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Briefing note

Technology, migration and the 2030 Agenda for Sustainable Development

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Key messages

- Highly-skilled migrants contribute substantially to technology innovation and research and development in destination countries – particularly high-income countries.
- Migrants and diaspora groups are an important channel for transferring technology from destination countries back to origin countries. This may be through knowledge they impart directly, remittances they send home, investments they make in origin countries, and support they provide for enterprise development and research institutions.
- Technology – particularly the digital connectivity offered by mobile phones – affects every aspect of migration: it provides access to information pre-migration, during journeys and in destination countries; facilities remittances; and helps migrants stay connected to families.
- Government management of migration relies heavily on technology, both in keeping people out and in processing migrants after they arrive. Some of these technologies raise concerns about migrants' rights, but others, such as blockchain, may prove to have more positive applications.

Migration and the 2030 Agenda for Sustainable Development: a briefing series

Migration is one of the defining features of the 21st century and significantly contributes to economic and social development everywhere. As such, migration will be key to achieving the Sustainable Development Goals (SDGs).

In a series of briefings, ODI, with the support of the Swiss Agency for Development and Cooperation (SDC), explains the relationship between migration and critical development issues that are central to the SDGs. The briefings provide a set of recommendations for governments and policy-makers tasked with delivering the 2030 Agenda.

1 Introduction

The issues of technology, innovation and productivity are mentioned in 10 of the 17 Sustainable Development Goals (SDGs) – 1, 2, 4, 5, 7, 8, 9, 12, 14, reflecting the importance of technological change in raising economic growth and living standards, and in reducing poverty. However, none of these terms are mentioned in SDG 10 on inequality, which includes the only target explicitly concerned with migration – target 10.7.

In this briefing, we discuss the technology–migration nexus and show its significance to a range of SDGs and achieving the 2030 Agenda for Sustainable Development. We demonstrate that migrants are (and have been) crucial for innovation and technological change processes in both destination and origin countries. And the use of technology and technological innovations is fundamental both to migration processes and to attempts by government authorities to manage migration – or restrict it.

1.1 Definitions

We use the following terms:

- **Technology** is understood here to mean systematised knowledge, often embodied in physical form, as a machine or instrument, used in production or consumption activities, or spelled out in a blueprint or piece of software.
- **Innovation** refers to a change in technology, a new idea or new knowledge used to create a new product or service, a new process of production or distribution of either products or services.
- Technology is evidently essential to all economic activity, but more significantly, innovation and technological change are essential to long-term **productivity** increases and to economic growth.

The technology 'lifecycle' distinguishes between:

1. The **production** of technology (innovation) – creating, developing and investing in new ideas and new knowledge results in new products, services or production processes. Innovation undertaken by firms may be disruptive (substantial changes to existing products and processes, or entirely new products/processes) or incremental (minor changes or improvements, which lower cost and increase competitiveness) (Christensen et al., 2015).
2. The **distribution** and **diffusion** of new technology – its adoption by 'follower' producers who wish to produce the new or changed product or service, or to adopt the new production process, to compete better with the innovator.
3. The **use** of new technology by consumers (individuals or organisations) – the use of the product or service in which new technology is embodied.

We consider the interaction between elements of the technology lifecycle and migration – both from origin countries to destination countries and the return of certain migrants and diaspora members.[1] We identify four main migration–technology interactions or pathways:

1. **Migration's impact on innovation – technology production – in destination countries.** Migrants and diasporas – especially highly-skilled individuals – have significant impact on innovation and research and development (R&D) activity in destination countries.
2. **Migration's impact on technology distribution and diffusion from destination countries back to origin countries.** Through their links with origin countries, migrants and diasporas may impact on the distribution/diffusion of existing technologies to those countries and on innovation there.
3. **Technology's impact on migrants' journeys and migration processes.** Use of technology has a significant impact on the migration experience, impacting on journeys, entry and integration into destination countries, and links with family and communities in origin countries.

1 The briefing focuses on international labour migrants (or 'migrant workers'), defined as individuals who moved from one country to another for the purpose of employment (International Organization for Migration (IOM), 2011). Where the briefing refers to other types of migrants, for example refugees, this is stated explicitly. Diasporas refer to migrants' children and later generation descendants, who identify in some way with their families' country of origin.

4. **Technology's use in migration management.** Technology is used – for good or ill – in migration administration and management by public authorities, to regulate border crossing, passage and settlement of migrants and refugees.

In the next section, we identify more explicitly how the SDGs address technology and migration. Section 3 then considers pathways one and two – migration's impact on technology, while section 4 flips the relationship around and considers how technology shapes the migration process (pathways three and four). We conclude by offering recommendations for boosting the potential contribution of migration and diasporas to the SDGs, through their impact on technology production and diffusion.

2 Technology, migration and the 2030 Agenda

The centrality of technological improvement for economic growth is underlined in SDG 8. Meanwhile, Goal 9 focuses directly on R&D and technological capabilities, pointing to their concentration globally in high-income countries, for which one reason is inward migration of highly-skilled workers from low- and middle-income countries – the so-called 'brain drain'. Goal 17, on global partnerships, addresses the unequal distribution of technological capabilities between global 'North' and 'South'. It emphasises the need to rebalance 'brain drain' with 'brain gain' – the return of highly-skilled migrants to origin countries – and 'brain circulation' – the transfer of knowledge and technology to origin countries by migrants and diasporas, partly through temporary return (we discuss both in section 3.2).

Goal 10 identifies solutions to specific challenges facing migrants: improved migration processes and lower remittance costs. Tackling both challenges depends on migrants' access to new technologies, especially mobile-phone and related digital technologies. But Goal 10 may also be undermined by governments' use of technology to close borders and prevent migration.

Several other SDGs are also of relevance: Goals 2 and 3, and 5–7, address the specific issues of: food security and agricultural productivity; environmental impacts on health; gender equality; water quality; and energy poverty, respectively. Developing countries' access to technological improvements in each of these areas is crucial, underlining the importance of their technological absorptive capacity and the effects of migration on this.

Table 1 lists key SDGs relevant to the technology–migration nexus, identifying the links and key mechanisms.

3 How migration contributes to the production and diffusion of technology

Migrants contribute significantly to R&D and innovation activities in destination countries and to diffusion. These contributions support a number of SDGs as mentioned – in particular, SDGs 8.2 and 9.5, on the centrality of technology and new innovations for economic growth and productivity, as well as SDG 17, on North–South technology partnerships.

The interaction between migration and technology through pathways one and two relates closely to the knowledge dimension of technology. This dimension, even when embodied in a physical good (like a machine), has both explicit and tacit elements. That is, some of the knowledge can be systematised and written down – or 'codified' – (explicit knowledge), while some cannot (tacit knowledge). Instead, the transfer of tacit knowledge – essential for technological change – requires direct interaction and communication between people via joint activities or formal and informal instruction (Polanyi, 1966). This cultural and linguistic dimension of technological change is relevant to how it is affected by migration.

Migrants' contribution to innovation in destination countries has been substantial. Partly this is because cultural diversity and difference encourages unconventional and out-of-the-box thinking and discourages groupthink, which is valuable for new ideas and knowledge creation. Unlike innovation, diffusion of already-created technology involves the transfer of tacit knowledge (as well as explicit) and thus relies on common language and culture, as well as local knowledge – especially when diffusion occurs in a different context, such as another country. Hence migrants and diasporas may contribute significantly to technology diffusion from destination back to origin countries.

Diffusion is partly determined by absorptive capacities – that is, the ability to assimilate and apply knowledge. This depends on stocks of technically competent managers, of highly-skilled people trained in science, technology, engineering and mathematics (STEM) fields, and of STEM organisations and institutions. Highly-skilled migration flows, both inward and outward, are evidently crucial for countries' absorptive capacities. This makes migration policy an important tool for technology and industrial development and economic growth.

3.1 Migrant impacts on innovation and knowledge generation in destination countries

The Nobel Prize provides an interesting indicator of migrants' contribution to innovation in technology. From its inception to 2016, the Nobel Prize was awarded 579 times to 911 people and organisations. Of the total of 350 winners residing in the US at the time of their award, more than 100 were immigrants born elsewhere. In fact, as a distinct category, US immigrant winners are second only to US-born laureates: their number exceeds that of

Table 1 Technology, migration and the 2030 Agenda for Sustainable Development

Relevant SDGs and targets	Link to migration
Goal 8 Decent work and economic growth	**Pathway: 1, 2**
8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation	Highly-skilled migrants participate in innovation and R&D in destination countries. Return migrants and diaspora networks support diffusion of new/improved technology into origin countries and R&D there.
Goal 9 Industrial innovation and infrastructure	**Pathway: 1, 2**
9.5 Enhance scientific research and upgrade technological capabilities in all countries	Highly-skilled migrants and diaspora members engage in R&D and technology production and diffusion in both destination and origin countries, with spillovers to other people and to institutions in both locations.
9.b Support domestic technology development, research and innovation in developing countries	
9.c Significantly increase access to information and communications technology (ICT)	
Goal 10 Reduced inequalities	**Pathway: 3, 4**
10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies	Digital apps and other mobile telephony technologies facilitate migration journeys and integration and are especially important for lower-skilled migrants and for refugees. Digital technologies may support government migration management but can increase migrants' risks. Technologies are used to close borders.
10.c By 2030, reduce transaction costs of migrant remittances	Financial technology ('fintech') apps can reduce remittances costs and increase security of transactions, and support migrants' financial inclusion, as well as financial development in origin countries.
Goal 16 Peace, justice and strong institutions	**Pathway: 3, 4**
16.9 Provide legal identity for all, including birth registration	Blockchain technology can expand provision of secure and portable birth certificates and documents.*
Goal 17 Strengthen global partnerships for sustainable development	**Pathway: 1, 2, 3**
17.6 Enhance regional and international cooperation in science and technology and innovation	Migration and diaspora networks contribute to technological partnerships for 'south' countries.
17.7 Promote environmentally sound technologies for developing countries	
17.8 Enhance capacity building mechanisms and enabling technology, in particular ICT	
17.16 Enhance the Global Partnership for Sustainable Development	

laureates born in any other country (Najam, 2017). In 2016, all six US Nobel laureates were immigrants.[2]

Numerous studies demonstrate highly-skilled migrants' role, through their participation in teams along with locals, in disruptive innovation (usually measured by R&D spending or patents). For instance, Hunt and Gauthier-Loiselle (2009) found that, in the United States during the 1940–2000 period, there was a strong causal relationship between rising population shares of immigrant college graduates and post-college immigrants, on one hand, and numbers of patents on the other.[3] They also showed that a college-graduate immigrant contributed at least twice as much to patenting than their native counterparts. Another

2 Three of the prizes – Peace, Literature and Economics – are not directly related to technology.

3 A 0.7 percentage point increase in the population share of immigrant college graduates and a 1.3 percentage point increase in the population share of post-college immigrants each increased patenting per capita by 12%.

study (Bosetti et al., 2015) quantified the contribution of skilled migrants in the European Union (EU) to innovation, showing significant positive effects on knowledge production and application (measured by patent applications and journal articles).

Bosetti et al. (2015) also find that cultural diversity due to migrant involvement and complementarities between locals and immigrants is an important contributing factor in improving productivity, problem-solving and improving the absorptive capacity of all employees within organisations. This is linked to the significance of tacit knowledge, which requires direct human interaction for its transfer, and without mobility remains fixed to specific locations and contexts. Migrant–local networks increase the scope of information available and facilitate 'agility' (speed and adaptiveness) by enhancing organisations' capabilities for disruptive innovation and by supporting competitiveness agendas.[4]

Box 1 Migrant pioneers and leaders in disruptive technology

A key component of the so-called 'fourth industrial revolution' – characterised, according to the World Economic forum, 'by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres' – is sustainable materials for use in new technologies. One recently discovered material, graphene, is considered the world's first two-dimensional material: ultra-thin and ultra-light, flexible yet immensely tough, it can act as either a conductor or a perfect barrier (Upadhyay et al., 2014). It was discovered at the University of Manchester, United Kingdom by a culturally diverse team of natives and immigrants, led by two Russian immigrant scientists who won the Nobel Physics Prize in 2010.

Graphene's discovery has spurred several ongoing innovations that are likely to contribute to SDGs 6 and 7, linked to water, waste reduction and clean energy. For instance, research at the University of Manchester led by an Indian immigrant scientist has prototyped graphene filters that separate organic solvent from water and remove water from gas mixtures to provide clean and cheap drinking water, lowering costs of commercial filtration and desalination. At the Ulsan National Institute of Science and Technology in South Korea, a US-born immigrant is researching graphene's use in increasing the life of traditional lithium-ion batteries for quicker, longer-held charging, which is very valuable for electric cars (Dumé, 2018).

Clustering effects[5] are also important for innovation and technology diffusion, and migration is important for cluster creation. For example, a majority of the population in parts of Silicon Valley, such as Cupertino and Berryessa, are migrants – mainly from China and India (Jiménez, 2018). Silicon Valley also provides considerable evidence for positive spillover effects from migrants to locals (though there are multiple other examples).

Much harder to measure than disruptive innovation is incremental innovation (and thus it is also more difficult to evaluate or attribute migrants' contribution to it). However, Lee and Nathan (2010) use survey data to show a positive and significant correlation between London firms' workforce and ownership diversity and their level of innovation activity, including incremental innovations. They do not claim causality but rather emphasise that diversity complements the main driving factors of innovation: firms' own R&D spending and collaboration with other firms.

Innovation is facilitated by institutional 'ecosystems' that underpin the provision of finance, information and physical facilities (labs, design workshops and factories) along with well-functioning regulatory organisations. Both government (local and national) and multinational corporations are critical for innovation and technology diffusion, the latter of which are important for stimulating and facilitating migration of highly-skilled employees, many of whom contribute to companies' innovation in destination countries.

But the role of migrants in high-profile innovation goes beyond the R&D lab. The stereotype that migrants have a stronger work ethic is common, but perhaps due to this or to a willingness to take risks, as reflected in their decision to move countries, many immigrants are highly successful entrepreneurs and senior executives. One recent tabulation showed that 15 of the top-25 US 'tech companies' (mainly in ICT), which are together worth over $4 trillion, have first- or second-generation immigrants among their founders. These companies included Apple, Amazon, Google and Facebook, and Ebay, PayPal, Tesla and Yahoo (Molla, 2018). In several of these corporations – Google, Microsoft, Pepsi – their Chief Executive Officers are immigrants. Examples abound outside the US too: Carlos Slim, who controls the major player in Mexico's telecoms sector (and was the richest man in the world in 2010), is a second-generation Mexican from a Lebanese family.

With their culturally diverse employee base, many of these companies contribute to the SDGs in developing countries through both their primary business activities and multiple corporate social responsibility initiatives. Google and Microsoft have developed long-term digital

4 While not implying that migrants are either necessary or sufficient for disruptive innovation, it is evident that they are a significant contributory factor.

5 A cluster is a geographic concentration of related companies, organisations, and institutions in a particular sector. Clusters arise because they raise firms' productivity, due to local assets and the presence of related firms, institutions and infrastructure that lowers production and transaction costs.

partnerships with multiple Indian and African civil society organisations and governments, and started open data initiatives, such as openAFRICA and Research Open Data, to improve local governments' policy-making. Alphabet, Google's parent company, is working on deploying high-speed internet to rural India through laser technology.[6]

And, in destination countries, young migrant tech entrepreneurs are also spearheading social innovations, with potential applications for SDG targets in countries of origin and other developing countries. For instance, UK-based company Logically, started by a 21-year-old Indian immigrant, is an artificial intelligence platform that helps citizens access credible information on government performance (SDGs 5.b and 16). Taarifa, developed by a group of young Tanzanian-Americans, is an open source web application that enables public officials to respond to citizen complaints about sanitation services (SDG 6).

Countless similar examples point to migrants' contribution to technology development in destination countries. To enhance innovation, technological progress and productivity growth, destination-country governments should promote highly-skilled inward migration and labour mobility, rather than constrain migrants' options through often-found restrictive quotas for foreign workers and rigid labour market policies and accreditation regulations.[7] Skilled immigrants are all too commonly forced to 'down-skill' – for example, doctors or engineers driving taxis, unable to practice their profession due to lack of accreditation of origin-country training and certification.[8]

Brain drain or brain gain?

Nonetheless, as SDG 17 underlines, capabilities for technology development are highly unequal among countries, and migration is a major factor in creating and reinforcing that inequality. Recent estimates suggest that highly-skilled (defined as tertiary-educated) migrants comprise about 25% to 30% of the world's 232 million migrants, but that more than 75% of highly-skilled migrants reside in OECD countries.[9] In fact, the number of highly-skilled migrants increased by 70% in OECD countries between 2000 and 2010, compared with a rise of only 35% in the tertiary-educated native population. The global concentration of highly-skilleded migrants is substantial: 66% are in only four countries, all English-speaking – Australia, Canada, the UK and the US. On the other side of the coin, over one-third of countries – almost all of them low- and middle-income – have had out-migration of more than 10% of their highly-skilled population, and for a sixth of countries, this share is over 20%.

Unsurprisingly, 'brain drain' arguments have dominated policy discussion (UNCTAD, 2007; World Bank, 2006; Kapur and McHale, 2005). Many argue that lower barriers to entry in high-income destination countries would exacerbate outflows of skilled people from poorer countries where they are a scarce resource, leading to suggestions that richer countries unilaterally adopt quotas on highly-skilled recruitment from poor countries (Collier, 2013). Many others propose that origin countries try to restrict out-migration by quotas or taxes. But these views, and indeed the 'brain drain versus brain gain' metaphor itself, are increasingly contested.[10] The role of migrants and diasporas in technology diffusion, to which we turn now, illustrates alternative narratives.

3.2 How migration contributes to diffusion and distribution of technology in origin countries

The 'brain drain' versus 'brain gain' narrative is, however, contested. One argument is that migration aspirations might in fact incentivise a greater demand for education and skills to enhance migration abilities, leading to a net rise in skills in origin countries, as many newly-skilled individuals ultimately remain rather than leave.[11] But perhaps a more persuasive set of arguments is that emigrants and diaspora communities enable a return inflow into origin countries of technology and other forms of knowledge, and contribute to a rise in origin countries' 'absorptive capacity', the ability to upgrade technology through diffusion or local innovation, which depends on skill pools and also strong institutions.

6 www.nextbigfuture.com/2017/12/india-will-deploy-two-thousand-google-laser-internet-links-for-highspeed-network-backbone.html

7 For a more detailed discussion on the barriers to migration set by destination and origin countries, see the poverty briefing on the same series (Hagen-Zanker et al., 2017).

8 The immigrant may still be better off, earning more in a 'down-skilled' activity in the destination country than from a professional activity in the origin country. But this is a sub-optimal social outcome, for both origin and destination countries. On 'behind the border' barriers to migrant entry and integration, see also Clemens (2011) and Collier and Vickerman (2001).

9 All statistics in this paragraph are from Kone and Ozden (2017).

10 For a critique of these arguments, see Clemens and Sandefur, 2014.

11 See Carling and Schewel (2018) for a different view of aspirations and ability in migration and how increased aspirations but a continued low ability to leave could lead to negative development outcomes.

Beyond 'brain drain'/'brain gain' binaries, metaphors such as 'brain circulation' and 'brain banks' may more usefully describe migrant and diaspora contributions to technology diffusion[12] (Collier and Vickerman, 2001; Lowell and Gerova, 2004; Agrawal et al. 2011; Clemens, 2011). Of course, a key consideration, as in all discussions of technology transfer and diffusion, is the absorptive capacity (the ability to learn and to integrate new technologies) of the receiving country – here the country of origin. In many cases, this may be very low – for example in low-income or fragile and conflict-affected states.[13]

Three key channels through which migrants and diasporas may support technological development in their origin countries have been identified: (1) direct technological and knowledge transfers; (2) diaspora investment and remittances supporting origin country economic growth and transformation; and (3) supporting entrepreneurialism in origin countries (Docquier and Marfouk, 2004; Clemens and Pritchett, 2016; Gelb, 2016). Many processes and projects will include elements of two or even all three of these channels.

Direct knowledge transfers from the diaspora

As noted, the tacit dimension of knowledge transfer means that language, context and cultural familiarity are crucial. As such, migrants in particular, as well as diasporas, have a vital role in technology diffusion. Quantitative analysis (Kerr, 2008; Filatotchev et al., 2009; Newland and Tanaka, 2010) has shown diaspora networks and return migrants to have a positive and significant effect on growth and export diversity of small and medium enterprises in countries of origin, through technology transfer. Many countries (for example India and Scotland) have established government ministries or agencies to incentivise diaspora networks to support local development through knowledge transfer. In other cases – Chile, Ireland, Nigeria and South Africa – the idea of building diaspora networks arose within the diaspora itself or from civil society in the origin country, with government subsequently taking on some responsibility.

Remittances and diaspora investment

The second channel for diaspora linkages to origin countries is financial flows: remittances and diaspora investment. Remittances are based on an interpersonal connection between sender and recipient (usually a household) and are one-way transactions or transfers, with no corresponding return of economic value to the sender. Diaspora investment is impersonal, received by firms, government agencies or non-government organisations rather than households, and are two-way transactions or exchanges, involving the return of an item of corresponding value by the recipient to the sender(s) (see Gelb, 2016). Both remittances and diaspora investment take various forms, in many of which knowledge and technology flow together with the money itself.

Remittances sent by poor and well-off migrants represent a significant proportion of gross domestic product (GDP) in many low- and middle-income countries and impact the macroeconomy as well as households and microenterprises (World Bank, 2006; 2016). Lower-skilled migrants' remittances are spent mainly on basic needs of families 'back home', but they also contribute to family investments in housing or education (Gelb, 2016; Hagen-Zanker et al., 2017), or in households' productive enterprises (Woodruff and Zenteno, 2001). These investments contribute to technology diffusion and upgrading of skill (and absorptive capacities), especially in poor communities. So, too, do remittances to community-based projects. Mexican immigrants in the USA have formed many hometown associations (HTAs) to invest in projects

Box 2 Diaspora supporting technology and knowledge transfer to origin countries

- The government of **Morocco** supports national research and technology initiatives, through programmes such as the International Forum of Moroccan Competencies Abroad. In 2009, the National Centre for Scientific and Technical Research in Rabat signed a memoranda of understanding with several bodies abroad, notably the Association of Moroccan Computer Scientists in France and the Moroccan-German Skills Network in Germany.
- The American Association of Physicians from India, comprised of more than 80,000 practicing physicians in the **US**, has invested in technological advances across small nursing homes and hospitals in rural India, providing medical accountability and legal training to doctors and improving digital information systems to maintain hospital records.
- **Colombia**'s Red Caldas network, set up with government assistance in 1991, was one of the first diaspora networks that succeeded in promoting collaborative research, training and knowledge exchange between domestic scientists and Colombian researchers abroad (Chaparro et al., 2006).

12 'Brain circulation' refers to knowledge flows in both directions between destination and origin countries, while 'brain banks' refer to pools of knowledge built up abroad but available to locals in the country of origin.

13 Clemens (2014) proposes 'global skills partnerships' where receiving countries finance training in sending countries to build skills pools large enough for both highly-skilled emigration and local skills needs.

such as school rebuilding in their origin communities. From 2001, the Mexican government provided matching funds via its 'Tres Por Uno' ('three for one') programme, mobilising around $15 million a year for more than 6,000 projects involving over 1,000 HTAs by 2010.[14]

Similar examples are found elsewhere. In the spirit of SDG 17, more than 40 France-based Senegalese diaspora organisations support a water fund in partnership with the Government of Senegal to develop water infrastructure to combat climate change, investing in water meters, rain-water harvesting and drainage in the Senegal river valley (Grillo and Riccio, 2004; Scheffran, 2011). Malian diaspora in France partnered with the Comité Immigration Développement Sahel (Sahel Development Immigration Organization) and the Rural Energy Services Company to expand rural electrification systems in several villages using renewable energy sources (SDGs 7.a).

Beyond remittances, **diaspora investment** draws on the savings of other, higher-income migrants and diaspora and takes many different forms, including equity in businesses in the origin country, or loans and bonds issued in the origin country to mobilise funds from destination countries for specific projects (Gelb, 2016).[15] Because diaspora investors want a financial return, they or the business or project promoter will try to improve profitability, often involving technology upgrading. For example, the Senegalese government's Retours Vers l'Agriculture ('return to agriculture') programme provides tax exemptions to new business ventures in Senegal, which enables the diaspora to promote hi-tech equipment and modernise agriculture, increase Senegal's exports, growth and sustainable food production, and supports SDGs 2.3, 2.4 and 2.5, and 8.2 (Panizzon, 2008).

UK-based Helios and Homestrings are examples of financial platforms that facilitate diaspora investment in SDG-linked sectors in developing countries of origin. Helios, which has over $3 billion in commitments in Africa, raises finance from the African diaspora and the wider capital market for projects in energy, transport, IT and financial services, as well as retail and consumer products. Homestrings is a web-based crowdfunding platform that allows diaspora members (and other investors) to select investments in origin countries, to finance medium- or large-scale African businesses in agriculture, technology, healthcare and renewable energy sectors, as well as public sector bonds. Both platforms facilitate knowledge flows to the businesses.

Even when they are not themselves sending money, strong diaspora networks may contribute to knowledge flows and technical capabilities in origin countries by acting as reputational intermediaries in their destination countries, encouraging investment into their origin country from non-diaspora businesses, who invariably bring in newer, more advanced technologies than generally available back home (Kuznetsov, 2007). One example is the role that the Indian diaspora in the US have played in the rise of India's IT industry (Box 3). Others include the ChileGlobal Angels and the US-based Irish Technology Leadership Group, which provide business mentoring and market knowledge and networks to start-ups in their origin countries.

Finally, the financial investment of diaspora and migrants – including remittances – create incentives to upgrade financial institution capabilities and regulation in origin countries. For example, remittance-based housing loans (as in the Philippines or Mexico) or diaspora deposits (common in many countries, but particularly significant in India) require enhanced risk-management capabilities in commercial banks.

Supporting entrepreneurialism in origin countries

The third channel involves diaspora networks fostering entrepreneurialism and business development in origin countries. This can take many forms, including migrants and diaspora returning to their country of origin to start their own businesses, or investing in start-ups with local partners – either as active participants in running the business or as only financial investors. Whatever form it takes, it is likely that knowledge and technology transfer to the country of origin will be part of the link, raising

Box 3 The role of Silicon Valley-based Indian immigrants in India's IT industry

The IndUS Entrepreneur (TIE) is a venture capital network started in 1992 to promote start-ups in both India and the US, especially in IT. TIE now has over 13,000 members in 61 chapters covering 18 countries and has contributed to creating businesses worth over $120 billion worldwide, providing mentoring and finance through venture capital, private equity and angel investments. Many TIE members were educated in India before migrating to the US, and many have now returned to India, as have US-born diaspora members. The migration flow in both directions has contributed to the IT clusters in Hyderabad and Bangalore, and their deep links with Silicon Valley. Some argue that major US IT multinationals decided to establish Indian operations during the 1990s, in large part because they had many Indian-born and Indian-origin employees in their US operations who promoted India as an investment destination and themselves moved back – at one point, 71 of 75 foreign investors in Bangalore's software technology park were headed by returned Indians (Kapur, 2007: 398, citing Ghemawat, 2000).

14 This is a tiny percentage of total Mexican remittances of about $24 billion per annum.

15 For example, the Ethiopian government issued 'Millennium Bonds' to finance hydroelectric energy generation (the Grand Renaissance Dam).

the absorptive capacity of local populations and spurring growth and development (Saxenian, 2005). There is much literature on the importance of inward investment into China by the Chinese diaspora in Hong Kong and Taiwan during the 1980s and 1990s, certainly one of the crucial mechanisms supporting the long-run development of China's industrial capabilities (Saxenian, 2006; Naughton, 2007: 416).

Return migration is a common form of migrant support for enterprise development and technological upgrading, especially in fast-growing developing countries with large diasporas, such as India, China or Korea (Wang, 2015; Kuznetsov et al., 2006). Returning migrants are a source of entrepreneurship, technology, marketing knowledge and business networks, as well as investment capital (Kapur, 2001; Brinkerhoff, 2006a; 2006b). Studies of migrants returning to Egypt have shown, for example, that they that tend to have higher skill-linked capabilities than non-migrants and are likely to be more entrepreneurial the longer they work abroad (McCormick and Wahba, 2003; Wahba, 2007). Even some migrants who have 'failed' in destination countries may have acquired skills and networks there that enable them to be competitive when they return to their origin country (where their arrival raises average productivity).

Two examples of return migration's diffusion of new SDG-related technology in origin countries are Digital Green and Escorts Heart and Research Centre in India. Digital Green was founded by a returning immigrant, who had emigrated to the US, and is an app-based company empowering smallholder farmers in India through technology and grassroots-level partnerships. Escorts Heart and Research Centre, set up by another returnee with extensive cardiac surgery experience in the US, uses world-leading surgery techniques including 'beating heart' and robotic surgery (Walden, 2003).

4 How technology use facilitates migration

Individual migrants and refugees use technology in a number of ways to enable and support their migration process. The combination of mobile phones, the internet and social media – together labelled 'digital connectivity' – is crucial, seen by the EU as 'a game changer for migration' (EPSC, 2017). Over the past two decades, the lower cost of handsets and internet access, along with the proliferation of mobile networks and phone apps, have enabled even poor people (migrants and others) to use the technology.

The uptake and use of ICT technology by migrants has substantial impacts on every aspect of the migration journey, especially for poor people, providing:[16]

- information on the quality of life and economic opportunities that are available elsewhere, which shapes aspirations, decisions to migrate and migration plans, including destination country preferences
- essential planning and travel information on the journey itself, including on transport options (official and informal such as people smugglers), transport costs, translation, and on safety, including avoiding difficult borders
- access to migrants' own or family financial resources for the journey, while in transit and upon arrival at the destination, via mobile money platforms
- information to facilitate re-settling in the destination country after arrival by accessing migrant networks and local information in the destination country
- continuing linkages with families and networks in their country of origin through messaging, voice call and social network apps available on mobile phones.

For refugees, digital connectivity is often a literal lifeline. Little wonder, then, that refugees are often willing to spend as much as a third of their income on mobile telephony, or to walk miles to access free Wi-Fi or reach a spot in a refugee camp where network connectivity is available (UNHCR, 2018). Mobile telephone access is an absolute necessity in this sense: 'So important were mobile phones that, on arrival [in refugee camps], many refugees asked for Wi-Fi or charging services ahead of food, water, or shelter' (GSMA, 2017).[17] The common experience of confiscation or inspection of refugees' mobile phones by immigration authorities exacerbates the trauma for many.[18]

Nonetheless, as with the consumption items mentioned, levels of mobile telephony use among migrants reflect deep income-, gender- and age-related inequalities. Recent analyses identify 'information precarity' as a challenge facing migrants generally, and refugees in particular; these groups may have inconsistent (and costly relative to income) access, lack control over their own data and experience anxiety about phones being used for surveillance of their activities (Wall et al., 2017). To help tackle such problems, the GSM Association launched a Humanitarian Connectivity Charter in March 2015, which has now been signed by 148 mobile

16 See Hamel (2009) for a good overview of the impact of digital connectivity on migrants, notwithstanding that rapid digital innovation makes a decade-old paper already somewhat dated. More recent research includes Gillespie et al. (2016) and Frouws et al. (2016).

17 Surveys have shown similar responses: see Leung (2010).

18 An internet search on 'mobile phone confiscation refugees' yields 577,000 hits, with the first page alone containing news reports on confiscations in six different OECD countries.

network operators operating in 106 countries. The Charter commits signatories to improving access to communication and information for those affected by humanitarian crises, with actions such as local SIM-card provision via the United Nations High Commissioner for Refugees (UNHCR) to new arrivals at refugee camps.

4.1 Facilitating integration

Mobile phones are a very important item for migrants settling into a new country and society, allowing them to access a wide range of essential information and services, including housing, employment or training opportunities, local health and transport, schools and childcare, cultural or religious events (especially within their own diaspora community). Phones also enable migrants to engage with the authorities processing their asylum or residency claims and are a personal security mechanism for vulnerable groups such as women domestic workers. The technology is more and more important to overcoming often overwhelming language barriers: language learning and translation apps are increasingly used both by migrants themselves and by NGOs which provide migrant support services in many countries.[19] And through social media platforms, they enable migrants to connect with migrant networks in the same destination country and further afield.

Apps that support migrant settlement are quintessentially public goods, and this is increasingly recognised by the investment of public or collective resources. Since the upsurge in migrant entry to Europe since 2015, public and private migrant service providers in destination and transit countries have created a proliferation of apps, including Ankommen ('arrive') in Germany, Love Europe in the Netherlands, Textfugees messaging service in France, and the TikkTalk platform that connects NGOs and interpreters in Norway (Wasik, 2017). An example outside Europe is the MySeoul app, created by the Seoul City government to improve, in particular, women migrants' access to information. There is arguably an 'over-supply' of apps, with many now out of date or redundant and limited inter-connection between them. Migrants thus tend to fall back on Facebook and other social media platforms to access information and build new social networks.

This underlines that mobile phones are not the answer to all migrants' challenges: though they reduce difficulties of accessing information and save time and money, migrants still need to learn the language in their destination country, find a job, secure and pay for housing, and register children with schools and health services (Iannelli, 2018). Furthermore, widespread use of phones and social media raises serious concerns about privacy and about potential surveillance by governments (Loh, 2016; Jumbert et al., 2018; McGregor, 2018). Many refugees from political conflicts fear country-of-origin surveillance, but it is a concern in destination countries too. In 2017, both Germany (despite opposition from the data protection commissioner) and Denmark expanded the legal powers of immigration officials to digitally search asylum seekers' phones.[20] German immigration officials argue that mobile phone data may point to inconsistencies in asylum-seekers' stories, and within six months of the law's enactment, they searched 8,000 phones (Meaker, 2017).

4.2 Staying connected

As recently as 2010, African refugees in Australia reported relying on ordinary postal services to communicate with families back home (Leung, 2010). Mobile phones have changed that by:

- enabling lower cost and faster remittances to provide financial support to families
- continuing emotional support to (and from) family members via messaging and Voice over Internet Protocol ('VoIP') software
- steady flows of news and cultural information from their 'home' country
- the potential for extensive political participation in both country of origin and the diaspora.

Social media is the most common software technology used by migrants and has fundamentally transformed their relationships – allowing them to both retain links with families and communities 'back home' and integrate into diaspora and local communities in the destination country (Benitez, 2012; Oiarzabal, 2012). But there are downsides: emotional 'support' can also be a means to controlling behaviour or increasing financial demands – either to or from the migrant – and this is likely to affect women more negatively. Some argue that continuing strong origin-country links may considered an obstacle to migrants' integration into their new countries because 'bridge burning', on the other hand, assists integration. However, it seems quite possible for migrants to simultaneously have strong ties with origin countries and be well-integrated into destination countries (Loh, 2016).

'Live', dynamic links between migrants and families and communities at home may have benefits for those communities too, in the form of 'social remittances' (Levitt, 1998, cited in Hamel, 2009). These are ideas and knowledge flowing back from destination to origin

19 They are also used as a communication tool by border police.

20 The German law allows authorities to look at the data on a migrant's phone only if the individual can't or won't provide proof of identity and nationality, such as a valid passport. Only meta data from the phone is accessible, and only by the German Migration Office. Meta data includes information about calls and messages (time, source or destination), as well as email addresses, websites visited, files downloaded and GPS location information (McGregor, 2018).

country, which we have discussed extensively in relation to technology and economic knowledge but which also relevant to social and political issues.[21] The notion of social remittances offers at least some promise of identity porosity and fluidity and a softening of the hard borders of nationalism. Interactions between nationalism and political conflict (including war) are, of course, complex. If newspapers were the technology enabling the nation to come into existence as an 'imagined political community',[22] then digital connectivity is the technological means for '*transnational* imagined communities'[23] in which 'connected migrants'[24] remain active members of their nation of origin. In this sense, mobile phones provide the 'social glue of migrant transnationalism' (Vertovec, 2004).

Beyond mobile telephony, the migration process has also been transformed by a range of financial technology ('fintech') institutions using phone-based apps rather than the costly physical infrastructure used by conventional financial institutions. Regulatory environments vary between countries – especially for cross-border transactions that are undertaken by migrants and involve exchange rates. But despite this, many fintech providers have been able to customise transaction services products for migrant customers, offering remittance transfers to, and bill payments in, their countries of origin. Some fintech start-ups allow migrants to open local (destination-country) bank accounts from abroad before their arrival.[25] The UN World Food Programme has developed technology with Carrefour and Mastercard, combining iris scanning with smart cards issued to each refugee, who can now shop at nearby supermarkets (McKinsey, 2016).

There are also a few examples of technologies that go beyond digital connectivity. Distance education programmes for language learning still depend on ICT, as does tele-medicine, including medical specialist consultations and tele-surgery for refugees in which specialists based abroad supervise theatre operations using web video links. Quite different, but equally useful, is flat-pack housing, developed by UNHCR with the Ikea Foundation, which uses a steel frame and solar energy panels and is replacing tents that last only 6 months (Robson, 2013).

5 How technology use facilitates migration management

5.1 Border crossing technology

'Dual use' technology with military and non-military applications has long been central to governments' efforts to increase the effectiveness and efficiency of controls. This has accelerated in recent years, with a rapid expansion in both scale and scope of what has been labelled the 'border industrial complex', a market expected to reach around $32.5 billion by 2021 (Dart, 2015; Hoffman, 2016).[26] Annual trade fairs such as the 'Border Security Expo' in the US or the UK Home Office-sponsored 'Security and Policing'[27] showcase a bewildering array of new hardware to collect information on people and goods as they cross borders, with data processing software returning analysis to border officials fast enough to halt the border crossings before completion.

Hardware includes cameras and radar surveillance equipment mounted on drones, blimps, helicopters or satellites, or on towers and other static platforms, for continuous scanning of long borders. It is claimed that some cameras can identify faces from hundreds of yards away, with sufficient detail to specify age, gender and ethnicity. Also used to detect movement along long borders are underground sensors. And there are greater ambitions: 'ROBOrder', under development by a consortium across 15 EU member states, is 'a border surveillance system with unmanned mobile robots including aerial, water surface, underwater and ground vehicles, capable of functioning both as standalone and in swarms (*sic*).'[28]

21 On a more prosaic level, the diffusion of mobile phones and ICT in some low-income origin countries may have been encouraged and accelerated by out-migration and the need to 'keep in touch'.

22 To use Benedict Anderson's (1983) evocative phrase.

23 Aksoy and Robins, 2002, cited in Hamel 2009 (emphasis added).

24 See Diminescu (2007), cited in Hamel 2009.

25 As do some conventional commercial banks in origin countries, as mentioned above.

26 About half of the US Department of Homeland Security's 2016 budget.

27 Established over 30 years ago and closed to the public and media, it is promoted as 'the premier platform for relevant UK suppliers … to demonstrate the opportunities presented by innovative cutting-edge technology' (www.securityandpolicing.co.uk/about).

28 Horizon 2020, Project ID: 740593. See https://roborder.eu.

Increasingly sophisticated scanning devices are used at official border crossings for people and personal baggage, and vehicles and goods containers. These use x-ray, heat radiation and infra-red technologies as well as automatic licence number registration (ALNR) and Radiofrequency Identification (RFID, or embedded chips). Biometric information – fingerprints, irises, facial images and voice – is collected and stored.

Donald Trump's campaign promise to build a concrete wall between Mexico and the US has led to an active debate among US government agencies and the security industry on the effectiveness and cost efficiency of a 'virtual wall' that relies on multiple technologies versus a physical (concrete) wall (Nixon, 2017).[29] Without suggesting that the latter may be more effective or more efficient – let alone more desirable – there are concerns about 'virtual wall' technologies: dysfunctionality due to weather conditions such as winds or storms, or due to extraneous factors such as animals or dense foliage; technical problems with the software, rendering it slow or error-prone; and, most importantly, continued reliance on human interpretation of data, which is error-prone but surprisingly often neglected by border personnel who give it limited credibility. The Secure Border Initiative Network, an earlier project to install camera and radar equipment on towers along the southern US border, was initiated in 2005 under then-President George W. Bush. By 2010, cost and technical problems meant that only 15 towers had been set up covering only 53 miles of the 2,100-mile border at a cost of $1 billion, and the project was cancelled.

The difficulties facing technological 'solutions' for border-crossing management are also illustrated by the maximum facilitation notion proposed for an invisible UK–EU border after the UK leaves the EU. It is argued that scanning goods and people will minimise – even eliminate – border-crossing time and disruption. However, the UK government has been unable to identify technologies already in operation that permit this, and eventually conceded they do not yet exist.

Notwithstanding its technical limitations, surveillance technology for border crossing control raises major concerns about potential impacts on privacy and human rights, not only of migrants but also of citizens. The physical range of technologies enables surveillance across entire border towns, including of local residents' daily activities, while the technologies can be easily adapted for policing uses by domestic security agencies unconnected with migration or border control.

Box 4 Blockchain and migration

Blockchain – or distributed ledger technology – is still in early stages of development but it is considered promising for both migrants' rights *and* welfare. One application being explored is in digital identity, to address SDG 16.9 ('legal identity to all…. by 2030'),[1] but extending naturally and importantly to migrants outside their country of birth. ID2020 was started in 2017 to create legal identities that are 'personal [unique], portable, persistent [lifelong] and private [access requiring the holder's consent]'. It uses blockchain and biometric data to underpin a decentralised and global 'identity market' based on 'interoperability' – that is, the ability of different IT systems and software to exchange data and use common information. Similar combinations of blockchain and biometrics could be used in asylum applications and migrant integration processes, where proof of legal identity is also crucial (Long et al., 2018). The European Parliament has set up a taskforce to discuss the potential of blockchain for refugee identification and related programmes.

Blockchain's indelibility and decentralised governance means it is central to emerging initiatives to enhance financial inclusion of migrants and refugees, and to manage public expenditures on these groups. The World Food Programme's (WFP's) pilot project, Building Blocks, in the Azraq refugee camp in Jordan, uses blockchain rather than smartcards to provide financial support to refugees. Under the scheme, WFP deposits vouchers directly into camp residents' virtual accounts for use at the camp supermarket, where residents are identified biometrically. WFP then pays the supermarket directly, eliminating banks and smartcards, improving security and efficiency, and saving 98% of bank charges (Kenna, 2017). Because records of all residents' transactions are retained by the system, blockchain (unlike smart cards) could enable migrants and refugees to build a consolidated financial history as they move across borders, operating the same virtual account. This would ultimately support their access to credit in destination countries. Blockchain could also enable safe and private transmission of remittances. Much will depend on the evolution of the broad stance of financial institutions and financial regulators towards blockchain: its potential uses in migration will inevitably follow from more general applications.

1 An estimated 1 billion people globally do not have a legal identity at present.

29 Trump demanded Congress authorise about $1.6 billion for the concrete wall.

5.2 Migration management

Looking at the broader migration management process, data processing technology in combination with biometrics is increasingly used to lower administrative costs and enhance systems integration and coordination. Developed with Microsoft, UNHCR's proGres Refugee Registration Platform is used to process asylum claims and to provide food and medical assistance in more than 300 refugee camps in 75 countries. The EU's Eurodac database stores fingerprints of asylum-seekers across all member states. Germany's Asyl Online project is an effort to integrate all national databases containing migrant and refugee information.

It is not only in OECD countries that technologies are of interest. Large migrant labour sending countries, such as Nepal and Bangladesh, are increasingly automating their migration management systems. In Malaysia, where migrants comprise 15% of the workforce, a Foreign Workers Centralised Management System (FWCMS) has been developed to link migrant workers' 'compliance, security, health and welfare' across both origin and destination countries. Linking origin-country embassies and destination-country employers into the system allows comprehensive monitoring. In 2017, FWCMS won a digital innovation prize for government and citizen engagement at a UN-linked awards ceremony. Like the mobile phone, FWCMS may assist migrants' integration into destination countries and help them to access employment, insurance, or health services. But, simultaneously, it also enables authorities to track and monitor migrants for 'security' or related reasons.

Other technologies also have costs as well as benefits: marine search and rescue (SAR) missions that rely on radar surveillance and communications technologies are crucial to prevent tragic loss of migrant lives in the Mediterranean. But people traffickers depend on governments' and NGOs' commitment to SAR, which enables them to cut costs, putting migrant lives at risk by providing inadequate boats while supplying passengers with satellite phones to contact coastal patrols. These examples underline the unsurprising conclusion that technologies are instruments with ambiguous impacts and benefits, which generally depend on users' motivations – that is, the social and political context – rather than on the technology itself.

6 Conclusions and policy recommendations

Technology, innovation and productivity are mentioned in 10 of the 17 SDGs yet are absent from SDG 10.7 (on safe, orderly and regular migration) and from SDG 10 (on inequality) more broadly. Migrants contribute significantly to the processes of innovation and technological change, and that the use of technology is crucial for all aspects of migration, though its effects depend in large part on its users' motivations. Our analysis has shown how important the technology–migration nexus is to the achievement of many SDGs (Table 1). And based on this, we draw several broad conclusions and provide targeted, pragmatic recommendations to policy-makers in destination and origin countries to help them harness the potential of both migration and technology.

Conclusion 1 Highly-skilled migrants make a substantial contribution to technology innovation in destination countries, especially high-income countries, underlining the importance of group diversity in creating new ideas and new knowledge

Highly-skilled migrants are deeply involved in R&D and innovation in destination countries, as members of teams producing technology across many activities and sectors. This group of migrants is also key to supporting ongoing development of domestic technological capabilities in destination countries, as founders, owners and managers of major global corporations. Workplace diversity resulting from immigrant employees contributes positively to creativity within teams and organisations and hence to innovation.

Recommendation: minimise barriers to highly-skilled immigration

- Destination countries should ease restrictive quotas on the numbers of highly-skilled foreign workers allowed to enter, and should reduce costly and lengthy visa application processes.
- Governments of destination and origin countries should explore the potential for entering into 'global skills partnerships' in which potential employers from destination countries financed training of highly-skilled workers in origin countries, only some of whom migrate, contributing to the pool of highly-skilled workers in both countries (Clemens, 2014).
- High-income destination countries, particularly English-speaking countries in which highly-skilled migrants are heavily concentrated, should expand the scale and scope of short-term academic and scientific exchanges and collaborative programmes, enabling cross-border collaboration on innovation and temporary rather than permanent migration of researchers and technicians.

Recommendation: mitigate 'down-skilling' of highly-skilled immigrants, so that they and their destination countries maximise their contribution

- As part of the 'global skills partnership', origin and destination countries should develop joint accreditation of training programmes and competency assessments to ensure that skills are transferable.
- Destination countries should strengthen skill-matching and other placement programmes to improve employment prospects for highly-skilled immigrants.

Relevant SDG targets

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation

9.5 Enhance scientific research and upgrade technological capabilities in all countries

Conclusion 2 Migrants and diaspora groups are a significant channel for transferring technology back to origin countries, through transfers of direct knowledge, remittances and financial investment, and through support for enterprise development and for research and scientific institutions in origin countries

Diasporas and return migrants, mainly those who are highly-skilled, contribute significantly to the diffusion of technology back to, and strengthening of R&D and business capabilities in, origin countries. They do so through various inter-connected channels – direct knowledge transfers, diaspora inward investment and remittances, and diaspora networks supporting local enterprise development. The simple notion of 'brain drain' versus 'brain gain' needs to be set aside in favour of 'brain circulation' and 'brain banks', which are potentially available to both origin and destination countries.

Recommendation: origin country governments should more actively promote and invest in diaspora networks and should partner with destination country governments to optimise the benefits for technology development from emigration

- Origin country governments should systematically and actively promote diaspora networks by establishing diaspora ministries or agencies and support diaspora business associations in destination countries, especially high-income countries.
- Together, origin countries and destination countries – especially the four English-speaking countries where most highly-skilled migrants are concentrated – should establish 'global technology partnerships' (parallel to global skills partnerships), which draw on the diaspora associations and groups that link the two countries.
  i. Global technology partnerships should address scarcities in origin countries of technology service providers – which are essential for technology transfer – by helping local firms to source, validate and adapt technologies, and provide legal and financial services to buyers. Diaspora associations should link service providers in destination countries with business development agencies and STEM and intellectual property institutions in their origin countries.
  ii. Operating within global technology partnerships, diaspora networks – particularly employees of large corporations with global reach – should also broker technology transactions that help to diffuse innovations *from* origin countries, particularly innovations that meet poor peoples' needs in SDG-linked sectors such as agriculture, water, energy, health and education but which are often unable to realise wider market potential due to lack of finance or business networks.

Relevant SDG targets

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation

9.5 Enhance scientific research and upgrade technological capabilities in all countries

9.b Support domestic technology development, research and innovation in developing countries

17.6 Enhance regional and international cooperation in science and technology and innovation

17.7 Promote environmentally sound technologies for developing countries

17.8 Enhance capacity building mechanisms and enabling technology, in particular ICT

17.16 Enhance the Global Partnership for Sustainable Development

Conclusion 3 Technology, particularly digital connectivity using mobile phones, affects every aspect of migration

Digital connectivity enables access to information on destination countries before migration, on transport and security during migration journeys, and on integration opportunities and services in new communities and destination countries. Digital connectivity also facilitates ongoing links with, and transfer of remittances to, families back home, and enables migrants to remain deeply connected and engaged with communities in origin countries, so underpinning migrant 'transnationalism'.

Recommendation: destination, origin and transit country governments should apply to all migrant groups the UNHCR's connectivity priorities for refugees: access, affordability and usability (UNHCR, 2016)

- Governments in destination and transit countries should strengthen partnerships with mobile phone operators to address 'information precarity' by enhancing access to mobile telephony and lowering its cost for refugees and all other migrants. Access should include free Wi-Fi provision in public spaces in destination countries'

immigrant communities (i.e. community and job centres, libraries, schools and places of worship).
- Governments in destination countries should provide public resources for the creation in multiple languages of 'integration apps' like Germany's Ankommen app, as well as their maintenance to keep their information content updated.
- Governments in destination and origin countries should use public resources to support the development and distribution to migrants of fintech apps that would lower remittance transaction costs to 3% in line with the target in SDG 10.c. This should include support to ensure regulatory compliance of the apps and transactions through them within countries' financial system regulation.

Relevant SDG targets

10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies

10.c By 2030, reduce transaction costs of migrant remittances

Conclusion 4 Migration management by governments relies heavily on information technology, both in keeping people out and in processing migrants after they arrive. This raises concerns about migrants' rights, but some emerging technologies such as blockchain may have potential for more positive applications for migrants and migration

Migration management technology illustrates clearly the potentially contradictory nature of technology: some technologies enhance well-being and enable realisation of rights and capabilities; others are a means to restrict and limit well-being and rights. The border-crossing technology market is growing rapidly. Most technologies on offer aim to reinforce control over human and goods traffic but are not generally as effective or as efficient as intended. Migration information management systems rely increasingly on digital and biometric technologies. These facilitate systems integration and may assist migrants but also reinforce migrant and refugee management as control, both at the border and 'behind the border'. Blockchain and biometric technologies may offer an alternative grounded more firmly on individual rights, enabling migrants more secure and portable identity documentation, which can help them enter and settle in transit and destination countries and enhance financial inclusion.

Recommendation: technological solutions to migration management implemented in destination, origin or transit countries need to be complemented by accountability mechanisms to fully protect migrants' rights

- Destination country governments need to establish safeguards, including transparent public accountability mechanisms and bodies, to oversee further development and use of technologies for surveillance and border-crossing control, for access to mobile phone data of migrants (and other groups) and for immigration databases, to ensure that migrants' rights and privacy are fully protected.
- Governments need to prioritise the development of blockchain technology for digital identification and for financial transactions and financial inclusion of migrants (and poor people in general), including for cross-border remittances.

Relevant SDG targets

10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies

10.c By 2030, reduce transaction costs of migrant remittances

16.9 Provide legal identity for all, including birth registration

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