries to find a path toward nature sustainability [*Cleveland et al.,* 1984; *Palmer,* 2018]. There must be a long-term co-integration between nature conservation and other green investments [*Costanza et al.,* 2015, 2017].

There are numerous useful initiatives in the world for developing the green economy and minimizing economic and social impact upon nature. Thus, in the US, wilderness values span the economic, environmental, and cultural spheres [*Proctor,* 2021]. The US National Wildlife Federation's first priority was to secure the passage of legislation that supported the North American Wildlife Conservation Model. The Federal Wildlife Restoration Assistance Act of 1937 resulted in the restoration of dozens of birds and mammals and stimulated countless conservation partners' work in recent decades. The Wildlife Act of 1964, championed by the Wildlife Society, established values still used today in state conservation in America. Since 2009, the USDA has provided more than 200 environmental innovation grants to support the search for new conservation solutions in a rapidly growing economy[2].

In Canada, environmental activities tend to be carried out in waves, closely associated with periods of activation of environmental sentiments in society [Locke, 2009]. One of the mechanisms for protecting protected areas in the Canadian Arctic was land ownership registration [Sahanatien, 2007]. Currently, Canada has approved a plan for climate change, green growth, and the conservation of natural values[3].

[1] For more details see the UNCED Convention on Biological Diversity (1992). https://www.cbd.int/doc/legal/cbd-en.pdf (date of access: 18.12.2020)

[2] US Department of agriculture https://www.usda.gov/topics/conservation (date of access 29.01.2021).

[3] Government of Canada https://www.canada.ca/en/environment-climate-change/news/2019/06/canadas-plan-for-climate-change-and-clean-growth.html (date of access 29.01.2021).

In 2002, Germany adopted the National Sustainable Development Strategy. Germany has also launched major cross-cutting initiatives in biodiversity, climate change, energy efficiency, and resource efficiency. The Energy Concept, the German Resource Efficiency program, and other ambitious environmental programs have helped Germany to significantly improve the energy efficiency, resource and carbon efficiency of the economy.

The United Arab Emirates supports sustainable development and provides a safe environment. Among the Gulf countries, the United Arab Emirates has been a leader in the application of clean technologies and alternative energy sources in the past few years [*Vaghefi et al.,* 2015].

A long-term African initiative, Great Green Wall (GGW), is being promoted to reduce desertification in the Sahel by planting a wide, uninterrupted strip of trees from Senegal to Djibouti. As a result, an integrated approach to large-scale land restoration, based on rural communities, led to the greening of approximately 12,000 hectares of degraded land between 2015 and 2017. However, the Great Green Wall initiative is still far from completion given of the creation of vast mosaics of green and productive landscapes where communities can thrive [*Connor, Ford,* 2014].

In this paper, the authors tested how economic, social, and environmental indicators influence Chinese wilderness areas' sustainable conservation. As a result of evaluating the ratio of a wilderness area (RWA), the ratio of protected wilderness area (PWA), and the ratio for wilderness area to population (WAP) for every China province, the authors obtained forecast models to predict the wilderness situation until 2030. The models' results can provide valuable information for the management of natural and protected areas. It is necessary to draw a general line, where on one side is economically sustainable growth and on the other, wilderness conservation. If a territory has economic growth with a high population density, then wilderness faces restrictions for conservation.

As for the research goals, the authors aimed at developing a protected wilderness area formula using similar logic to Kaya's equation. The equation components were further analyzed using principal component isolation analysis (PCA) and seasonal autoregressive integrated moving average model (SARIMA). Several research studies use such methods when analyzing components influencing ecological factors [*Kosman et al.*, 2019; *Palmer,* 2018; *Rasker,* 2006; *Wuerthner,* 2018]. However, only a handful of studies develop and make use of variants of the Kaya identity formula. Thus, the authors found it useful to create a formula using the same logic as the Kaya equation for analyzing components influencing China's wilderness situation. The presented methods and results will be useful not only in the context of studying the influence of economic and social factors upon the natural environment of China, but also in the context of studying other countries' green sustainable growth.

Methodology

Data Availability

Research data sources are described in Table 1, including land use, railway, road, population density, and investments in environmental protection. The authors use China inland data. Environmental data was obtained from the China Environmental Statistical Books, from 1970 to 2018, and from the EPS database[4]. Economic and social data were obtained from the China Statistical Data Books, 1970-2018. RWA/RPWA/WAP calculations were done based on Vladimir Bocharnikov's methodology [*Baklanov et al.*, 2018; *Bocharnikov, Huettman,* 2019]. Python 3.4 was used for modeling[5].

Kaya Identity for Wilderness Conservation

The identity developed by Yoichi Kaya is a specific application of the I = PAT identity, which relates human impact upon the environment (I) to the product of population (P), affluence (A), and technology (T). The authors were inspired by the Kaya formulation [*Kaya, Yokoburi,* 1997]. The Kaya identity is a tool used to understand and measure how CO_2 emissions and their underlying drivers change [*Lester, Finan,* 2009]. GDP growth is composed of GDP per-capita and population growth is connected to emissions with the Kaya identity [*Palmer,* 2018]. The Kaya identity states that total CO_2 emissions are the product of population, GDP per-capita, energy intensity, and carbon intensity (Equation 1.)

$$F = P \times G/P \times E/G \times F/E, \quad (1)$$

Where,

F — CO_2 emissions from human-made sources

P — Population

G — Gross Domestic Product (GDP)

E — Energy consumed

Thus, using the Kaya equation, we could analyze G/P = GDP per capita, E/G = Energy Intensity of GDP, F/E = Carbon Intensity of the energy supply.

In this study, the authors used the same logic and modified Kaya identity formula into the Protected Wilderness Areas (further — PWA) equation (Equation 2):

[4] EPS database http://olap.epsnet.com.cn (date of access: 29.01.2021).

[5] The Python code is written for calculating and the paper data are available at the GitHub at the following link: https://github.com/rufimich/enviromental_paper (date of access: 29.01.2021).

$$PWA = PWA/WA \times WA/LA \times LA/(RL+HL) \times (RL+HL)/GDP \times GDP/EC \times EC/WW \times WW/TIEPC \times TIEPC/P \times P \quad (2)$$

Where,

PWA — Protected wilderness area;

WA — Wilderness area

LA — Land area

RL — Railway length

HL — Highway length

GDP — Gross Domestic Product

EC — Energy consumption

WW — Wastewater discharge

TIEPC — Total investments in environmental pollution control

P — Population

The wilderness area ratio (RWA), protected wilderness area ratio (PWA), and protected wilderness area (sq.km) divided by the P — population (mln. people) (WAP) (Equations 3-5) were calculated based on Vladimir Bocharnikov's methodology [*Bocharnikov, Huettman,* 2019; *Baklanov et al.,* 2018].

$$RWA = WA/LA, \quad (3)$$

Where *WA* — Wilderness area (sq.km), *LA* — Land area (China) (sq.km).

$$PWA = PWA/WA, \quad (4)$$

Where *PWA* — Protected wilderness area (sq.km), *WA* — Wilderness area (sq.km)

$$WAP = WA/P, \quad (5)$$

Where *WAP* — Protected wilderness area (sq.km), *P* — population (mln. people).

The methodological research scheme is presented in Figure 1.

The authors identified the three indices (RWA/PRWA/WAP) for the evaluation of wilderness conservation. Detailed indicators can be seen in Table 1.

It was assumed that some trends determine the progress of wilderness conservation in Chinese provinces. Trends are independent of one another. As a result, it can be argued that every trend changes in its space, represented by one or more dimensions (components-vectors). Due to the independence of the trends, it can be observed that their space or "orthogonality" to each other is zero.

To remove economies of scale in the indicators, the authors used normalization. To do this, the authors used a reduction method for the standard normal distribution [*Zimmerman,* 2003].

$$Z_{ij} = \frac{x_{ij} - \overline{x}_j}{\sigma_j},\ i = 1,2\ldots,n; j = 1,2\ldots p, \quad (6)$$

Where,

$$\overline{x}_j = \frac{\sum_{i=1}^{n} x_{ij}}{n}, \sigma_j = \sqrt{\frac{\sum_{i=1}^{n}(x_{ij} - \overline{x}_j)^2}{n-1}}, \quad (7)$$

For the defined trends concerning the wilderness situation in the Chinese provinces for the period of 1970-2018, the authors used principal component isolation method analysis (further — PCA) (Figure 2) [*Features,* 2011].

PCA is a linear compression method for multidimensional space. It is based on the rotation of axes in space to find their optimal location. The axis's location is considered optimal if it allows you to describe the maximum diversity in the data:

$$\sum_{i=1}^{n}\sum_{l=1}^{m}\left(x_{il} - a_{0l} - \sum_{j=1}^{p} a_{jl}\sum_{q=1}^{m}(x_{iq} - a_{0q})\right)^2 \to \min, \quad (8)$$

where

$X = \{x_1, x_2, \ldots x_n\}$ — is an array of objects (the set of all points in multidimensional space);

k — is the number of parameters describing each of the objects;

$a_0 = \frac{1}{n}\sum_{i=1}^{n} x_i$ — is the distribution center of all points in multidimensional space;

$a_1 \ldots a_m$ — is the set of orthogonal vectors defining the axes of the selected components.

Algorithm for extracting PCA components:

1. The center of distribution of points of the array is determined $a_0 = \frac{1}{n}\sum_{i=1}^{n} x_i$;

2. The direction of the first orthogonal vector a_1 (the first principal component) is determined based on the given optimization function;

3. The projection onto the first principal component is subtracted from these points:

$x_i := x_i - a_0 - a_1(a_1, x_i)$.

4. The proportion of the remaining variance is estimated:

$D_1 = \sum_{i=1}^{n}\sum_{l=1}^{p}(x_{il})^2 \cdot$;

5. If the remaining variance D_1 is large, then the second principal component is introduced, and so on, until the variance in the remaining data is reduced to reasonable error.

The PCA method can be used for evaluating Chinese provinces' wilderness situation in the future.

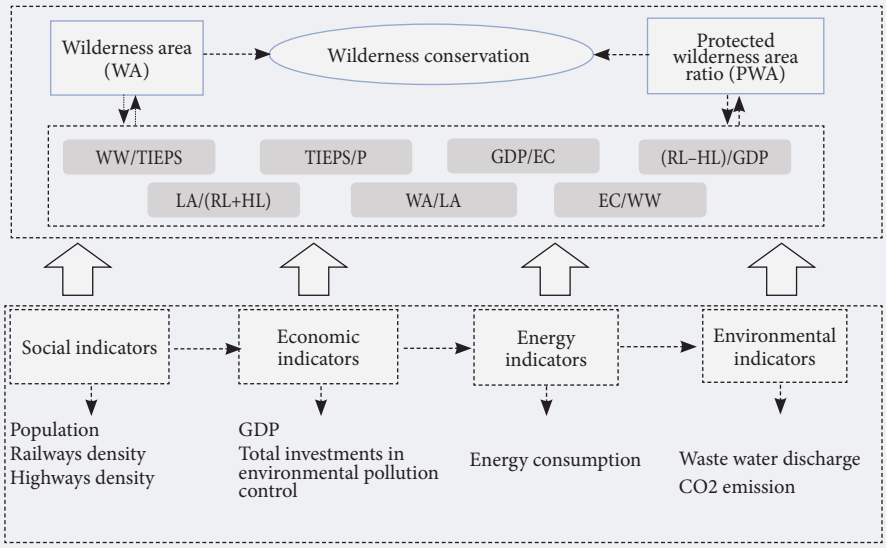
The Beijing, Tibet, and Shandong provinces are shown as an example. For other provinces' modeling calculations, see the attached file to the paper. The structure is not unique and can be adopted for each province or different applications. The authors firstly analyzed province-level protected wildness areas and then did a decomposition using variations of the wilderness identity. The indicators could be selected to map directly to every component of wilderness protection (Equation 3).

Results

Kaya Modified Wilderness Patches Formula Results

China's thirty-one provinces were analyzed according to the modified protected wilderness formula.

Figure 1. **Methodological Research Scheme**



Source: compiled by the authors.

Wilderness area calculation result maps are presented in supplementary materials to the research. The authors chose only three provinces as the most "visual" for the China wilderness situation and as the most representative. The three areas are different from each other – Tibet with the greatest number of wilderness areas, Shandong with the smallest wilderness areas, and Beijing as the area with a high population density and small wilderness areas but a high level of the wilderness protection. For every province, a forecast was done up to 2030 under the multi-factors scenario (Figures 3-5). Beijing increased enormously in GDP/EC, that is the energy efficiency increased exceedingly over the past 40 years. Similarly, TIEPC/P increased possibly due to the difficult ecological situation in Beijing.

Beijing WA/LA has not changed since 1978. The Beijing government has been constructing natural preserves over the past 30 years, but the growing population mostly made up of outsiders (37.9% of the permanent residents) forced Beijing to exploit the land area. Such a phenomenon also appears in other big cities, for example, in Shanghai. However, Beijing has planned negative growth of urban construction (counter-urbanization) by 2035. It aims to reduce the constructed land from the current 2,860 to 2,760 sq. km by 2030. GDP/EC increased sharply, implying that Beijing's economic development is no longer heavily dependent on the consumption of energy.

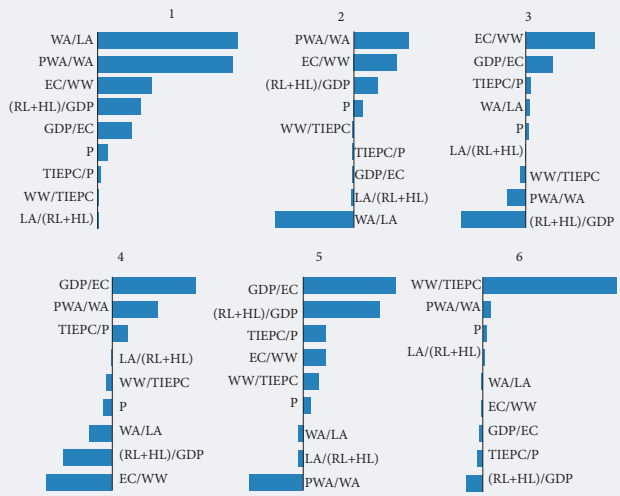
Tibet's WA/LA PWA, and PWA/WA from 1978 until 2018 remained the same. At the same time, Tibet EC/WW and GDP/EC increased. There are 47 protected wilderness patches in Tibet covering an area of 41.4 mln. sq.km in total. Meanwhile, Tibet has the second largest land area in China, with a high altitude that brings about inconveniences for traffic and a stably low population balanced by birth rate, death rate, and brain drain. This results in a conspicuously high level of WA/LA and PWA. The energy efficiency grew slightly over the 40-year period. The Chinese government is building an ecological barrier for the Qinghai-Tibet Plateau by massive afforestation. This

Table 1. **List of Research Indicators**

Indicator	Code	Measure
Social		
Population	P	bln
Railway length	RL	km
Highway length	HL	km
Economic		
GDP	GDP	bln
Total investments in enviornmental pollution control	TIEPC	bln
Energy		
Energy consumption (10 thousands of standard coal)	EC	ga/ population
Environmental		
Land area, sq. km	LA	thousands of hectares
Wilderness patches area,	WPA	thousands of hectares
Ratio of wilderness area	RWA	%
Protected wilderness area (1000 sq.km)	PWA_SQ	thousands of hectares
Ratio of protected wilderness areas	RPWA	%
Ratio wilderness area/population	RWP	%
Wastewater Discharge	WW	thousand meters cub

Source: compiled by the authors.

Figure 2. **Kaya Wilderness Identity Component Analysis**

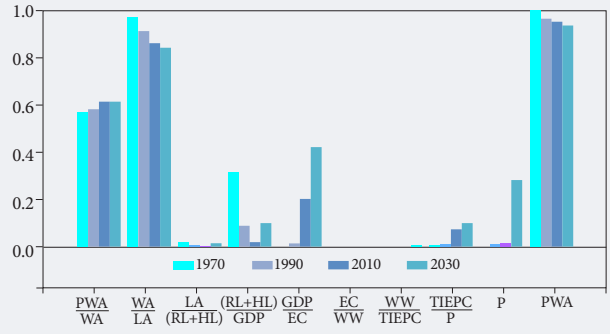


Source: compiled by the authors.

behavior induces a sharp increase of the wilderness area in Tibet and Qinghai. A large increase in the population is expected by 2030 following the opening of the Qinghai-Tibet railway. Transport convenience in Qinghai and Tibet, and industrial and economic development as well as urban construction are smoother, thus retaining more indigenous people and attracting outsiders. Therefore, by 2030, protected areas are expected to decrease in size due to the demand for housing and food as a result of industrial development and population growth.

Shandong EC/WW rapidly increased because of the TIEPC/P lack of investments. Shandong PWA/WA stagnated for a long time. Nevertheless, (R+HL)/GDP was increased, which may be because Shandong has transferred its economic structure from one dominated by a single industry to various ones. Shandong has 86 protected wilderness areas covering 1.1 mln. sq.km., albeit colossal population growth. What is more, Shandong together with Hebei and Henan are located on the Huang-Huai-Hai Plain, where agriculture is flourishing, thus arable land occupies a large area.

Figure 4. **Tibet Analysis for the Period 1978-2018**



Source: compiled by the authors.

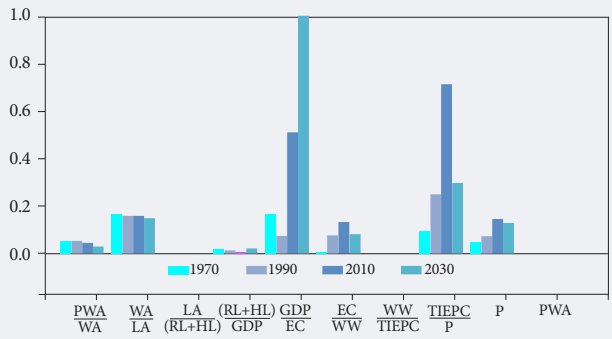
PCA results

The authors evaluated every province according to the Kaya modified identity component analysis (Table 2, Figures 6-10).

First component, 33% variability. The most significant values of this component are possessed by Tibet (47 protected wilderness patches, 41.4 mln. sq. km) and Qinghai (11 protected wilderness areas, 21.8 mln. sq.km), Xinjiang (27 protected wilderness patches, 21,494,365 sq.km), and Sichuan (167 protected wilderness patches, 9,006,856 sq.km). The lowest wilderness indicators are seen in Beijing (20 protected wilderness areas, 133,966 sq.km.) and Hebei (35 protected wilderness areas, 587,268 sq. km) because of the increasing populations in these provinces. On the other hand, Hebei's industrial system is strongly based on coal, steel, and textile industries, which all rely heavily upon land resources.

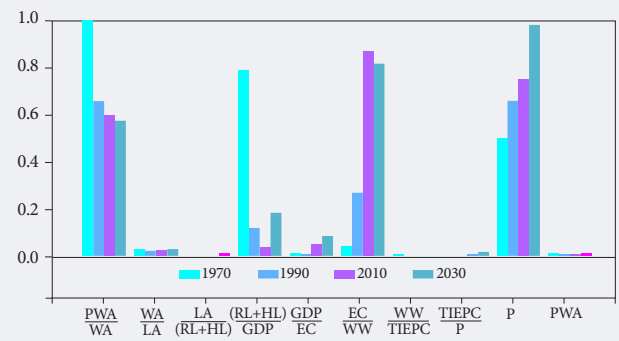
Second component, 25% variability. On the one hand, there are provinces with large wilderness territories,

Figure 3. **Beijing Analysis for the Period 1978-2018**



Source: compiled by the authors.

Figure 5. **Shandong Province Analysis for the Period 1978-2018**



Source: compiled by the authors.

Table 2. **Kaya Wilderness Identity Component Analysis**

	1	2	3	4	5	6
PWA/WA	0.648626	0.506946	-0.187239	0.343734	-0.406296	0.037251
WA/LA	0.663000	-0.725034	0.051394	-0.175843	-0.019821	-0.009151
LA/(RL+HL)	0.014633	-0.011236	0.003877	-0.008797	-0.035328	0.008868
(RL+HL)/GDP	0.206144	0.219079	-0.647432	-0.381764	0.568404	-0.128007
GDP/EC	0.164741	-0.007912	0.262397	0.648581	0.659313	-0.028756
EC/WW	0.257215	0.400941	0.683103	-0.513748	0.169738	-0.009462
WW/TIEPC	0.015156	0.004186	-0.060457	-0.043689	0.116060	0.989485
TIEPC/P	0.017780	-0.007498	0.054383	0.119379	0.174957	-0.041277
P	0.056218	0.091213	0.031995	-0.065965	0.051136	0.019061

Source: compiled by the authors.

such as Xinjiang, on the other – Shandong with a high proportion of protected areas and low emissions per unit of energy consumed. This component ranks the provinces by the degree of the struggle to preserve the environment from Xinjiang and Inner Mongolia to Shandong. A positive trend is growing in almost every province, especially in Sichuan.

Third component, 17% variability. This phenomenon sets the difference between provinces and the overall trend in their development. The trend is associated with two correlated factors: the values of GDP per kilometer of roads (in the formula it is written in the reverse form: the number of roads per 1 unit of GDP) and the amount of energy consumed per 1 unit of flows. Both of these indicators are growing in all provinces. To a greater extent, this was manifested in Guangdong, to a lesser extent in Yunnan.

Fourth component, 9% variability. This is related to energy consumption and its share of GDP and wilderness areas. The developed territories with a large number of non-energy-efficient industries (like Guangdong) have a small value of the component, at the other pole are Beijing, Hainan, and Taijing, where high energy efficiency is the key to survival.

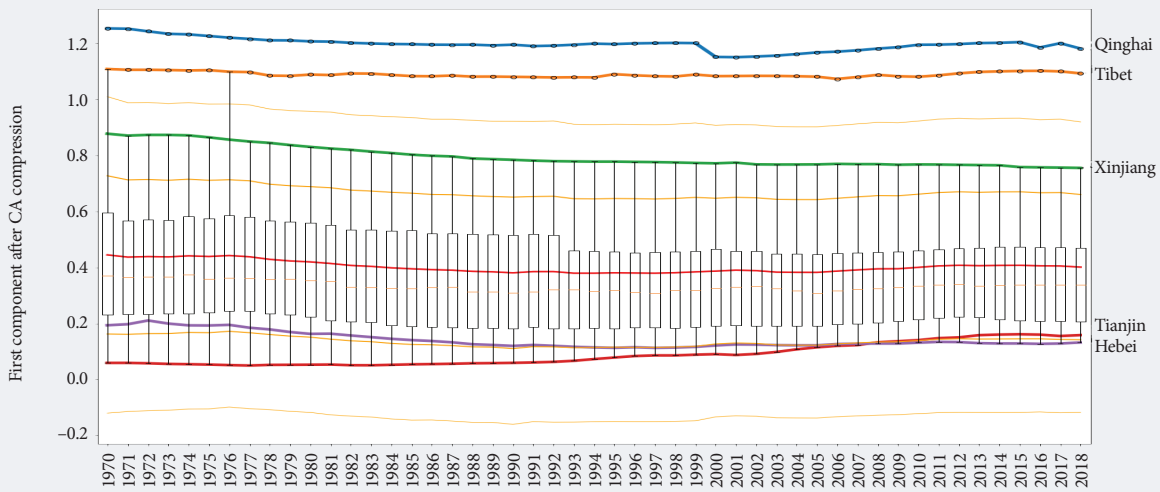
Fifth and sixth components, 8% and 4% variability, respectively. These distinguished the difference between small provinces. The fifth component reflects the difference in GDP, while the sixth component reflects the difference in the area. These components are not essential for the complete analysis.

Then, the authors used the first and second components to build trends concerning wilderness conservation in China from 1970 to 2018 (Figure 10). In Figure 10, the red lines mean devastated, emptied lands. Blue lines mean fresh wilderness patches.

Figure 10 demonstrates that Tibet, Qinghai, and Xinjiang have the most wilderness areas. Sichuan and Gansu have a trend toward exhausted, drained lands. Xinjiang produces a lot of oil and gas and is part of the "One belt – One road" territory. Tibet and Qinghai have many wilderness patches, but a low level of economic development due to inconvenient transport infrastructure caused by the high altitude (the first railway in Tibet and Qinghai was opened on July 1, 2006 with the length of 1,956 km). .

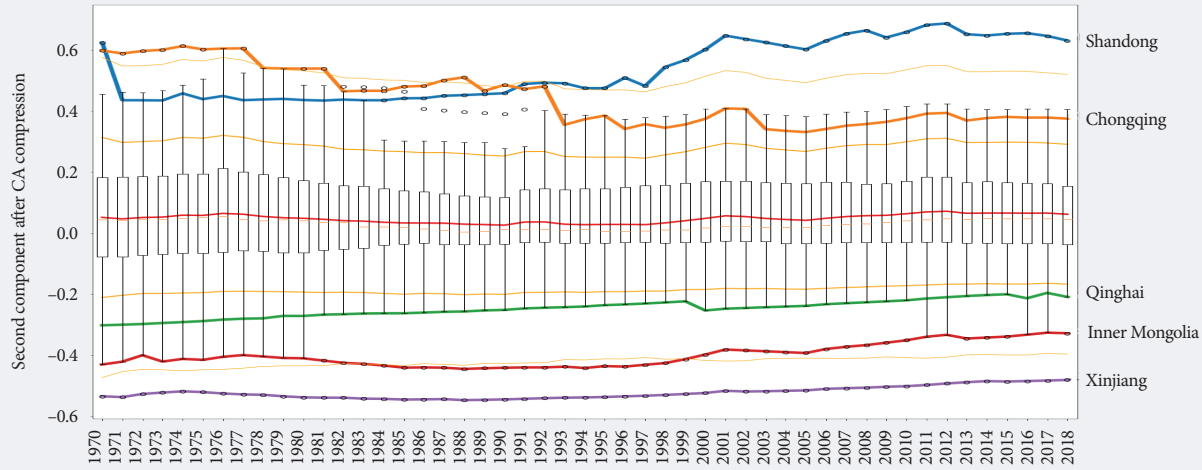
Gansu and Sichuan tend toward economic development and may therefore risk moving away from wilderness zones. Inner Mongolia, Heilongjiang, and

Figure 6. **Trends in the First Component Analysis after PCA Compression**



Source: compiled by the authors.

Figure 7. **Trends in the Second Component Analysis after PCA Compression**



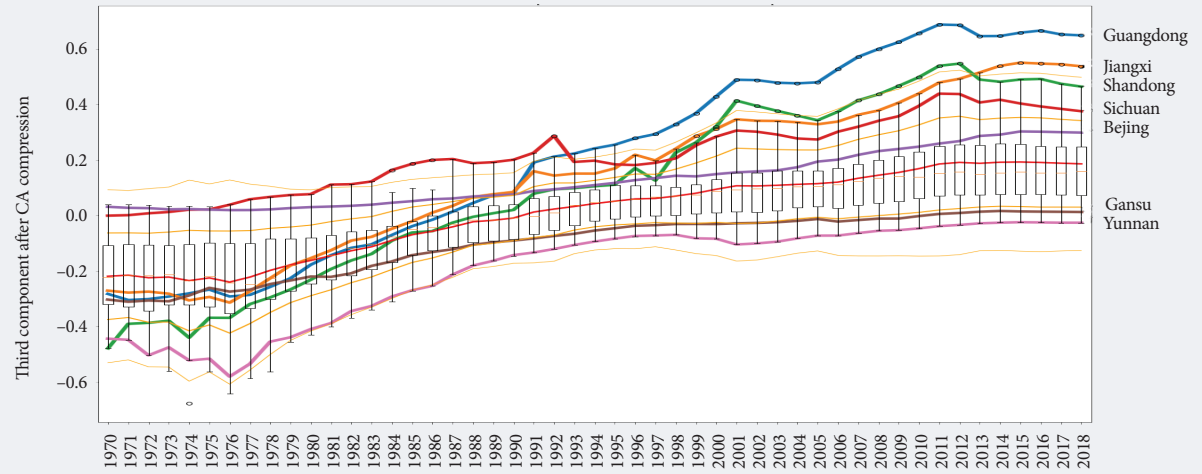
Source: compiled by the authors.

Jilin, all in the northern part of China, have few wilderness patches. All other provinces tend to have more devastated lands.

Figure 10 shows exciting results: in the 1970s, the wilderness situation in the provinces was not the same as it is now. For example, Anhui in the 1970s had the same features as Hunnan, however, nowadays it is like Guanxi. Chongqing and Hubei in 2018 also have transitioned into similar conditions. Nowadays, all "mini" provinces are linked together. It was also noticed that all the provinces in the middle of China with small land areas and mild altitudes were huddled, partly because they have much in common with regard to economic, social, and geographical indicators, so they usually take similar measures. For example, these provinces are centers of the manufacturing and coal industry in China.

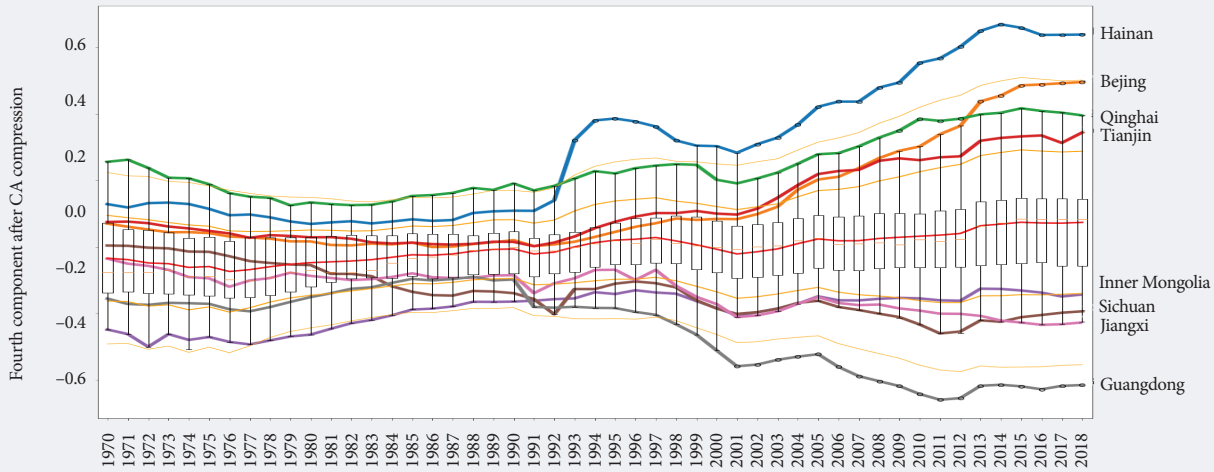
The analysis showed that Tibet, Xinjiang, Hainan, and Qinghai have the largest wilderness areas for every person per capita. Shandong, Hebei, Jiangsu, Jilin, Hubei, Zhejiang, and Liaoning on the contrary, have the smallest wilderness areas per capita. Shandong has the second largest population among the provinces in China. Indeed, the highest wilderness area ratio can be observed in Tibet, Gansu, Guanxi, Yunnan, Xinjiang, Qinghai, Guizhou, and Inner Mongolia. The lowest wilderness area ratio can be observed in the Shandong, Henan, Jiangsu, Zhejiang, Chongqing, and Hubei provinces. Thus, in these provinces industries are fully developed and have large population densities (Shandong is the second, Henan is the third) within a small area. Zhejiang has the most significant growth rate together with Guangdong concerning population. In 2018, Zhejiang's population

Figure 8. **Trends in the Third Component after PCA Compression**



Source: compiled by the authors.

Figure 9. **Trends in the Fourth Component after PCA Compression**



Source: compiled by the authors.

increased by 1.41%. Shandong has the highest level of economic potential among the top three Chinese provinces. Inner Mongolia, Heilongjiang, and Jilin are all in the northern part of China and have small wilderness areas. All other provinces have a tendency toward devastated lands. Tibet and Qinghai have many wilderness patches, but a low level of economic development. However, these areas are the main areas for the construction of the "One Belt-One Road Initiative".

Conclusions and Recommendations

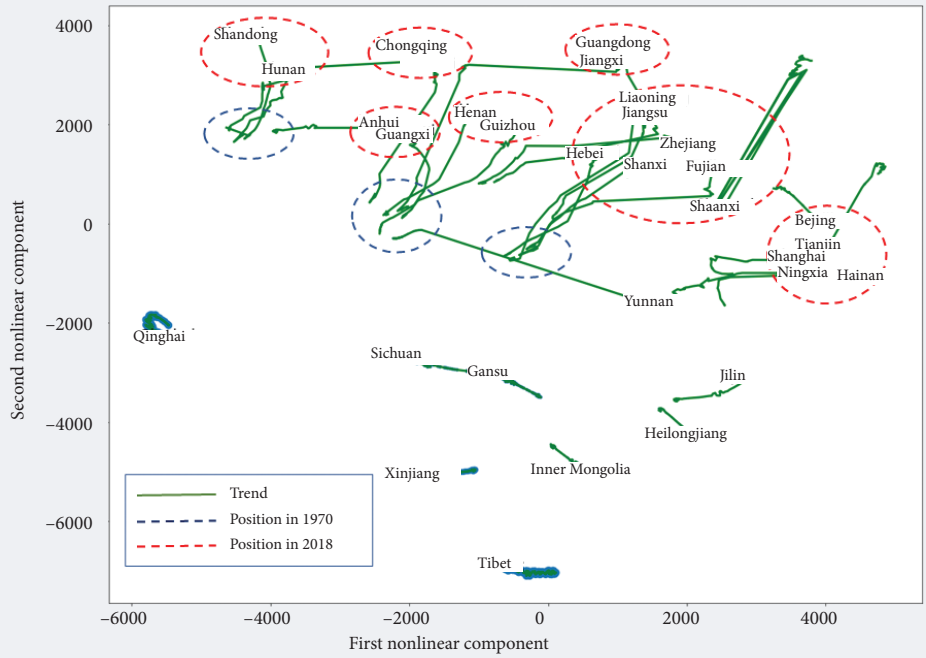
The authors found that the RWA/PWA evaluation alongside the modified Kaya wilderness identity components analysis produced fruitful and controversial results. In the 1970s, the wilderness situation of the Chinese provinces was not the same as it is nowadays. For example, the situation of Anhui in the 1970s was similar to that of the Hunnan province, while nowadays it is closer to Guanxi province due to the different environmental policies and regulations carried out. Chongqing is the neighbor of Hubei and nowadays it also has a similar wilderness situation. It has been observed that all the provinces in the middle of China with small land areas and mild altitudes were huddled, partly because they have much in common economically, socially, and geographically, so they usually take similar political measures.

China needs to develop the environmental economy in the interest of sustainability and economic competitiveness. Future research areas are based on wilderness geography to support green economy projects and programs [*Bocharnikov,* 2019]. As a consequence of ensuring "green growth", conflicts between ecological interests and business priorities should be minimized. The same conflict can be observed between environmental priorities and industrial programs and the creation of new and the modernization of existing transport corridors [*Vasiev et al.,* 2020]. China is still a largely agricultural country with a large population. In order to expand the arable land area, people are willing to destroy the forest and grass cover to open up the land and reclaim the lakes for farmland, which has caused great harm to the environment. The level of soil erosion is very severe in China.

The authors' opinion is that one of the reasons for this is that the principles of ecological economics and political ecology do not take into account laws that are developed in the real economy given that China has already started to develop territories that were considered wilderness areas before. The authors observe the following trends:

- In most Chinese provinces, the situation is leveled smoothly (development trends are moving away from wilderness). Meanwhile, an exception occurs in small provinces as they become similar to each other concerning wilderness conservation trends. From the perspective of ecological environmental management, it is mainly a natural ecosystem and watershed unit or airspace unit;
- However, the situation in China's northwestern provinces differs greatly. The geographical and regional background in such locations varies significantly, so it is impossible to regard them as a whole system and analyze them merely in the geographic dimension;
- In the 1970s, the first trend for moving out from wilderness began in the following provinces: Hunan, Henan, and Hebei. Nowadays, the situation is similar in all other provinces. They have

Figure 10. **Trends in Chinese Provinces' Wilderness Conservation for the Period 1970-2018**



Note: the red lines mean devastated, emptied lands; blue lines mean fresh wilderness patches.
Source: compiled by the authors.

all moved away from wilderness conservation. Moreover, the analysis illustrates a slow trend away from the wilderness in China's inner-middle and inner-western provinces, such as Anhui, Hubei, and Jiangxi as a result of their rapid development. Indeed, Jiangxi, Hubei, and Anhui have the highest economic potential among all provinces in China.

There are many valuable practices in the world for developing the "green economy" and minimizing its impact on nature. States have developed different points of view concerning the green economy: for developed countries in the first place this concerns jobs and welfare competition, while for developing countries the focus is on sustainable development and solving problems of poverty, and finally, for the BRICS countries, states emphasize energy efficiency. Nowadays, China's new "ecological civilization framework" is one of the most effective initiatives aligning green economic growth with wilderness protection. The new ecological legislation covers all provinces and considers nature conservation throughout the whole country [*Xi*, 2000].

The authors suggested a few ways of developing wilderness research studies in the future:

- Develop methods to measure how economic factors influence wilderness areas;
- Develop multidisciplinary methods to study the transversal linkage between social, energy, and environmental indicators and the wilderness patches.
- Develop methods to illustrate the cost of wilderness for humanity.

Therefore, when dealing with the relationship between sustainable growth and wilderness conservation, the government needs to insist upon implementing a green sustainable policy. The CPC has put forward measures such as reverting farmland to forests, grasslands, and lakes, and returning grazing land to grasslands. The challenge lies in increasing data availability on wilderness in China and the rest of the world and this must be addressed by involving appropriate definitional and habitat criteria and support plans for protecting and monitoring such areas effectively. The implementation of these measures would increase China's forest coverage, significantly expand the area of lakes, and regulate the climate and flood flow. China's ecological environment is expected to be significantly improved.

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Foresight for Small and Medium Enterprises in the Context of the Circular Economy

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Abstract

Small, medium, and micro enterprises make important contributions to economic growth and employment. Based on evidence from of the tire processing industry in Ecuador, this article assesses the development prospects for such companies in the context of the transition to a circular economy. The methodological basis of this study is scenario planning. Five scenario hypotheses are proposed and the probability of their implementation is estimated. The most optimal scenario (in which all five hypotheses are realized) is feasible and subject to a set of measures, including the development of new management and marketing tools, the involvement of universities and research centers in the creation of new low-cost waste processing technologies, and the organization of a special fund to support research and development in companies focused on the circular model.

Keywords:
strategic foresight; scenario planning; management; MSMEs; circular economy

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The economic contribution of micro, small, and medium enterprises (MSMEs) can hardly be overestimated. In OECD countries, MSMEs constitute 99% of all enterprises. In terms of employment generated, it is estimated that nearly 65% workers are employed at SMEs and nearly 30% of people work in a micro-enterprise [OECD, 2019]. The business dynamism, the development of technology, the reduction of barriers, and telecommunications have helped SMEs access the global market [*Dabić et al.*, 2020]. Nevertheless, most SMEs do not have any formalized strategies and a narrow assessment of the competitive environment. Latin America's MSMEs, in addition to exogenous challenges[1], particularly face such obstacles as an internal firm structure based on family ties that makes MSMEs vulnerable in terms of management, leadership style, and competition.

Despite this, there are some positive aspects to emphasize, such as the flexibility and adaptation to new production matrices in times of crises that regularly occur due to high volatility, uncertainty, ambiguity, and business complexity [*Doheny et al.*, 2012; *Bennett, Lemoine*, 2014]. Making the firm's dynamic capabilities work implies a continuous training process as well as restructuring strategies and business models.

Without a doubt, MSMEs in Latin America consider implementing the emerging circular economy paradigm a space for great opportunities that particularly allow for improving environmental quality. In this region, each inhabitant generates almost one kilogram of garbage per day (231 million tons of waste annually) and only 4.5% of waste is recycled in the entire region [*Kaza et al.,* 2018]. To approximately four million people in Latin America, their main source of income is generated by recovery, separation, and informal commercialization of garbage [*Stephenson, Faucher,* 2019]. The Ministry of Environment (El Ministerio del Ambiente, MAE) of Ecuador has made important efforts to regulate the recovery, disposal, and management of waste tires in the country with a key role played by specialized MSMEs in this field. However, in order for these companies to be able to solve the assigned tasks, they must improve their competencies. In turn, the government will have to improve the mechanisms of external regulation of their activities [*Laure et al.,* 2017].

The current worldwide recycling technologies for waste pneumatic tires allow for various products (see Table 1). However, the demand for certain types of products is not balanced due to the fact that the obtained "raw material" rarely meets the required characteristics, which means alternative solutions must be found [*Dobrotă et al.,* 2020]. The most efficient alternative is devulcanization that allows for significantly expanding the range of the new rubber materials and, accordingly, the range of products in demand [*Dobrotă, Dobrotă,* 2018].

This study analyzes the possible futures of MSMEs in the waste pneumatic tire sector employing the strategic foresight methodology. It results in the proposal of improvements in the growth of the activities of these enterprises and generating information that can improve national public policy regarding the circular economy. The methodology used and results obtained are important for studying the performance of these companies in other production cycles linked to the circular economy paradigm.

Literature Review

Large companies are led by executives with professional experience and management skills to manage them efficiently and effectively. While the fundamental nature of MSMEs (family-owned, small-sized, and focused on survival) makes it impossible to establish a rigid management scheme like those of large companies [*Block,* 2012; *Migliori et al.,* 2020]. In MSMEs, the founder generally assumes the functions that can decide upon the future of the organization [*Herrmann, Nadkarni,* 2014; *Vandekerkhof et al.,* 2018; *Diéguez-Soto et al.,* 2018]. Traditionally family firms have been adverse to hiring external managers to the top management team in an attempt to retain family control [*Breton-Miller et al.,* 2011; *Vandekerkhof et al.,* 2015]. On the other hand, studies show that, provided that when nurturing a specific corporate culture, the hiring of non-family personnel enables an increase in the dynamic capabilities of a firm [*Teece et al.,* 2009; *Dekker et al.,* 2015; *Howorth et al.,* 2016; *Wilden et al.,* 2016]. Such a culture involves coordination and collaboration programs, information sharing across functions and firms' departments, as well as the rapid codification and integration of knowledge gained as a result of dynamic interactions of employees both with internal and external partners [*Cohen, Bailey,* 1997; *Zahra et al.,* 2004; *Gunday et al.*, 2011; *Un, Asakawa*, 2015; *Cassia et al.*, 2012; *Chirico, Nordqvist*, 2010; *Volberda et al.*, 2010].

In Ecuador, MSMEs have a share of 99.53% of all enterprises, while microenterprises correspond to 90.81% (Table 2). MSMEs in Ecuador operate in the following sectors: food, construction, graphics, wood, metallurgy, electrical, textiles, chemicals, and ICT [*Burneo,* 2016]. As of 2018, there were 899,208 enterprises, of which 816,553 were microbusinesses and 64,117 were small businesses.[2]

Regarding sectors linked to the circular economy paradigm (companies that work with waste as inputs for new products), efforts to encourage the creation of a productive cycle are very recent, but the creation of

[1] According to a World Bank report, MSMEs generally face external problems such as corruption, taxation, excessive regulations, lack of credit and an unstable political environment [World Bank, 2017].

[2] According to the Instituto Nacional de Estadística y Censos (INEC).

Table 1. **Used Tire Utilization Matrix**

Types of use and/or enhancement	By-products obtained
Retreading	Retreated tires
Shredding (intermediate stage of use)	Rubber powder, rubber pellets, rubber chips
Recycling for artisanal purposes	Household goods, car details
High-tech recycling	Road coatings
Pyrolysis	Fuel
Co-processing	Construction materials, electric power

Source: Ministry of Environment, 2019. https://www.ambiente.gob.ec/, accessed 02.02.2021

the Plan for the Integrated Management of Used Tires (PIMUT)[3] represents a significant advance and a precedent for managing other waste. Ecuador discards millions of tires annually, a portion of which is reused for retreading, but most are either incinerated or deposited in open-air dumps, threating the environment. In Quito, there are 25 companies involved in the environmental management of used tires[4], 20 of which have environmental permits issued by the MAE, but only four are large companies (following the classification criteria presented in Table 3). Only seven environmental management companies use more than 80% of their existing capacity, of which four are MSMEs.

The Ministry of the Environment (MAE) has established progressive and incremental targets for the recovery of waste tires for importers and/or producers of tires in Ecuador.[5] The PIMUT detailed the process to be followed by importers and producers in relation to the marketing chain, communication mechanisms, collection, return, accumulation, transport, treatment, final disposal, and export. Through the PIMUT, a productive cycle linked to the circular economy paradigm has been activated. The large companies must recover the waste with the support of environmental managers, in the shape of MSMEs. According to the management capacity of MSMEs, the generation of a fair market for the effective use of this type of waste and the promotion of the inclusion of MSMEs within new production cycles was expected. However, among the initial challenges were limited demand and a high cost of new technologies versus the costs of the management of the tires received, which does not promise significant gains in the short term. Aid from the government represented by the MAE leads to certain, positive shifts, but they are not sufficient from a business point of view.

In the entire country, there are only three companies (MSMEs) possessing the often expensivecapacities to shred used tires: Rubber Action, Ecollantas, and Incinerox. Rubber Action was faced with decreased demand in 2019 due to the saturation of the market with used tires (unshredded residue). The company asked the national government to encourage the use of the tire powder. However, aid from the government was insufficient, which is why Rubber Action sought allies at several universities in Ecuador, especially in the city of Quito in attempt to design a less costly processing technology.

Table 2. **Structure of Ecuadorean Companies According to Their Size**

Size of business	No. of businesses
Micro business	816 553
Small business	64 117
Medium A business	8 529
Medium B business	5 749
Large business	4 260
Total	899 208

Source: compiled by the authors using [INEC, 2019].

Study Method

The aim of this study is to generate future scenarios on the operations of MSMEs dedicated to the management of waste pneumatic tires in Ecuador. These scenarios have been generated through a strategic foresight methodology. The research is divided into three stages:

- Literature review, reviewing the theories related to management at MSMSs, identifying the main components of the strategic foresight methodology and, thus, choosing the most appropriate tools according to the research objective.
- Interviews and working sessions with stakeholders about variables and hypotheses, based on the defined strategic foresight methodology.
- Data collection from experts and data processing using the tools defined at stage one to obtain the future scenarios matrix.

The research and practice of strategic foresight has a tradition that reaches back to the late 1940s [*Coates et al.,* 2010]. Foresight grew out of the pioneering work of

Table 3. **Classification Variables: Company Size**

Size	Annual sales (USD millions)	Number of affiliated staff members
Large	More than 5	200
Medium B	2–5	100–199
Medium A	1–2	50–99
Small	0.1–1	10–49
Micro	Less than 0.1	1–9

Source: compiled by the authors using [INEC, 2019].

[3] Approved by the Ministerial Agreement No. 20 of 2015. Finished at 2020.

[4] Currently, the organizations dedicated to the management of waste pneumatic tires are within the Standard International Industrial Classification E3830.02 related to the recovery of rubber products such as used tires to obtain raw materials [INEC, 2020].

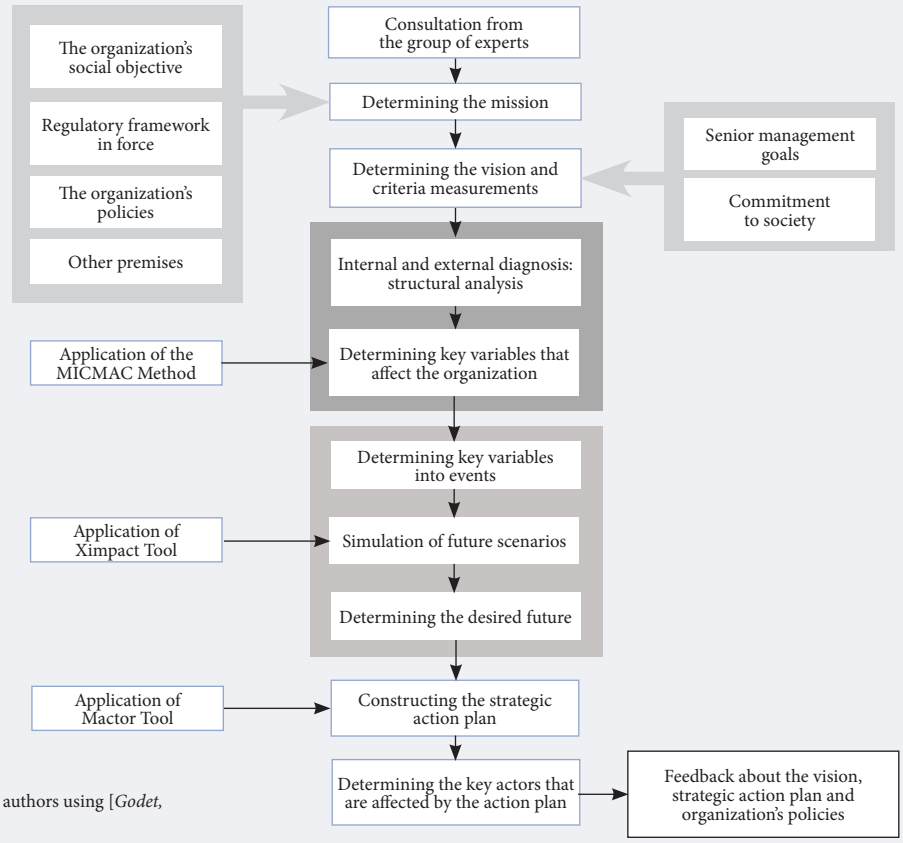
[5] Through the National Program for the Integrated Management of Solid Waste (Spanish acronym: PNGIDS) under Ministerial Agreement 98 in 2013.

Bertrand de Jouvenel and Gaston Berger [*de Jouvenel,* 1967; *Berger,* 1964] who emphasized the need to create shared future perspectives in a management group. In the run of the following decades, numerous research studies used mathematics, probability, and operational research to establish some techniques in relation to the scenario method, structural analysis, cross-impact matrices, and the strategies established by actors. These tools have allowed foresight to be used at any type of company [*Medina Vásquez,* 2006].

Scenario planning is a key ally of organizations in terms of strategic planning. It allows for comparing various alternative evolution paths and choosing the preferred one [*Schwartz,* 1996]. Two types of scenarios stand out: exploratory scenarios, which start from the past and present trends that allow for futures; and anticipatory scenarios, which originate with the outlines of a desired future [*Godet, Durance,* 2011]. In business areas such as finance or human resources and also in studies related to the environment, the scenario planning technique is applied to understand future contingencies about a local or national problem. In the field of technology, scenario planning is also valid, for example in Indonesia, Hutajulu et al. established two scenarios for 5G implementation, a model that was designed by analyzing the respondents' ideas [*Hutajulu et al.,* 2020]. As with other tools of strategic foresight, scenario planning allows decision makers to establish a course of action, predict the effects, and incorporate strategic resources in order to achieve a significant competitive position [*Rohrbeck,* 2012; *Peter, Jarratt,* 2015; *Gavetti, Menon,* 2016].

Scenario planning is used in our study to evaluate the possible future scenarios of MSMEs dedicated to the management of waste pneumatic tires in an increasingly complex business environment. The authors chose this sector because in Ecuador since 2020, a roadmap toward the circular economy has been established in which the public and private sectors participate, emphasizing the MSMEs dedicated to the management of waste pneumatic tires. The initial step was the signing of a National Pact for a Circular Economy in which more than 160 organizations committed to support the lines of action to implement this concept and is a sign that shows the future based on four pillars: sustainable production, responsible consumption, integrated waste management, and policy and financing mechanisms for circular projects.[6] With this background, we consider it is important to carry out this exploratory research using strategic foresight to establish future scenarios that will allow MSMEs to define strategies to face the rapidly changing and complex environment. The strategic foresight method is structured around several stages, as shown in Figure 1.

Figure 1. **Stages of Strategic Foresight**



Source: compiled by the authors using [*Godet, Durance,* 2011].

[6] https://www.produccion.gob.ec/ecuador-camina-firme-en-la-ruta-de-la-economia-circular/, accessed 13.02.2021.

Interviews with Experts

The questionnaires were compiled during preliminary working sessions with experts to link the questions to the objective of the study: the situation of MSMEs dedicated to the management of tire waste. The list of experts was determined, chosen based on their knowledge and experience in the sector, using the "Propone" method and software, which facilitates calculations by establishing a weight based on the criteria considered for each expert [*García Peñalvo,* 2010]. The experts' background is provided at the Table 4.

Five hypotheses were defined as a result of interviews in relation to (1) production optimization, (2) quality inputs, (3) efficient management of financial resources, (4) obtaining by-products, and (5) the research and development processes.

Analytical Tools

After a bibliographic review of the method and its components, we decided to use the following tools, which corresponded to the study's objective.

MICMAC analysis. The acronym MICMAC comes from the words "cross-impact matrix multiplication applied to classification" [*Godet et al.*, 2007]. The MICMAC structural method seeks to analyze, in a qualitative way, the relationships between the variables that make up a system within a company, organization, society, country, and so on. The objective of the MICMAC Structural Analysis is to identify the main variables, influential and dependent, as well as the essential variables for the evolution of the system. Using MICMAC software, a list of 11 variables of the MSMEs' sector of waste pneumatic tire management was made and relationships between the variables were determined and the key variables established.

MACTOR analysis. The MACTOR method (Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations) proposes a way for analyzing the role played by the stakeholders in the study dynamics [*Godet et al.*, 2007].

Table 4. **The Experts Background**

Expert	Position, background
1	Ministry of Environment- Specialist of the National Program for the Integral Management of Solid Waste (PNGIDS).
2	Secretary of Environment of the Municipality of Quito - Director of Environmental Policies and Planning.
3	Manager of Proyección Futura-Gestión y Reciclaje Integral de Neumáticos. Environmental Manager who develops and implements management systems for integrated waste management.
4	Manager of Ecocaucho-Industria Recicladora de Caucho S.A.: company dedicated to the manufacture of recycled rubber products through the management of end-of-life tires.

Source: compiled by the authors.

Table 5. **Identified Variables**

No.	Long label	Short label
1	Management of input purchases	inputpurch
2	Storage capacity	StorCap
3	Transport capacity	TranspCap
4	Production capacity	ProdCap
5	Quality processes	QualProc
6	Operating costs	OperCosts
7	Financial resources available	FinanRec
8	Workforce productivity	WorkFProd
9	Strategic planning	StratPlan
10	Research and development/innovation	R&D
11	Commercial strategies (market and sales)	Mkt&Sales

Source: compiled by the authors.

SCIM analysis. The SCIM (Systems and Cross Impact Matrices), developed at the Battelle Institute in Geneva, is designed is to determine the probability of the scenarios created according to the hypotheses defined. For each expert, the probability of each scenario is calculated using a quadratic minimization method. The results are obtained for each expert and over the set of experts, establishing the weighted average of the probabilities calculated for each expert [*Quinteros, Hamann,* 2017]. Once the probability solutions of the scenarios are calculated, a choice criterion is introduced: it is established as the ideal solution that corresponds to the set (probabilities of the scenarios). The most probable scenario is the one with the highest possible value (on the average that the experts considered when answering the questionnaire). The solution that meets this criterion is obtained by the simplex algorithm, since it is a linear function to be optimized under linear problems[7]. When a system of *N* hypotheses is considered (sets of hypotheses or scenarios), it is possible to choose which of the *N* possible hypotheses should be taken into account due to the probability of realization, which is estimated on the scale from a probability of 1 (very weak) to a probability of 5 (very probable). Then the probabilities of the scenarios are established, in which the analysis of the experts' responses is carried out thus providing a probability for each of the *N* possible combinations of the *N* hypotheses [*Astigarraga,* 2016].

Results

The tools of the prospective method were applied to the operations of the MSMEs dedicated to the management of waste pneumatic tires to determine future scenarios and identify strategies that allow for better performance and competitiveness.

The ***MICMAC Analysis*** covered the 11 variables (Table 5). These variables were crossed in the direct impact matrix (Table 6), in which each cell represented the relationship of two variables:

[7] http://es.laprospective.fr/Metodos-de-prospectiva/Los-programas/70-Smic-Prob-Expert.html, accessed 15.02.2021.

Table 6. **Matrix of Direct Impacts**

	1. Inputpurch	2. StorCap	3. TranspCap	4. ProdCap	5. QualProc	6. OperCosts	7. FinanRec	8. WorkFProd	9. StratPlan	10. R&D	11. Mkt&Sales
1. Inputpurch	0	1	1	1	1	1	1	0	0	1	0
2. StorCap	0	0	0	0	1	1	1	0	1	0	0
3. TranspCap	0	0	0	0	0	1	1	1	1	0	0
4. ProdCap	1	1	1	0	1	1	1	1	1	1	1
5. QualProc	1	1	1	0	0	1	1	1	1	1	1
6. OperCosts	0	0	0	0	1	0	0	1	1	1	1
7. FinanRec	0	0	0	1	1	1	0	0	1	1	1
8. WorkFProd	0	0	0	1	1	1	0	0	1	1	1
9. StratPlan	0	0	0	1	1	1	0	0	0	1	1
10. R&D	1	1	1	1	1	1	1	1	1	0	1
11. Mkt&Sales	0	0	0	1	1	1	1	0	1	1	0

Source: compiled by the authors.

Table 7. **Matrix of Indirect Impacts**

	1. Inputpurch	2. StorCap	3. TranspCap	4. ProdCap	5. QualProc	6. OperCosts	7. FinanRec	8. WorkFProd	9. StratPlan	10. R&D	11. Mkt&Sales
1. Inputpurch	11	14	14	29	40	42	25	20	38	38	34
2. StorCap	9	10	10	15	21	22	16	13	21	19	18
3. TranspCap	11	11	11	12	18	19	15	14	19	18	18
4. ProdCap	21	23	23	33	51	53	35	33	52	49	48
5. QualProc	20	21	21	27	43	45	30	30	45	43	43
6. OperCosts	12	14	14	19	30	31	22	19	30	28	26
7. FinanRec	13	16	16	26	37	40	27	21	37	34	31
8. WorkFProd	13	16	16	26	37	40	27	21	37	34	31
9. StratPlan	10	13	13	24	33	36	23	17	32	30	27
10. R&D	21	23	23	34	51	53	35	33	52	48	48
11. Mkt&Sales	13	16	16	26	37	40	28	21	37	34	30

Source: compiled by the authors.

0: No influence

1: Weak influence

2: Average influence

3: Strong influence

Q: Potential influence

By raising this matrix to the successive powers (1,2,3...) until it was stable (so that the order of the factors is not altered), the indirect impact matrix shown in Table 7 was achieved. In this matrix, the sum of each column generated the dependency value and the sum of the values of each row, that is, the total dependency value. This procedure was applied for each variable.

As a result of this process, five key unstable variables were identified in case of MSMEs. These are: Production Capacity, Research & Development, Quality Processes, Management of Input Purchases, and Financial Resources. These key variables are those considered in this study for the development of the next stages of scenario design.

MACTOR Analysis allowed the authors to identify the stakeholders who influence and control the key variables in one way or another. At the same time, the main objectives linked to the key variables pursued by the stakeholders were identified (Table 8).

SCIM Analysis resulted in the formulation of the scenario hypotheses for each variable; the results are shown in Table 9.

Experts were consulted about the probability of fulfilling the proposed hypotheses. Forms were structured for simple, conditional positive, and negative probabilities. By means of an interview, the experts analyzed and filled out the forms that were then processed using SMIC software, thus obtaining the future scenarios.

Scenario Probabilities

After the probabilistic analysis, we constructed the various combinations of either performance, or the lack thereof, within the hypotheses, which generated multiple future scenarios with varying probabilities of realization (Table 10). The code representing the scenario is composed of a two-digit number representing the hypothesis followed by five spaces for single-digit numbers (only 0 and 1) representing the five key hypotheses. The figure "0" indicates that the hypothesis has not been fulfilled, whereas "1" indicates that it has been met. For example, if scenario 17 is presented as 17 - 01111, then scenario 17 is interpreted as having fulfilled hypotheses 2, 3, 4, and 5, whereas hypotheses 1 has not been fulfilled (as it has a value of 0). Table 10 shows the probability of carrying out the possible sce-

Table 8. **List of Identified Actors and Objectives**

Stakeholders	Chamber of Small and Medium Industry (CAPEIPI)
	Ministry of Environment
	Environment Secretary Office for the Municipality of Quito
	Micro-Entrepreneurs: Environmental managers
Objectives	Optimize the operation/production phase that generates value
	Establish processes to achieve research and development
	Develop quality by-products
	Acquire inputs from suppliers that provide quality and conform to environmental policies
	Establish a system for the optimization of financial resources

Source: compiled by the authors.

Table 9. **List of Variables and Assumptions about the Probabilities that Future Hypotheses Come True**

Variable	Future Hypothesis (Time horizon = 5 years)
Production capacity	The MSMEs in the sector will have a production process that generates value and an environmental policy
Research & development	The MSMEs in the sector will have a process that encourages research and development
Quality processes	The MSMEs will be producing quality by-products while protecting the environment
Management of input purchases	The sector's MSMEs will have an efficient input purchasing process and suppliers that provide quality and comply with an environmental policy
Financial resources	There will be a system for the optimization of financial resources

Source: compiled by the authors.

narios that respond to the combination of their occurrence or non-occurrence. Note from the accumulated percentage column that the trend core is given by 10 scenarios that represent more than 70% of the realization of all the hypotheses. Two of them have a greater presence — scenario 32 and scenario 1 — which individually have a probability of occurrence of 16.30% and 15.30%, respectively.

The Selection of the Best Scenario

If the most likely scenario would have only 0 values, it could be called a "total extermination" [*Mitma et al.,* 2009], which is scenario 32 in our case study as it has 00000 and is the one with the highest probability of occurrence (16.30%). This can also be called the trend scenario. On the other hand, the scenario we call the "Garden of Eden" in our research is scenario 01 – 11111, which also has a high probability of occurrence (15.30%), but this one will require strategic actions.

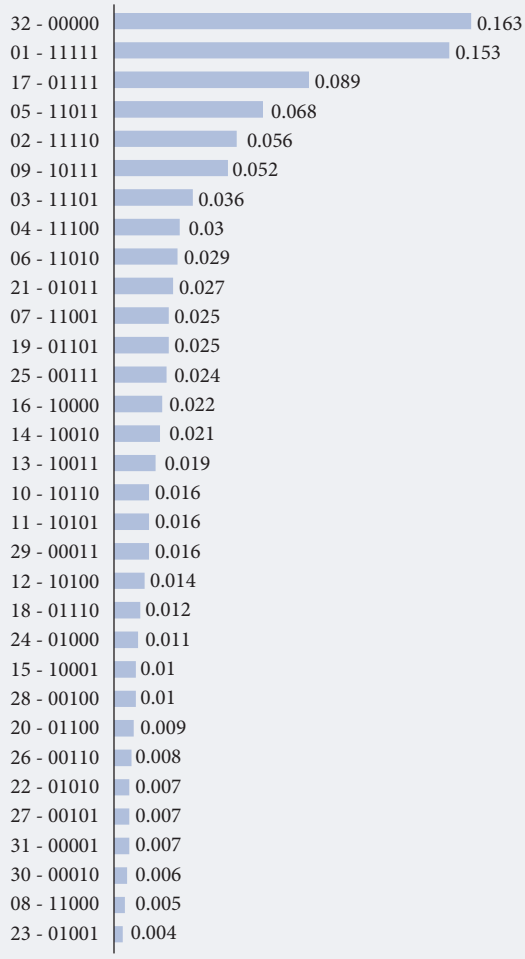
Table 10. **Probability Matrix for Each Scenario**

Scenario	H1	H2	H3	H4	H5	Group of experts (indiv prob)	Prob (%)	Accum (%)
32 - 00000	0.146	0.097	0.19	0.183	0.2	0.163	16.30	16.30
01 - 11111	0.137	0.294	0.182	0.038	0.115	0.153	15.30	31.60
17 - 01111	0.081	0.099	0.164	0.021	0.081	0.089	8.90	40.50
05 - 11011	0.111	0.078	0.04	0.047	0.064	0.068	6.80	47.30
02 - 11110	0.05	0.093	0	0.038	0.097	0.056	5.60	52.90
09 - 10111	0.062	0.143	0.024	0.031	0	0.052	5.20	58.10
03 - 11101	0.058	0.006	0.011	0.047	0.058	0.036	3.60	61.70
04 - 11100	0.008	0	0.073	0.031	0.041	0.03	3.00	64.70
06 - 11010	0.045	0.012	0.024	0.031	0.033	0.029	2.90	67.60
21 - 01011	0.04	0	0.032	0.029	0.035	0.027	2.70	70.30
07 - 11001	0.048	0	0	0.04	0.036	0.025	2.50	72.80
19 - 01101	0.012	0.005	0.058	0.029	0.021	0.025	2.50	75.30
25 - 00111	0.027	0	0.064	0.011	0.016	0.024	2.40	77.70
16 - 10000	0.016	0.034	0.018	0.003	0.038	0.022	2.20	79.90
14 - 10010	0.004	0.023	0.017	0.021	0.042	0.021	2.10	82.00
13 - 10011	0.029	0.028	0	0.039	0	0.019	1.90	83.90
10 - 10110	0.017	0.003	0	0.029	0.034	0.016	1.60	85.50
11 - 10101	0.025	0.015	0	0.039	0	0.016	1.60	87.10
29 - 00011	0	0	0.021	0.018	0.042	0.016	1.60	88.70
12 - 10100	0.015	0	0.03	0.022	0.003	0.014	1.40	90.10
18 - 01110	0.021	0.002	0	0.038	0	0.012	1.20	91.30
24 - 01000	0	0.049	0	0.006	0	0.011	1.10	92.40
15 - 10001	0.007	0.013	0	0.031	0	0.01	1.00	93.40
28 - 00100	0.014	0	0.023	0.015	0	0.01	1.00	94.40
20 - 01100	0	0	0.018	0.03	0	0.009	0.90	95.30
26 - 00110	0.008	0	0	0.026	0.005	0.008	0.80	96.10
22 - 01010	0	0.006	0	0.029	0	0.007	0.70	96.80
27 - 00101	0.002	0	0.013	0.019	0	0.007	0.70	97.50
31 - 00001	0	0	0	0.012	0.024	0.007	0.70	98.20
30 - 00010	0	0	0	0.017	0.015	0.006	0.60	98.80
08 - 11000	0.017	0	0	0.008	0.002	0.005	0.50	99.30
23 - 01001	0	0	0	0.022	0	0.004	0.40	99.70

Note: The values in the two last columns express the probabilities of the scenarios calculated for each expert and for all experts together. The process performed by the SCIM software gives a median solution through a quadratic minimization program and using the data obtained from the surveys.

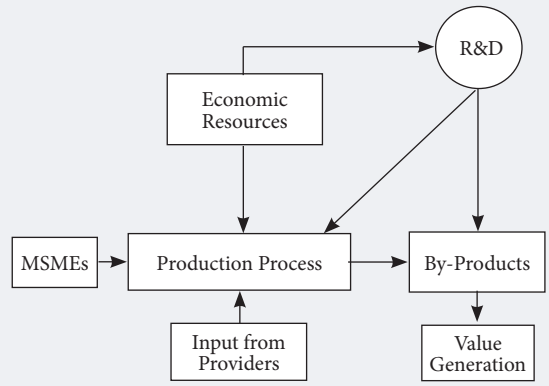
Source: compiled by the authors.

Figure 2. **Probabilities of Scenarios in the Form of a Histogram**



Source: compiled by the authors using SMIC software.

Figure 3. **Hypothesis Model and Its Relationships – Best Scenario (15.3%)**



Source:compiled by the authors using [*Mojica*, 1999].

The hypothesis model and its relationships with the best scenario are represented in Figure 3, while Table 11 displays strategic alternatives considering the five hypotheses.

Discussion and Conclusions

In Ecuador, as in many Latin American countries, MSMEs are the drivers of economic growth and job creation, as well as key contributors to the emerging circular economy model. The views of experts and stakeholders that participated in this study provided important key information about the future of MSMEs that manage waste pneumatic tires in Ecuador. To elaborate upon the possible scenarios for these MSMEs, five hypotheses were constructed. The results of the prospective tools show that scenario 32 — in which no hypotheses are fulfilled — has a 16.3% probability of occurrence, whereas scenario 01 — in which all five are fulfilled — has a 15.3% probability. The processing of expert views made it possible to establish recommendations for the most desirable scenario in which all the hypotheses were fulfilled. These results suggest that for there to be a significant change in these companies, all the variables must be met. That represents a key difference from large companies, where improvements in one area (e.g., finance) may improve the performance of the rest of the areas. Opportunities for the development of MSMEs, as a rule, are limited due to the lack of a qualified management system, the building of which is not considered by the owners of said enterprises as a key resource for development, and therefore they do not seek to master new management and marketing technologies.

As for the MSMEs in waste pneumatic tire management in Ecuador, one of their most relevant weaknesses currently is simply a lack of market consolidation. This is partly due to the fact that plans established in 2013 and 2015 did not consider how to stimulate the last links in the production cycle, namely the market for new products derived from the processing of tire waste. The public, and particularly consumers, do not know enough about needs that can be satisfied by the by-products obtained from waste pneumatic tires. However, marketing capabilities are complex coordinated patterns of skills, knowledge, and activities through which companies transform available resources into market-related value outputs. MSMEs can achieve better organizational performance by developing a market orientation that involves how the MSMEs understand the desires and needs of the market. The challenge of facing the technological advances that affect MSMEs is evident, as well as the effects of the changes in the environment. These are the factors that could threaten the performance of the organizations. To respond them, MSMEs need to develop managerial skills and partnership links that foster knowledge exchange. MSMEs alongside public administration must design strategies to address this challenge. For example: (1) the stimulation of the market through the certification of these products using an ECO seal or

Table 11. **Strategic Alternatives**

Hypotheses	Strategic alternatives
H1: The MSMEs in the sector have a production process that generates value and has an environmental policy.	• Generate financial policies that help firms acquire the appropriate technology. • Strengthen a permanent collaborative link between companies engaged in the marketing of products made from processed pneumatic waste.
H2: The MSMEs of the sector have an efficient process of input purchases and suppliers that provide high-quality materials alongside an environmental policy.	• Create and implement a management capacity development plan for MSMEs of this sector • Defined process for identifying suppliers that offer high-quality materials
H3: The MSMEs have a system for the optimization of financial resources	• Define processes to access financing, training, and fiscal incentives with an established guarantee system. • Training of existing personnel and hiring of specialists in the handling of economic and financial issues. • Establishment of a management style that optimizes financial resources.
H4: The MSMEs of the sector will produce high-quality by-products while protecting the environment.	• Conduct exhaustive market research to identify existing and potential demand. • Design marketing strategies in product, price, market, and promotion. • Incorporation of technology and technical knowledge to increase quality. • Design strategies that drive sales' growth and profit generation in the sector.
H5: The sector's MSMEs have a process that encourages research and development.	• Involve universities and research centers to find new improvements for production and management processes of waste pneumatic tires. • Implement a national fund for Research, Development, and Innovation (R+D+I) linked to MSMEs that support circular economy practices.

Source: compiled by the authors.

an environmental certification; (2) positioning of local and international products through labels such as "made in Ecuador"; (3) a linkage to national and international spaces of fair trade; and (4) linkages between large companies and MSMEs (through corporate social responsibility), to promote effective cooperation.

Although the consolidation of the pneumatic waste sector (under a circular economy logic) has the potential to continue growing, prospective studies can only serve as a starting point from which to generate strategies, especially in countries with a high level of economic instability such as Ecuador. Designing and implementing a strategic plan is difficult for MSMEs, however, this study's recommendations are aimed at assisting companies in Ecuador and other countries in this regard. The proposed recommendations should be studied and included in a binding instrument (the next phase of the Plan for the Integrated Management of Used Tires of the Ministry of Environment of Ecuador, for example, given that this plan expired in 2020) in order for the sector to continue moving forward.

Other points necessary for advancing in the study of MSMEs in the used tire sector is to highlight the potential links of these companies with large private and public companies. It is also important to study how the market for products derived from tire dust or shredded tires could be consolidated

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Corporate Practices of Green Human Resources Management

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Abstract

Green education and development has a great impact upon improving the environmental performance of companies. Using the example of Iranian small and medium-sized oil and gas enterprises, this article evaluates the practices' effect on environmental performance. The survey covered 386 employees from 30 companies. The most common measures of green human resources management were analyzed. All these practices have a positive and significant effect on the environmental performance of companies. The action of green education and development was introduced as the most effective measure. The results also demonstrated that four practices of green human resources management have a positive and significant impact upon performance due to environmental knowledge. Companies can use the findings of this research when implementing the green human resources management practices and continuous improvement initiatives for the environmental performance

Keywords: green skills; green human resources management practices; environmental performance; small and medium-sized enterprises; environmental knowledge of employees; oil and gas industry

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Undoubtedly, the corporate world is the major beneficiary in the discussion on environmental issues, and thereby, it is seen as an important part of the solution to resolve environmental hazards. Over the last several decades, a general consensus has raised the need for their active engagement in environmental management [*González, González,* 2006]. Several units of an organization, including marketing, information technology, and finance, need to work together to implement any corporate environmental program to make a positive and common impact, among which, the human resources management unit is recognized as a highly important factor [*Pham et al.,* 2019; *Clair, Milliman*, 2017; *Jaramillo et al*., 2018]. There is clear evidence, based on which, a large portion of the workforce in the business world have strong feelings about the environment, since in today's era, employees show more commitment to and greater satisfaction with organizations that actively participate in accepting and approving green activities.

Researchers confirm that green human resources management practices and measures have a significant impact upon the environmental performance of the organization by reducing waste and increasing organizational productivity [*Jabbour,* 2013; *Pham et al.,* 2019]. Previous studies suggest that environmental knowledge affects the employees' green behavior and their participation in environmental activities [*Angelovska et al.,* 2012; *Pan et al.,* 2018; *Guzman et al.,* 2020]. It is one of the important components that shapes people's attitudes toward environmentally friendly behaviors [*Zhao et al.,* 2014].

The development of green practices is of particular importance for Iran, which, like many other countries, encountered many problems over the course of recent decades, including those related to industrial pollutants. The severity of environmental pollution from waste in cities and concentration of industrial centers is such that it has drawn the attention of scientific and executive sources for the correct disposal or principled recycling of these materials.

This study seeks to evaluate the effect of green human resources management measures through the impact of environmental knowledge upon environmental performance using evidence from small and medium-sized companies operating in the Iranian oil and gas industry.

Theoretical Framework and Hypotheses

The green resources management measures and environmental performance

Green management addresses preservation and the optimal use of scarce natural resources [*Goswami, Ranjan,* 2015; *Renwick et al.,* 2016; *Yu et al.,* 2020]. It is directly responsible for creating a work environment that understands green practices, performs them, honors them, and also protects green goals in the human resources process, including recruitment, training, compensation for services, and the development and promotion of human capital [*Mathapati,* 2013]. Saeed et al. examined the effect of green human management measures on employees' environmental behaviors and introduced green human resources management measures affecting such environmental behavior as employment and green choice, green education and development, green performance appraisal, green reward and compensation, and green empowerment [*Saeed et al.,* 2018]. By selecting appropriate programs concerning the training of the organization's employees, the managers of human resources can promote the employees' awareness of environmental issues and this awareness can improve the performance of the organization in the area of environmental issues [*Egri, Herman,* 2000; *Ahmad,* 2015]. Thus, green HRM practices constitute a necessary change in the manufacturing industry [*Yong et al.,* 2020]. The green training and development of employees describes the environmental management values for them and trains them in methods for reducing waste, increasing environmental awareness within the organization, and also provides the employees with an opportunity to participate in solving environmental problems [*Zoogah,* 2011; *Paillé et al.,* 2014; *Daily et al.,* 2012]. The environmentally friendly ideas of all employees, regardless of their position and place in the organization, should be welcomed in order to implement green empowerment, doing so will increase their interest in environmental issues [*Ahmad,* 2015] and strengthens environmentally friendly behaviors [*Kim et al.,* 2019] Accordingly, the first hypothesis of this study will be as follows:

H1: The environmental performance of small and medium-sized manufacturing companies is positively and significantly impacted by Green Human Resources Management Practices, such as: green selection and employment (H1a), green education and development (H1b), green empowerment of employees (H1c), green payment and reward (H1d), and green management and performance appraisal (H1e).

The impact of the mediation role played by employees' environmental knowledge

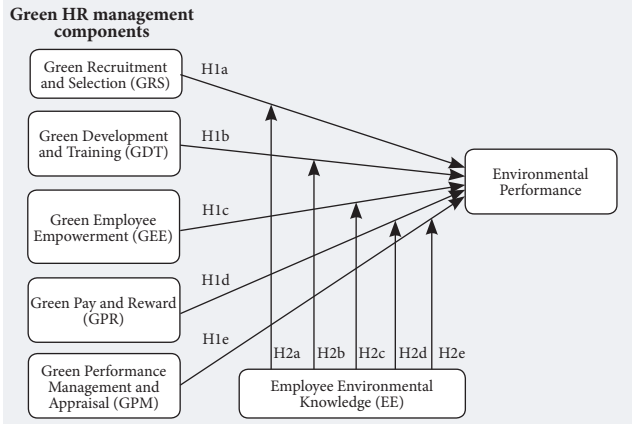
Knowledge management involves the process of optimally combining knowledge and information at an organization and creating a proper environment for production [*Hajimohammadi et al.,* 2019]. Cheng and Wu [*Cheng, Wu,* 2015] found that if employees have more knowledge about environmental issues and solutions, they can react better regarding said issues. Hence, one can say that environmental knowledge can play a mediating role in the relationship between green human resources management measures and environmental performance. Accordingly, the second hypothesis of this study is as follows:

H2: *Green human resource management practices through employees' environmental knowledge have a positive and significant impact upon the environmental performance of small and medium companies in such*

dimensions as green selection and employment (H2a), green education and development (H2b), green empowerment of employees (H2c), green payment and reward (H2d), and green management and performance appraisal (H2e).

According to the research goal and hypotheses, the conceptual model of this study is shown in Figure 1.

Figure 1. **The Research Conceptual Model**



Source: compiled by the authors.

Methodology

Data collection

We used a questionnaire in this study to collect the research data. All the questionnaire questions were assessed based on a five-point Likert scale. The values of this scale were defined from 1 (very weak) to 5 (very strong). We adapted our questionnaire from the questions used in previous studies [*Saeed et al.,* 2018; *Nejati et al.,* 2017; *Paillé et al.,* 2014] to measure exogenous variables. We used the Cronbach's alpha test to measure the reliability of the variables (Table 1). According to the criterion value (0.7), one can say that the reliability of exogenous external variables of the research is confirmed. The questionnaire questions are provided in Table 2.

The statistical population of this study consisted of small and medium-sized companies manufacturing equipment for Iran's oil and gas industries. The number of small and medium companies operating in this industry in the survey was estimated at 84 companies. We randomly selected 30 manufacturing companies as statistical sample members. In the next step, using the databases of the selected companies, we identified and selected the respondents for the questionnaires by using the judgmental method and according to the opinions of senior human resource managers, accounting for 386 subjects. The selection criteria for these individuals were chosen based on the opinions of the companies' human resources managers, which included having necessary knowledge and experience related to the human resources management measures, green human resource management, green management, environmental knowledge management, and environmental performance. After identifying these individuals, the questionnaires were distributed electronically among them. Three weeks after the distribution, 318 completed questionnaires were collected. It should be noted that the return rate of the completed questionnaire was estimated to be 0.82 (more than 80%), which is an acceptable rate. In addition to the questions related to the exogenous, endogenous, and mediating variables of the research, we had also included some questions about the demographic characteristics of the respondents in the submitted questionnaires. These questions covered information on the gender, level of education, and work experience of people in the studied fields (Table 3).

Table 1. **Cronbach's Alpha Values for the Studied Variables**

Variable	Cronbach's Alpha
Exogenous variables (Green HRM dimensions)	
green selection and employment	0.81
green training and development	0.86
green empowerment	0.83
green payment and reward	0.92
green performance management	0.88
Mediating and endogenous variables	
environmental performance	0.85
environmental knowledge	0.94

Source: compiled by the authors.

We used the partial least squares structural equation modeling (PLS-SEM) method in this study for the analysis of the data, fitting the conceptual model of the research, and testing the hypotheses. The PLS modeling is widely used in a variety of fields, including management sciences [*Wen,* 2010]. Lisrel's approach focuses on maximizing the covariance and the PLS modeling focuses on variance maximization. PLS is a variance-based approach, which needs fewer conditions compared to similar structural equation techniques such as Lisrel and Amos [*Liljander et al.,* 2009]. For example, unlike Lisrel, the PLS path modeling is more suitable for actual applications. This approach will be more desirable especially when the models are more complex [*Wen,* 2010]. In cases where the study aims to analyze causal relationships and prediction, the PLS path modeling method is preferred to covariance-based techniques such as Lisrel [*Hair et al.,* 2014]. The PLS modeling is performed in three steps [*Hulland,* 1999]:

- the measurement model is examined through validation and reliability analyses and confirmatory factor loads analysis.
- the structural model is evaluated by estimating the path between the variables and determining the fit indices of the model.

- the fit of the general model is validated through the GOF criterion.

Evaluation of the measurement model

In this process, the composite reliability (CR) tests and average variance extracted (AVE) are conducted and examined to obtain convergent validity and the correlation rate. A reliability above 0.7 associated with an average variance of at least 0.5 are the two conditions required for the convergent validity and correlation of a construct [*Ching Lin, Chih Huang,* 2009]. Factor loads greater than 0.5 also indicate good reliability for the studied constructs [*Fornell, Larcker,* 1981]. The Cronbach's alpha shows the level of reliability (reliability of internal consistency) of the construct. Values higher than 0.7 are considered desirable for the Cronbach's alpha, while values lower than 0.6 are considered undesirable. The divergent validity is also measured by the interaction factor loads method and the Fornell-Larcker method. The first method includes examining the interaction factor loads in which the correlation of the indices of a construct is compared with that structure and the correlation of that index with other constructs. If the correlation of the indices of a construct with the construct other than itself is greater, the divergent validity is questioned [*Ringle, Sarstedt,* 2011]. The second method is the one presented by [*Fornell, Larcker,* 1981]. According to this method, the divergent validity is confirmed if the squared average variance extracted of each construct would be more than the correlation between the constructs.

Structural model evaluation

The path coefficients are the most basic criteria to measure the relationship between constructs in the model. In the case of path coefficients, the coefficient sign of the significance level should be considered. The paths in which the coefficients signs are opposite to the di-

Table 2. **Questionnaire on Green Human Resource Management Practices**

Item	Questionnaire Statements
Green Recruitment and Selection (GRS)	• Recruitment messages include environmental behavior/commitment criteria on environmental management aspects of the organizations. • My organization indicates or makes transparent its environmental performance (past and current) in recruitment messages. • My organization includes environmental criteria in the recruitment messages. • My organization expresses its preference for recruiting candidates who have competency and attitudes predisposed toward participating in corporate environmental management initiatives in the recruitment message.
Green Development and Training (GDT)	• Providing environmental training to the organizational members (employees and managers) to develop the required skills and knowledge. • Providing training to learn or adapt environmentally friendly best practices (e.g., reducing long-distance business travel and recycling). • Providing environmental awareness training among the workforce. • Providing environmental education to the workforce. • Providing training to the staff to produce a green analysis of workspace. • Conducting training needs analyses to identify green training needs of employees.
Green Employee Empowerment (GEE)	• Introducing green whistle-blowing and help-lines. • Providing opportunities for the employee to get involved and participate in green suggestion schemes and joint consultations for environmental issue problem solving. • Offering workshops or forums for staff to improve environmental behavior and exchange their tacit knowledge.
Green Pay and Reward (GPR)	• The company offers nonmonetary and monetary rewards based on environmental achievements (sabbatical, leave, gifts, bonuses, cash, premiums, promotion). • I suggest new practices that could improve the environmental performance of my organization. • At work, I question practices that are likely to hurt the environment. • In my work, I weigh the consequences of my actions before doing something that could affect the environment.
Green Performance Management and Appraisal (GPM)	• Environmental behavior/targets and contributions to environmental management are assessed and included in performance indicators/appraisal and recorded. • This organization provides regular feedback to the employees or teams to achieve environmental goals or improve their environmental performance. • This organization establishes environmental management information system and environmental audits. • This organization incorporates corporate environmental management objectives and targets with the performance evaluation system.
Employee Environmental Knowledge (EEK)	• I know about the problem of environmental pollution caused by chemicals. • I have good knowledge about the environmental issues. • I can see with my own eyes that the environment is deteriorating. • I am aware of how to protect the environment from pollution. • I am aware of climate change. • I know what clean energy is and how to promote it. • I have knowledge of landfill waste and its hazards. • I am aware of unsustainable consumption. • I know about land degradation and ways to stop it.
Environmental Performance (ENP)	• Our firm reduced waste and emissions from its operations. • Our firm reduced the environmental impacts of its products/services. • Our firm reduced its environmental impact by establishing partnerships. • Our firm reduced the risk of environmental accidents, spills, and releases. • Our firm reduced purchases of non-renewable materials, chemicals, and components.

Source: compiled by the authors.

Table 3. **Demographic Characteristics of the Respondents**

Item	Number of respondents	Share (%)
Gender		
Male	255	80
Female	63	20
Education level		
Bachelor	98	31
PhD	31	10
Work experience in human resources management, safety, knowledge, and operations		
Under 5 years	67	21
5–10 years	86	27
10–15 years	93	29
Over 15 years	73	23

Source: compiled by the authors.

rection claimed in the hypothesis will lead to the non-confirmation of the hypothesis. Some researchers, including [*Cohen,* 1988], believe that the path coefficient greater than 0.1 indicates a certain amount of impact on the model, and some others, including [*Chin,* 1998] suggest that the value of 0.2 is the basis for showing the accuracy of the relationship between the constructs, and thus, confirming the research hypotheses at a confidence level of 95% [*Hair et al.,* 2010]. The t-value also indicates the accuracy rate of the relationship and is used to test the hypotheses in the PLS-SEM algorithm.

Fitting the general model

According to the structural equation modeling algorithm, the goodness of fit is used to examine the fit of the general model, which controls both measurement and structural parts. This criterion was introduced by [*Tenenhaus et al.,* 2004] and is calculated according to the following relationship:

$$GOF= \sqrt{(average(Communality)\times averageR2)}$$

The criterion is defined by three values of 0.01, 0.25, and 0.36 as weak, moderate, and strong values [*Wetzels et al.,* 2009].

Results

Based on the PLS-SEM algorithm, we evaluated the measurement models at the first stage. The results of the evaluation of reliability criteria (Cronbach's alpha and composite reliability), convergent validity, and the results of factor loads measurement of the research variables given in Table 4 suggest that the values obtained for factor loads are higher than 0.5, those for the Cronbach's alpha are higher than 0.7, and the composite reliability values are higher than the specified criterion, i.e., 0.7. Also, the result obtained from the convergent validity criterion shows that the convergent validity values of all research constructs are higher than the standard value of 0.5. The Fornell and Larcker

Table 4. **The Results of the Evaluation of Factors Loads,**

Construct	Item	Factor loads
Green selection and hiring	GRS1	0.709
	GRS2	0.502
	GRS3	0.709
	GRS4	0.597
Green training and development	GDT1	0.624
	GDT2	0.647
	GDT3	0.640
	GDT4	0.693
	GDT5	0.834
Green empowerment of staff	GEE1	0.625
	GEE2	0.744
	GEE3	0.742
	GEE4	0.721
	GEE5	0.580
Green payment and reward	GPR1	0.631
	GPR2	0.831
	GPR3	0.700
	GPR4	0.451
Green management and performance appraisal	GPM1	0.711
	GPM2	0.634
	GPM3	0.803
	GPM4	0.631
Employees' environmental knowledge	EEK1	0.738
	EEK2	0.599
	EEK3	0.558
	EEK4	0.627
	EEK5	0.774
	EEK6	0.545
	EEK7	0.599
	EEK8	0.680
	EEK9	0.723
Environmental performance	ENP1	0.668
	ENP2	0.652
	ENP3	0.752
	ENP4	0.778
	ENP5	0.717

Source: compiled by the authors.

method [*Fornell, Larcker,* 1981] was used to measure the divergent validity of the research constructs.

The results of Table 5 reveal that given that the obtained squared average variance extracted from each structure is higher than the correlation between the constructs, the divergent validity of the research constructs is confirmed. These results indicate a good internal consistency for the measurement model and report the fit of the model. As a result, the measurement model is confirmed.

After confirming the measurement model, the structural model was evaluated according to the PLS-SEM algorithm using the BOOTSTRAPPING command in the PLS software. In this command, a large number of sub-samples are extracted by the substitution method. Substitution means that whenever an observation is randomly extracted from the sampling population, before extracting the next observation, it goes back to the sampling population. That is, the population from which the observations are derived always contains similar elements. Therefore, an observation can be selected more than once or not at all in all the sub-samples. The number of bootstrapping samples should

Table 5. **The Results of the Evaluation of Cronbach's Alpha, CR, and AVE**

Construct	Cronbach's alpha	Composite reliability	Convergent validity
Green selection and hiring	0.728	0.726	0.503
Green training and development	0.824	0.819	0.579
Green empowerment of staff	0.812	0.814	0.670
Green payment and reward	0.749	0.755	0.545
Green management and performance appraisal	0.792	0.790	0.587
Employees' environmental knowledge	0.868	0.869	0.627
Environmental performance	0.837	0.839	0.511

Source: compiled by the authors.

be high but it should be at least equal to the number of valid observations in the total data.

In this study, 5,000 bootstrapping samples were considered to calculate the significance level of the path coefficients. The results of this command are reported in Table 6. In the structural equations modeling method, after fitting the measurement models, the fitting of the structural model of the research is investigated. In analyzing the structural model, the relationships between latent variables (constructs) with each other are analyzed and the criteria of significance coefficients t-value and the coefficient of determination or the same, R^2, are used to fit the model.

The significance t-values are used to evaluate the fitting of the research structural model by several criteria that the first and most basic criteria are significance coefficients t or the same t-values. The values of t greater than 1.96 indicate the accuracy of relationships between the constructs, and as a result, the research hypotheses are confirmed at a 95% confidence level. According to the results, all the numbers on the paths are higher than 1.96. This indicates that the paths are significant, the structural model is fit, and the research hypotheses are validated. These results are reported in Table 4.

The second criterion necessary for measuring the structural model fit is to determine the coefficients of determination, or the same R^2 related to the endogenous latent variables (dependent variable) of the model. This criterion is used to connect the measurement and structural components of the structural equations modeling and represents the effect of an exogenous (independent) variable on an endogenous (dependent) variable. It should be noted that the R^2 values of the model are calculated only for the endogenous constructs of the model and the value of this criterion is zero for the exogenous constructs of the model. There are three values of 0.19, 0.33, and 0.67 introduced as weak, moderate, and strong criteria of R^2 criterion [*Chin,* 1998]. Given that the value of R^2 for the environmental performance variable was calculated to be 0.444, considering the three values of the criterion, the suitability of the structural model fit is confirmed.

The results of testing the first hypothesis showed that all five measures of green human resources management have a positive and significant impact upon the environmental performance of the studied companies. As a result, the first hypothesis of the study was confirmed.

The result of testing the second hypothesis of the research, which sought to evaluate the effect of the mediating role of the employees' environmental knowledge upon the relationship between green human resources management measures and environmental performance of the studied companies, revealed that the mediating role of environmental knowledge in the relationship between the four measures, namely, the green selection and employment, green training and development, green empowerment of employees, and the green management and performance appraisal respectively with path coefficients of 0.485, 0.759, 0.512, and 0.380 are confirmed. In the case of the green payment and reward measure, given the value of the path coefficient of 0.105 and the t-value of 1.267, which is less than the criterion value of 1.96, this component was not confirmed. However, since four of the five sub-hypotheses related to the mediating role of environmental knowledge were confirmed, one can say that environmental knowledge plays a mediating role in the relationship between green human resources

Table 6. **The Results of Evaluating the Divergent Validity of Constructs**

Construct	1	2	3	4	5	6	7
Green selection and hiring	0.709						
Green training and development	0.702	0.760					
Green empowerment of staff	0.633	0.745	0.818				
Green payment and reward	0.659	0.750	0.810	0.738			
Green management and performance appraisal	0.694	0.753	0.815	0.655	0.766		
Employees' environmental knowledge	0.643	0.667	0.795	0.671	0.668	0.791	
Environmental performance	0.630	0.618	0.723	0.621	0.563	0.667	0.714

Source: compiled by the authors.

management measures and environmental performance. Thus, the green human resources management measures have a positive and significant impact upon the environmental performance of small and medium-sized manufacturing companies operating in the oil and gas industry through the employees' environmental knowledge.

After evaluating the structural model, the general model was fitted using the GOF criterion. We used the mean of R^2 values equal to 0.444 and the average common values obtained as 0.341, in calculating the GOF criterion.

GOF = = 0.389

As can be seen, the value of the GOF criterion is equal to 0.389. This value, according to the three criterion values of 0.01, 0.25, and 0.36 as weak, moderate, and strong values for GOF, indicates a strong overall fit of the model.

Discussion and Conclusion

In this study, we examined the effect of green human resources management measures on environmental performance according to the mediating role of the employees' environmental knowledge of small and medium-sized manufacturing companies active in the Iranian oil and gas industry. As revealed by the results, one can say that the studied companies can improve their environmental performance by implementing green human resources management measures as well as promoting environmental knowledge among their employees. Table 7 summarizes the results of testing the main hypotheses and sub-hypotheses related to green HRM practices with the relevant recommendations for businesses.

The results of testing the five sub-hypotheses of the second hypothesis (H2a, H2b, H2c, H2d, H2e) revealed that environmental knowledge plays a mediating role in the relationships between the measures of green selection and employment, green training and development, green empowerment of employees, and green management and performance appraisal and that these actions of green human resources management have a positive and significant impact upon the green environmental performance. Green training and development especially plays a crucial role in this regard.

According to the results, it can be concluded that the role of human resource management can be considered successful by turning ordinary employees into green employees and refers to policies, methods, and systems that transform the employees of a green organization for the benefit of the individual, society, natural environment, and business. Human resource management measures for green staff are the prelude for building a green organization. Green human resource management refers to those human resource management actions that ultimately lead to reducing the negative effects of actions or increasing the positive environmental impacts of the organization. Accordingly, it is recommended that managers of manufacturing companies pay special attention to the environmental knowledge of employees to achieve green environmental performance and take measures such as strengthening environmental knowledge of employees through holding continuous and purposeful training courses, choosing and hiring employees with a high level of environmental knowledge, and defining the employees' performance appraisal criteria based on their level of knowledge and awareness of environmental programs and provide the organization with conditions suitable for the continuous improvement of the environmental performance.

The Research Limitations and Suggestions for Future Research

The present study faces some limitations as do other research studies. Since it was an exploratory study, the research findings are limited by the sample size and the results may change if the sample size changes. Also, different views on the research subject among mem-

Table 7. **The Structural Model Evaluation Results and Hypotheses Testing**

Hypothesis	Path	Path coefficient	t-value	P-value	Test result
H1: Direct effect					
H1a	GRS →ENP	0.523	2.072	0.004	supported
H1b	GDT →ENP	0.884	3.007	0.000	supported
H1c	GEE →ENP	0.380	2.189	0.002	supported
H1d	GPR →ENP	0.420	1.980	0.048	supported
H1e	GPM →ENP	0.711	2.865	0.000	supported
H2: Mediator effect					
H2a	GRS →EEK →ENP	0.485	2.333	0.001	supported
H2b	GDT →EEK →ENP	0.759	3.422	0.000	supported
H2c	GEE →EEK →ENP	0.512	2.451	0.000	supported
H2d	GPR →EEK →ENP	0.105	1.267	0.072	not supported
H2e	GPM →EEK →ENP	0.380	2.147	0.008	supported

Source: compiled by the authors.

Table 8. **Recommendations on Green HRM Practices that Enable the Improvement of Firms' Environmental Performance**

Hypothesis	Linking path between variables	Path coefficient	Previous studies that confirm hypothesis testing	Recommendations for businesses
H1a	GRS →ENP	0.523	[*Masri, Jaroon,* 2017; *Roscoe et al.,* 2018]	Choosing employees interested in environmental activities, considering the environmental background of individuals in the recruitment process as well as focusing on the implementation of environmental principles by employees in the employment interview questions
H1b	GDT →ENP	0.884	[*Paillé et al.,* 2014; *Bombiak, Marciniuk-Kluska,* 2018; *Rawashdeh,* 2018]	Facilitating the employees' participation by providing training and preparing programs to improve the employees' skills and knowledge, promoting the employee's environmental behavior by holding training courses related to environmental issues in the workplace, and thereby, developing the employees' environmental knowledge
H1c	GEE →ENP	0.380	[*Rawashdeh,* 2018; *Mishra,* 2017]	Gathering the opinions and suggestions from the employees concerning environmental issues by formulating the necessary processes and encouraging employees' further participation
H1d	GPR →ENP	0.420	[*Saeed et al.*, 2018; *Paillé et al.*, 2014; *Ahmad,* 2015]	Creating the necessary motivation for environmental activities among employees by operationalizing measures such as defining rewards and appropriate payments for employees with proper performance in environmental activities, rewarding employees who have achieved environmental goals or exceeded the defined goals
H1e	GPM →ENP	0.711	[*Paillé et al.,* 2014; *Mishra,* 2017; *Rawashdeh,* 2018; *Saeed et al.,* 2018]	Setting specific environmental goals for employees and defining performance appraisal criteria with an environmental approach so that achieving environmental goals by employees would be considered an important criterion in evaluating their organizational performance

Source: compiled by the authors.

bers of the statistical population can affect the results. The studied population in this research study included small and medium-sized manufacturing companies active in Iran's oil and gas industry. Accordingly, the results obtained are specific to these companies and cannot be generalized to apply to all organizations and companies. It is recommended that researchers conduct future research on this topic at other organizations as well as manufacturing and service companies in the oil and gas industry worldwide and other industries. Given that five important measures of green human resources management were used as effective variables on the environmental performance in this study due to their frequent use in previous studies related to the manufacturing industry, it is suggested that researchers examine the impact of other green human resources management measures, including green human resources planning and green safety management and discipline concerning environmental performance in future research. The employees' environmental knowledge variable was used as the mediating variable in this study. Based on this fact, it is suggested that researchers use variables such as green commitment and green lifestyle as mediating variables in future research. Since both objective and subjective knowledge can be examined to measure the environmental knowledge of employees, due to the limitation in data collection, this study focused only on subjective knowledge. Thus, it is recommended that a study be conducted in the context of objective and subjective knowledge simultaneously to measure environmental knowledge in the future.

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