Journal of the Knowledge Economy
https://doi.org/10.1007/s13132-023-01235-7

Conceptual Bases of a Quantitative Method for Assessing the Transferability of Medical Technologies Across the Rich-Poor Divide

Vuk Uskoković[1,2]

Received: 10 January 2022 / Accepted: 24 February 2023

Abstract

In spite of the global advancements in science and technology, the disparity in the quality of life across the globe continues to increase, particularly so in terms of the access to cutting-edge medical technologies. Opportune transfer of technologies across the rich-poor divide lessens the global economic inequalities and fosters the sustainability of the global economy, but not all technologies are equally transferrable across this gap. Here, a method for quantifying the transferability of technologies has been postulated and preliminarily tested by considering twelve state-of-the-art medical technologies and three comparatively impoverished regions of the world: West Bengal in India, Xinjiang in China, and the former Yugoslav state of Montenegro. The results of the analysis demonstrate that neither the gross economic productivity of the region of interest nor its level of poverty can be the sole determinants of the transferability of technologies. Rather, a complex network of scientific, technological, infrastructural, socioeconomic, and cultural factors defines the extent of transferability of new technologies across the rich-poor divide. The proposed model helps to discern which of these factors represent the most critical hindrances in the transfer of technologies. It is argued that the most dependable technologies to transfer are old and proven ones, but the best ones for ameliorating the rich-poor divide are juvenile technologies in formative stages of their development, which also happen to be employing simplistic ingenuity and resourcefulness in their design. The analysis performed here makes it apparent that models for assessing the social value of technologies should inextricably tie the scientific factors with the socioeconomic and humanistic. Countless technical models of various natures could be devised with this holistic principle in mind.

✉ Vuk Uskoković
vuk21@yahoo.com; vuk.uskokovic@tardigradenano.com; vuskokovic@sdsu.edu

[1] Advanced Materials and Nanobiotechnology Laboratory, TardigradeNano LLC, Irvine, CA 92604, USA

[2] Department of Mechanical Engineering, San Diego State University, 5500 Campanile Dr, San Diego, CA 92182, USA

Keywords Biotechnology · Medical devices · Nanotechnology · Technology transfer

Introduction

In spite of the global advancements in science and technology, the disparity in the quality of life across the globe has continuously broadened over the past centuries. This is especially so with respect to the availability of cutting-edge medical technologies. Smart phones and their apps, fast-processing computers, and automobiles may have penetrated every corner of the planet, but the difference between the types of medical treatments available to patients in the rich parts of the world and the quality of treatment available to patients in poor parts of the world continues to be staggeringly high.

Transferability of technologies across the rich-poor divide is rarely taken into account in the R&D sector despite its having an evident, albeit indirect, effect on the depth of this divide. Simply, technologies with a low degree of transferability would have a harder time crossing this gap and would tend to stay within the limits of the wealthier regions of the world, as opposed to transferable technologies, which could readily cross this divide, thereby diminishing its extent. Earlier, it was inferred that models for assessing the potential of technologies to aggravate or heal this divide could be created using qualitative methods (Uskoković, 2021a). Such models are built on the premise that no technologies are neutral from the socioeconomic and cultural standpoints, as each of them affects the totality of the social space. To illustrate this, a simple thought experiment could suffice, such as that of imagining one world promoting the development of therapeutic medical devices, and another fostering the development of preventative medical devices; whereas the diseases would be tackled only after their symptoms become manifested in the former scenario, proliferation of causes leading to these symptoms would be stood in the way of in the latter scenario, thus demonstrating how the choice of technologies affects the existential bases a top of which human cultures, sciences, healthcare, and economies develop.

Moreover, as pointed out by E. F. Schumacher in the 1970s (Schumacher, 1998), not all technologies are viably transferable to any given underdeveloped setting in the world. Rather, some technologies are better and some less suited to be integrated into a poor communal setting—hence, the different degrees of "appropriateness" ascribable to them. Ideally, as Schumacher held it, technologies are to be adapted to the new settings rather than inertly exported thereto, with little forethought involved in the process. Still, quantitative methods for assessing the transferability of advanced technologies have been thoroughly lacking, especially such that would take into account humanistic parameters alongside the technological and economic alone. And given that technologies are not neutral and do dramatically affect the cultural bedrock of the society (Heidegger, 1954), these effects extending beyond the standardly considered, economic ones should be taken into account by all means. Economic decisions in the developed world, on the other hand, are being increasingly made through sole reliance on computational models, which take into account free market competition, trends, and other conditions, along with governmental regulations, production capacities, and user base proclivities. Problematically, however, these models are rooted in obvious fundamental fallacies, one of which, identified exhaustively earlier (Farley & Daly, 2006), has been the treatment of the natural resource depletion as a source of income rather than an intrinsic cost. Another major deficiency has come from their not including the effects of social segregation caused by the economic activities assessed. Neither do they take into account the spiritual enrichment or impoverishment due to these activities. Therefore, the intrinsic difficulties of quantifying the qualitative aside, creating technological models that take into account humanistic parameters and are performed to mitigate the adverse effects of life standard segregation are of paramount importance for sustainability of the planet and of human civilization.

Here, an attempt has been made to formulate one such quantitative and more holistic model for assessing the transferability of new technologies across the rich-poor divide. For that purpose, twelve technologies of the author's choice are being rated using a number of distinct parameters with respect to three comparatively impoverished regions of choice.

Model

Individual parameters included in the transferability score evaluation are listed in Table 1. Parameters were assigned different score ranges, being as low as 3 to 5 for the less decisive parameters or as high as 0 to 5 for the most critical ones. Within the broadest scale of 0–5, scores 5, 4, 3, 2, 1, and 0 corresponded to “high”, “moderately high”, “average”, “moderately low”, “low”, and “impermissibly low”, respectively, while the scores became narrowed, albeit preserving the same range from high to low, for scales reduced in range, e.g., 1–5, 2–5, 3–5, or

Table 1 Parameters included in transferability score evaluation and their corresponding score ranges

Parameters	Score range
A. Affordability and technical ease of production	1–5
B. Affordability and technical ease of installation	3–5
C. Affordability and technical ease of usage	3–5
D. Ease of operational training	4–5
E. Affordability and technical ease of troubleshooting/repair/replacement	1–5
F. Outcome improvement over the existing solutions	0–5
G. Environmental benefit (inverse of environmental cost)	1–5
H. Compatibility with existing infrastructure	0–5
I. Facilitation of further innovation using modest resources	2–5
J. Compactness and mobility to, from, and beyond the point-of-care	1–5
K. GLP and GMP necessitation	2–5
L. Patient-friendliness	2–5
M. Potential for local production (inverse of the necessity for importation of whole or parts)	2–5
N. Potential for co-creational design or innovation	3–5
O. Healthcare gain per QALY saved	0–5
P. Cultural congruence	1–5
Q. Public approval	0–5
R. Smoothness of the regulatory path	0–5
S. Systemic improvement in the societal quality of life	2–5

Table 2 Data of interest for the three regions of the world chosen for the analysis

Region/country	Size (mi^2)	Population (millions)	GDP per capita (US$)	Population below poverty line (%)	Dominant economic sector
West Bengal	34,267	90.32	1500	19.98	Tertiary/services (53.0%)
Xinjiang	642,800	25.85	7700	9.90	Tertiary/services (51.2%)
Montenegro	5,333	0.62	7700	24.50	Tertiary/services (76.6%)

Table 3 Twelve advanced medical technologies of choice rated for their transferability scores

Technology
1. Origami paper-based diagnostic assay
2. Microfluidic lab-on-a-chip for electrochemical immuno-biosensing
3. Telemedicine with unmanned aerial vehicles
4. Multimodal MRI/PET/CT imaging
5. Imaging-guided, nanoagent-mediated photodynamic therapy
6. Glassy carbon brain-machine neural signal interference
7. Topical inorganic nanoparticle antimicrobials
8. Nanoparticles functionalized with ligands for cell-targeted drug delivery
9. Injectable hydrogels for tissue regeneration
10. High-throughput screening of traditional medicines for personalized treatments
11. Bioprinted cardiac patches
12. Graphene e-skin for tactile perception

4–5. Each parameter in Table 1 was assigned a single score with respect to a particular technology in question and the region where the given technology is to be transferred to. The individual parameters were averaged with the geometric, not arithmetic means, so as to allow parameters assigned 0 in theory to completely annul the transferability and deem the given technology intrinsically nontransferable to a given region. Hence, the expression for the transferability score, T, is given as:

$$T = \sqrt[n]{x(1)x(2)\dots x(n)}$$

where $x(1)$ to $x(n)$ refer to the n number of transferability parameters listed in Table 1. For the model implemented here, $n = 19$.

Regarding the individual parameters, they were deduced via free thinking on the subject, without using any explicit literature on transferability, notwithstanding that many of the proposed parameters could be backed with appropriate literature references. Some of these parameters are self-explanatory, such as the demands for low production, installation, training, usage, and repair costs (Table 1, A–E), considering that the affordability of resources is a critical limitation for innovation in poor settings. In fact, a prior literature meta-analysis (Bauer & Brown, 2014) ranked “affordability” as the second most cited among 49 emergent indicators of appropriateness of technologies in a new social setting, right after "the community input". Clearly, innovation in the medical sector has to display a finite degree of improvement in terms of diagnostic precision or therapeutic outcome relative to the existing solutions (Table 1, F), lest there be no incentives for replacing the old with the new. This is one of the parameters assignable 0 as the score and given the ability to annul the net transferability score in cases where technologies do not provide even an incremental improvement over the technologies already in place. In addition to the direct financial costs of implementing the new technology, the environmental costs associated with setting it in place and using it must be accounted for (Table 1, G). Understandably, technologies that fare better from the environmental standpoint should always be given a priority over equally effective technologies with a more adverse ecological footprint. Despite the fact that green technologies frequently lack the efficiency and, thus, the financial incentive of their more traditional counterparts and the fact that poor countries are often typified by a paucity of environmental standards and regulations (Nguyen et al., 2022), studies have shown that given the supportive technology acquisition policies in place (Fu & Zhang, 2011), green technologies may have an edge over the more environmentally polluting ones when it comes to their transfer to less developed social settings (Hamhami et al., 2020). What is more, various global economic stimuli schemes are likely to emerge in the near future, which would allow developing countries to subsidize the transition to cleaner and more sustainable technologies (Ng et al., 2021; Bai et al., 2020).

Next, standalone advanced technologies have a nil long-term prospect, as their only way to thrive is within a pre-existing technological base. For this reason, the implementation of some new technologies is critically dependent on a specific infrastructure, and when this infrastructure is missing, the usage value of the technology gets annulled; hence, the ability of the infrastructure parameter to receive 0 as a value (Table 1, H). The traditional maxim according to which "the poor should be taught how to fish rather than given the fish" is best summed in the parameter measuring the potential of the technology to foster further innovation in the new setting with the use of modest resources (Table 1, I). A prior study conducted in the context of China's green economic efficiency, for example, demonstrated that increasing the level of independent innovation associated with the newly introduced technologies facilitates this and a whole plethora of other industrial efficiencies, along with the economic growth (Zheng et al., 2022). Also, it has been recognized that the more labor-intensive and the less capital-intensive technologies, the greater their transferability to low-income and developing settings (Menck, 1973). Massive and bulky technologies often disable such innovative alterations, especially so in the current times when the ecological consciousness, unexplainably, is regressing and disposability is the new norm. In contrast, simpler, low-cost technologies often have a natural open-source structure to themselves, allowing for innovation spanning from ad hoc DIY to more sophisticated amendments, depending on the amender's preferences and capabilities. Correspondingly, technologies that are more compact and easily transportable between different points of care are favored over the bulky ones that must stay in place (Table 1, J). Such technologies with sufficient degrees of miniaturization and portability are often titled point-of-care technologies and are intended for use at or near the sites of patient presentation (Haney et al., 2017).

So far, these technologies have mostly been used for diagnostic purposes, as exemplified by mobile mammography, pulse oximeters or blood glucose monitors, and very rarely as a treatment option. Relatedly, technologies that could be fabricated in whole or in part locally must be favored over those that require international importation (Table 1, K). A plethora of prior studies on international technology transfer have shown that the success of technological acquisition critically depends on the existence of domestic capacities to fabricate and maintain the technology through local manufacture (Schmidt & Huenteler, 2016).

Technologies vary in terms of the level of good laboratory and/or manufacturing practices (GLP and GMP, respectively) that they are in demand of (Table 1, L). Clearly, technologies that do not require higher level biosafety procedures, clean rooms, or intense sterilizations are in favor when it comes to transfer to settings where even the most elementary sanitations are a challenge. The fact that fully detailed GLPs accompany protocol transferability documents even in the pre-validation stage (Southee & Curren, 1997), in fact, is sufficient to infer that the complexity of laboratory processes associated with a new technology is directly reflected in the complexity of its transfer. Patient-friendliness is a universal criterion (Table 1, M) because technologies such as a transdermal microneedle patch or an orally consumed device would always be welcomed by patients more than surgically inserted implants, just as well as noninvasive diagnostic tools, such as a salivary lateral flow assay, will be more desirable than nuclear magnetic resonance or excision biopsy, regardless of whether the implementation milieu is rich or poor. Co-creation (Table 1, N) is a concept with extraordinarily diverse semantics (Uskoković, 2011; Uskoković, 2015b; Uskoković, 2018), which predicts that technologies developed and applied within a broader multidisciplinary niche will fare better than those stemming and operating under narrow specialization conditions. Accordingly, the development of affordable medical technologies is shown to be directly proportional to the degree of involvement of engineers, scientists, health professionals, and businessmen (DePasse et al., 2016). The necessity of bringing experts from different professions together is a natural way of fostering networks of cross-disciplinary cooperation, which has positive repercussions at different levels of the local scientific and technological multiverse. This participatory mode of technological development (Patnaik & Bhowmick, 2022) has been considered a critical grassroots component of efforts to mutually adapt new technologies and developing countries to one another. Another key parameter with the ability to boost or annul the proposed innovation is that of the net financial gain for the healthcare system and the local economy per quality adjusted life year (QALY) saved for patients subjected to the treatment with the new technology (Table 1, O). QALY analyses are a form of cost-benefit analyses in the medical realm (Uskoković, 2021b) and are especially important in cases where the affordability of the treatment is a critical notion. The results of such analyses can disprove the long-term viability of particular treatments and call for the search for less costly and/or more effective ones. Many eastern European countries, for example, implement the 3 times per capita GDP/QALY threshold to determine which therapies or diagnostic procedures will be reimbursed by the national insurers and which will not (Gulácsi et al., 2014). One caveat of the use of QALY as a parameter in the model proposed here is that for diseases that are universally challenging to treat, it intrinsically favors the therapeutic approaches over the diagnostic ones in endemically poor regions where no sophisticated therapies are possible to match the positive diagnostic findings.

The lower section of Table 1 contains less palpable parameters, which are hardest to evaluate because of their more humanistic character. The first among them is that measuring cultural congruence between the new technology and the social setting in which it is to be integrated (Table 1, P). Indigenous people are often resistant to the introduction of instruments that appear ostensibly foreign to their milieu, fearing their acting to disrupt the local state of social harmony. In fact, the receptiveness of the local communities, which may be at odds with that of national governments, is said to be a key factor preventing a smooth transfer of technologies (Huh & Kim, 2018). Some technologies also could be said to resonate better with the characteristics of the local culture than others (Uskoković, 2021a). Here, it is instructive to discover analogies between traits of technologies and features of other cultural products—be it music, movies, literature, fashion, or other technologies—that are either well received or rejected by the local communities. Governed by the adage that "what people want and what people need is rarely the same thing", it could be concluded that this parameter measuring cultural congruence may or may not have the similar value as the parameter measuring the public approval of the new technology (Table 1, Q), which is yet another parameter capable of annulling the transferability of the invention in scenarios where the public is overwhelmingly against the intrusion of such or similar products into their lives. Now, just as cultural congruence and public reception may not equate, so it is with the public approval and the state administration approval, which need not be aligned at all times. Since governmental constraints often do not coincide with the public disapproval, the public approval and the smoothness of the regulatory path (Table 1, R) correspond to two separate parameters in the model. These constraints can often be unsurmountable, which is why this parameter may have 0 as the value. One example of a technology that is not transferable due to social factors may be that of copper-bearing intrauterine devices for emergency contraception in countries such as Honduras or Costa Rica, where emergency contraception has been prohibited by law. Likewise, efforts to export hypersensitive mercury thermometers to Uruguay or sphygmomanometers to Cuba would provoke similarly intractable barriers because these countries have already phased out these mercury-containing medical devices from the healthcare practice (Rustagi & Singh, 2010).

A word of caution is needed here, given that whenever a nil value is assigned to a specific parameter in the model, this may change, either through an external intervention or through ad hoc amendments to the invention. For example, the transfer of wireless glucose sensors to regions without the required telecommunication networks in place may be given 0 for the infrastructural parameter at first, but more in-depth analyses might show that one such technology should not be automatically discarded as nontransferable to the given region because of the possible ad hoc solutions, such as connection to the satellite signal. Finally, the last parameter in Table 1 (Table 1, S), referring to the systemic improvement in the quality of life, is the finickiest and most difficult to narrow down or measure because it does not correspond to a sole improvement in the physical wellbeing of the individual subjected to the use of the device, but rather to an overall improvement of the social state of welfare across different strata, including the cultural, communicational, psychological, economic, health-wise, and, last but not least, spiritual. In short, the closer the effect of the medical technology approaches quiescent healing modalities, of both body and spirit, the closer it will be to earning a perfect score for this parameter. In contrast, the more the use of the technology disrupts the social fabric of communion and tears the social connections apart, degrading the culture and diminishing the spirituality of the system, the closer its score will be to 1.

Three Regions Chosen for the Technology Transfer

Rural areas of three different regions of Eurasia were chosen for the test transferability score evaluation: West Bengal in eastern India, Xinjiang province in western China, and Montenegro in southeastern Europe. Nominal gross domestic products (GDPs) per capita for these regions in 2020 were \$1500 for West Bengal and \$7700 for Xinjiang and Montenegro. When it comes to remote rural areas of these regions, the given GDP values do not reflect veritably the general state of poverty, which is significantly higher than in the urban centers. Still, healthcare service networks considered here are assumed to be tied to these urban centers. West Bengal is a region of India where poverty has been endemic and in many cases extreme, especially in the given rural regions. Despite the past legacy of this region in education among other sectors, its currently poor infrastructure and few educational institutions and hospitals coincide with the pockets of poverty across the district (Bhandari & Chakraborty, 2015). Out of 32 provinces in China, Xinjiang is the one with the highest poverty rate of 9.9%. As for Montenegro, out of 6 countries recognized by the United Nations that emerged from the breakup of Yugoslavia, it is the one with the highest poverty rate of 24.5%, albeit being narrowly traced by Serbia (23.2%), followed by North Macedonia (21.5%), Bosnia and Herzegovina (18.6%), and Croatia (18.3%), and being significantly higher than the poverty rate in Slovenia (13.3%). Approximately 25% of the country's GDP is derived from tourism, while the unreported and untaxed touristic transactions are estimated to exceed the economic value of the registered ones by three times (Anon, 2008). Xinjiang and Montenegro were deliberately chosen because of their identical GDPs normalized to population size so as to test the hypothesis that GDP alone could not be a sole indicator of the transferability of technologies and that other factors of influence must prove to be more important. Table 2 lists this and other data of interest pertaining to these three regions of the world.

Twelve Technologies Chosen for Transfer

Twelve cutting-edge medical technologies were selected for the analysis (Table 3). None of them have been, to this author's knowledge, commercialized in the developing regions of interest. These technologies will be briefly discussed in this section.

Paper-based diagnostic assays have emerged as an economical version of more expensive enzyme-linked immunosorbent assay (ELISA) or even bulkier techniques such as gas/liquid chromatography or mass spectrometry, capitalizing on the ability of porous and hydrophilic cellulose in paper to drive the liquid flow through capillary action without any external power sources (Yan et al., 2022). Folding such papers, like origamis, brings reactants loaded in different compartments of the device into contact and activates the reaction, which eventually provides a colorimetric result. Here, one such blotted paper assay is chosen as an exemplary low-cost, small-sample-volume, rapid-output diagnostic device (Table 3.1), but the score for it would be similar as that for many other paper-based assays. It is contrasted by higher-cost self-powered microfluidic chips for electrochemical immunobiosensing (Table 3.2), as constructed by traditional photolithography or soft lithography (Haghayegh et al., 2022). Another high-tech tool proposed for use in medicine are drones, that is, unmanned aerial vehicles (Table 3.3). They have been either used in the recent years or proposed for use as vehicles for the transportation of therapeutics and microbiological samples between clinical centers and remote areas, but also as telecommunication means for diagnosis and perioperative patient evaluation (Rosser Jr et al., 2018). Their ability to facilitate a medical intervention without a direct human-to-human contact led to the surge of interest in their use during the COVID-19 pandemic (Maity et al., 2022).

Multimodal diagnostic tools, such as those combining magnetic resonance imaging (MRI), positron emission tomography (PET), and optical computed tomography (CT) scanning (Galgano et al., 2021), were developed to compensate for the deficiencies of each of these single imaging tools alone and present the fourth advanced medical technology of choice here (Table 3.4). Theranostic agents capable of simultaneously performing the diagnostic and therapeutic interventions, especially when the therapeutic effect is being triggered by the sensing of a disease marker, represent a particularly hot area of medical research today (Uskoković & Drofenik, 2021). One platform included in this analysis is a nanoparticulate agent incorporated inside an imaging-guided system to perform a photodynamic therapy (Gu et al., 2021) (Table 3.5). Next, glassy carbon electrodes have been hailed as biomaterials of choice for probing the brain interface (Table 3.6) because of their superior biocompatibility, electrochemical stability, and potential for functionalization compared to those of many metal electrode standards (Uskoković, 2021c). Such electrodes have been used to detect dopamine and serotonin signals and also deliver neurologically stimulatory impulses to the brain (Nimbalkar et al., 2021; Castagnola et al., 2021), whereas their main downside comes from the demanding methods for production, usually requiring high-temperature treatments that last days in duration.

Inorganic nanoparticles have incessantly competed with polymeric, protein-based, and lipid-based nanoparticles for medical uses (Uskokovic, 2015a). Although the repertoire of applications for the latter formulations may have been broader, some inorganic systems, such as iron oxide as contrast agents in MRI, plasmonic gold in surface-enhanced Raman spectroscopic imaging, or silver in antimicrobial wound dressings, have been indispensable. Recently, simple and inexpensive, highly biocompatible calcium phosphate compositions have been shown to have considerable antibacterial properties (Wu et al., 2018; Uskoković et al., 2019; Wu et al., 2021), and numerous other equally economical compositions are expected to be on the horizon (Table 3.7). Their optimization for competitive antimicrobial activities would lead to the erasure of the more toxic formulations, such as silver, copper, or zinc oxide, off the market chart. These or other nanoparticle compositions could also be functionalized with molecular moieties allowing for a specific molecular recognition of receptors overexpressed on the membranes of pathogenic cells and for their targeting and selective destruction (Wu et al., 2017; Mohd-Zahid et al., 2021) (Table 3.8). Such an approach presents the most elegant one in the effort to solve the poor effectiveness and toxicity issues of chemotherapies for cancer and other diseases that localize to specific tissues or organs, but are treated systemically. Inorganic or organic systems could also be formulated as stable and injectable colloids, in which case they could be delivered in a less invasive manner than that requiring open surgery (Uskoković et al., 2017; Wang et al., 2022; Rau et al., 2020). Such injectable formulations provide for a highly patient-friendly means for facilitating wound healing and tissue regeneration (Table 3.9).

In many underdeveloped regions of the world, traditional herbal medicines are favored over the commercial pharmaceuticals, eliciting a strong sociocultural bias at times. Methods for combining a high-tech, westernized approach to pharmacy practice with the one relying on traditional, indigenous medicines could be envisaged in analogy with the earlier coupling of folk remedies to high-throughput imaging devices (Fu, 2021). It would take the form of a high-throughput instrumentation for screening the efficacy of a plethora of herbal formulations at once to single out the most effective one or a few for a particular individual (Table 3.10). Personalized medicine is often being criticized for its expensiveness, for the potential abuse of privacy issues by the insurers, and for widening the gap between the rich and the poor (Taylor & Al-Saeed, 2010), but one such combinatorial method proposed here may be a way for closing this gap and lowering the level of mistrust existing between the favorers of the traditional and of the modern medical approaches. Among the contemporary fabrication techniques, the form of additive manufacturing known as 3D printing stands out as the most popular one because of its convenience in designing a variety of geometries across a number of spatial scales in an additive, layer-by-layer fashion. This technique has been recently used to produce a vast number of different medically operative materials and devices, one of which, considered here, are cardiac patches (Bejleri et al., 2022) (Table 3.11). Finally, graphene, a monoatomic layer of graphite, has become in the recent years a hottest material for a variety of applications, and one niche it has found is in applications for artificial skin with enhanced electrical sensing performances (Wei et al., 2022) (Table 3.12).

Scoring Results and the Discussion

Results of the transferability score assessments for the twelve different technologies with respect to their intended transfer to West Bengal, Xinjiang, and Montenegro are presented in Tables 4, 5, and 6, respectively. In addition, the comparison of the average transferability scores for all the twelve technologies combined and the three regions in question is presented in Fig. 1, whereas the comparison of each individual technology with respect to its transferability score for the three aforementioned regions is shown in Fig. 2.

Across all the technologies sampled, their combined transferability to Xinjiang is nearly significantly higher than the transferability to West Bengal or Montenegro, between which no significant difference was observed in total (Fig. 1). In fact, the transferability of each twelve individual technologies was higher for Xinjiang than for any of the other two

Table 4 Twelve advanced medical technologies of choice rated for their transferability scores with respect to areas exemplified by West Bengal, India

Technology	Parameters scoring 0	Parameters scoring 1	Parameters scoring 2	Parameters scoring 3	Parameters scoring 4	Parameters scoring 5	Net score
1. Origami paper-based diagnostic assay	/	O	S	F, R	E, H, K, M, N, P, Q	A, B, C, D, G, I, J, L	3.82
2. Microfluidic lab-on-a-chip for electrochemical immuno-biosensing	/	A, E, O	G, I, K, M, R, S	F, H, P	N, Q	B, C, D, J, L	2.62
3. Telemedicine with unmanned aerial vehicles	/	G, P	E, H, I	C, M, R, S	A, B, D, F, L, N, O, Q	J, K	2.98
4. Multimodal MRI/PET/CT imaging	/	A, E, H, J, O, P	I, M, R	B, C, G, N, Q, S	D, F, K, L	/	2.11
5. Imaging-guided, nanoagent-mediated photodynamic therapy	/	A, E, H, J	G, K, L, M, R	B, C, F, I, P, S	D, O, Q	N	2.30
6. Glassy carbon brain-machine neural signal interference	/	H, O, P, R	A, E, F, I, J, K, L, M, Q, S	B, C, G	D	N	2.00
7. Topical inorganic nanoparticle antimicrobials	/	/	/	F, K, P, Q, S	C, E, L, N, O, R	A, B, D, G, H, I, J, M	4.07
8. Nanoparticles functionalized with ligands for cell-targeted drug delivery	/	/	F, R	E, K, O, P, S	A, B, C, G, H, L, M, Q	D, I, J, N	3.61
9. Injectable hydrogels for tissue regeneration	/	/	R	G, K, O, P, S	A, C, E, F, H, L, M, Q	B, D, I, J, N	3.79

Table 4 (continued)

Technology	Parameters scoring 0	Parameters scoring 1	Parameters scoring 2	Parameters scoring 3	Parameters scoring 4	Parameters scoring 5	Net score
10. High-throughput screening of traditional medicines for personalized treatments	/	/	A, E, H, J	G, I, M, O, R	B, C, D, F, K, L, N, S	P, Q	3.28
11. Bioprinted cardiac patches	/	/	A, G, H, J, K, L, M, P, R	B, C, E, F, I, O, Q, S	D, N	/	2.55
12. Graphene e-skin for tactile perception	/	A, H, P, R	F, G, I, M, O, Q, S	C, J	D, K, L	N	2.08

Table 5 Twelve advanced medical technologies of choice rated for their transferability scores with respect to areas exemplified by Xinjiang, China

Technology	Parameters scoring 0	Parameters scoring 1	Parameters scoring 2	Parameters scoring 3	Parameters scoring 4	Parameters scoring 5	Net score
1. Origami paper-based diagnostic assay	/	/	/	F, S	E, K, N, O	A, B, C, D, G, H, I, J, L, M, P, Q	4.47
2. Microfluidic lab-on-a-chip for electrochemical immunobiosensing	/	A, E	G, I, K	F, H, O, P, R, S	M, N, Q	B, C, D, J, L	3.00
3. Telemedicine with unmanned aerial vehicles	/	G	E, I	C, Q, S	A, B, D, F, L, N, O	H, J, K, M, P, R	3.54
4. Multimodal MRI/PET/CT imaging	/	A, E, J	I	B, C, F, G, M, N, P, S	D, H, K, L, O, Q	R	2.78
5. Imaging-guided, nanoagent-mediated photodynamic therapy	/	A, E, J	G, K, L, P	B, C, I, M, Q, R, S	D, F, H, O	N	2.53
6. Glassy carbon brain-machine neural signal interference	/	P	A, E, F, I, J, K, L, O, Q	B, C, G, H, R, S	D, M	N	2.47
7. Topical inorganic nanoparticle antimicrobials	/	/	/	K, O, S	C, E, L, N, Q, R	A, B, D, F, G, H, I, J, M, P	4.30
8. Nanoparticles functionalized with ligands for cell-targeted drug delivery	/	/	/	E, K, P, Q	A, B, C, G, H, L, O, R, S	D, F, I, J, M, N	4.04

Table 5 (continued)

Technology	Parameters scoring 0	Parameters scoring 1	Parameters scoring 2	Parameters scoring 3	Parameters scoring 4	Parameters scoring 5	Net score
9. Injectable hydrogels for tissue regeneration	/	/	/	G, K, O, P	A, C, E, L, Q, S	B, D, F, H, I, J, M, N, R	4.18
10. High-throughput screening of traditional medicines for personalized treatments	/	/	A, E, J	G, I, O, R	B, C, D, F, K, L, M, Q, S	H, P	3.45
11. Bioprinted cardiac patches	/	A, G, J, K, L	B, C, E, F, H, I, O, P, S	D, N, Q, R	M		2.94
12. Graphene e-skin for tactile perception	/	A, E	G, I, O, P, Q, S	B, C, F, J, R	D, H, K, L, M	N	2.61

Table 6 Twelve advanced medical technologies of choice rated for their transferability scores with respect to areas exemplified by Montenegro

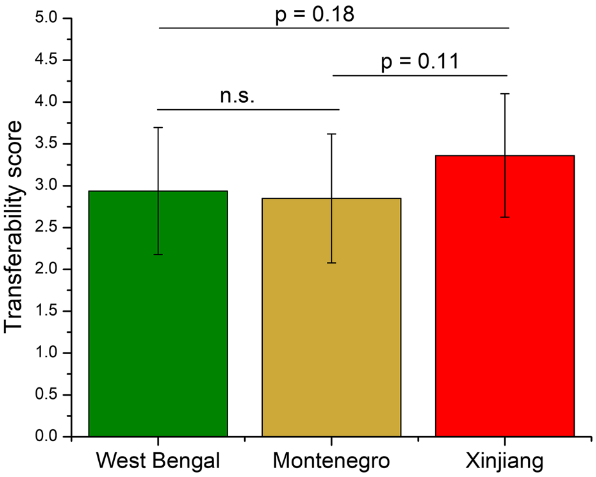
Technology	Parameters scoring 0	Parameters scoring 1	Parameters scoring 2	Parameters scoring 3	Parameters scoring 4	Parameters scoring 5	Net score
1. Origami paper-based diagnostic assay	/	/	S	F, P, Q, R	E, K, M, N, O	A, B, C, D, G, H, I, J, L	4.03
2. Microfluidic lab-on-a-chip for electrochemical immunobiosensing	/	A, E, H, M	G, I, K, O, P, Q, R, S	F	N	B, C, D, J, L	2.33
3. Telemedicine with unmanned aerial vehicles	/	G, M, P, Q	E, H, I, O, R	C	A, B, D, L, N, S	F, J, K	2.54
4. Multimodal MRI/PET/CT imaging	/	A, E, J, M	I, P	B, C, F, G, N, O, S	D, H, K, L, Q, R	/	2.50
5. Imaging-guided, nanoagent-mediated photodynamic therapy	/	A, E, J, M	G, K, L, P	B, C, H, I, O, Q, R, S	D, F	N	2.31
6. Glassy carbon brain-machine neural signal interference	/	H, M, O, P, Q, R	A, E, F, I, J, K, L	B, C, G	D, S	N	1.93
7. Topical inorganic nanoparticle antimicrobials	/	/	/	K, O, P, R, S	C, E, F, H, L, M, N, Q	A, B, D, G, I, J	3.98
8. Nanoparticles functionalized with ligands for cell-targeted drug delivery	/	/	/	E, H, K, M, P, Q, R	A, B, C, G, L, O, S	D, F, I, J, N	3.81

Table 6 (continued)

Technology	Parameters scoring 0	Parameters scoring 1	Parameters scoring 2	Parameters scoring 3	Parameters scoring 4	Parameters scoring 5	Net score
9. Injectable hydrogels for tissue regeneration	/	/	M, P, R	G, H, K, O, Q, S	A, C, E, L	B, D, F, I, J, N	3.51
10. High-throughput screening of traditional medicines for personalized treatments	/	M, Q	A, E, J, P, R	F, G, H, I, O, S	B, C, D, K, L, N	/	2.63
11. Bioprinted cardiac patches	/	/	A, F, G, H, J, K, L, M	B, C, E, I, O, P, Q, R, S	D, N	/	2.61
12. Graphene e-skin for tactile perception	/	A, E, H, M, O, P, Q, R	G, I	B, C, F, J	D, K, L, S	N	1.98

Parameters included in evaluation are assigned individual letter symbols, as listed in Table 1

Fig. 1 Average transferability scores for the twelve medical technologies and the three developing regions of the world: West Bengal, Montenegro, and Xinjiang. Error bars represent standard deviations and *p* values the statistical confidence intervals. The acronym n.s. stands for "not significant"



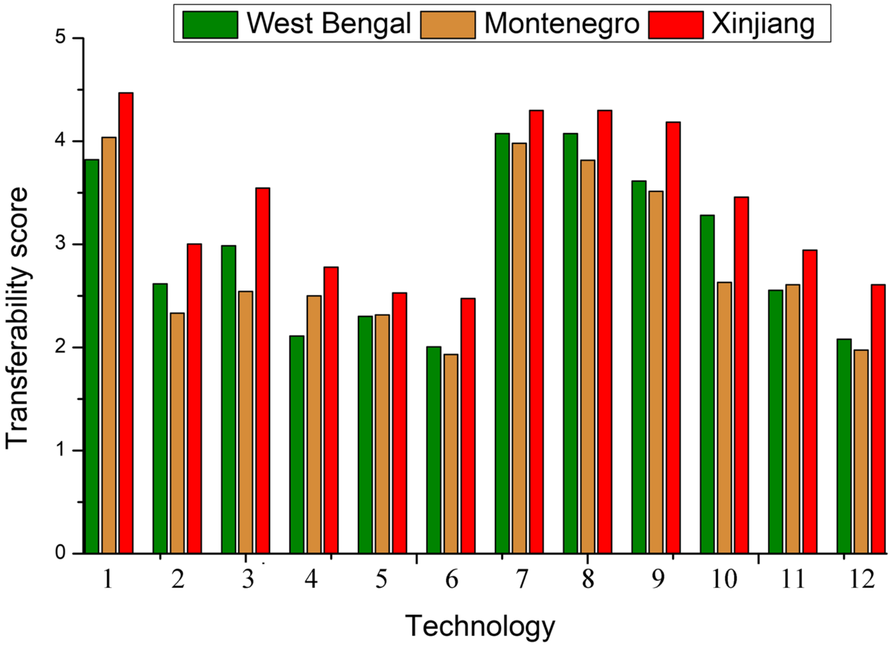


Fig. 2 Comparative transferability scores for each of the twelve medical technologies assessed and for the three developing regions of the world: West Bengal, Montenegro, and Xinjiang. Individual technologies are numerated in Table 3

regions assessed (Fig. 2). Because the GDP per capita for Xinjiang and Montenegro are the same, this indicates that this economic parameter is by no means a good measure of transferability. The higher transferability of eight out of twelve technologies to West Bengal than to Montenegro, which has approximately five times higher GDP per capita than the former and significantly higher life standard and human development index (0.816 for Montenegro vs. 0.641 for West Bengal), indicates that total poverty cannot be a measure of transferability either. Clearly, the size of the gap between the developed and the underdeveloped is neither directly nor inversely proportional to the transferability of technologies. Rather, the totality of technological, socioeconomic, and cultural factors determines how transferable a technology will be when brought to a developing ground. In contrast, comparatively crude indicators of economic development, such as GDP or the Gini index—the latter of which is used as the measure of income inequality within a social group—cannot be used to unequivocally assess the potential to accommodate a new technology. It is inevitably correct that the technology transfer depends directly on the level of economic development of a country, but these sole economic parameters must be synergized with a myriad of sociocultural factors to yield a more veritable assessment of the propensity of a social system for the acquisition of new technologies.

The justification of each of the 684 assessments performed during the analysis (3 countries × 19 evaluation parameters × 12 technologies) spans beyond the scope of this discussion, for which reason only some of the cases where a technology scored critically low or exceptionally high with respect to one of the evaluation parameters will be mentioned for different regions. For West Bengal (Table 4), for example, multimodal MRI/PET/CT imaging displayed the lowest acceptable score for record five different parameters, the major reason being the inadaptability of the technology to rural clinics whose resources permit mostly general practice and critical care, without any elaborate diagnostics. In contrast, the origami paper-based diagnostic assay and the topical nanoparticle-based antimicrobial displayed the highest scores for record eight different parameters, which was largely due to the portability and low cost of these technologies, their ability to be self-applied, and also the great need for affordable antibiotic creams among rural populations where the incidence of infected superficial wounds is comparatively high (Mahato et al., 2019; Chakraborty et al., 2012). For Xinjiang (Table 5), multimodal MRI/PET/CT imaging and imaging-guided, nanoagent-mediated photodynamic therapy displayed the lowest acceptable scores for record three different parameters, both because of the affordability and portability reasons, whereas the origami assay displayed the highest score for record twelve different parameters, the reasons here being not only intrinsic to the technology in question, but also tying to the general cultural receptiveness to timely diagnostics, solid medical innovation bases, and cultural reasons, too, which will be discussed shortly. As for Montenegro (Table 6), graphene e-skin for tactile perception displayed the lowest acceptable score for record eight different parameters, with the reasons largely boiling down to the virtually nonexistent research or industrial interest in robotics or any augmentative sensory technologies in this country. Montenegro is by approximately two orders of magnitude smaller in population than West Bengal or Xinjiang (Table 2), and with the population of just over half a million, understandably, many of the globally state-of-the-art technologies are bound to remain completely outside of the scope of academic or commercial interest. As with West Bengal and Xinjiang, the origami assay displayed the highest score for the largest number of evaluation parameters, predominantly owing to the intrinsic elegance and effectiveness of the technology.

Overall, the transferability scores ranged from 1.93 at the lowest (brain-machine interface, Table 3.6, in Montenegro) to 4.47 at the highest (origami assays, Table 3.1, in Xinjiang). Based on the data obtained from the assessment, any transferability scores equal to or higher than 4.0 on the scale of 0–5 should be considered as indicative of excellent transferability, whereas any scores equal to or lower than 2.5 on the same scale could be considered as nontransferable at the current state of affairs. Differences between different regions of the world notwithstanding, some technologies definitely emerge as more transferable than others. Obviously, the technologies that employ an ingenious simplicity in design, such as the origami paper assays (Table 3.1) or the topical inorganic antimicrobials (Table 3.7), have an advantage over the more expensive and exquisite ones, such as graphene-based skin grafts (Table 3.12), the brain electrodes (Table 3.6), or imaging-based techniques (Table 3.4-3.5). Technologies employing cost-effective chemical processes, such as functionalized nanoparticles for targeted drug delivery (Table 3.8) or wound healing fillers (Table 3.9), also stand out over those employing hard engineering strategies (Table 3.2, 3.5-3.6) or overly elaborate and difficult-to-replicate materials processing methods, such as 2D material structure fabrication (Table 3.12) or 3D printing (Table 3.11). Many of the inorganic nanoparticle compositions could be synthesized with the use of inexpensive reagents and soft chemistry techniques, practically on kitchen stoves (Uskoković et al., 2020), and can also be sterilized using robust methods, without the concern that the material would degrade or lose its unique structural properties in the process. This is drastically different from materials requiring clean room environments, pricey organic reactants and catalysts, or devices composed of many mechanical parts, for which assembly and repair are a greater challenge. Still, the fact that the inorganic nanoparticles with antibacterial properties for topical applications (Table 3.7) have similar transferability scores as more chemically complex nanoparticles designed for injection into the blood or soft tissues (Table 3.8-3.9) suggests that the expediency of the application presents a strong determinant alongside the efficiency of the process. Still, as suggested by the markedly higher transferability scores derived for paper-based, flow-through diagnostic assays (Table 3.1) relative to those employing intricate photolithographic microfluidics (Table 3.2), the inexpensive ingenuity of the production method is a critical parameter defining the transferability of technologies.

One important trend demonstrated by the model is that simple and effective diagnostic technologies are more transferable to regions of the world where the poverty is endemic than their more complex and high-tech but also pricier counterparts. Clearly, mobility beyond the point-of-care centers is an important criterion for transfer, as deducible from the lower score for traditional imaging technologies (Table 3.4-3.5) than that for the pocket ones (Table 3.1-3.2). However, when two of such technologies are equally compact and portable, the advantage is given to the one that is easier to handle, reproduce in a generic form, and upgrade with the use of modest resources and technical skills. Initially, it was expected that the underdeveloped areas would be more receptive to diagnostic methods than to the therapeutic ones, simply because of the lesser practical demands accompanying their implementation, alongside the greater levels of patient-friendliness. However, it turns out that therapeutic devices are equally welcome, especially when they are minimally intrusive to the patients and are rooted in comparatively simple fabrication protocols. Paper-based flow-through assays (Table 3.1) thus prove to be negligibly more transferable than injectable colloidal systems for drug delivery (Table 3.8) or wound healing (Table 3.9). The treating of pivotal health challenges, such as cancer or infectious disease, is an important advantage in facilitating the transferability of such technologies.

The point that a technology is more transferable, however, does not answer a broader demand, which is that for the technology to solve a particular health issue. Diagnosing a disease in a setting that has no opportunity to provide the treatment for a given disease, for example, makes such technologies superfluous to some extent and unable to solve the central issue in question, that is, the disease. This provides just enough of the boost in the public reception of therapeutic technologies to compensate for the greater outcome predictability and patient compliance of the diagnostic technologies. In addition, the universal and rather commonsense trend emerging from this analysis is that technologies that are either very new or experimental in nature are more likely to be met with reserved public reception and have a rockier regulatory path before them than technologies that have a steadier record of safe and efficacious performance.

For most technologies analyzed, cultural factors (Table 1, P–S) had a critical effect on determining the transferability score. One trend noticeable here is that diagnostic devices are more welcomed in the Chinese region of interest than elsewhere, thus conforming to the common cultural presumptions, according to which the tradition of acknowledging the existence of a disease and its corporeal cause, then openly tackling it, is intrinsic to the Chinese culture, whereas a more transcendental perspective is rooted in India and that of “valiantly” shunning early diagnoses as unnecessary in Montenegro. Cultural factors entwine with the technological ones to also predispose Xinjiang to be a more favorable site for the local production of technologies than it is the case with West Bengal or Montenegro. The great majority of cultural products consumed in India, over 95% of them, are produced domestically (Cowen, 2007), and with this in mind, the cultural resistance to importation of foreign products, even in other fields of human interest, including medicine, is expected to be higher than in a country such as Montenegro, a candidate to the European Union and a member of the NATO alliance as of 2005 and 2017, respectively, or in any other countries where the products from the developed countries are held in higher regard than their locally produced counterparts. As for China, given its basing the economy on inexpensive production so as to enforce the high export rate and the low import rate, the import of products is being considered with reservation from many different angles, and local production is favored instead. In contrast, the ideas originating from the developed countries are being copiously adopted, as the result of which the competence and the will in the region to adapt the foreign technologies and reproduce them locally are being boosted, elevating the respective components of the net transferability score.

Another example where cultural biases had a major effect is that of a markedly lower transferability of medical drones (Table 3.3) in Montenegro than in West Bengal. Infrastructural reasons for this difference aside, primarily in terms of a poorer road connectivity in West Bengal than in Montenegro, the resistance to drones in India, as per the 2014 Pew report (Pew Research Center Report, 2014), was least among 44 countries surveyed, second to Israel, and therefore, their uses for the provision of medical diagnosis or even treatment are likely to be accepted in this country, as opposed to Montenegro, where, as in all European countries surveyed, the majority of population disproves drones for any uses. The NATO bombing campaign from 1999, which this author witnessed first-hand in Montenegro, has also left the memory of misuse of unmanned aerial vehicles and erroneous striking of civilian targets, explaining partially the public resistance to this robotic technology. The receptiveness to the use of drones for telemedicine was the highest in Xinjiang, but so was the cultural congruence with paper-based diagnostics, in part because origamis foldable into cranes, which are considered holy in China and many other countries of the Far East, can be the catalyst for the expansion of their usage from popular pastime to medicine. Also, being a part of the European continent, in Montenegro, the traditional herbs are used as a pharmacotherapy less commonly than the synthetic drugs, in contrast to the more pervasive usage of these natural medicines in various parts of China and India. This was projected in the public and administrative hesitation to install high-throughput selection methods for sorting through these natural pharmaceutical libraries for a personalized medicine approach (Table 3.10) in Montenegro compared to the more welcoming administrative responses in West Bengal and Xinjiang.

Limitations of the Model

Limitations of converting a multidimensional phenomenon that the transfer of a technology is into a single digit are inevitably bound to be many. One of such demerits becomes obvious when two settings aimed for the transfer receive identical scores for a particular technology, but for obviously different reasons. For one setting, for example, the score reduction could be due to the hampered regulation and public majority disapproval, while for another, it could be due to technical and/or infrastructural deficiencies. In such situations, by looking at the score alone, the analyst would not know where the improvements are to be made or whether the low score is mainly due to the intrinsically low transferability of the technology itself or due to challenges posed by the social setting. Another case where scores per se would be incomparable is when a very advanced technology stands out over the existing solutions better in a poorer market, but the viability of its integration to it is slimmer from the infrastructural or regulatory standpoints, as opposed to the very same technology being more technically incorporable in a richer setting but at the cost of lower marketability. This is why the transferability scores deduced from these analyses should always be accompanied with the tables containing complete sets of scores pertaining to individual parameter. This would offer a clear view of parameters that scored low, thus highlighting the critical areas where progress is to be made to increase the transferability of the given technology. Another limitation of the model, as applied here, is that a single researcher's perspective was used as the input, producing potential biases favoring technologies lying within his field of expertise over others, in spite of the best effort to remain neutral and objective with regard to them all. More ideally, therefore, consortia of researchers, alongside possible public surveys, should provide a collective input to yield more credible transferability scores.

Yet another limitation of the model stems from its intrinsic focus on technology per se. In other words, this is not a model that takes into account any of the socioeconomic features of the region to which a technology is to be transferred independently of the technology in question. Some of these key socioeconomic features in a free market economy include the market size and the climate on the market from which commercial opportunities pertaining to the import of the new technology arise. Obviously, the transfer of biomedical technologies can be supported and financed at the federal level, but most commonly, it is the incentives for corporations in the biotech sector to capitalize on the export of an existing technology to a new locality that are the drivers of the transfer. Moreover, the world's poorest countries are seldom devoid of corruption, political favoritism, and other partisan practices that act as impediments to economic development (Simović, 2021), which poses a detailed understanding of the local economy and politics as a critical factor to understand before engaging in any realistic transfer of technologies, and yet this acquaintance with the features of the local economy is not an explicit part of the model. The model, rather, is strictly technology-centric, which is both its strength and its weakness.

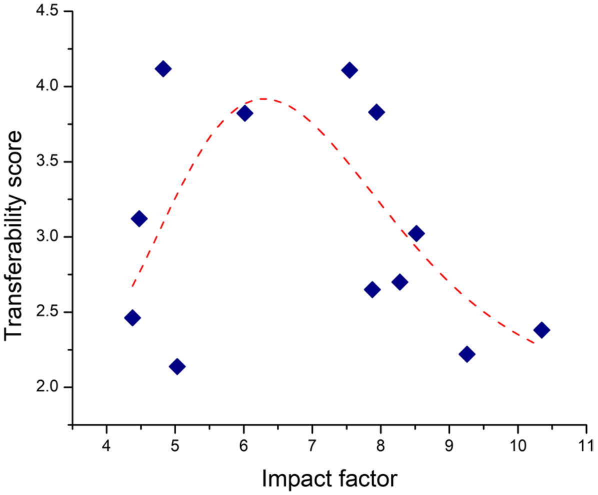
Finally, receiving a low transferability score should not be viewed as a death sentence for a technology. Technological innovations and changes in the socioeconomic or infrastructural statuses in the underdeveloped regions of interest may change, and opportunities for the transfer of the given technology may reappear. To justify the inertness of the technological development in developed parts of the world with respect to thinking about the transfer to underdeveloped countries, the argument of maturation of technologies is often invoked. In particular, it is said that new technologies, especially the exquisite and expensive ones, must "mature" before they become available to masses and classes beyond the circles of the privileged. Maturation as a concept, however, has been defined disproportionally to the frequency of its usage, like many terms from the business portion of the biotech vocabulary. Especially in the context of the technology transfer to a poor country, it is not clear what maturation would technically imply, let alone that by the time infrastructural and technological bases ready to accept the new technology have "matured", the given new technologies may no longer be new. In that case, overmaturation would precede the maturation, so to speak, shedding shadows on the exactitude of this term. What is more, even in developed settings alone, some medical technologies never mature, one example of which may be tissue engineering constructs supplemented with morphogenetic growth factors. These medical devices were hailed early on as being on par with stem cells in terms of regenerative capacities (Uskoković & Uskoković, 2017), but then it turned out that they caused abnormal bone growths, neoplasms, and reproductive problems, as was the case, most famously, with Medtronic's *Infuse* bone cements, which were approved for use in spinal vertebrae repair in 2002, but then led to around 10,000 patient lawsuits in years that followed (Turner, 2022). This is only one out of many technologies whose astronomical costs were justified by the need for the technologies to "mature". However, once steady patterns of side effects were registered, the technologies were discarded well ahead of their maturation date. This explains why experimental concepts lacking the history of reliable use face public and regulatory hurdles and are more difficult to transfer than technologies well proven in practice. This is a fundamental paradox, given that the best technologies to transfer are those that are in formative stages and that can engage the local researchers in their reshaping and adapting to the local infrastructure and needs of the populace. One way to solve this paradox is to create bridges of communication and trust between researchers in the rich and the poor parts of the world and engage them in translational thinking in the earliest stages of the design of technological blueprints and proofs of concept. The second important impetus should come in the form of the awareness that simple, elegant, and resource-effective technologies have a tendency to score better on the transferability test such as the one devised here. Whenever possible, researchers should resort to such creative and resourceful ideas, as opposed to indulging in the modern-day idea that the more complex and expensive is always the better.

In the end, learning from technologies that either overly ripened or never matured is essential for allowing the developing societies to learn from the developed ones—notwithstanding the arrogance implied in the term "developed"—and perform what is often christened a "leapfrog" effect (Uskoković et al., 2010). In a sense, they would learn from the failures of the developed world and catch up with it over a finite period of time, thus diminishing the gap between those who live in abundance and those who struggle in poverty. Therefore, like all assessments, the one presented here should ideally be seen as an opportunity to learn and evolve rather than to provide judgments set in stone. This is especially so because the aforementioned lack of neutrality of technologies implies not only their effect on the totality of the social space surrounding them, but also the reverse effects of this space on the prospect of these technologies. As a result, divorcing the effects of the intrinsic nature of technologies from the effects of the tangled network of commerce, insurance policies, and regulations on the translatability of the given technologies is, strictly speaking, an impossible task. The example of blueprints for perfectly mature technologies that remain indefinitely locked in corporate files simply because of the lack of financial interest or capacity to push the product to the market may be invoked here to remind us of how substantial and decisive these nonscientific factors determining the fate of technologies are. For these reasons, breaking down the process of the technology transfer into numerous factors, such as that attempted here, cannot be denounced as reductionist in essence so long as these individual factors are not viewed as definite and factual. Rather, they are a guide for highlighting the factors that stand in the way of an effective transfer and devising strategies for their improvement.

Are the Most Transferable also the Most State-Of-The-Art?

As a topping on the cake in this discussion comes the question whether the most transferable technologies deduced from the analysis described here are also the ones given the most priority and room for publication in the world's most prestigious publication platforms. To answer this question, a plot was constructed (Fig. 3), showing the average impact factors of scientific journals publishing research on each of the twelve technologies analyzed here in 2021 as a function of their transferability scores. The trend evidently shows that the most transferable medical technologies are not

Fig. 3 Transferability scores for the twelve test technologies averaged for the three regions of interest and represented as a function of the 2-year impact factors of journals publishing research on them in 2021 as per the Scopus database. Bibliographic search was carried out by inputting three keywords for each technology (Table 1). The average number of hits per technology was 30 ± 24. Dashed red line represents the best nonlinear fit of the data points



discoverable in high-impact journals, which appear to favor the research of comparatively low potential for transfer across the rich-poor divide. Research reports pertaining to the most transferable technologies are not discoverable either in journals on the low end of impact factors; rather, they are found most prominently around the middle of the impact factor range. This demonstrates that technologies that make up all the fad of a science era are not the most transferable ones. Instead, the search for the technologies with the largest potential for transfer to the poor regions of the world should bind us to less expected of places. To put it simply, things that heal the world, as ever, are to be looked for not in spotlights, but in the darker corners.

Conclusion

A proof-of-concept method for quantifying the transferability of technologies was devised in the form of an assessment sheet containing nineteen independent parameters. The model was tested with respect to twelve state-of-the-art medical technologies and three comparatively impoverished regions of the world, namely, West Bengal in India, Xinjiang in China, and the former Yugoslav state of Montenegro. The results of the analysis demonstrate that neither the gross economic productivity nor the degree of poverty can be the sole determinants of the transferability of technologies. Rather, a complex network of scientific, technological, infrastructural, socioeconomic, and cultural factors defines the extent of transferability of new technologies across the rich-poor divide. The proposed model helps in discerning which of these factors represent the most critical hindrances in the transfer of technologies. For many of them, cultural factors assumed the dominant role in determining the transferability scores, indicating that they should be more commonly incorporated into models for assessing the potential of new technologies to create social impact. It is argued that the most dependable technologies to transfer are old and proven ones, but the best ones for ameliorating the rich-poor divide are juvenile technologies in formative stages of their development, which also happen to be employing simplistic ingenuity and resourcefulness in their design. It is also argued that transferability of technologies should be considered early on in their design, ideally upon their very inception. These findings reiterate that models for assessing the social value of technologies should inextricably tie the scientific factors with the socioeconomic and humanistic. Countless technical models of various natures could be devised with this holistic principle in mind.

Declarations

Competing Interests The author declares no competing interests.

References

Anon. – "Strategija razvoja turizma u Crnoj Gori do 2020. godine", Ministry of Tourism and Environmental Protection of Montenegro, , retrieved from http://www.bjelasica-komovi.me/wp-content/uploads/2015/01/Strategija-razvoja-turizma-Crne-Gore-do-2020.-godine-1.pdf (2008).

Bai, Y., Qian, Q., Jiao, J., Li, L., Li, F., & Yang, R. (2020). Can environmental innovation benefit from outward foreign direct investment to developed countries? Evidence from Chinese manufacturing enterprises. *Environmental Science and Pollution Research, 27*, 13790–13808.

Bauer, A. M., & Brown, A. (2014). Quantitative assessment of appropriate technology. *Procedia engineering, 78*, 345–358.

Bejleri, D., Robeson, M. J., Brown, M. E., Hunter, J., Maxwell, J. T., Streeter, B. W., Brazhkina, O., Park, H. J., Christman, K. L., & Davis, M. E. (2022). In vivo evaluation of bioprinted cardiac patches composed of cardiac-specific extracellular matrix and progenitor cells in a model of pediatric heart failure. *Biomaterials Science, 10*(2), 444–456.

Bhandari, L., & Chakraborty, M. (2015). *Spatial poverty in West Bengal*. Mint (March 3, 2015), retrieved from https://www.livemint.com/Opinion/dXPv8bp492mKX9rirXX0hK/Spatial-poverty-in-West-Bengal.html.

Castagnola, E., Thongpang, S., Hirabayashi, M., Nava, G., Nimbalkar, S., Nguyen, T., Lara, S., Oyawale, A., Bunnell, J., Moritz, C., & Kassegne, S. (2021). Glassy carbon microelectrode arrays enable voltage-peak separated simultaneous detection of dopamine and serotonin using fast scan cyclic voltammetry. *Analyst, 146*(12), 3955–3970.

Chakraborty, P. P., Thakurta, S. G., Satpathi, P. S., Hansda, S., Sit, S., Achar, A., & Banerjee, D. (2012). Outbreak of cutaneous anthrax in a tribal village: A clinico-epidemiological study. *Journal of Association of Physicians of India, 60*(2), 11–15.

Cowen, T. (2007). *Some countries remain resistant to American cultural exports*. The New York Times (February 22, 2007), retrieved from https://www.nytimes.com/2007/02/22/business/22scene.html.

DePasse, J. W., Caldwell, A., Santorino, D., Bailey, E., Gudapakkam, S., Bangsberg, D., & Olson, K. R. (2016). Affordable medical technologies: bringing value-based design into global health. *BMJ Innovations, 2*(1), 4–7.

Farley, J. & Daly, H. (2006) Natural capital: The limiting factor. *Ecological Engineering, 28*(1), 6–10.

Fu, M. (2021). Drug discovery from traditional Chinese herbal medicine using high content imaging technology. *Journal of Traditional Chinese Medical Sciences, 8*(3), 198–204.

Fu, X., & Zhang, J. (2011). Technology transfer, indigenous innovation and leapfrogging in green technology: the solar-PV industry in China and India, *Journal of Chinese Economic and Business Studies*, *9*(4), 329–347.

Galgano, S. J., Calderone, C. E., Xie, C., Smith, E. N., Porter, K. K., & McConathy, J. E. (2021). Applications of PET/MRI in abdominopelvic oncology. *Radiographics, 41*(6), 1750–1765.

Gu, W., Hua, Z., Li, Z., Cai, Z., Wang, W., Guo, K., Yuan, F., Gao, F., & Chen, H. (2021). Palladium cubes with Pt shell deposition for localized surface plasmon resonance enhanced photodynamic and photothermal therapy of hypoxic tumors. *Biomaterials Science, 10*(1), 216–226.

Gulácsi, L., Rencz, F., Péntek, M., Brodszky, V., Lopert, R., Hevér, N. V., & Baji, P. (2014). Transferability of results of cost utility analyses for biologicals in inflammatory conditions for central and eastern European countries. *European Journal of Health Economics, 15*, S27–S34.

Haghayegh, F., Salahandish, R., Zare, A., Khalghollah, M., & Sanati-Nezhad, A. (2022). Immuno-biosensor on a chip: Aa self-powered microfluidic-based electrochemical biosensing platform for point-of-care quantification of proteins. *Lab on a Chip, 22*(1), 108–120.

Hamhami, A., Amrani, A. K., & Smahi, A. (2020). Environmental economics in Algeria: Eempirical investigation into the relationship between technological policy, regulation intensity, market forces, and industrial pollution of Algerian firms. *Environmental Science and Pollution Research, 27*, 45419–45434.

Haney, K., Tandon, P., Divi, R., Ossandon, M. R., Baker, H., & Pearlman, P. C. (2017). The role of affordable, point-of-care technologies for cancer care in low-and middle-income countries: A review and commentary. *IEEE journal of translational engineering in health and medicine, 5*, 1–14.

Heidegger, M. (1954). *The question concerning technology, and other essays*. Harper Perennial.

Huh, T., & Kim, H.-J. (2018). Korean experimentation of knowledge and technology transfer to address climate change in developing countries. *Sustainability, 10*, 1263.

Mahato, G., Hansda, B., & Banerjee, N. (2019). Ethnobotanicals used for the treatment of skin diseases with special emphasis on carbuncle disease from Purulia district of West Bengal in India. *Pharmacognosy Journal, 11*(4), 745–753.

Maity, R., Mishra, R., & Pattnaik, P. K. (2022). A review of flying robot applications in healthcare. *Intelligent Systems Reference Library, 213*, 103–111.

Menck, K.-W. (1973). The concept of appropriate technology. *Intereconomics, 8*, 8–10.

Mohd-Zahid, M. H., Zulkifli, S. N., Abdullah, C. A. C., Lim, J., Fakurazi, S., Wong, K. K., Zakaria, A. D., Ismail, N., Uskoković, V., & Mohamud, R. (2021). Gold nanoparticles conjugated with anti-CD133 monoclonal antibody and 5-fluorouracil chemotherapeutic agent as nanocarriers for cancer cell targeting. *RSC advances, 11*(26), 16131–16141.

Nimbalkar, S., Samejima, S., Dang, V., Hunt, T., Nunez, O., Moritz, C., & Kassegne, S. (2021). Graphene on glassy carbon microelectrodes demonstrate long-term structural and functional stability in neurophysiological recording and stimulation. *Journal of Neural Engineering, 18*(5), 056035.

Ng, A. W., Nathwani, J., Fu, J., & Zhou, H. (2021). Green financing for global energy sustainability: prospecting transformational adaptation beyond Industry 4.0. *Sustainability: Science, Practice and Policy, 17*(1), 377–390.

Nguyen, H. T., Hoang, T. G., Nguyen, L. Q. T., Le, H. P., & Mai, H. X. V. (2022). Green technology transfer in a developing country: Mainstream practitioner views. *International Journal of Organizational Analysis, 30*, 699–720.

Patnaik, J., & Bhowmick, B. (2022). Determining appropriateness for management of appropriate technology: Aan empirical study using factor analysis. *Technology Analysis & Strategic Management, 34*, 125–137.

Pew Research Center Report. (2014). Global opposition to US surveillance and drones, but limited harm to America's image. Retrieved from https://www.pewresearch.org/global/2014/07/14/global-opposition-to-u-s-surveillance-and-drones-but-limited-harm-to-americas-image/

Rau, J. V., Fosca, M., Fadeeva, I. V., Kalay, S., Culha, M., Raucci, M. G., Fasolino, I., Ambrosio, L., Antoniac, I. V., & Uskoković, V. (2020). Tricalcium phosphate cement supplemented with boron nitride nanotubes with enhanced biological properties. *Materials Science and Engineering: C, 114*, 111044.

Rosser Jr., J. C., Vignesh, V., Terwilliger, B. A., & Parker, B. C. (2018). Surgical and medical applications of drones: A comprehensive review. *JSLS : Journal of the Society of Laparoendoscopic Surgeons, 22*(3), e2018.00018.

Rustagi, N., & Singh, R. (2010). Mercury and health care. *Indian Journal of Occupational and Environmental Medicine, 14*, 45–48.

Schmidt, T. S., & Huenteler, J. (2016). Anticipating industry localization effects of clean technology deployment policies in developing countries. *Global Environmental Change, 38*, 8–20.

Schumacher, E. F. (1998). *Small is beautiful…25 years after*. Hartley & Marks.

Simović, M. (2021). The impact of corruption on economic growth in the countries of southeast Europe. *Transformations in Business and Economics, 20*(1), 298–308.

Southee, J. A., & Curren, R. D. (1997). A prevalidation process. *Comments on Toxicology, 6*, 27–35.

Taylor, D., & Al-Saeed, E. (2010). Can (and will) governments afford personalized medicine? *Personalized Medicine, 7*(5), 587–595.

Turner, T. (2022). *Infuse bone graft lawsuits*. Drugwatch, retrieved from https://www.drugwatch.com/infuse/lawsuits/.

Uskoković, V. (2011). Co-creation of experiential qualities. *Pragmatics & Cognition, 19*(3), 562–589.

Uskoković, V. (2015a). Nanostructured platforms for the sustained and local delivery of antibiotics in the treatment of osteomyelitis. *Critical Reviews™ in Therapeutic Drug Carrier Systems, 32*, 1.

Uskoković, V. (2015b). The Odyssey of co-creation: sailing between Scylla of solipsism and Charybdis of objectivism. *Biocosmology–Neo-Aristotelism, 5*(2), 226–239.

Uskoković, V. (2018). Flipping the flipped: the co-creational classroom. *Research and Practice in Technology Enhanced Learning, 13*(1), 1–24.

Uskoković, V. (2021a). Nanomedicine for the poor: a lost cause or an idea whose time has yet to come? *Nanomedicine, 16*(14), 1203–1218.

Uskoković, V. (2021b). Health economics matters in the nanomaterial world: Cost-effectiveness of utilizing an inhalable antibacterial nanomaterial for the treatment of multidrug-resistant pneumonia. *Technology in Society, 66*, 101641.

Uskoković, V. (2021c). A historical review of glassy carbon: Synthesis, structure, properties and applications. *Carbon Trends, 5*, 100116.

Uskoković, V., & Uskoković, D. (2017). Nanotechnologies for preventive and regenerative medicine: Quo Vadis, Domine? In V. Uskoković & D. Uskoković (Eds.), *Nanotechnologies for Preventive and Regenerative Medicine: An Emerging Big Picture*, *Micro and Nano Technologies Volume Series* (pp. 513–566). Elsevier.

Uskoković, V., & Drofenik, M. (2021). Gold-embellished mixed-valence manganite as a smart, self-regulating magnetoplasmonic nanomaterial. *Materials Chemistry and Physics, 271*, 124870.

Uskoković, V., Ševkušić, M., & Uskoković, D. (2010). Strategies for the Scientific Progress of the Developing Countries in the New Millennium: The cases of Serbia, Slovenia and South Korea. *Science, Technology & Innovation Studies*, 6(1), 33–62.

Uskoković, V., Ghosh, S., & Wu, V. M. (2017). Antimicrobial hydroxyapatite–gelatin–silica composite pastes with tunable setting properties. *Journal of Materials Chemistry B, 5*(30), 6065–6080.

Uskoković, V., Tang, S., Nikolić, M. G., Marković, S., & Wu, V. M. (2019). Calcium phosphate nanoparticles as intrinsic inorganic antimicrobials: in search of the key particle property. *Biointerphases, 14*(3), 031001.

Uskoković, E., Uskoković, T., Wu, V. M., & Uskoković, V. (2020). …And all the world a dream: Memory effects outlining the path to explaining the strange temperature-dependency of crystallization of water, a.k.a. the Mpemba effect. *Substantia, 4*(2), 59–117.

Wang, X., Qiu, L., Wang, C., Gao, Z., Zhou, S., Cui, P., Jiang, P., Hu, H., Ni, X., Du, X., & Wang, J. (2022). Nanodot-doped peptide hydrogels for antibacterial phototherapy and wound healing. *Biomaterials Science, 10*(3), 654–664.

Wei, S., Liu, Y., Yang, L., Wang, H., Niu, H., Zhou, C., Wang, Y., Guo, Q., & Chen, D. (2022). Flexible large e-skin array based on patterned laser-induced graphene for tactile perception. *Sensors and Actuators A: Physical, 334*, 113308.

Wu, V. M., Mickens, J., & Uskoković, V. (2017). Bisphosphonate-functionalized hydroxyapatite nanoparticles for the delivery of the bromodomain inhibitor JQ1 in the treatment of osteosarcoma. *ACS Applied Materials & Interfaces, 9*(31), 25887–25904.

Wu, V. M., Tang, S., & Uskoković, V. (2018). Calcium phosphate nanoparticles as intrinsic inorganic antimicrobials: the antibacterial effect. *ACS Applied Materials & Interfaces, 10*(40), 34013–34028.

Wu, V. M., Huynh, E., Tang, S., & Uskoković, V. (2021). Calcium phosphate nanoparticles as intrinsic inorganic antimicrobials: Mechanism of action. *Biomedical Materials, 16*, 015018.

Yan, Y., Zhao, D., Li, W., Li, X., Chang, Y., Zhang, Q., & Liu, M. (2022). An origami paper-based analytical device for rapid and sensitive analysis of acrylamide in foods. *Micromachines, 13*, 13.

Zheng, X., Yu, H., & Yang, L. (2022). Technology imports, independent innovation, and China's green economic efficiency: An analysis based on spatial and mediating effect. *Environmental Science and Pollution Research, 29*, 36170–36188.