

New economics of assistive technology: A call for a missions approach

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New economics of assistive technology: A call for a missions approach

Sarah Albala*, Catherine Holloway[^], Victoria Austin[^], and Rainer Kattel*

Abstract

An estimated 90% of the one billion people who require a particular assistive product (AP) do not have access to that device. The lack of an AP, a device which helps to enable human life, is especially poignant within low- and middle-income countries. Issues that affect access to appropriate AP are currently seen through the lens of supply and demand side failures. Actions and policies that try to address access to assistive technology (AT) through a limited market failure perspective will not be able to deliver AT in the comprehensive way necessary to meet need, while ensuring the AT is user-appropriate and of high quality. In order to meet user need, new thinking is needed that recognises the value of AT by considering how the AT innovation ecosystem creates meaningful economic and social value. In order to unleash the full potential of AT value, this paper proposes a public sector-led, mission-oriented approach. While setting the mission and the directionality is the role of government, NGOs, industry, AT users and the charity sector are able to drive forward the agenda of AT access through their own essential and complementary roles. A mission-oriented approach will use tools such as market-shaping and stakeholder co-creation to set an agenda by which AT innovation and access can be positioned as a meaningful step in tackling societal challenges. Through a missions approach the value of AT will be properly captured and society can come closer to addressing issues surrounding healthy ageing, enabling human capability and equity.

Keywords: Assistive technology (AT), missions, market-shaping, LMICs, SDGs

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1. Introduction

Assistive technology (AT) can help increase a person's quality of life by enabling people to go to work, to school or to participate fully within their communities and families. AT is an umbrella term covering the systems and services related to the delivery of assistive products, such as wheelchairs, eyeglasses, hearing aids, prosthetics and personal communication devices. Assistive products are defined by the WHO as, "any external product (including devices, equipment, instruments or software), especially produced or generally available, the primary purpose of which is to maintain or improve an individual's functioning and independence, and thereby promote their well-being." Further, the primary purpose of an AT "is to maintain or improve an individual's functioning and independence to facilitate participation and to enhance overall well-being. They can also help prevent impairments and secondary health conditions" (WHO 2020). With over 1 billion people who need AP such as wheelchairs, glasses or prosthetic limbs, the cumulative market need is large and is further expanding due to the relationship between AT need and an ageing population. The 2004 World Health Survey found that the prevalence rate of disability in the adult population was 11.8% in high-income countries and 18% in low-income countries (WHO 2011). One estimate of the financial burden of disability globally amounts to a worldwide loss of GDP of between \$ 1.37 and 1.94 trillion¹ (Metts 2000). Even if awareness were to be raised regarding the substantial individual and financial burden disability incurs when not met with the necessary resources, the problem would still persist. The current market system of AT manufacturing and delivery, which consists of heterogeneous and fragmented markets with hampered innovation models, is not able to meet true need. Further, the public sector has yet to recognise the value of investing and supporting AT. The repercussions of the current AT system failures are felt even more poignantly within low- and middle-income countries (LMIC).

In this paper we contend that AT needs to be reframed as an issue of innovation dynamics and as an essential component to achieving the Sustainable Development Goals (SDGs) (MacLachlan 2019; Tebbutt et al 2016). This is in contrast to the dominant market approach that has created a situation whereby high-quality AT is delivered only to a few resource rich-places while less well-resourced settings receive cheap and ineffective AT. The current delivery practice of AT is in part linked to how an AP is historically viewed as an optional aid or instrument whose markets are poor in delivering to those in need. APs need to be framed globally as essential devices that can enable human capability, create new economic activities and employment, and reduce financial burden on the care system. The current dominant approach to AT stems from the perspective of social and health needs rather than through the lenses of innovation. In order to bolster access to AT, as well as rethink the AT system, this paper will propose what it would mean to take on a public sector-led missions-based approach, which, through its ability to bolster AT innovation, would increase access to these life-altering devices through multi-stakeholder collaboration.

To do this the paper is broken into seven sections. Sections 2 and 3 will seek to examine the current AT marketplace, with a particular focus on low- and middle-income countries which greatly

¹ This number was calculated by extrapolating the results of a research study which estimated the GDP lost due to disability in Canada (the Canadian Study) to the rest of the world using UNDP's unemployment rate estimates and GDP estimates for 206 nations.

lack access to AT. Some of the supply and demand side issues and barriers that arise under the current AT market place and which effect AT dissemination within two commonly used assistive products will be briefly laid out. A more expansive assessment of the different modes of AT innovation and delivery will also be included, offering insight into the more macro and structural issues that persist in AT investment and delivery. In order to expand beyond looking at AT from only a supply and demand market failure perspective, in section 4 the paper then pivots to propose how AT value and impact could be examined through an innovation lens. Having provided an overview of AT innovation domains, and thus possible areas for AT value to be assessed, sections 5 to 7 provide the theoretical approach and propose how to harness AT innovation further and galvanise public sector investment through a mission-led market-shaping approach. Within these sections (5 to 7), the conceptual foundations of missions and market shaping are laid out, and the reader is directed to areas of opportunity whereby an AT mission approach could be applied by considering the kinds of activities, policies and stakeholder arrangements. The final sections (6 and 7) also serve to underline how AT could be structured as a mission through a vision of enabling human capability, and points to existing international policy frameworks that provide the initial impetus to secure government investment and interest.

Thus, overall, it will be shown that in order to address access to AT sustainably, interventions into the AT marketplace need to go beyond simply market fixing to resolve the fundamental issues behind why AT access is limited. This paper puts forward a government-led mission approach which will fundamentally impact how AT is viewed, invested in and valued within society. While setting the mission and the directionality is the role of government, NGOs, industry, AT users and the charity sector are also essential to driving forward a mission

2. AT as a fragmented marketplace: Case studies in low to middle income contexts

2.1 LMIC supply and demand side barriers

There are 50 essential priority APs defined by the WHO (WHO 2019), ranging from wheelchairs to pill organisers, communications software and screen readers, to incontinence pads, each representing a very different marketplace. While these products are seen to be priority products, there are many times this number of assistive products and, in some cases, hundreds of product versions within a single type of product – for instance, manual wheelchairs. Wheelchairs are one of the most commonly used APs. Four in five people who need a wheelchair live in LMICs and these countries account for the highest unmet need (Product Narrative: Wheelchairs 2019). While wheelchairs are one of the more commonly thought of and visibly present devices that help to enable human capability through mobility, so many other devices that are classified as APs exist and are not reaching populations in need (Product Narrative: Wheelchairs 2019).

Hearing aids are another well-known AP where there is great population need. Indeed, 466 million people globally have disabling hearing loss, with this number expected to double by 2050 due to ageing populations, and new cases of hearing loss caused by untreated ear infections, ototoxicity,

and noise exposure (WHO 2020).² WHO estimates that more than 72 million people worldwide would benefit from the use of hearing aids, but less than 3% in LMICs have them. Hearing aids are not one size fits all, and are differentiated by amplification power and technology, sound processing capabilities, style, battery types used and special features (Product Narrative: Hearing Aids 2019).

Despite the clear need for these APs, the way in which they are currently designed, manufactured, distributed, provided and explained to users, repaired, upgraded and adapted is not conducive to meeting the ever-growing need. As an example of the complex and proliferated market and system failure issues, a breakdown of the demand and supply side challenges found within the hearing aid and wheelchair market are presented in Table 1. This table reiterates what is already known about the challenges of the AT marketplace as viewed from a traditional supply and demand perspective. Much of the information regarding the supply and demand side features of hearing aids and wheelchairs was sourced and adapted from recently published product narrative reports on the WHO's website (Product Narrative: Hearing Aids 2019; Product Narrative: Wheelchair 2019).

Table 1. An overview of supply and demand side barriers present in the hearing aid and wheelchair marketplace within LMICs

	Wheelchairs	Hearing aids
Supply side	<ul style="list-style-type: none"> ▪ Lack of design feedback loop between user and supplier ▪ Global manufacturers not interested in entering LMICs ▪ Manufacturing appropriately designed and higher quality products for LMICs financially unfavourable for companies 	<ul style="list-style-type: none"> ▪ High cost of hearing aid production even after volume-based negotiations ▪ Five main industries dominate landscape and don't allow for lower cost entrants even in LMICs ▪ Price mark-up throughout supply chain, increasing cost for buyer
Demand side	<ul style="list-style-type: none"> ▪ Lack of awareness concerning need for appropriately fitted AP ▪ Low political will and involvement; donor funding supplying 'free' product inhibits further market investment and development ▪ No common consensus on appropriately designed wheelchair standard 	<ul style="list-style-type: none"> ▪ Lack of public, private and donor financing for the purchase of hearing aids ▪ Limited government involvement ▪ Service delivery and product selection outdated or inadequate ▪ Service provision capacity constrained and fragmented
Other contextual factors	<ul style="list-style-type: none"> ▪ Lack of quality standards and assurances ▪ Fragmented funding procedures ▪ Need for data to demonstrate true extent of unmet need ▪ Need to substantiate the value of wheelchair to spur interest and investment 	<ul style="list-style-type: none"> ▪ Lack of quality standards and assurances ▪ Fragmented funding procedures ▪ Limited visibility on the potential and current market in LMICs

² See: <https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss>.

A further description of the barriers in the hearing aid and wheelchair market are further discussed in the text immediately following. By providing a general overview of the market systems of two of the most common APs, this section of the paper hopes to present insight into the major structural issues present within the AT marketplace and underline why a market-fixing perspective that only slightly improves, but perpetuates, the existing models of charity and globalised corporation AT design, production and delivery are inadequate to meet need. Market fixing is limited in its approach, because the underlying notion behind market fixing is that the markets can be understood as self-correcting or in a state of partial equilibrium, which justifies the 'all else equal' static approach. In contrast, underlying a market-shaping approach is the Keynesian concept of uncertainty and the idea that the economy shifts between different equilibria or disequilibria over time (Kattel et al 2018).

2.1.1 Wheelchairs: A case study

Wheelchairs make up one of the larger sections of the AT marketplace. The wheelchair industry has several mainstream companies with billion-dollar revenues, large scale manufacturing and international sales and distribution channels (Borisoff 2011). Yet, even though wheelchairs make up one of the most significant sections of the AT market, of the more than 200 wheelchair manufacturers operating in the US, only five companies had sales in excess of one hundred million dollars. In the case of wheelchairs, the supply landscape is relatively fragmented with the five largest manufacturers controlling less than 50% of the global mobility market. Even large-scale suppliers have a limited presence in LMICs and mostly operate via local distributors. Leading global suppliers have limited interest in LMIC markets due to low and erratic funding and demand, a reliance on a distributor network that is often poorly developed in LMICs and a need to develop products with specific design features. Various NGOs and faith-based organisations fill that gap and deliver low-cost, manual wheelchairs that are specifically designed for LMIC environments.

A small number of LMIC governments procure wheelchairs directly and provide them through facilities and programmes under health, education and/or social welfare ministries/departments. In these instances, wheelchairs are typically tendered for at the country or regional level, generally based solely on cost. The final price offered to LMIC buyers increases due to high shipping costs and, in some cases, import duties. Small volumes and limited competition among distributors further raise the price. As it can be a lengthy and challenging process to obtain custom wheelchairs, local distributors often limit their wheelchair offering to those that can be easily obtained and warehoused to serve the largest number of people, leading to a higher volume of standard wheelchairs (Product Narrative: Wheelchair 2019).

Wheelchair provision may sometimes incorporate involvement from local manufacturers, but an assessment of such local production sites reveals that these products are often of lower quality compared to imports and, further, these companies usually have higher cost structures compared to larger production sites from abroad. One noted benefit of local AT production within LMICs, though, is that since these manufacturers are at least nearby this may in turn reduce final product costs by eliminating shipping costs and intermediary supply chain steps. Further, a manufacturing and distribution site in-country may also enable greater user specificity if proximity to the

manufacturer translates into better user AT design feedback loops. Still, these small companies will often struggle due to low and erratic demand.

2.1.2 Hearing aids: A case study

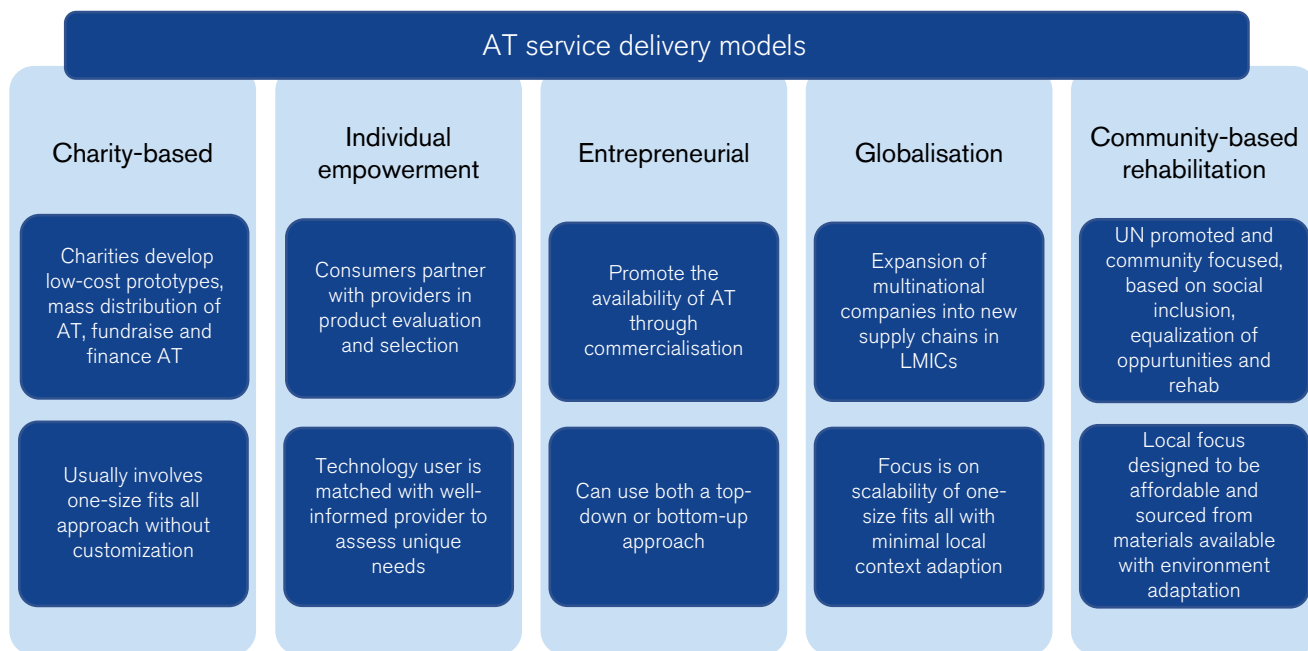
Hearing aids, while a completely different device with varying supply chain structures, face similar supply and demand side challenges to wheelchairs and other APs, due to reliance on the charity-based models and limited multinational industries for production. In the hearing aid market, there are five major companies which control 90% of the market. While there is greater market consolidation in hearing aids (as well as a reasonable profit margin), which should give such companies flexibility to lower prices in LMICs, manufacturers are reluctant to reduce rates for fear of price erosion in higher income countries (Borisoff 2011). The donor landscape in hearing aids is limited and fragmented with most funding for NGOs coming from corporate social responsibility (CSR) initiatives. There is no one bilateral donor that is heavily engaged in the hearing space and those donors that do engage usually provide resources through grants which get distributed between NGOs and social enterprises, often through wider disability programmes, around the development of innovations in hearing screening and care, provision of hearing aids and support of ear and hearing care strategies. In the absence of public spending and given the constrained size of the private market, NGOs and CSR initiatives are sometimes the only hearing aid provision occurring within a country. Most NGOs rely on individual donations, corporate donation matching schemes and support from CSR initiatives, such as those from leading suppliers, to fund their hearing aid screening and provision activities.

2.2 Current AT delivery model options within LMICs

Currently, the charity-based model is one of the key AT delivery mechanisms existing within many local as well as global communities. In this model NGOs are credited with providing materials, engaging in low-cost prototype distribution and development, participating in mass distribution, fundraising and refurbishing existing apps (Adya et al 2012). Beyond this role in the AT supply chain, such actors serve a critical function in value creation for social ends (Berger and Neuhaus 1977).

Based on these case studies and the available literature, it appears that the dominant models for AT within LMICs rely on a mixture of globalised conglomerates and variants of charity-based models. Other models, such as the entrepreneurial model, which entails setting up and investing in local workshops that produce and supply products that are adapted to user preferences also exist (Adya 2012). However, the entrepreneurial model is often critiqued in the literature for not providing a high enough quality product while being unable to meet a fraction of the demand.

Figure 1. Current AT delivery models.



Source: Adapted from Adya et al 2012

The charity-based and globalisation models appear to be the most prominent models and dictate how APs are innovated, produced, supplied and experienced by users within LMICs. The current delivery options available within LMICs tend to produce a power relationship whereby LMIC users are reliant on the sporadic willingness of companies and donor agencies to supply APs, often with inappropriate fit and poor quality. LMICs are not viewed as a viable market in their own right, because the fragmented nature of the supply chain makes it appear, both for multinational companies and local players, that AT innovation and production is not worth investment. Further, the fundamental and intrinsic value of AT as it is currently framed does not provide a strong narrative for governments to become involved. This combination of globalisation and charity-based models has resulted in low quality AT, as the simple presence of AT, even if it is poorly matched to the user's needs, may come across as having already met the needs of the user. 'Free' is often seen as 'better' by those running small charities or living on under \$1.25 per day, even if the quality is so poor it has the potential to cause long-term damage (Samant et al 2013).

Complexities arise as not only are there many variations of supply chain models and innovation processes within the hearing aid and wheelchair space, but this overview only gives a glimpse of two commonly identified APs out of the hundreds which are available and that users need. Thus, while the AT marketplace is heterogeneous due to the variety of AT user needs and the breadth of materials, functions and technologies the AT landscape encapsulates, the more prominent models of AT delivery are based either on variants of sporadic charitable giving or are linked to the activities of monopolistic globalised industries. Overall there is little interest in investing in AT, as under the current market landscape the economic demand is viewed as limited and would not enable any real return on investment. Further, market demand may be warped as those with a disability predominantly live in low-resourced settings whereby the means to purchase AT is

beyond the resources available and often, when AT is purchased within LMICs, the purchaser is not necessarily the user (Morgon Banks et al 2017).

Thus, the AT market in LMICs is one of complexity and fragmentation. The current approach has perpetuated an economic and value system whereby companies fail to understand true user need as demand and orient economic value assessments solely on production costs, manufacturing and distribution channels.

3. Current role of government in the AT market

Currently, LMIC governments are either not allocating sufficient funds and/or are providing variable financial resources for the procurement and provision of wheelchairs, hearing aids and other APs. In some cases, resources are drawn from specific ministry or department budgets, such as social welfare, education and defence. However, the funding is typically insignificant and fragmented. For example, South Africa, on the higher end of spending, commits approximately 3% of its annual public health budget to wheelchairs. Comparatively, Romania commits only 0.04% of its annual National Fund for Social Health Insurance to wheelchairs. Similarly, governments are not prioritising procurement of hearing aids (Product Narrative: Wheelchair 2019). In Malawi and Kenya there is no procurement of hearing aids taking place at a national level. Where a limited number of countries do procure hearing aids for public provision, procurement volumes tend to be far below the immediate need, as characterised by growing waiting lists in places such as South Africa (Product Narrative: Wheelchair 2019).

Procurement and distribution or provision in its current form is linked to a variety of barriers; no single ministry has complete oversight over procurement and provision within government or across partners; different ministries have differing levels of infrastructure or human resources to deliver and maintain wheelchairs; some ministries lack the supply chain or logistics capacity to effectively deliver products appropriately, which leads to a mass distribution model, whereby one wheelchair type is given out with limited service; different ministries have differing mandates on the population served and therefore some populations are left behind. According to the wheelchair product narratives, in Kenya the National Council for Persons with Disability and the National Fund for the Disabled—semi-autonomous government entities linked to the Ministry of Labour and Social Protection—allocate yearly funds to the purchase of wheelchairs.

Programmatic investments have also included both country-based initiatives and global initiatives. A few examples of investments include an Indonesian programme to integrate wheelchair service into the healthcare system, a multi-county programme in partnership with World Vision to support appropriate delivery of wheelchairs in five countries, and a Georgian programme to establish wheelchair production and provision. For many countries, regardless of whether the funding comes from the Ministry of Health or another government entity, the amount spent on wheelchair provision is negligible (Product Narrative: Wheelchair 2019).

Involvement by governments in hearing aids is even more limited. Instances globally where governments have tried to be a market player in this particular AT environment can be seen in Brazil, India, Botswana, Vietnam and the Philippines. In these countries, governments focused on

local production to mitigate the cost of hearing aid import duties. In such a model, manufacturers might be incentivised, if volumes are sufficient, to supply semi-knocked-down kits to small, local businesses that then assemble hearing aids locally. Semi-knocked down kits usually only require the transducer(s) to be soldered onto the printed circuit board and the unit closed with small screws. The assembly model has had limited success, because ultimate cost reductions are small, manufacturers are wary of quality control on the final product and they may have to disassemble existing stock of hearing aids to provide the broken-down kits.

Thus, the main challenge has consistently been generating and maintaining demand to sustain production levels. High political interest for local manufacturing by governments is rarely accompanied by support to procure the final product and to allocate public funding

4. The many domains of AT innovation

4.1 AT innovation chain

This paper seeks to expand upon supply and demand market failure framing by focusing on the larger question of AT value. While in a strongly market-oriented world funders and investors define value according to returns on investment, such assessments of value are quite limited. Rather, we argue that AT value should be understood as a form of public value. Measuring public value will help to further enhance conversations concerning priorities and decisions. By having a public value orientation, it will help government to decide on what actions should be taken, based on which decision pathway will most likely enable multiple direct and indirect beneficial consequential effects with long-term implications on the economy, healthcare and social services (BEIS research paper number: 2020/044; Mazzucato and Kattel 2019; Mazzucato 2017).

In order to create public value from AT, we argue that public agencies must have the capacity to create and lead ecosystems that generate innovation. As the creation of public value is a collective process, actors must be identified throughout the innovation chain and the nature of their relationships understood so as to crowd in investment.

This is a shift from the current economic thinking of AT, which has focused on addressing supply and demand side market failures, and has led to efforts which have only further crystallised a current system that has failing investment, and impediments to the creation and delivery of AT processes. In order to truly leverage meaningful and sustainable investment that will increase user access, AT will be approached through the lens of innovation. Rethinking AT entails contextualising AT design, production, dissemination and usage as part of a larger ecosystem of innovation. Through this approach, one might be able to articulate the particular innovation themes within the AT market that can serve as a useful platform from which to drive larger industrial and economic growth. Given the importance of understanding AT value through an innovation lens, which will enumerate the many uncaptured ways AT can positively impact the economy and larger society (therefore building a case for AT value), this section seeks to articulate the current domains of AT innovation.

Innovation can occur in the domain of a product. This would entail a new or significantly improved product or process, which might include alterations in technical specifications, components, materials, software, the product's user friendliness or other functional characteristics. AT innovation can also take place from a supply side standpoint. This would involve an improvement in the service delivery method or model of an assistive product, inclusive of changes in service provision techniques through process or software. Lastly, AT innovation can be found in the domain of procurement, whereby there is a new or significantly improved financing method for assistive products or supply services (Holloway et al 2020).

An example of AT innovation with LMICs is illustrated in Figure 2. The AT accelerator model encourages home-grown innovation within low-resourced settings in multiple domains. This approach, based on a traditional start-up model, is popular and derives its value from short development cycles, rapid viability, business driven experimentation, iterative product releases and validated learning.

Figure 2. AT accelerator model

Figure 2. An innovation case study: AT accelerator model

These accelerators entail certain characteristics, such as the groups brought into the accelerator process must:

- Undergo a highly competitive application process;
- Secure pre-seed investment; and
- Endure a limited time frame of event and mentoring support (Innovation WP for WHO background paper).

Innovate Now (iN) is such an accelerator in Africa, which hosts AT start-ups from three to six months. Through an innovative active learning model it seeks to increase AT innovator skills in entrepreneurship, business and product topics. Those that go through the accelerator programme are then pressure-tested through mentors and live lab tests, before being polished in the investment community. The accelerator model shows tremendous promise in its promotion of home-grown business, though its structure suggests a focus on product innovation without having the support and ability to address procurement and supply side innovation domains. These domains are also important to consider, especially for newly developing local firms that may need further support to ensure a sustainable, scalable and accessible business model.

We now will look more specifically into the particular domains of AT innovation. When we consider product innovation, it is about the particular kinds of investment into the development of an AT product that reimagine the AT product and technology base, and may lead to delivering a disruptive technology that has greater spillover effects. Within the domain of AT product innovation, AT technologies have the potential to be transformational, both for AT users and for the broader system that facilitates their usage. With a plethora of disruptive technologies and practices, such as 3D printing, augmented reality, machine learning, peer production, co-design and task shifting, we are now able to create new ways of doing things that would have been

previously unimaginable. The connection between AP and other technological products can be seen through the spillovers in AT product design and development from product innovations in defence and aerospace (Lane 1999). However, right now, product innovation is experiencing a significant lag in how it is diffused, from the initial innovation pilot phase that prototypes how an AT may address a user's needs through to the innovation's transfer into the marketplace.

One of the other major barriers for the AT market is the constant rate of innovation, replacement and abandonment (Laure et al 2015). Innovation, perhaps more so than in other markets, is often viewed as a challenge in the AT market, as each new technology that is introduced can potentially surpass the older one with regards to efficiency, effectiveness and potentially price (Laure et al 2015). This creates further disincentives for firms wanting to invest in a particular technology and scale up the product, as the life of a product and potential for it to be sold in a steady fashion is often finite. Larger firms are more adept at doing this and may be able to reap further reward from AT innovation when a technology transfer can take place.

Part of AT product innovation entails the R&D process. AT products that successfully pass through this process will also be able to inspire investment, either for the particular technology or for the firm. A fruitful R&D process can also provide opportunities for firm and technology scale-up. Yet there is a substantial split in the AT R&D processes globally due to the largely separate market areas – cheaper options for lower income individuals or better, more expensive options for higher income individuals (Rohwerder 2018). This mode of promoting innovation is based primarily on profit maximisation within higher income countries with no interest in advancing wider public benefit. The impact on the public should be considered as the public purse serves as the primary funder of science, technology, health or education. Such public funding for innovation often contributes to industry outputs and further pushes the boundaries of the possible (Constantine et al 2006).

Innovations can also occur along the lines of service provision, whereby new ways are found to connect users to AT products. This would require innovative thinking about how to engage players who historically have not been captured within the AT provision system. Innovations in delivery can take place by removing production bottlenecks within national or regional networks, removing intermediaries (such as physical stores and warehouses), and streamlining activities and leveraging technological innovations (enhancement of e-commerce and means of connecting supplies, users, patients). Currently on the supply side, the rate of innovation transfer is poor in AT due to a restrictive innovation space, which can be characterised by an opaque mix of monopolies and charities (Vernardakis et al 1995). These factors create entry barriers for new innovative initiatives and often deepen existing market failures in AT products. Further monopolies can be present by profession (e.g. optometrists) or by product manufacturers (e.g. hearing aid manufacturers).

Innovation in procurement may entail business models becoming innovative in how they deliver patient-centric, sustainable and adaptable assistive products. Smaller companies that lack proper cash flow may have difficulty pursuing a new innovation and getting it developed, as to do so would require people and investment for product design, prototype development and design iteration, intellectual property analysis and protection, market testing and feedback, and manufacturing considerations. These various components of the innovation system are often

outsourced to different companies, industries and research institutions (Borisoff 2011), which creates difficulties for alignment and barriers to costing the system as a whole. Such business models require flexible and dynamic arrangements whereby partnerships are formed with stakeholders that are important (though may not be necessarily viewed as such at first glance) to the AT ecosystem. Greater consideration of the AT stakeholder network is also important as through closer examination the market would recognise that there is currently a principal agent split between those buying and procuring AP, which often differ from those who use the AP, especially within a low-income country setting (Tangcharoensathien et al 2018). The marketplace, and its underlying system of innovation, is one of incomplete information as a result of the fragmentation in the innovation and delivery chain.

The AT market is viewed as one that is based on a supply-push or demand-pull cycle. AT firms respond to this cycle and, after the creation of an AT innovation in which an evaluation from a technical and consumer perspective takes place, a market evaluation will occur which considers the technical and user benefits (Lane 1997). A market evaluation takes into account product distribution, marketing channels and the overall distribution chain. Within AT, the product's price will often increase as a product moves from manufacturers, through wholesalers and distributors to a retailer, and eventually the customer. With all the added costs in the supply chain, and the inability of consumers to afford the end price, less than 10% of devices will show sufficient potential to merit pushing the device through to the manufacturing stage (Lane 1997).

The ongoing system of AT innovation and delivery, which predominately stifles rather than stimulates innovation, can be obstructive and can lead to high costs for products which are of a desirable quality, while providing sub-standard products and services for the vast majority of the global population. In turn, overall production levels of usable and appropriate AT are far below what is needed for universal global coverage. Often this results in expensive AT by the time it reaches the user, as cost control is only considered after the innovation process is completed, instead of building in affordability at inception.

This review of the AT innovation ecosystem highlights some of the ways in which AT innovation domains add larger value, and how innovation is an essential component to delivering appropriately fitted, scalable and accessible ATs. While AT innovation can be found across the areas of product, supply and procurement, work still needs to be done to address barriers in AT innovation, particularly within LMICs. Within the literature the focus of innovation appears to be mainly based in the domains of product, followed by supply and service delivery, whereas innovations in the arena of procurement are rarely discussed. This need to bolster the AT innovation system, with a particular emphasis on the domain of procurement and investment, provides fodder for the argument that the market requires an alternative approach in order to direct innovation in procurement and investment. A missions framework may be such an approach as it could fundamentally address innovation in procurement and investment, and thus enhance AT access.

4.2 Recognising AT as an Innovation and Technical Change

Keith Pavitt argued in his seminal article that technical change follows a sectoral pattern (Pavitt 1984). The way products and related change, “is largely a cumulative process specific to firms. What they can realistically try to do technically in future is strongly conditioned by what they have been able to do technically in the past” (Pavitt 1984: 353). He showed how supplier-dominated firms in agriculture and science-based firms in electronics follow deeply different innovation patterns (e.g. in agriculture, technology is mostly supplied by non-agricultural firms; in science-based companies, technology is developed in-house). This insight was developed further into the idea of sectoral innovation systems. Malerba argues that, “A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products” (Malerba 2002: 250).

We propose that in order to understand innovation in AT, we need to recast ATs as economic sectors. ATs are today predominantly understood (both in academic and policy discussions) from health and social perspectives. In these perspectives ATs form a more or less coherent group of products. Yet, from the perspective of technological change and innovation, ATs exhibit rather different sectoral dynamics: wheelchair production, for instance, is dominated by a few large-scale providers with relatively homogenous user demand; for eyeglasses there is a multitude of small producers with highly diversified user demand.

Understanding different innovation dynamics in different AT sectors can be illustrated with examples from industries as diverse as vaccines (Azimi et al 2017; Batson et al 2006; Robertson et al 2017) and green technology (Mathews 2017). Within the green economy, for example, investment and innovation in solar photovoltaics has led to a year on year fall in the cost of associated energy costs which “have been falling by 28.5 per cent for every doubling of production, which has occurred every two to three years.” (Mathews 2020).

Such reductions then make technology affordable and therefore ripe for pairing with innovative financing models. Key to these dynamics have been public investments that ‘crowded in’ or created the market for private investors and users. In short, successive waves of innovations led to both better products and cheaper solar photovoltaics. Adapting this model of how directed, and successive, waves of innovation may result in cheaper and better product may have applicability within the realm of AT. A possible way to direct AT innovation in the domains of product, supply and procurement could be towards achieving a grander global mission. This direction would be based on distilling the greater purpose of what AT hopes to achieve for both its users and larger society.

We propose that AT policies should combine focus in innovation dynamics and human capabilities: directionality of AT innovations should be defined through enhancing human capabilities. In our view this can be achieved through applying a mission-oriented approach to AT. Given all the barriers and the way in which the current approach to AT is riddled with systemic issues, we argue that AT needs to be based on new economic foundations that go beyond fixing market and system failures, and focus on shaping markets to unleash AT innovation dynamics. This requires theoretical and policy frameworks and toolkits that rely on the understanding that economic

growth has not only a rate, but also a direction; the latter is an outcome co-shaped by multiple actors across the society (Mazzucato 2016, 2018a).

Yet, much of existing economic and innovation policy relies on the idea that policy makers should fix well-specified and measurable market failures. However, as argued already by Nelson (1959) and in particular by Arrow (1962), the market failure approach is good at identifying problems, such as areas with under-investment in R&D, but is a poor guide to identifying areas with the potential highest 'social profit' (Nelson 1959: 298).

5. Moving beyond market fixing to embracing a missions approach for AT

5.1 Theory behind missions

The dominant approach to public policy is derived from neoclassical economic theory, in particular microeconomic theory and welfare economics. This approach emphasises the idea that, given certain assumptions, individuals pursuing their own self-interest in competitive markets give rise to the most efficient outcomes (Samuelson 1947; Mas-Colell et al 1995: 539-40). Efficiency is understood in a utilitarian sense, whereby an activity is efficient if it enhances someone's welfare without making anyone else worse off (so-called Pareto efficiency). Under these conditions, the role of government intervention is in practice often limited to addressing instances where the market is unable to deliver Pareto-efficient outcomes.

Such 'market failures' arise when there are information asymmetries, transaction costs and frictions to smooth exchange, or non-competitive markets (e.g. monopolies) or externalities, whereby an activity harms another agent not directly connected with the market transaction (e.g. pollution), or coordination and information failures hamper investment (Rodrik 1996).

We can see such frameworks in action in the AT sector: despite its potential for significant societal impact, if properly produced and distributed, the AT sector is confined by a normalised, institutionalised and systematised standard of assessment as determined by certain ideas of value creation and production. This has ramifications for innovation outputs. While certain elements of innovation, in particular early-stage R&D, can be considered to be public goods and thus a case for public policy provision can be justified, it is assumed that the private sector is the more efficient innovator, possessing greater entrepreneurial capacity and better able to take risks given the pressure created by competition. In contrast, the state is viewed as risk-averse and in danger of creating government failure if it becomes too involved in industrial policy by 'picking winners'. Its role is to level the playing field for commercial actors – mostly through supply-side inputs such as better skills or the removal of market frictions – and then get out of the way.

5.2 Existing 'market-shaping' efforts and the need to expand beyond

Within the global health sector, we can turn to instances where players tried to address barriers in health access and delivery by directing the market place. These actions, which are under the USAID's definition of market-shaping, take steps to bring together key stakeholders from government, industry and NGOs in order to address supply and demand side barriers. The idea of market shaping has been applied to various global health problems throughout the last decades. For instance, through USAID efforts to reduce the cost of antiretroviral drugs for HIV by 99% in 10 years, increase the number of people receiving malaria treatment, or double the number of women receiving contraceptive implants in four years while saving donors and governments \$240 million, market shaping has addressed large-scale market barriers (Product Narrative: Wheelchair 2019; Product Narrative: Hearing Aid 2019). Market shaping can play a role in enhancing market efficiencies, improving information transparency, and coordinating and incentivising the numerous stakeholders involved in both demand and supply side activities. Examples of market shaping interventions include: pooled procurement, de-risking demand, bringing lower cost and higher quality manufacturers into global markets, developing demand forecasts and market intelligence reports, standardising specifications across markets, establishing differential pricing agreements, and improving service delivery and supply chains.

Market-shaping interventions often require coordinated engagement on the demand and supply side. Successful interventions are tailored to specific markets after robust analysis of barriers and look to coordinate action on both demand and supply side. These interventions are catalytic and time-bound, with a focus on sustainability, and are implemented by a coalition of aligned partners providing support where each has comparative advantages.

Market shaping as it has been taken up by different international agencies and sectors has achieved meaningful momentum towards trying to address some of the key barriers to access. However, even with real efforts made by government agencies to do things such as creating PPPs, offering tax abatement schemes, encouraging accelerator and business investments, along with activities that have reduced intermediary supply chain costs or enabled greater bargaining power during the tendering process, such reforms, which rely on variants of cost reduction and consolidation schemes to reduce intermediary costs and enable greater business investment, are neither fully sufficient nor implemented in a way where the true visions behind market shaping are actualised.

In order to address the issues of scale and access to AT that are appropriate and which will truly enable human capabilities, a much more comprehensive approach, which both recognises the fundamental role of innovation, the need for active government investment and involvement, engagement of AT users and citizens, and which places the true value of AT at the core of its policies, is essential.

Market creation and shaping policies which emphasise the public sector as a market shaper recognise the implicit flaw in assuming the private sector is always the more efficient and capable actor to resolve issues. By contrast, we argue that policy discussions should focus on policy approaches that recognise both market and government imperfections and failures – and also the fact that it is impossible or even undesirable to attempt to remove all of them at once – and the

need for policies that support scale economies, dynamic learning effects and cross-sectoral spillovers (Rodrik 2009; Mazzucato 2013). The state's ability and willingness to take risks, embodied in transformational changes, requires an organisational culture and dynamic capabilities that welcome the possibility of failure and experimentation, and are rewarded for successes so that failures (which are learning opportunities) can be covered and the next round financed (Kattel and Mazzucato 2018).

The evolution of technological change has historically required active public investments across the entire innovation chain, from basic research to applied research, early-stage finance to firms willing to innovate, and procurement policies that have resulted in the ability of small, innovative firms to scale up (Mazzucato 2013). These investments have created new technology and innovation frontiers for private companies to move towards and seek new competitive advantages (Nelson and Winter 1974; Mowery 2011). In this context, industrial and innovation strategies become key pillars to achieve transformational societal change, and a particular way to do this is by identifying and articulating new missions that can galvanise production, distribution and consumption patterns across various sectors (Mazzucato 2017, 2018a). Missions can be used as a mechanism to focus research, innovation and investments on solving crucial problems. With a strategic direction, missions enable new possibilities of bringing different actors to spur on collaboration and help redefine what these cross-sector relationships can look like. Missions, in other words, offer a new vision of how different economic actors co-create value, and the types of capabilities, relationships and tools that are required in this process.

5.3 Applying a missions approach to AT

AT markets require a comprehensive approach, not only to fix existing failures, but also to bring in the dynamic effects of innovations, such as decreasing costs, learning across the value chains, increased responsiveness to user needs and so forth (Ferri 2015). Such a comprehensive approach could be provided by AT-related policy missions as these offer the opportunity to determine the direction of AT innovation by helping public, private and third sector actors to make strategic investments across several fields, and by nurturing new innovation and industrial landscapes to grow. Currently there is a dearth of evidence capturing best practices for ensuring a functioning global marketplace. The lack of evidence is, in part, a result of the varied AT market landscape.

The way these markets are currently situated though must not be seen as an outcome of a natural process that cannot be influenced or interfered with. Markets are always co-produced rather than self-regulating. Joint action is necessary in order to make markets more effective, raise consumer welfare, and promote specific rights and values (Ferri 2015). Through the proper leveraging of policy interventions and partnerships, and the recognition of the government as both a historic and current market shaper – and often also market maker in places where there are no suppliers – there is potential for an increased production of accessible goods, an adjustment or reduction of prices, and a greater choice of ATs that are properly matched to the user through a system which is fit for purpose. This approach would extend beyond existing market options, which tend to favour mass-market technologies and procurers' preferences, by providing additional ATs that are further designed around users' capabilities and quality of life (Holloway 2019).

In essence, a mission-oriented approach would recognise and bolster the essential components of the AT ecosystem. Due to the varied landscape of AT, it is important to engage not only the government and the private sector, but to fully embrace the varied and essential roles that social enterprise, local and international civil society, universities, individual AT users, informal markets and innovators play. This would directly address barriers in the current marketplace involving demand side factors such as awareness and political will, and, on the supply side, appropriate design and production economics. However, the role of government is pivotal in creating a market and policy landscape which is tilted towards innovation and equality. In this way it can play a varied and vital role in shaping the AT ecosystem, both through its traditional and recognised role of governing, financing, and creating policy and legislation, along with performing less traditional parts which are beyond defined state craft. Through government embracing such a role this would also address barriers on both the supply and demand side concerning provision, preferred product profile, competitive landscape and cost-efficient supply chains.

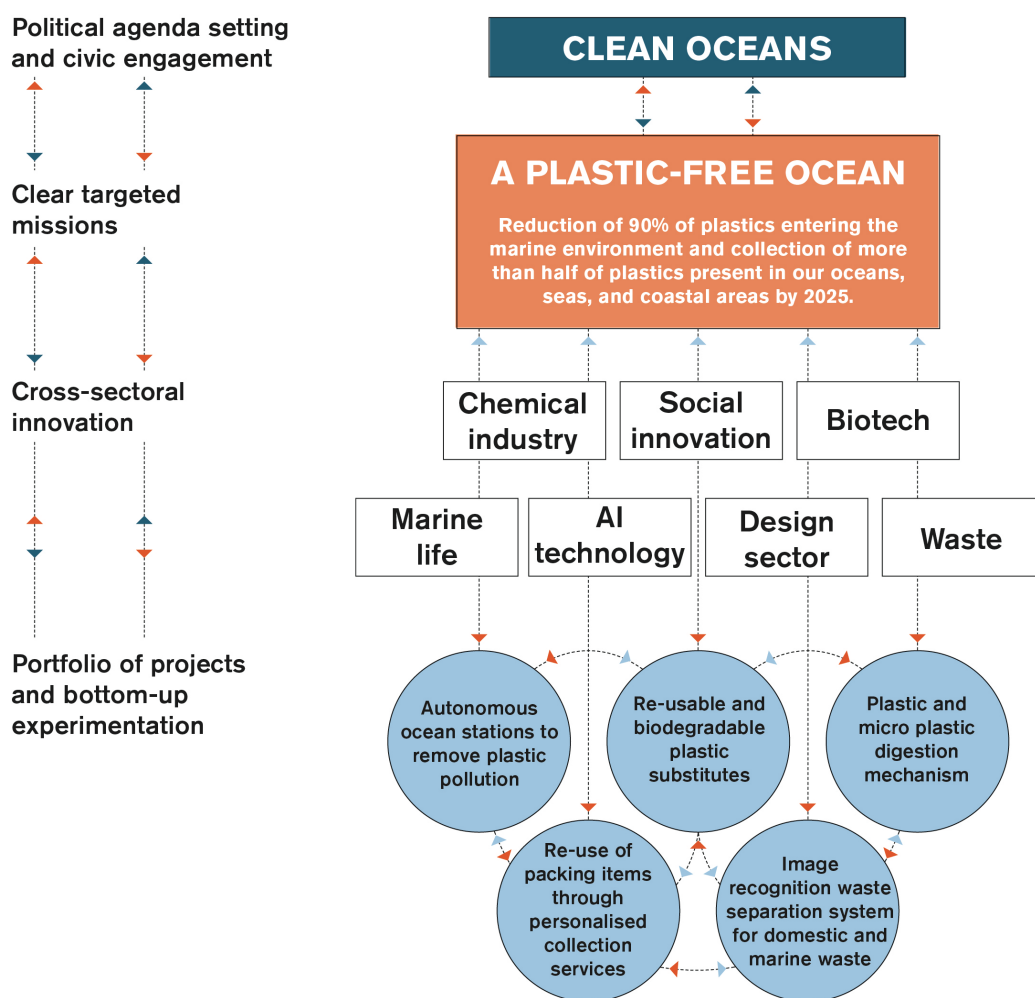
If we adopt a mission-led approach we should engage with existing policy strategies while rooting the agenda in the outputs of deliberative commissions which put at the centre AT users' priorities and experiences. Perhaps one of the most critical lessons from past mission-oriented policy-making and implementation approaches is the realisation that, in addition to public and private investment, they require accompanying institutional innovations (Kattel and Mazzucato 2018). Institutional innovations can range from transformative changes in rules and regulations to new forms of public-private partnerships, and from new organisational designs to new forms of accounting and evaluation practices (MOIS 2019).

A report for the European Commission titled *Mission-Oriented Innovation Policy: Challenges and Opportunities* (Mazzucato 2018) sets out a framework for developing a series of cross-sectoral missions and projects within missions. This framework sets out that missions must satisfy five criteria. They must:

1. Be bold and inspirational with wide societal relevance;
2. Be direction-oriented and abide by a measurable or time bound target;
3. Be ambitious, but have realistic research and innovation actions;
4. Be cross-disciplinary and cross-sectoral; and
5. Contain multiple bottom-up solutions (Mazzucato 2018).

To illustrate, take SDG 14: 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development. This could be broken down into various missions, for example 'A plastic-free ocean' (Figure 3). This could stimulate research and innovation in methods for clearing plastic waste from oceans or in reducing the use of plastics, innovation in new materials, research on health impacts from micro-plastics, behavioural research and innovation to improve recycling or drive public engagement in cleaning up beaches. Each of these areas could be broken down into particular 'projects', with policies serving as the meso-level providing the glue between the larger mission agenda and the particular projects taken up.

Figure 3: A mission-oriented approach to cleaning the oceans



Source: Mazzucato 2018b: 24.

Examples of mission-oriented thinking with regards to AT were evident in parliamentary proceedings within the UK where it was discussed how AT could be incorporated into the government's industrial strategy, which set out to tackle the grand challenges of artificial intelligence, mobility and the ageing society. This industrial strategy led by the UK government would be designed in such a way that it would "boost the economy, build on the country's strengths and embrace the opportunities of technical change." This approach explicitly entailed fostering research grants, regulatory policy and efforts to build consumer trust in new technologies. As part of the broader discussion of tackling the grand challenges, it was noted by experts how enabling AT access not only addressed the challenge of an ageing society, but could also greatly address artificial intelligence and mobility (All-Party Parliamentary Group for Assistive Technology 2018).

Using the UK industrial strategy example, at a global level, INGOs, NGOs, foundations, charities and AT advocacy groups, along with national governments would need to come together in order to understand how the activities and various components of the AT ecosystem, its subsequent innovations and the issue of AT access, add value to greater society as well as adding explicit value within particular sectors. It is essential that each of the actors that are both currently in the

AT ecosystem, as well as other actors that are not currently involved or are only seen as being slightly involved, are brought into this discourse to break away from silo- and sector-based problem solving.

By first setting out to form this large commission of engagement there can be meaningful input as to how to set an agenda and mission that engages with recognised, understood and also not yet explicit AT value. NGOs, foundations, charities and AT advocacy groups can feed their own experiences into such a commission and create more apt feedback into national governments, so as to best create a direction which has proper feed-in from those actors that are already greatly involved and to share that with national governments. Leveraging the role of each of these actors and connections can then be directed towards achieving larger societal missions. A juncture is needed between private and public sector, and NGOs can create this by leveraging their unique expertise in order to advocate and influence activities, operationalise goals, and build institutional and social capacity (Teegen et al 2004).

Specifically, through a missions approach, demand for AT could be stimulated through the integration of services via the incorporation of procurement and provision of AT within health and social care systems. Resources would be funnelled so as to limit market fragmentation and support innovation across the AT value chain. If international purchasing agencies embedded the objectives of a global mission to reach more people with AT in their scoring criteria, it would alter the tendering process and public sector investment, which would enable a more stable and sustainable pathway for overall AT investment. Enhanced AT investment by a mix of public, charitable and private sectors would inherently create greater opportunities to take on innovative approaches for AT. It would do this by allowing for a mixed risk profile for local companies to test and experiment with AT designs and ideas, so that higher quality and more user centred focused APs, which are most suitable for the user's environment, are created. Missions would motivate an ideal and progressive standard for AT based on innovative technological thinking founded in notions of enhancing economic opportunities.

Overall, the uptake of a market-shaping and mission-oriented approach would help to address current challenges found within the innovation domains of product, supply and, in particular, procurement by bringing together stakeholders and enhancing public sector interest and investment.

6. Galvanising around AT to tackle global grand challenges

Considering the previous discussion of how AT could take on a mission-oriented approach and how one would restructure the AT stakeholder environment to enable such a mission, it should be noted that AT access in its own right would not qualify as a mission. A mission requires a remit that brings together global action, and entails an agenda with a precise target that is of great societal relevance; one which has the potential to stimulate innovation across the system. While not everything can be a mission, a mission-oriented approach is still a useful framework for many policy agendas and can have significant impact. Access to AT on its own may not qualify as a

mission, but when we consider how AT access fits into a larger call for equity, reduction of a disease burden, and is linked more specifically into the SDGs, it becomes evident that AT access is a vital component of larger societal missions involving health, equity and autonomy.

Globally, there is increasing interest in tackling the 'grand challenges' facing modern societies through such new economic policy frameworks that enable policy makers to address the issue of the directionality of growth. Within the UK there have already been policy discussions surrounding the UK government creating a fifth Industrial Strategy Grand Challenge on Assistive Technology. This would signal that the government recognises the vital role that AT could play in closing the disability employment gap and revitalising the UK economy. The existing four grand challenges also serve as a platform to support the development of a wide range of AT products. For instance, the Ageing Society Grand Challenge could be seen to foster further investment and, through the recognition of the role of AT as part of a healthy ageing platform, will create new demands for technologies, products and services which involve AT (House of Commons 2018). If LMICs were to take on a similar approach to that of the UK with regards framing AT as part of a larger mission, along the lines of enabling human capabilities, this would ensure there was a framework and agenda which investment and activity could latch on to and drive forward.

Internationally, there are already policy frameworks in place that prompt action from AT system stakeholders and can be utilised to rethink AT economics and resourcing. The United Nations Convention on the Rights of Persons with Disabilities lays out international policy that aims to secure disabled persons' rights. One of the four rules on the precondition for equal participation requires that states ensure the development and supply of AT to assist people with disabilities. Further, beyond support for the development, production, distribution and servicing of AT, states are also required to support the dissemination of knowledge about such products. Lastly, because states ought to enable persons with disability to have access to such products, financial accessibility is essential (MacLachlan et al 2018).

At a global level, the SDGs agenda exemplifies this approach by ensuring that the most marginalised are included in the collective approach to growth. A call for a unified global effort to look further into the barriers within the current system took place at the World Health Assembly, which urged, "Member states to develop, implement and strengthen policies and programmes to improve access to assistive technology" (WHA 2018). It also asked the Director-General to prepare, by 2021, a global report on effective access to assistive technology.

Even within EU state aid law there are regulations which are meant to achieve equality for people with disabilities based on accessibility, participation, equality, employment, education and training, social protection, health and external action (UNCRPD 2010). An interpretation of these regulations could easily point towards using such policies as a toolbox for direct improvements in the availability and access to AT within the EU internal market.

Thus, while the distribution of AT in and of itself is not recognised as a grand challenge, the distribution of AT can be one facet of a larger vision for promoting the SDGs, human equity and human capabilities. There is ample evidence that APs have a significant positive impact on people's lives generally, as well educational and economic outcomes (Federici et al 2016; Perelmutter et al 2017). Further, the AT sector can greatly contribute to the economy and society

at large as the AT sector is world-leading in hardware manufacturing and software development, and is at the forefront of many innovations (All-Party Parliamentary Group for Assistive Technology).

For governments to embrace AT, AT innovation and access will have to be situated in a larger narrative of human capability. There are already numerous platforms for which the delivery and access to AT is an essential building block to accomplishing that mission. Sen and Nussbaum's capability approach describes human capability as the goal which society should strive for rather than simply striving for human productivity (Nussbaum and Sen 1993). Thus, AP as innovations could be promoted and developed as part of a spectrum of policies which seek to achieve the mission of human capability. The capability approach links together the need for a mission to be driven by larger societal goals, and provides the direction of growth that AT innovation and access would bolster

7. Conclusion and the Path forward for AT

By setting up a global partnership and adopting a global mission of halving the deficit of AT provision (by reaching 500 million people) by 2030, the global community has begun to adopt mission-led thinking. This now requires real 'buy-in' and political backing, an operational delivery plan and function, and significant political and financial backing.

The aim of this paper was to propose a model beyond the current AT paradigm, which is often steeped in a market failure rationale. We propose a mission-oriented approach to AT which will enable a greater rate of innovation (thus directing and mobilising AT investments) and subsequently greater access to well-suited AT devices. This paper contends that addressing AT access only through a supply/demand, market fragmentation lens will only result in solutions that are market fixing. Efforts such as embracing the charitable model further and trying to scale that up in order to deliver more APs to individuals may result in a temporary increase in AT delivery in the short term, but effectively only emboldens a flawed and unsuccessful system which relies on international business to give away outdated APs.

As part of this larger vision of assessing, exploring, evaluating and capturing the value of AT, a critique was made which highlighted some of the flaws in current thinking about AT economic value. If the goal is to achieve accessible, individualised and scaled AT for the global community, governments may first need further evidence and understanding of the many kinds of AT value and a mapping of the many arenas in which the AT ecosystem is interlinked. This paper has opened up and made known the various venues in which to now seek and enumerate that AT value; such as by enumerating and capturing the impact its innovation system has on the larger economy, or the way AT will help to achieve larger societal missions (such as the mission of healthy ageing in the UK). While historically it has been hard to capture such value through economic models, this paper thus concludes by proposing the production of an additional study which will map out areas in which the AT ecosystem engages and demonstrates AT value by considering impacts created by the various kinds of AT innovation. Through a further exploration of AT value, a more specific agenda on how to implement a market-shaping and missions

approach can be detailed and brought forth to an AT missions commission, so as to ensure public sector investment goes towards AT investment of the greatest value. Only through rethinking how to understand the AT environment will the AT landscape be best able to leverage stakeholder networks and policy-action layouts in order to achieve the intermediary goal of increasing access to assistive technology and a larger societal mission of enabling human equity and capability.

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