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The Digital Skin of Cities:

Urban Theory and Research in the Age of the Sensored and Metered City, Ubiquitous Computing, and Big Data

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Abstract

A "digital skin" of the city is coming into being. This skin consists of a sensored and metered urban environment. The urban world is becoming a platform for generating data on the workings of human society, human interactions with the physical environment, and manifold economic, political, and social processes. The advent of the digital skin opens up many questions for urban theory and research, and many new issues for public and urban policy, which are explored in this paper.
Keywords: Big data, urban theory, urban research, social science, smart cities
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INTRODUCTION

Information and Communications Technologies (ICT) will play increasingly important roles in the future management and governance of cities, as well as the interactions and experiences of people who live in them. In the near term, sensors will be integrated into nearly all parts of the physical urban fabric, creating a "digital skin" composed of connected, digitally-enabled objects, network nodes, communication devices, and posts for monitoring and analyzing data fed into servers. The digital skin will involve many kinds of participants: individuals, and public and private organizations and governments.

As with any major technological change, the recent public discourse has become crowded with predictions and speculations about the new digital infrastructure and its possibilities in the urban realm. The "smart" city (we prefer "digital," "sensored" or "metered") is often presented as offering solutions to the social, political, economic, and environmental problems faced by city-regions. The contributors to this thick discursive field include technologists, engineers, civic activists and policy-makers, with narratives that are both pragmatic and normative. Thus far, however, there has been a dearth of theoretical engagement with the arguments and assumptions underlying these claims. In this paper, we therefore identify the major facets of the digital skin and the claims made about them. We then argue that social science – and especially urban theory – should be used to frame research around these claims, and hence to motivate both rigorous empirical research and level-headed normative reflection on the potentialities of the digital skin and both its intended and unintended effects. It is time, in other words, to subject the digital skin to a research program in the social sciences.

WHAT IS THE DIGITAL SKIN?

The digital skin of cities consists of the widespread implantation of sensors into urban and household environments, together with ubiquitous mobile broadband communication technologies that can transmit both deliberate communications and automated user data. In this section we review four major dimensions of the digital skin, in the areas of big data, smart urban management, public participation and governance, and digital intermediation of social interaction.

The City as a Source of Big Data

The Economist magazine writes that "cities are turning into vast data factories", with the "physical and digital world… becoming increasingly intertwined" (*Economist*, 2012). This statement references the advent of the "Big Data" era. Big data is, essentially, everything captured or recorded digitally by modern information and communications technologies such as networked sensors, "smart" objects and devices, the web and social media. It can take the form of text, web data, tweets, sensor data, audio, video, click streams, log files, banking and purchase data, social network chatter, traffic flow sensors, mobile phone GPS trails, and smart energy meters (Eaton et al, 2012). The superlatives abound, and even if they consist of a certain hyperbole, nonetheless capture a real trend. More than 30 million networked sensor nodes are now present in the transportation, automotive, industrial, utilities, and retail sectors, and the number of these sensors is increasing at a rate of more than 30 percent a year (Manyika et al, 2011). There are currently 10 billion connected consumer devices; it is projected that this may rise to as many as 50 billion by 2020 (Ericsson, 2011). A global telecommunications company collects billions of detailed call records per day from 120 different systems and stores each for at least nine months. An oil exploration company analyzes terabytes of geologic data, and stock exchanges process millions of transactions per minute (Schroeck et al, 2012). Taken together these components produce the "digital breadcrumbs" or "digital exhaust" of the modern age.

Many of the first big data concepts and methods were pioneered by private-sector technology companies such as Google, Facebook, Amazon, IBM, Yahoo, and Twitter. These companies found themselves sitting on enormous quantities of data, which they leveraged in order to refine their recommendation, advertising, and search engines. In 2009 a cross-section of prominent academics laid out an agenda for what they labeled "Computational Social Science" in *Science* magazine. Noting just how much information our digital, networked lives produce, the researchers stated their belief that "digital traces… can be compiled into comprehensive pictures of both individual and group behavior" (Lazer et al, 2009), including greater insight into the spatial, temporal, and typological dynamics of economic, communications, interaction, and proximity patterns (Hidalgo, 2012). Crucially, these patterns can be aggregated up to the societal level, and also disaggregated at the level of individual agents, offering fine-grained detail on millions, or even billions, of actions, choices, and behaviors. The big data community believes these new methods and tools will prove analogous in the social sciences to the introduction of the microscope in the natural sciences at the dawn of the scientific revolution (cf, Barabasi, 2012; Christakis, 2012; Pentland, 2012).

As the ultimate complex and noisy human system, cities have been the focus of many of these claims. Big data are proposed as an important new source of insights into the management, governance, and experience of urban life, through their applications to transportation systems, resource distribution and operations, or emergency services, among many others. There are already several university-based research programs devoted to developing expertise in the manipulation and processing of big urban data, including the Center for Urban Science and Progress at New York University. Much in the same way that GIS was institutionalized as a technique for analyzing and representing urban data, we can expect big data-driven urban analytics to occupy a greater and greater role in the practice of urban planning, management and policy design.

Management Systems ("Smart Cities")

"Smart" urban management consists of the use of ICT-based technologies "to deliver more effective and efficient public services that improve living and working conditions and create more sustainable urban environments." (Menychtas et al, 2011). As the European Platform for Intelligent Cities (EPIC) expresses it:

> Technological advances mean that aspects of the operation and development that city managers have previously been unable to measure – and therefore unable to influence – are increasingly being digitized. This instrumentation creates brand new data points about, for example, the efficiency of a city's water or transport systems. In addition to being instrumented, different parts of a city's systems can be interconnected, so that information flows between them. With

> the greater digitization of and interconnection of a city's core systems, the newly gained information can be used for intelligent and informed decision-making. (Menychtas et al, 2011: 12).

The hardware needed to enable these control systems is not yet fully known or developed, but will likely involve many visual, auditory, and environmental sensors. Linked to this intake of information will be the ability to process it using new types of software, involving some mix of monitoring and troubleshooting tools; analytics (i.e., statistics, programming, & operations); and platforms providing access and visualization.

Major technology companies such as IBM are developing the products and services to provide, operate and maintain these management systems. Representative projects include a NASA-like, integrated operations center in Rio de Janeiro that houses all city departments under one roof; the use of analytics and "predictive policing" intended to improve public safety in Memphis; integrated fare management for multi-modal transportation in Singapore; and a cloud-based, meter-driven portal to allow Dubuque (Iowa) residents to manage their water usage. Cisco Corporation, another early entrant to the field of ICT-driven urban management, seeks to create what they call "Smart + Connected Communities" through the provision of integrated network services to residents, businesses, infrastructure providers, and government managers (Kondepudi and Baekelmans, 2012). Another example of private-sector involvement is a smaller software firm, Living PlanIT, emerging from Portugal, whose Urban Operating System (UOS) provides "unified sensor data acquisition, real-time control, historical database[s], [an] analytics engine, and [a] application hosting platform for urban environments." Cities can be said to be "smart", for example, when streetlamps signal that they no longer work; when curbs tell the city about who parks where, at what times, and at what frequency; when continuous temperature information is fed back from various parts of the urban built environment; when pedestrian patterns or park use are mapped and analyzed; when crime, traffic accidents, and other incidents are mapped and analyzed in an ongoing manner.

The core promise of management systems advocates is that, by making cities "smart", we will better manage our infrastructure; make better decisions on future infrastructure; provide better services; and improve the overall quality of urban life.

Governance and Participation

ICTs are also proposed as a means to improve citizen and user participation in the governance of cities, via platforms enabling greater involvement in public decision-making and greater scrutiny of public agencies. They can, in addition, make more data available to non-governmental users, and as means to enable better coordination amongst different public agencies. These are known collectively as the "governance and participation" dimensions of the digital city. Early movers in this space include national, state, and local governments; private sector vendors; non-profits; traditional planning services; and NGOs and community-based organizations. Public datasets available for free use, re-use, and redistribution are a primary component of these efforts, through what is known colloquially as the "open data" movement. A second element is more interactive: making information available on websites for comment, feedback and deliberation, and then allowing users (such as individuals, firms, or organized groups) to interact with one another or with public decision-makers (administrative, legislative), either through general public comment and debate, or two-way individual communication and feedback.

There are many examples of such initiatives. For example, in December 2009 Barack Obama issued Executive Order M-10-06, the "Open Government Directive" (Orzag, 2009). This directive required executive departments and agencies to take affirmative actions to achieve the following goals: publishing government information online; improving the quality of government information; creating and institutionalizing a culture of "open" government; and creating an enabling policy framework for open government. Significant outputs of these federal efforts have already resulted. Data.gov, for example, provides descriptions of federal datasets (metadata), as well as information about how to access and use government datasets. In May 2012 the executive branch released an open-source product called the Open Government Platform (OGPL), containing a data management system and social networking features (Data.gov, n.d.). Similar efforts have been embraced by national governments around the world.

Public sector users most often rely on technology packages developed by private sector vendors.

For example, Socrata is a Seattle-based firm, and a leading developer of open data services, to “enable federal, state, and local governments to dramatically improve the reach, usability and social utility of their public information assets.” (Socrata, n.d.). Socrata offers three services to their customers, which thus far include a number of prominent cities, states, and federal agencies. First, they identify and prioritize “raw data to host online, followed by the process of cleaning and transforming the data so that it is accessible by an external audience." Second, they create a "central repository for government data downloads, combining a directory for finding datasets, a state-of-the-art dataset analysis and visualization capability, community participation and moderation, and an advanced set of sharing and social media features." Third, they offer "tools [to] enable dataset publishers to use web analytics to track civic engagement" (Socrata, 2009; nb).

Data.gov and its private sector providers are essentially centralized vendors of data and interaction to a variety of publics. But there exist alternative approaches. Code for America, for example, is a non-profit organization with a stated mission to help make governments more “open, connected, lean, and participatory” (Code for America, n.d.). The organization recruits fellows from the technology industry and embeds them for a year with local governments nationwide to solve specific civic challenges through customized web platforms. Traditional planning consultancies are also becoming providers of interactive city planning services. *Open Plans* is a non-profit technology organization that builds open-source software with a particular focus on transportation issues and open, participatory city planning. Their goal is to create “better planning outcomes through the intersection of planning, technology, and public participation” (OpenPlans, n.d.). Significant Open Plans initiatives include: community-edited directories of public meetings; open-source platforms for local news gathering; applications to help agencies “crowdsource” streetscape improvements; and forums for city transportation officials to share best practices for urban bikeway design (OpenPlans, n.d.).

The NGO and community-organization sectors are increasingly utilizing interactive technologies as well. These efforts extend the notion of crowd-sourcing to funding, thus potentially opening up new avenues for creating CBOs in a decentralized way through virtual interaction. A number of examples of this phenomenon can be cited: community-led, and -funded environmental projects in local neighborhoods; forums allowing citizens to support major planning projects in exchange for government approval or tax breaks; platforms allowing citizens to review local development project proposals; and vehicles for citizens to invest in local real estate, purchase equity in development proposals, and "build the city [they] want to live in" (Lepeska, 2012).

The developments described in this section open up forms of interaction between citizens, firms, organizations and government that were hitherto impossible. Many of the theoretical assumptions underlying their emergence can be found in a tantalizingly-entitled book, *The Wealth of Networks*, where Benkler (2006) argues that the IT-laden world is replacing an industrial economy with a "networked information economy;" that this will lead to a major increase in what he calls "non-market production" centered on the creative activity of individuals, not big organizations; that large-scale cooperative efforts based on peer production of information, knowledge and culture will replace hierarchical ways of producing these outputs; that these technologies enhance the ability of liberal, democratic societies to pursue what he calls their core political values of "individual freedom, a more genuinely participative political system, a critical culture, and social justice" (Benkler, 2006: 8).[1]

Real City, Virtual City

As noted, new technologies provide inputs from embedded sensors, mobile devices, and databases to enable mapping and locating. Taken together, they allow a digital representation of the city; visually in the form of maps and images; and informationally in the form of lists, recommendations, tags, and categories of what exists in the urban environment. In some ways, we are coming to choose what to do, where, when, and with whom, on the basis of this new digital representation. Fundamentally, this phenomenon is not entirely novel - it should be remembered that agents in cities have always mixed information from their direct experience with the environment with information derived from their membership in wider social networks that are not necessarily local. This has always generated a mixture of sharing with those around us and of parallel but separate lived realities in close proximity.

There are, however, crucial differences that must be acknowledged between the past and present. Not only are ever-larger doses of information derived from information technologies as opposed to traditional social networks, this information is being channeled to agents through the platforms of major private-sector firms such as Google, Facebook, Yelp, Twitter and others. The digital skin of cities is thus heavily structured by the algorithms, presentation styles, search channels, and economic incentives of these private-sector actors. These developments can be expected to alter our experience of the city by augmenting, annotating, indexing, and filtering "reality," much in the same way that the Google page algorithm influences the use of information.

An example of where urban social experience may be headed beyond current standardized search, recommendation, and communication platforms is a product called "CitySense," developed by Sense Networks, offering "real-time nightlife discovery and social navigation" via the display of sensed, real-time activity over a live heat map. Using billions of points of historical positioning data, it is able to "normalize live location data originating from tens of thousands of devices and users moving throughout a given city" (Sense Networks, n.d.). These are the possibilities that inform MIT researchers Nashid Nabian and Carlo Ratti, who imagine a new conversation between residents and private-sector platforms over the space of the digital city. Here, people play key roles as "agents of sensing, regulation, and actuation" and act as "hyper-individualized 'users'" in landscapes that have been turned into "info-scapes" (Nabian and Ratti, 2011). The core, underlying promise is that more information will improve the experience of urban social life and lead to the creation of many useful and efficient services. If this vision of the digital city is less, or differently, based on face-to-face contact, local and contextual knowledge, and high-trust social networks, then there are likely to be significant changes in the sociological, cultural, and economic nature of cities.

A CRITICAL EXPLORATION OF THE DIGITAL SKIN

Many participants are shaping the rapidly-proliferating discourses and narratives about the digital city. There is exhilaration about the new modernity it may offer, and significant hyperbole, and with that comes hyperbole and vague metaphors ("sentient cities," "a universe of self-replicating code;" a "planetary nervous system"). The basic tropes of these discussions are similar to those in previous technological revolutions. Participants draw on rational planning, cybernetics, and systems theory; they see social, environmental, economic and political problems as amenable to engineering solutions; they emphasize efficiency as a means to achieve social, economic, and environmental goals; they generally do not involve themselves in issues of distributional justice or ends, but instead focus on means. The narrative of Carlo Ratti of MIT, for example, embodies these features:

> Th[e] feedback loop of digital sensing and processing could begin to influence various complex and dynamic aspects of the city, improving the economic, social, and environmental sustainability of the places we inhabit. Feedback loops could grow inside one another: buildings and other spatial devices throughout the city could become probes and ambient displays, but also evolve into real-time, responsive devices in their own right. (Ratti, 2011: 8)

As in the past, the challenge for analysts of this emerging phenomenon is to be fully involved in taking its potential seriously, while avoiding the tendency for hyperbolic narrative and discourse to cloud analytical clarity and realism. In the second part of this paper, we therefore propose ways that social science theory can frame the questions for rigorous research on the nature and effects of the digital city.

Epistemology: How to Use Digital Breadcrumbs for Research

It is frequently claimed that the "digital breadcrumbs" that comprise big data will lead to a new, comprehensive understanding of the constituent components of our social systems, casting new light on all manner of social processes, from the micro to macro. New analytics enable "sense" to be made, or thought to be made, through inductive analysis at a scale never before possible. In contrast, a good deal of mainstream science is heavily hypothetico-deductive in method, driven by an incremental process of falsification of previous hypotheses, while subjecting anomalous results or inductive anomalies to new hypotheses. Empirical social science has historically been limited not only by the quantity of data available, but by the fact that it is typically reported in aggregations (data categories such as "city," "census tract," "industry," "occupation," "age" and so on) that eliminate much of the agent-level heterogeneity of human social life. These pre-existing categories, of course, reflect theoretical assumptions that they are relevant, and their relevance is always debatable. That having been said, the idea of tacking back in an inductive direction -- "seeing what the data say" in any direction or possible pattern – represents a powerful rejection of what most science has been done in the past several hundred years. It leads some in the technology industry to declare, with considerable hubris, that we are on the verge of being able to see relationships that are obscured by deductive epistemology, and thereby reach a new level of depth and completeness in understanding human social life. In extreme versions, these visions take the form of the futuristic "singularity" theory that has many adherents in Silicon Valley, the notion that we will soon be able to upload all of human experience into the world's computing system and see what emerges out of it in terms of patterns, categories, interactions and structures that we have never before been able to see, much less conceptualize (Vinge, 1993; Kurzweil, 2005).

Big data will undoubtedly give rise to many newly-observable statistical regularities. But what sense can be made of such regularities? As it was put recently:

> A big data analysis might reveal, for instance, that from 2006 to 2011 the United States murder rate was well correlated with the market share of Internet Explorer: Both went down sharply. But it's hard to imagine there is any causal relationship between the two. Likewise, from 1998 to 2007 the number of new cases of autism diagnosed was extremely well correlated with sales of organic food (both went up sharply), but identifying the correlation won't by itself tell us whether diet has anything to do with autism (Marcus and Davis, 2014).

Another problem is that small-number, but very important phenomena, cannot be identified by big data. For example, it may be possible to identify the many factors that are associated with people who commit mass murders. But for the population of individuals who have those factors, only a tiny number will actually commit such murders. This may not be a problem for large-number telemarketing, where identifying, on average, such characteristics enables the marketing firm to get some customers. But it is a problem for public policy, where only the result of identifying the people who will commit mass murders counts. This group, however, involves the contextual, infinitely small-number, recombination of background elements into "consciousness" and "meaning" that generate small numbers of actions from backgrounds that are widely distributed in the population. There are, hence, also deep ethical issues when such correlations are used for social and predictive control of human agents who may not be the agents we really want to find.

Big data derived from the web also has status quo bias and circularity:

> ….the echo-chamber effect, which also stems from the fact that much of big data comes from the web. Whenever the source of information for a big data analysis is itself a product of big data, opportunities for vicious cycles abound. Consider translation programs like Google Translate, which draw on many pairs of parallel texts from different languages — for example, the same Wikipedia entry in two different languages — to discern the patterns of translation between those languages. This is a perfectly reasonable strategy, except for the fact that with some of the less common languages, many of the Wikipedia articles themselves may have been written using Google Translate. In those cases, any initial errors in Google Translate infect Wikipedia, which is fed back into Google Translate, reinforcing the error (Marcus and Davis, 2014).

Making sense in general requires more than correlations. Molecular biologists, for example, would very much like to be able to infer the three-dimensional structure of proteins from their underlying DNA sequence, and scientists working on the problem use big data as one tool among many. But no scientist thinks you can solve this problem by crunching data alone, no matter how powerful the statistical analysis; you will always need to start with an analysis that relies on an understanding of physics and biochemistry. Sense, and even predictive accuracy, will therefore often not be extracted from correlations, even of the most sophisticated type.

Rationalism and its Limitations in Social Science and Planning

This is hardly the first time that technological optimism has been advanced as a way to solve or preempt social, political, and economic problems. Though examples are numerous in all areas of human life, urbanists now look back on twentieth-century ideologies of modernism and rationalist city planning as naïve, if not deeply misplaced. Modernism and rational planning had many successes, at certain limited scales, such as individual buildings and developments; it was when they were elevated to all-purpose solutions to systemic problems of human collective life that they lost their compass. Large-scale master-planned cities, the apotheosis of modernism, including Corbusier’s Chandigarh or Costa and Niemeyer’s Brasilia, were explicitly premised on the belief that the problems of the city could be solved through scientific approaches to urban design. Their focus was on logic, order, efficiency, functionality, and – above all – a self-proclaimed “rationality,” as the way to wipe out the irrational effects of tradition in urban life; modernist utopias for the jet age (Holston,1989). The bet of Brasilia’s designers was that by leveraging a self-evidently rational design, self-evidently rational ends would follow: an egalitarian, scientific, forward-looking, economically efficient society. Costa and Neimeyers’ hubris would prove short lived, however, as the rational apartment blocks were invaded with traditional, grafted-on spaces and functions, and squatter settlements surrounded the sterile planned city. As the critic Benjamin Schwartz notes, Brasilia “is quite correctly regarded as a colossally wrong turn in urban planning" (Schwarz, 2008). In the United States the experience of urban renewal was also a stark failure, with neighborhood after neighborhood demolished and thousands of residents displaced, raising concerns about legitimacy and participation, and heightened rather than lowered segregation, which vex cities to this day. Yet at the time of Brasilia or American urban renewal, modernist logic seemed invincible, self-evident and hence ineluctable: large-scale apartment blocks were efficient, healthy and desirable; highways were spectacular achievements of efficient engineering; piercing boulevards through older neighborhoods would bring about fluidity and beauty in the urban environment; and the list could go on, rather depressingly. A new brand of utopian, master-planned smart cities, in such places as the UAE, Ecuador or Korea, are now appearing on the global urban landscape, embodying the assumptions about rationalist planning that were embodied in the earlier failed experiments. It seems obvious, at the present time, to ask ourselves whether the dominant symbol of the failed modernist era – the ‘machine’ – is not simply being replaced with overweening optimism about the current information age: the network, algorithm, index, or control system. We quote at length here:

> ….we may conceive of the digitally enhanced, postmodern city as a cybernetic mechanism that accommodates interaction and actuation in its capacity as a spatial system capable of extracting contextual information, acknowledging the inhabitants’ desires and needs, and adopting behavior patterns based on what it learns. (Nabian and Ratti, 2011: 18)
>
> In the context of ubiquitous information services, the city shall not only be seen as a place of social interactions, financial transactions, a network of technology nodes, a geographical agglomeration area or as a political landscape, but more as an actuated multidimensional conglomerate of heterogeneous processes, in which the citizens are the central component. In other words, the city can be regarded as a complex near real-time

control system, creating a feedback loop between the city itself, the city management and the citizens, which is achieved by pervasive sensing… (Resch et al, 2012: 175)

The view adumbrated above contrasts sharply with what much urban theory has to say about the nature of the city. Since the 19th century, urban theory as espoused by Tonnies, Simmel, Weber and Durkheim focused on cities as sites of the complex and varied social interactions of modern society (Tonnies, 1887; Durkheim, 1893; Simmel, 1903; Weber, 1921). All saw the city as an environment in which a kaleidoscopic combination of people and information occurred and in which, as a result, the structures of traditional society, based on kinship and interpersonal knowledge, clan and village, were fundamentally weakened. In their place, new structures of social life were created, based on choice, ascriptive identity, individualism, unplanned and un-planable contacts and encounters, embodied personal ethics, as well as participation in democratic processes (and occasional mob rule), within a liberal social order. This is the city of spontaneous unplanned interactions described in Jane Jacobs' classic work on Greenwich Village in New York City (Jacobs, 1961). The high modernists in architecture and planning, such as Corbusier and Niemayer, tried to plan this modernity in a rational and centralized way, and this internally inconsistent approach would end in failure. The language of feedback and control in the current discourse about the digital skin may appear to involve more room for spontaneity and decentralized interactions, but upon closer examination, at the core of this vision is what Jaron Lanier (2010) calls "cybernetic totalism," where individuals are channeled and shaped to be "users" of a "cybernetic mechanism," with its in-built categories of interaction and algorithms that reinforce mass culture and median tastes and preferences. This is because a geo-tagged map or an algorithmically organized index may create "filter bubbles" and an unintended, but still very real, virtual segregation or, its extreme opposite, herd effects that end up limiting diversity and creating the "Hotelling effect" on a massive scale within the space of the city.[2] In other words, the viewpoint of cybernetic totalists really does run counter to the social science and humanities view of the city, as represented in the long line of thought from Weber to Jane Jacobs: the city as a place of spontaneity, heterogeneity, and limited chaos. These latter characteristics are not considered weaknesses of the city, but great strengths, as shapers of complex and creative human beings, and as sources of individual and collective creativity.

Finally, as the technological revolution unfolds, so do problems of hacking, cyber-terrorism, cyber-war, and the classical political dilemma, in a liberal democratic society, of the tendency for citizens to be subject to a Panopticon (Bentham,1995). The sensored and metered city, its buildings, infrastructures, and households, will generate unprecedented amounts of data that will also become vulnerable to potential disruption or misuse. New security concerns will necessarily lead to new measures for protecting and hence keeping secret, certain data and their sources, and the ways they are aggregated and processed.

Social Choice and Public Choice Theory

It is not just the modernism of the machine age that failed to live up to many of its predicted positive effects on human society; the internet itself has also failed to live up to the hyperbolic predictions that it would usher in major improvements in the social order (cf. Benkler, 2006). The internet has vastly expanded and reshaped opportunities for aggregate economic efficiency, and in some areas, for new forms of human choice, autonomy and satisfaction. It does not follow that digital interaction solves problems of collective choice, or obviates the need for universal rules and government, and public goods. But this is not the dominant perspective in the technology vendor world. For example John Perry Barlow's widely circulated letter of protest against the Communications Decency Act of 1996, "A Declaration of the Independence of Cyberspace" (Barlow, 1996), speaks of "increasingly obsolete information industries" and global governments as "weary giants of flesh and steel" whose presence was not welcome in cyberspace. It states that the 'citizens' of the internet were forming their own Social Contract and that the internet's governance would emerge from "ethics, enlightened self-interest, and the commonweal." It argued further that traditional legal concepts of "property, expression, identity, movement, and context" did not apply and that a "Civilization of the

Mind" would emerge in cyberspace. More recently, Peter Thiel has expressed a set of views that are apparently widespread in upper spheres of the world technology elite, that the IT revolution is largely a replacement for government and all collective action (Packer, 2011). There is obviously a wide range of social and political views among the technology elite of the USA and the world, and we need therefore to beware of caricature. But these views do not seem rare or marginal; one need only spend a limited amount amongst the literature of smart cities or open data or big data to ascertain a dominant utopian flavor where traditional forms of collective action, with all of their messiness, conflict and high transaction costs, are replaced by superior forms of automatic, crowd-based, or decentralized interactions, and that these types of interaction systems will have better, more efficient, more satisfying outputs than what they are to replace (Lanier, 2013).

In their skepticism about collective ("social") choice, the technologists are in good company with much serious social science. From Lionel Robbins (1938) to Kenneth Arrow's "impossibility theorem" in the 1950s, (Arrow, 1951) and echoing modern Liberalism from Adam Smith and John Stuart Mill, we know that collective choice is difficult, contentious, and usually leaves many dissatisfied parties, no matter what the domain of decision may be. Arrow's model shows that sequential and hierarchical choices (as in multiple-round elections) lead to progressively high levels of unsatisfied preferences. Large-scale social choices are also "intransitive," meaning they involve different dimensions that have no single index to rank them and thereby allow us to optimize our many desires.

But social scientists also recognize there are arguments in favor of social choice, which underlies collective provision of certain goods and services, and rules for guiding private action. In the design of infrastructure, health care, the tax system, urban neighborhood planning, land use regulation, drug safety, the air traffic control system, and so on, there are externalities, economies of scale, irreversibilities and sunk costs, positionalities, and many other features that require social choice and collective provision. Digital technologies may indeed extend the realm of individual choices in markets to some of these areas; but they are unlikely to do so in all.

Moreover, more efficient utilization of infrastructure will have indirect effects that require more social choices. For example, even if totally automated highways flow more smoothly than current ones, economic models show that ultimately more people will drive as a result, leading to frustration in getting access to highways or increased overspill onto surface streets (Duranton and Turner, 2011). Thus any urban resource that is supply-inelastic or positional (e.g. land, locations and buildings) will remain the object of substantial competition for its use, even if it is managed more efficiently and in part precisely because it is better managed and therefore more attractive. To put it more bluntly, engineering and good management have never eliminated problems of politics and the allocation of scarce resources; they just alter the contours of the choice set.

This is where some of the more revolutionary or utopian promises about a decentralized, interaction-governed world enter: they suggest that because we can radically improve access to information and lower transaction costs, social choice can become something more generalized, through the new "wisdom of crowds." It is difficult to extend this logic to social choices of the type mentioned above, for the simple reason that they are not about "transitive" dimensions of things that can be traded off against one another, and hence an optimal point on a single index attained. Instead, they are about possibly incompatible and mutually exclusive views of the world. Some advocates then make a softer claim: that the "dialogue" or interaction will itself move actors toward consensus. But this certainly has not been in evidence in the break-up of the public information sphere away from traditional journalism and media into the more diverse world of the internet, because it seems to have been accompanied by silo-ing and sorting, rather than mutual comprehension. Digital interaction creates "weak ties," not trust-based strong ones; the hard work of politics and building consensus does not come about through interactions on social networking sites, especially where identities are anonymous (Gladwell, 2010). Thus, for the promise of more involved and better-informed citizenry and serious debate to be realized, the terms of engagement may have to be changed. Digital citizenship, involving authenticated identities and commitment processes, may be required if the moral hazards of anonymous interaction on the internet are to be avoided, and even then, the classical problems of making collective choices will still exist.

Private Choices and Public Goods

The process of disintermediation is a widespread feature of economic development, as when local travel agents were mostly eliminated once travelers were able to access airline and hotel websites online to manage their own reservations. Current examples include AirBnB and Uber. Disintermediation is supported, in theory and evidence, as a welfare-producing process, when it increases the amount and type of information available to consumers, effectively increasing the ability of consumers to compare cost and quality, and hence making it more likely that the Law of One Price will function in reality, and across more extensive markets. The issue then becomes: is a fully digitized urban environment likely to generate these effects, and especially with respect to locationally-fixed goods and urban land itself?

With respect to land, local knowledge about neighborhoods has generally been necessary in order to make good investment decisions. Only a few, highly exposed (generally central city) areas, have offered truly cosmopolitan knowledge of their local quality to the entire world (e.g. downtown Manhattan, central London, and so on). But what if that became the norm? Local real estate agents would perhaps disappear or have their roles (and their economic monopoly power) redefined; demand curves for land in many cities in the world would be merged together and dramatically reshaped. A host of other effects on how prices are formed for services, land, and locations in cities might arise, with major implications for zoning, management, housing policy and local planning.

In a similar vein, Benjamin et al (2007) examine a land record digitization project in Bangalore, India. This project, promoted as a pro-poor, pro-transparency initiative, in reality led to “increased corruption, much more bribes and substantially increased time taken for land transactions”, facilitating the capture of vast quantities of land by large players in the land markets. In this case, information previously available only in local contexts became available to those outside the local context. Only those with the wherewithal to make sense of the information (through data mining or other means of investigation) were able to increase their use of the new, digitized data. In practice, open data enabled outside actors with different sensibilities, attachments, and interests to establish control of local land resources, where members of the local community found themselves excluded. Thus, disintermediation and de-contextualization went hand in hand, with important distributional consequences. The research team concluded that

> ….when e-governance projects intervene in land issues, the political economy of land markets rather than techno-managerial features of the project can shape outcomes. By raising fundamental issues in understanding the societal aspects of e-governance, it highlights the need to replace politically neutered concepts like 'transparency', 'efficiency', 'governance', and 'best practice' [with] conceptually more rigorous terms that reflect the uneven terrain of power and control that governance embodies (Bhoomi, 2007: 3)

This is not a surprising outcome, since urban land has highly complex attributes that are bundled together, and as a consequence there is no comprehensive index for comparing the quality and value of land and buildings. This leads to what are known as backward-bending preferences or Condorcet problems in making choices. Understanding these, even with abundant digital descriptions, require significant skills and analytical tools, much in a way analogous to understanding complex financial products. It is unlikely that large numbers of people will have such abilities, no matter how much data they are given.

Increased commodification (or "market-ization") is a related probable consequence of big and open data. Private companies have every incentive to utilize the digital breadcrumbs to which they have proprietary or indirect access, and many useful services will likely result from their efforts. It does mean, however, that the actions and behaviors that are sensed by big data, and many of the interaction spaces themselves, are potentially subject to commodification – a result we are already seeing in the web space with search and information (Google), and social media and recommendations (Facebook and Yelp). Thus, digital parking meters allow congestion pricing for on-street parking, but this creates an incentive for parking to become a source of revenue for cities and not a public utility, or even for scalpers to re-sell on-street parking for private gain. Is this shift subject to explicit political debate, with the stakes laid out for citizens?

In discussing open data initiatives in the United Kingdom, Jo Bates notes the tension between the fact that datasets are available for use at marginal cost (which is generally close to zero for digital assets), but commercial interests are allowed to build products off the "backs" of the public data. She states that

> ….whilst democratic ends are claimed in the desire to enable 'the public' to hold 'the state' to account via these measures, there is an issue in utilizing a dichotomy between the state and a notion of 'the public' which does not differentiate between citizens and commercial interests. The 'we' in this construct thoroughly displaces the notion of citizens as state ("we are the state") to a 'we' that is a mass of private interests (both individual and commercial) outside the state. (Bates, 2012: 8)

Thus Lanier (2013) warns against the role of "Siren Servers" – large private vendors who control huge swathes of the information economy and will have disproportionate control over the future development of the economy and society thanks to the winner-take-all dynamics enabled and amplified by the internet.

The Political Content of Algorithms

Beyond the control of data itself, there is the related issue of the algorithms and systems that will be used to process and interpret the data, and thereby inform subsequent interventions. In "The Relevance of Algorithms," Tarleton Gillespie notes that

> …algorithms play an increasingly important role in selecting what information is considered most relevant to us, a crucial feature of our participation in public life… [and] provide a means to know what there is to know and how to know it, to participate in social and political discourse, and to familiarize ourselves with the publics in which we participate. They are now a key logic governing the flows of information on which we depend… (Gillespie, 2012: 1)

Thus, the advent of smart energy grids, water systems, roads, and parking allocation systems is, as noted in Part One, a significant potential advance in the management of cities. Paradoxically, such smart systems are likely to be more opaque to non-technically educated citizens and users than existing systems. As is, few citizens understand how their electricity is produced and priced. Most, however, do understand where parking is and how it is priced and how it affects the neighborhoods in which they park. Most can see traffic jams form, though few have the conceptual tools for understanding why they form. If smart systems can reduce traffic jams and increase access to parking, most citizens will be satisfied, whether or not they understand exactly how such beneficial impacts were generated.

But algorithms will also have distributional consequences. They are unlikely to be transparent to citizens, and are likely to be presented as inevitable. In addition, there is increasing generation of new algorithms by machines themselves, a form of artificial intelligence. Imagine that public policies or management practices are guided by algorithms that have themselves been generated by machines that were originally programmed by algorithms. From a public policy perspective, who is making the choice? How does the public get access to information on algorithms which evolve "automatically," and on how those developments affect what information is presented to them? What are their effects on real systems of service delivery or infrastructure management?

Neither citizens nor political leaders have ever had full purchase on the socio-technical systems in which they live. They rely on experts, but don't necessarily know how good the experts are (Giddens, 1990). Smart city technologies will thus present the public sphere with another round of information asymmetry and technical complexity, and attention should be paid to enhancing the ability of the public sphere to understand not only what it is deciding about, but how and with what assumptions the tools that generate information and choice sets were themselves developed and chosen.

The persistence of real economic geography and real society, and their inequalities

Some of the discourse on smart cities and the digital skin implies – without being fully explicit about it – that new technologies will somehow level the playing field of places (cities, regions, nations). These arguments that we live in a "flat world" or that "distance is dead," have found no substantial support in the scholarship on the economics of globalization. The landscape of economic specialization is more differentiated than ever, spatial income hierarchies are not disappearing, and location continues to matter in productivity and technological innovation (Leamer, 2007; Moretti, 2012). For example, in the last two decades, the industry which depends most on information technology -- the financial services industry – has actually increased its level of spatial concentration in its most innovative and highly-rewarded employment. The geographical concentration of the finance industry is counter-intuitive, since this is an industry whose product is weightless, highly virtual, and has close to zero transport costs to its final market. Financial services is concentrated because its production process depends on informal knowledge and on human relationships, which require considerable face-to-face contact. The economic value of these relationships and meetings is thereby enhanced by its ability to serve geographically-dispersed markets with the final product (the "deal") (Storper and Venables, 2004).

Thus, the digital skin may indeed make it possible to better manage more places. And this can be expected to have positive effects in both highly-developed and less-developed cities, and possibly to raise the standards of living in disadvantaged cities. But it does not follow that they will help even the landscape of richer and poorer places. It does not even follow that smart city technologies will substantially help meet basic needs in the world's poorest cities. Moreover, given the underlying forces of economic geography to create a hierarchy of richer and poorer cities and regions in the world, the richer places will have more ability to benefit from expensive digital technological systems, very likely widening their advantages over less wealthy places. Many providers such as IBM implicitly acknowledge this in their marketing material, where they note the 21st century will see a "global war for talent", and that "Smart Cities" will be those that improve service delivery to attract the best and brightest (Dirks et al, 2010). The real geography of an unevenly-developed world of richer and poorer cities, regions and countries will not be effaced by the digital revolution.

CONCLUSION: URBAN THEORY AND RESEARCH ON THE DIGITAL CITY

The digital skin is a nascent portfolio of technologies, still very young, and the implementation of these technologies is just beginning. As such, this is an optimal time to begin understanding their potential for resolving problems and their potential unintended effects. Technologists, public servants, and all manner of public and private-sector actors are needed who will understand the potential of the digital skin to enhance human welfare - yet they will be caught in a force field of asymmetrical and partial information, rapidly changing markets, very big financial stakes, competitive hubris, and career ambitions. For this to happen, rigorous empirical research on the processes and effects of the digital skin is needed, and such research must be framed by questions identified by social science theory.

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NOTES

1 Benkler (2006) does note that there are many impediments to the emergence of these benefits, especially the "new enclosure movement," which he thinks might foreclose access to the new technologies and to information, but the bulk of his book is devoted to the "nature" of these technologies which, in his view, promote decentralized, flatter social hierarchies, critical intelligence, more participation, and greater freedom and justice.

2 The Hotelling Effect is the canonical model of the two ice cream vendors on the beach who ultimately move to the center of the beach, through game theory type interactions, in order to capture market share. It is used as a locational model, but also as a model of serving the "median" taste rather than the tails of a distribution of preferences.

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