Computing Devices for All: Creating and Selling the Low-Cost Computer

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***Abstract*—In the past decade, several projects have explored the possibility of enabling human development for economically underserved populations by giving people direct access to modern computing technology. The main economic and distributional hurdle in the access of such provision has been the prohibitive cost of computing devices. The quest for lowering this bar has resulted in research into solutions aimed at modifying existing technology to reduce the cost through innovation with the software, hardware, and distribution processes. Some common threads are manifested across such projects, both in terms of the approaches to building new technologies, and the subsequent outcomes. Using two important case studies we generate some hypotheses about the possibilities and barriers to new technology development for poor populations.**

***Index Terms*—Low cost computing, Developing Regions, ICT**

I. Introduction

The changing face of the development worker is manifest nowhere else more than in the budding field of ICTD. The period associated with the beginning of ICTD thought and activity – the 1990s and 2000s, was marked prominently by the technology boom and the sudden expansion of market economies worldwide. This created a new wave of thinking of technology as having transformatory potential across all groups. The controversial idea born of this time was that of technology allowing a leapfrog – i.e. a movement from a state of stagnation to one of sudden accelerated growth. For the macro-economy, this meant the move from agrarian to industrial or service. A few academic commentators did endorse this idea of a leapfrog (Mansell 1998[1] Castells 1998[2]); most faith in the idea of computers leading to development came from white papers of major international organizations such as the UNDP[3][4], the ILO[5] (ILO-WER 2001), the ADB[6], the World Bank and OECD[7] and finally from management gurus[8]. This period also saw the composition of development workers change from the traditional quadrilateral of government, agency, academia, and grassroots social worker, to including a number of new groups – most prominently an overflow of young socially- driven graduates, corporate social responsibility executives, and young tech boom retirees looking to reinvent themselves in social enterprise. This new breed grew through the period of extraordinary growth and change relating to technology, thus attracted to the idea that the quantum leap of in western economies and the lives of ordinary people turned millionaires could be replicated in helping solve many development gaps. This, along with the brimming cash overflows at technology companies looking to invest tax-free monies in areas valuable to their businesses, led to an explosion of interest in ICTD. A key movement in this area has been the alchemic search for the inexpensive computing device for the poor user.

In late 2005, the inexpensive computing debate was a hot topic in the ICTD space. Online discussion groups, were abuzz with activity over the MIT $100 laptop following its formal prototype unveiling at the World Summit on the Information Society (WSIS) in November 2005. The device had been much talked about right from the project's germination stage, for several months preceding the summit. The first actual sight of the hand-crank-appended prototype suddenly woke the world to the near-future reality of a mass-produced cheap computer invading the homes of the poorest of the poor. Neither the idea nor even the device itself were new, but the fact of its being unveiled at an international event of magnitude, in the presence of the UN Secretary General Kofi Annan himself, marked the seriousness with which a very influential segment of the development and technology community had taken the issue of 'computing for all.' Heated debate followed over the technical design of the device, its utility, means of marketing, and its competing products. These debates brought the community together, and tore it apart, tabling a range of issues – with social scientists and community workers entering discussions with technologists or entrepreneurs on technological determinism, and development in general. These deliberations brought back into limelight several past attempts at building low-cost computing devices [9]. Two such devices were the Simputer (Simple Inexpensive Multilingual Computer), a PDA-type computing device developed in Bangalore, India, and the Computador Popular, a low-cost, low-function computer conceived in Brazil. Online discussions comparing the MIT laptop and the Simputer address a variety of issues ranging from the concentration of R&D in developed nations to the appropriateness of the laptop interface for the illiterate [10]. The Computador Popular offers useful comparison with the MIT laptop on two other fronts – bulk production and marketing.

This study looks in depth into the development and outcome

trajectories for the Simputer and the Computador Popular, framing them against the literature of research and development in developing countries, and on the perceived role of computers in human development. This will not be the first time the Simputer and Computador Popular, two very different projects, have been compared (Warschauer 2003[11], Fonseca 2004[12]). We argue that the need to look at these two projects is renewed, especially in the environment of the $100 laptop's possible unveiling as a real world product. We propose that these seemingly different products offer vital lessons on the development and deployment of ICTs in the environment of economic backwardness.

The type of device and the populations served are different in both cases, yet the projects shared four significant commonalities:

- Both projects meant to address the technology need of a population that was not perceived as being adequately served due to pricing
- Both projects were conceptualized not by an explicit market interest, but primarily by technologists hoping to find, or create a market based on price-point – though neither enjoyed the success that was envisioned.
- Both projects received a pre-product hype that may or may not have worked favorably towards outcomes
- Neither project enjoyed backing from major computer manufacturers

We contextualize these factors to the $100 Laptop to see which of these patterns repeat, and how they may impact future studies on low-cost device research and production for developing regions.

II. Research and Development in Developing Regions

The ideas of digital exclusion and a research concentration (in the developed world) are closely connected. Among the earliest intellectual contributions to the idea of a technological / digital divides was by Hans Singer, who saw the evolution and concentration of technology in developed regions as having important consequences for inequality. In calling it an international technology dualism, Singer studied the internal inequalities in developing countries, associating those with larger inequalities across the international issues – making the case that the technological innovations of the world were designed primarily to serve the technical issues of developed nations (Singer 1970[13]). This idea linking the utility of first-world technologies to developing region practical usages raises the concern of the concentration of international R&D, and what in turn this means both for product development, and (of lesser relevance here) to the local loss of R&D staff from within developing regions.

The first issue raised by Singer is of particular importance and relevance to the debates surrounding the MIT $100 Laptop, and for that matter to a great extent into the relevance of the computing interface itself in development contexts. There are numerous technical and economic difficulties involved in transposing a technological innovation from an origin location to a country with a different system and unique contextual issues (Stewart 1977[14], Lall 1992[15]). Simultaneously, there has been literature on the economic un-sustainability of developed world technologies for developing world, and on the idea that local design and engineering skills can be usefully deployed for very high quality communications infrastructure given the right assistance. (Brewer 2005[16])

The second issue, which we visit briefly, is that of whether the capability of R&D is itself being eroded in developing regions – both through manpower loss, and through capital and distribution networks that support western-made, mass produced goods. The idea of a "brain drain" has been an important question in the early technology and development writing. The concentration of technology and subsequent dualism also causes a work-associated glamour of being at the "frontier of technology" which in turn leads to a brain drain (Singer 1970). This work also aligned well with influential thought on regional development and destitution (Myrdal 1971 [17]). With regard to the development of home-grown technologies in the developing world, despite the early exodus of engineers (Carrington 1999[18]) and its immediate economic losses (Bhagwati 1976 [19]), the eventual engineer networks assisted the creation of institutions that contributed dramatically to economic growth in the 'sending nations' and also set the basis for local R&D (Saxenian 2002 [20]). Such R&D, starting off as low-cost output zones, eventually turned to high-value added production – but still continued to have products targeted at international, rather than local markets (Reddy 1997 [21]). The same fate was projected among top universities in developing regions, which turned to globally fashionable research than locally relevant work (Goldemberg 1998 [22]). Consequently, the cases of both the Simputer and the CP are particularly interesting, as they both provide counter-examples to this dominant paradigm, signifying a possible early sign of change in the view of technology products for the developing world. In the case of the CP – the broad design was done at the UFMG (Federal University of Minas Gerais) though it never got as far as specific components. The Simputer, conceptualized and designed at the Indian Institute of Science (IIS) in Bangalore, had a few imported components but the core design was entirely home grown, partly funded through the university and partly through private early capital. In the case of the Simputer, following the product design, the software and platform were also developed in India, and the code opened for developers to create applications for. This need for software application development for specific platforms is an additional barrier for new products in the market – especially so for those in developing regions that cater to smaller markets.

Both cases point at the importance of capital in research funding in the developing world especially at the product development phase. It is seen that research is heavily skewed against finding solutions for the problems of the developing world, due to the lack of returns. (Nowhere is there greater evidence of this than in healthcare research funding [23]).

This discussion of R&D in the ICTD field suggests three important trends for developing regions:

1. There are some manpower shortages in R&D because of historical brain drain, but trends show the reversal of these due to the networks of professionals and some amount of return migration, and economies of research in developing regions
2. Since applied R&D efficiency is deeply tied to the market penetration of a product, developing countries may be at a disadvantage (using the instance of a computing-platform here) since products need a large community of application developers to bring utility to a product.
3. The orientation of R&D towards western, or globally marketable ideas means universities, and subsidiaries of major research groups (HP Labs, Texas Instrument etc.) for instance use the research capabilities primarily for cost savings which are transferred to more efficient product delivery for (often) western products.

III. Contextualizing the Comparison Between Computador Popular and the Simputer

The reasons for comparing the Computador Popular and the Simputer relate both to the devices themselves as well as to the regional and temporal contexts in which they were developed.

The Computador Popular was a project initiated by the Brazilian government and UFMG with the goal of increasing access to computers and the Internet to low-income populations, by significantly bringing down hardware costs. It was to be a simplified desktop computer running open and free software, backed by production incentives from the government and a convenient line of credit to the population, to provide basic internet access and productivity software.

The Simputer was originally designed as a handheld device to be usable by low-income, low literacy rural populations in India – aiming to provide universal access – not only in terms of affordability, but also easier usability. It was to be appreciably simpler to use than a standard computer, with text-to-speech capability, comparatively inexpensive, and both small and mobile. It was envisioned as purchased and used through time-sharing arrangements.

A. Brazil and India in the ICTD context

Brazil and India make an interesting comparison because the two are seen as important spaces of ICTD activity and as emerging markets especially for technology manufacturers. Both are among the world's top ten largest nations in terms of size and populations, and have massive modern urban hubs, contrasted against relatively sparsely populated and underdeveloped rural stretches.

Due to privatization of infrastructure services in both nations, household access to power and communications have grown rapidly. This growth has coincided with an expanding class of people who are either users or potential users of technology services. Table I compares both countries in terms of key indicators of technology usage.

An interesting comparison is that both countries represent a very comparable size of "immediate" market despite India being five times the size in population. This is due to the higher per capita income and rate of urbanization in Brazil.

Another interesting fact from the table is that India has a lot more people sharing resources than Brazil – as is clear from the Internet usage activity. Brazil has a little over one Internet user per computer, whereas India has close to three. Moreover, this is a continuing trend in India. In most developed nations, this ratio is below 1 Internet user per computer [24]. This is an important factor to consider in the different choices of technology between Computador Popular, which was meant as a standalone single-user device as opposed to Simputer which was envisioned as a computer purchased and shared over multiple users.

In both countries, the government has had an important role in the promotion and use of ICTs. The Brazilian government focuses on three major areas, digital government services, universal access to ICTs, and infra-structural development (integration of different networks, deployment, and security), and are based on the direction set forth by the Information Society Program [25], created in late 1999 by the Ministry of Science and Technology. The usage of ICT by the government is arguably the most advanced of the three areas, with at least 72% of the government services to the population provided through the Internet [26]. Despite the relatively weak position of Brazil on a number of developmental indicators, the government ranks highly on an international scale in its use of IT. However, inequalities persist at the consumer level, mirroring the low GINI score ranking of the nation. According to the Digital Inclusion Map [27], 72% of homes with access to computers belong to the richest 20% of Brazilian households, while 3.5% of these belong to the poorest 40% households.

The Indian government has in 1998 set forth an 'IT for All' policy, and is active in keeping a low level of regulation for

TABLE I
COMPARISON ON KEY INDICATORS

Indicator	2001		2003	
	Brazil	India	Brazil	India
GDP	$2959	$483	$2864	$560
Phone lines	73.7 M	54.1 M	107.9 M	91.2 M
Phones per 100 persons	42.38	5.19	59.78	8.44
PCs	14.3 M	7.5 M	19 M	13 M
PCs per 100 persons	8.22	0.72	10.71	1.21
Internet users	13 M	16.6 M	22 M	35 M
Internet per 100 persons	7.48	1.59	12.1	3.24
Internet Users / Computer [a]	**1.10**	**2.21**	**1.13**	**2.68**
Adult literacy			88.4	60.1
Gini Coefficient			59.3	32.5

Source: UNDP HDR 2003, ITU Basic Indicators 2004 Report
[a] Number of Internet users per computer

telecommunications. The original mandate of this program was to ensure that every village in India had a telephone and an Internet connection. The village telephone scheme covered about 85% of Indian villages by 2003, from less than 10% in 1991. The value of software and services exports in India has grown to a total of 17% of the total export market in 2005 (though it accounts for less than 4% of the GDP as a sector, and employs less than 0.2% of the workforce). The central government and a number of state governments perceive the development of the services sector, especially IT, as critical to the future of their economies.

IV. Computador Popular

By the year 2000 political rhetoric in Brazil was flush with ideas of priorities to effectively transition to the "Information Society" by providing universal access to ICTs. The government also viewed its role as fundamental in providing access to ICTs for lower income populations, in order to prevent these very technologies from increasing the gap between the rich and the poor. In December of that year the government turned to academia to specify and build a prototype of a cheaper computer. The initiative turned into the Computador Popular (CP) – or Popular Computer – project, with a target mass production price of US$300. This price was 20% cheaper than a computer one could by, and would mean that an additional 10 to 20% of the population would be able to purchase it through financing.

A. Basic Concept

CP, as proposed, was to come basically in two configurations, with different goals: a stand-alone machine, to be used mostly at home to access the Internet and with common applications such as word-processing and spreadsheets; and a networked institutional version to be used in a thin-client style, with back support from a more powerful server. In both the goal was a computing platform providing the user with access to "digital information" in the forms currently exchanged over the Internet, i.e., mostly Web content and documents (word processor/spreadsheet) files.

It is important to understand the goals and assumptions that led to the design decisions. The design is for a desktop computer, to be used in a fixed location, with electricity and at least a phone line. In schools and telecenters, better connectivity was assumed, as was literacy in the Portuguese language. Given Brazil's demography, it seemed clear that a project scaled to these assumptions would cover a large portion of the population.

The design aimed at providing a straightforward user experience and interface. The graphical user interface was simplified, and the system software was stored in a read-only partition of the storage medium. This allowed the system to be resilient to power outages and computer viruses, for example, bringing down the maintenance cost.

The final cost of the Computador Popular was to be kept down by a combination of factors:

1. use of commoditized off-the-shelf components, possibly of the previous generation;
2. removal of some components (mainly the hard drive)
3. use of Free and Open Source Software (FOSS)
4. provision of incentives for the companies producing compliant machines.

In the networked version, intended for use in schools, telecenters, and small and medium business, the cost of installing and maintaining a lab of CP's is measurably smaller than an equivalent solution using normal PCs. Given the appropriate connectivity with a central server, the client machines can be configured with no disk or permanent storage, by transferring programs and data over the network to the server.

B. Hardware and Software

The specifications that follow are those published for the prototype of the CP in 2001[28], and some alterations, as described from personal communication with involved members.

- Processor: AMD K6-II 500Mhz, on a SiS 530 motherboard
- Audio, VGA (SiS 6306), Ethernet, 56K modem, IDE interface integrated on-board
- Memory: 64MB RAM
- Storage: Disk-on-chip Flash, 32MB
- Slot for a second flash card
- Ports: 2 USB, mouse, keyboard, 1 parallel, 1 serial
- 2 USB ports, 1 parallel port, 1 serial port
- No hard disk

User files would be stored either in a second Flash memory device, or on the network, via possible service providers.

The software in the CP was composed of the GNU/Linux operating system, together with general purpose applications, including a Web browser, email software, media player, and office software. All of the software was free and open source, which had an important impact on cost. However, the more important aspect of using FOSS was its customizability to the exact needs of the project, and the possibility of the maintenance of an open specification that would not depend on commercial interests of individual companies. In the initial phase of the project, the academic sector, through a group formed at a federal university, would customize and maintain a standard software distribution for the CP.

The software was heavily customized with two main goals. First, unnecessary features were removed so that the system software could fit the Flash memory of the device. Second, the user interface, based on the KDE desktop environment, was simplified, by removing excessive icons and menu items.

Non-essential programs and configuration options were removed, and common programs could be started from a simplified launch bar. The central element of the interface, the Web browser, was permanently and automatically running. The project leveraged on a large body of open source software already localized to the Portuguese language, and the user interface had a look and feel that would be familiar to users

with previous experience with Microsoft Windows, while remaining as simple and objective as possible.

Another key goal was to minimize the need for maintenance, and the system software was in a read-only portion of the Flash memory, meaning it could not be affected by abrupt shut downs, power failures, or even computer viruses. The motto was to ask as few questions as possible to the user, and have the user have as few questions as to the operation of the device as possible.

C. Outcomes

No unit of the CP was ever produced. We discuss several factors that contributed to this outcome, some conjectured reasons, and also some indirect impact that the project had.

For a series of circumstances, the government abandoned the project. This was a decisive setback, because of the focal role expected of the government in propping the undertaking through financial aid in both ends of the market chain: by providing tax incentives for companies manufacturing the 'CP Certified' devices, and by providing cheap financing to individuals purchasing the CP.

In 2001, a major energy crisis hit the country, forcing the government to prioritize its efforts in remedying the situation. Some key persons in the government who were pushing for the project were relocated, as were some important funds for the project. This suggests the *high vulnerability to political or circumstantial priorities, of projects which rely to a large extent on government action*. As a result, no concrete plan for the tax incentives, nor for the loan policy or certification process for industries were issued.

Another influencing factor at the time was a proposal, by the Ministry of Education, to install 280,000 computers in public schools countrywide. The request for proposals specified that most of these computers would have to be Microsoft Windows based, which precluded solutions based on the CP to be used. This contradiction points out the fact that *it is important to ensure that all government offices that may be involved in projects of this nature have a consensual view of the solutions*. The aforementioned request for proposals was considered illegal, but was never reissued.

However, it was not just the government who caused the project not to go forward. The computer manufacturers in Brazil did not show interest in producing the CP. It is not clear whether some manufacturers would be interested in producing the CP even if the government had gone through with the tax incentives. This can be due to three main reasons. The companies feared that:

1. The CP would interfere negatively with the sales of their more expensive computers
2. The CP would face tight competition from the gray market computers
3. Linux would not be widely accepted by the consumers

To analyze the outcome, it is useful to distinguish the two proposed uses of the CP, the residential, standalone version, and the institutional use.

For the first case, that of the standalone use, we conjecture that there wasn't enough of a technology differentiation from the existing technology (regular PCs) to disturb the market equilibrium at the time. Indeed, the gray market computers, responsible for 75% of the market in Brazil [29], have almost no cost due to taxes or to software. Clearly, these devices would be strong competitors to the CP. At the other end of the spectrum, companies feared that consumers would buy the CP and then purchase other components to make it comparable in power to non-subsidized computers.

The situation was more amenable for the institutional use of the CP. As we noted, in this case the proposed technology provides a true and measurable reduction in cost when compared to traditional technologies. The thin-client architecture of the CP results in a lower initial cost, and lower maintenance/administration costs. Besides, a single CPU can be used simultaneously by more than one user, by connecting more than one set of interfacing peripherals (keyboard, mouse, and monitor) to it.

Industry did show some interest in this application of the CP. There are at least two examples in Brazil of companies that are commercially pursuing solutions that are very similar to the CP, even though they do not bear the name. The solutions are not targeted to poorer segments, but rather as cost saving solutions to enterprise and school environments. In another example, HP has a solution based on Linux that allows four users to share a single CPU, reducing costs.

V. SIMPUTER

The definition of the Simputer as a Simple Inexpensive Multilingual Computer is important in surveying its projected uses. The Simputer was originally planned to be a stand-alone computing device with a simple user interface, and features like speech synthesis that made it work for very low-attainment users. Various usage models were considered, but the key to the 'Inexpensive' aspect was the shared model. Our analysis here is of the PicoPeta Simputer, 2003 version. There are more recent versions, but the basic specifications remain the same.

A. Basic Concept

The device was to enable large groups of users to share one device, possibly purchased communally. Individual users were expected to own smart cards that enabled them to store their information offline. A potential owner for a Simputer would thus be a village council, or a cooperative, or any group of people willing to share it. Public funds could potentially be applied towards such purchases.

The simplicity aspect was to be addressed through a very friendly interface with intuitive panels and graphics. The shared usage model also relied on the multilingual feature. Speech-enabled devices in homes were expected to play an inclusive role in the more remote regions of India, where literacy can be low.

Users would also be enabled to use online communications through the devices for a variety of daily tasks that could be made easier using technology. An alternate usage model was mediator-oriented, in which the end-users of the Simputer were

to be traveling data gathering professionals, often working in remote parts of India. In this case, the Simputer would work much like a PDA, but enabled with its unique features, it offered a potentially easier learning curve for rural grassroots workers who may or may not be literate enough to use a standard PDA.

Hardware Design decisions took into account the infrastructural shortcomings of India, yet, the device could perform optimally given some minimum electricity availability and wireless connectivity. The cost saving of the Simputer would have to be seen in its comparison to personal computers – rather than to other PDAs. The device itself was originally meant to be priced low by virtue of addressing an entire community's needs, thus having a lower per-capita cost than an immobile personal computer.

B. Hardware and Software

The Simputer uses some off-the-shelf components, and is fabricated in India. Current versions of the Simputer come in a hardware-software bundle. The hardware specifications are as follows:

- Processor: Intel StrongARM processor
- Memory: 32 MB of DRAM, expandable up to 64 MB
- Storage: 32 MB of Flash memory for permanent storage, expandable up to 128 MB, CompactFlash being supported, for increased storage
- Ports: 1 USB and 1 serial
- Connectivity: internal modem, infrared port, support for WLL (CDMA and corDECT), can connect with GPS devices, phone jack.

The software on the Simputer is integral to the device; much of it having been tailored to perceived functions. The Simputer operates on a Linux platform, using the Malacca interface (in the case of the PicoPeta Simputers). This is based on IML standards (Integrated Mark-up Language).

Some of the highlights of the software include: a simplified interface, integrated with an efficient development environment for rapid and low cost development of custom applications and content. This also has the benefit of maintaining a consistent interface across applications. Also, the text-to-speech capabilities are useful for some of the intended application for end-users. The Simputer uses Dhvani for its regional language text-to-speech functions, and the Flite engine for English. Both softwares are open source, and at this stage, Flite is at a more mature stage of development than Dhvani. The smart card interface allows for shared and authenticated use of the device. It has a PC-based simulator to test and debug applications. Native Development platforms include X-Windows, Perl/Tk, TCL/Tk, MySQL. As in the case of the CP, software development leverages a large body of existing open source software, and there was considerable development and customization with local knowledge into the product.

C. Outcomes

From its initial conception in 1998, the Simputer project was primarily run by academic researchers. The team developing the Simputer included approximately 35 researchers, professionals, and students from the Indian Institute of Science, Bangalore. Two companies spun out of the project – Encore and PicoPeta, the latter being set up by the four professors from the IIS.

After the initial funding by angel investors, the product did not make a significant impact on the venture capital industry. The project eventually received funding from the Indian government's Technology Fund, and arguably, was consistently supported by the availability of university research community.

The design prototypes were ready for production by 2001, but getting the product to the market took until 2003. Simputers did make it to the market, but were available mainly through direct company orders, and at the time of writing (December 2005), about 4000 Simputers had been sold – some institutional purchases were being used for traffic control purposes. There are no formal numbers available on total sales. In the earliest documents price was envisioned to be Rs. 5000 (~$100) (Manohar 1998 [30]) while the prices in 2004 in the ready product phase from the two companies was in the range of Rs. 12000 –Rs 22000 (~$240 - $440). A Simputer at these prices came in at about thrice the cost of lowest-end PDAs at the time.

The fact that the project was unable to raise adequate funding from the VC market was an unfortunate start to the product's life, and perhaps testament to the weak innovation funding situation in developing nations. It is difficult to speculate if funding at the right time would have helped the company bring out a product that could truly compete internationally. While ground-breaking technologies have often been government funded, these have usually been scientific research oriented or highly experimental in nature. In the case of the Simputer, the device did not exactly fit into either category, and should intuitively found takers in the financial markets. The Simputer's slow start would suggest that the existence of private funding may be a strong indicator in forecasting the success of a technology project that has a development motivation.

In its active deployments, there was limited evidence of end-user consumer purchases in rural India. The Simputer has made ground in the mediator-use model, and some projects involve the use of the devices by data collection agents. The test projects have worked with Indian languages. PicoPeta has documented some case studies in fields such as electricity spot billing, land records procurement by village accountants, rural children education, and data collection for loans and savings for farmers. Of these, only the educational project was less mediator-based. It was also the only one to make full use of the Simputer's capabilities, most notably text-to-speech. This raises a question of whether the Simputer's software could be used on other Linux-based handheld computers.

The Malacca environment (for the PicoPeta Simputer) was free, but not open source. There are several other projects

using the mediator-use model, implementing healthcare and e-governance functions. These could technically use software designed for the Simputer, if the software were unbundled from the hardware. However, there hava never been plans for such separation.

The Simputer was basically designed as a general-purpose device for a specific audience – those with limited literacy skills, or an inability or lack of context in operating computing devices that were oriented around the use of the English language. Every additional element increases the complexity of design, therefore cost. Thus, theoretically, it is a handheld device that can manage a number of different applications. It is possible then that the design model and the usage model are not entirely aligned. Most low-attainment users would intuitively be using one or a very few specific applications, this means the Simputer probably is a far more powerful device than it may need to be. An examination of the device shows that with the exception of a smart card attachment, there is limited innovation in the hardware, making it quite comparable to a general purpose PDA.

While the economic and market related factors that affected the early adoption of Simputer are important, the limited evidence of the use of PDA-type devices by low-attainment users suggests that the hardware interface may have needed a lot more work, perhaps specific devising to the application to be used. The widespread use in low-attainment communities of mobile phones, cash registers, courier service scanners, television remotes or calculators suggests that even devices not optimized for specific populations, can be adopted effectively where there is a perceived need. In each of these, there was already existing demand for the products before they reached the users.

Bringing the PDA interface to low-attainment users without the contextual establishment of their utility then seems like a quantum leap. This is a strong argument in favor of creating general audience devices for specific purposes with strong existing applications as a cheaper and more efficient design option.

VI. Theoretical Perspectives on the Outcomes

A. Technology versus Market-driven projects

The underlying concept of filling the affordability and access gap for computing products may indicate that both the Simputer and the CP were addressing a market-driven need. We argue, however, that both are fundamentally technology-driven products. When seen as information devices, these were technology products conceptualized and developed in a top-down fashion to be deployed as potential information and technology solutions, rather than products derived as being the best possible solution for the information needs of the market they addressed.

There is a risk of oversimplifying the complex demographics of the Indian technology product consumer and market. Most computer users in India are functional English speakers. Functional English speakers are also the predominant chunk of the top 10% of the Indian economy (Pal 2003 [31]). Non-English speakers have relevant web content, but arguably not enough to merit recurrent owned usage (as opposed to occasional shared community usage.

It is also not clear whether the basic perceived empowering benefit of the Simputer was the information available through the device, or the physical usage of the device, and the technological familiarity gained thereby. Technologists are probably better equipped to deal with the latter case than the former – evidence in the case of both the Simputer and the CP indicates that creating a 'reason' for people without an innate use of technologies to own or use devices is a far more complex issue.

Indeed, some thought behind the Simputer could have arisen from the way in which power users of technologies eliminate middlemen from their own lives using technology. This is a fundamental question of contextualizing achievable technology to its utility. The box-office scalper is clearly in professional danger, as perhaps are the typists who earn a living out of typing out court documents that need precise formatting, as word processing and e-commerce make life easier for millions. But the similar argument for low-attainment users, that access to information networks can free them from dependence on intermediaries does not seem to have operated on the same logic. To simplify, it was intuitive to conclude that Simputers could bring crop sale prices from thirty miles away to farmers in India and thus eliminate dependency on middlemen. But what role did the middleman really play in the farmer's life? A source of spot credit? An insurer for stable pricing? Evidence from the performance of rural information centers shows that these questions are not trivially answered.

If the model of usage is bringing the device all the way to the impoverished in India, the perceived material cost of learning to use a Simputer and owning a smart card has to be lesser than the perceived long-term cost of intermittent trips to government offices, or the marginal price improvement on produce. This is a complex economic problem, because it requires us to look into the decision-making process of people who are potentially at the poverty line, and do not have perceived long-term cost decisions structured in the same fashion. A top-down model of designing shared technologies for development is additionally prone to assumptions on group purchase behavior.

The technology-driven component in both projects outweighed the needs orientation. While the failure of CP to take off may have had more to do with supply-side economics, there was no evidence that the market for computing products could have expanded rapidly at the $300 price point that CP was aiming to hit, given the fact that the solution offered at this price would be Linux-based, and thus different than the standard-use devices in Brazil. Many of the intended buyers were existing computer system users, who needed the price incentive to turn into computer owners. If they had familiarity with computers, it would probably be with Microsoft Windows-based machines, the then de facto standard in

business as well. This raised questions on the 'quality' of the product, and the cost of the transition. This is a non-trivial factor, as the consumer sees the lowered price of a product as coming with an additional price tag of an unfamiliar operating system, and resulting learning curve. The government in Brazil has since then fostered the use of GNU/Linux based solutions internally, which will eventually trickle to businesses, but at the time the market may not have been ready to accept the proposed software solution.

While the economic side of market-drive in the case of the Simputer has not been tested (since it could not be produced at the original price of $100), the demand gaps relating to content submit a persuasive argument of contextual mismatch between the device and the perceived information needs of the populations served.

B. Focus – User Interface versus cost-saving

A fundamental distinction between the two projects is that CP focuses on creating a market through cost-saving by more cost-efficient existing hardware and software options, whereas the Simputer rejects existing solutions, and develops an entirely new product with a user-interface focus.

The distinction between India and Brazil is important here – the CP was designed taking into account a large educated, linguistically uniform, urban population that did not have access to computing, but given the devices, could reasonably work out the functionalities of the interface. Given the complications of several different scripts, hundreds of mutually unintelligible dialects and very low literacy skills, the pressure on creating a friendly interface was more apparent in India.

This however, raises the question of how far should devices for underserved populations aim to assist within the parameters of limited skills? Can technology enable greater information equity and yet continue to reinforce inequity on the technological skill itself? Given that the paradigm of desktop computing (and arguably, MS Windows) has become a standard in the personal and professional spaces, and the most prevalent interface to the services available through the Internet, does the death of the digital divide coincide with the universal adoption of desktop computing?

Should the focus then be on creating standardized solutions across the entire economic sphere and develop the supporting infrastructure to bring people up to speed, or are devices like the Simputer to provide an alternate user-interface?

In theory, if bringing technology at the user level to all Indians is a goal, then there a fairly strong case *against* creating a device such as the Simputer. It has been seen with the cell-phone, that electronic devices are usable by illiterates, but whether they allow a transition into being able to use computers is questionable. The PDA, a closer device, is not as easy to use, nor necessarily a good stepping stone to computers either. The challenges of bringing large adult populations in India from functional illiteracy to using a non-intuitive handheld screen with small characters, visualizations and a stylus interface are practically insurmountable. This is also true for populations in similar conditions in poor urban and rural areas in Brazil, as well as in most any developing country. But should succeeding generations be using friendly stepping-stone technologies? Or would enforcing a standardized computing curriculum in schools be a preferable solution?

There is little doubt that the Simputer's intended audience does exist, and is extremely difficult to design a useful system for. Further, as this segment of the population grows older, it will be plagued by an even greater gap than it faces today. It should also be recognized that with low high school enrolment rates, and poor basic infrastructure, succeeding generations will continue to have 'digital destitutes' who will continue to present a user-interface design question-mark for the economists, technologists, and policy makers who are concerned with issues of technological equity.

The Simputer project's eventual funding through the government may suggest an ominous lack of belief by private industry in investing research and development funds on a model of user interface design for low-income, low-attainment populations. Ironically, the CP, which did exactly the opposite, creating an affordable computing solution at prevalent educational attainment rates, got no industry support either. This suggests that the design focus was just one among several reasons for the Industry's perceived poor free market viability of the two products.

C. General purpose versus market/need-specific products

The CP provides access to a general-purpose interface – the Web – to allow for applications to be deployed by independent providers. Given the connectivity model assumed, it is arguable that this may not have been the most optimal solution. The Simputer provides an environment for development of different applications that run locally, with a potentially consistent interface. The CP is a largely tried-and-tested product, with fairly consistent usage patterns across users, in comparison.

The Simputer's originally targeted population did not have any one or few specific needs that the device addressed. The Simputer wasn't a dairy application or an e-Governance data collection device. At the same time, the hardware/software combination wasn't economically optimized to serve as a general purpose PDA (which has definable standard functions) or a device with functions spanning across its target populations. So while the Simputer can use a range of applications do a number of things such as bill payment, information gathering – there weren't standard functions (like the calendar / organizer in the PDA, or the browser / word processor in the average computer) that all its users were expected to use regularly.

This lack of a general purpose usage model is likely to be a critical challenge for Simputer from this point on as it attempts to compete with the standard personal computer, which has fairly established basic usage patterns, with the key differences being at higher level specific applications.

That being said, these usage patterns may tend to apply

more to home users than to institutional buyers. Home PC buyers are a fraction of commercial and institutional buyers, who sometimes run their own packages or platforms, the operators of the computing devices may have little or no exposure to systems outside of these applications.

Market-specific products can thus be more tailored to the needs of a uniform group (thus institutions are a natural fit), whereas the world of IT for development deals with fairly complex, and diverse populations – thus a black-box solution for the technology needs of underserved populations is a complex, possibly unattainable product proposition.

D. Institutional versus consumer sale focus

There is a persuasive argument that reliance on institutions – both public and private, as production and sales partners, may have affected the programs. Both the projects saw an important role to be played by institutions as conduits of redistributing the technology products. In the case of the Simputer, despite the focus on the utilities to the retail user, there was a perceived role of governments or NGOs buying devices that would be used at the village level. The CP had two main variations: one for institutional use, and another for individual residential use. Even in the latter case, the Government had a fundamental role in facilitating loan schemes for individuals who wished to purchase the CP.

The need to address a product directly to a mass market of consumers adds a lot more pressure to the manner in which the business models are perceived. Creating a product that has a perceived need by the end user, and thus mass market potential, is key to making that a sustainable product. Both the CP and the initial designs of the Simputer failed in reaching this mass market, either for being too expensive, too general purpose, or not competitive enough with existing technology. The CP was not perceived by the industry as a viable product for retail to individual consumers, and it is only its institutional version – that supposed to be used in multi-unit installations – which has enjoyed some acceptance by the industry. The Simputer also has not found its way into the hands of individual consumers: most significant test users of the Simputer have been of the institutional nature: schools, banks, government agencies, and the like. Interestingly, it is this approach that the MIT $100 Laptop has taken, selling to governments in large quantities rather than appealing to consumers directly.

VII. CONCLUSIONS

In the next decades, new devices and technological solutions for the problems of underdevelopment will continue to find their way to markets – often using incremental technology, some marketing innovation to differentiate from packaged consumer electronics – much like the two projects discussed. Though neither project received the market successes envisioned by founders, the two are landmark projects - presumably much future research on device development and manufacturing in the ICTD space will look back at the work of these pioneering projects for lessons.

Today, the MIT $100 Laptop combines some of those – it echoes the device innovation approach of the Simputer, and the corporate marketing approach of the CP. We can draw some parallels to the two projects we discuss, some seemingly in the right direction and some cautionary in nature. The MIT project bypasses the initial need for a market, for it is by design tied to large volume purchase orders from governments. By this very reason it also depends on a continuity of government policies, a factor that proved troublesome especially in the case of the CP. It also has a very clear target at children: if there is an impact on a non-user adult population it will be induced by children's usage at home. Arguably, the hype over the Simputer in its early days was much alike what the $100 Laptop has had, especially considering the Simputer itself was initially meant to be a $100 device. However, the top-down, technology-driven aspect is much exacerbated in the MIT project, which is a worrisome disconnection from target populations, driving away from the contextualization essential for the continued success of ICTD projects. Lastly, the disconnect from local technical expertise raises the issue of continued technical support. Experience shows that post installation computer care is a major issue in remote regions, even for desktops; for laptops there will be a higher hurdle to scale.

As 2005 draws to a close, it is not yet clear if the $100 Laptop will come to fruition, or if it does, whether people will adopt computer giveaways with the same enthusiasm as which governments have underwritten them. What is interesting, and in some senses tragic, comes out of our discussion of R&D in the developing world. Despite the multitudinal historical problems of R&D, it is in fact slowly permeating small enclaves in the developing world - but the focus of research remains strongly in a western paradigm. As indeed does the ownership of that research - usually by western multinationals which can afford the capital investment for research, and the powerful productization potential to back up that research. If there is one lesson to be learnt, it may well be that the main missing elements for both the CP and the Simputer were some basic market thinking, the research label of an MIT, and a spokesperson who can move governments and large industry players. Indeed, should the MIT $100 Laptop fail, only to be replaced by an international brand name $100 Laptop, it would only further solidify this argument.

In conclusion, we return to our introductory overview of the ICTD field as a whole, to ask whether the experiences with the Simputer and CP, and so far with the $100 laptop suggests that many of the failures of products to take off were deeply reflective of the market and social conditions. The assumption of technology as being a solution for development has also piggybacked on the idea of a market being manipulable (as in the case of shared devices, and processes such as massive institutional purchases) for such products. Consequently, it is very important to revisit our assumptions about technology's role in development as a part of a constantly regenerative process of intellectual inquiry.

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