

## ANNALS OF THE NEW YORK ACADEMY OF SCIENCES

Issue: *Paths of Convergence for Agriculture, Health, and Wealth*

# Agriculture, health, and wealth convergence: bridging traditional food systems and modern agribusiness solutions

Laurette Dubé,<sup>1,2</sup> Patrick Webb,<sup>3</sup> Narendra K. Arora,<sup>4</sup> and Prabhu Pingali<sup>5</sup>

<sup>1</sup>Desautels Faculty of Management and <sup>2</sup>McGill Centre for the Convergence of Health and Economics (MMCHE), McGill University, Montréal, Québec, Canada. <sup>3</sup>Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts. <sup>4</sup>Clinical Epidemiology, The INCLEN Trust International, New Delhi, India. <sup>5</sup>Charles H. Dyson School of Applied Economics and Management, Cornell University, Ithaca, New York

Address for correspondence: Laurette Dubé, 1001 Sherbrooke Street West, Montréal, H3A 1G5, QC, Canada. laurette.dube@mcgill.ca

The causes of many vexing challenges facing 21st-century society are at the nexus of systems involved in agriculture, health and wealth production, consumption, and distribution. Using food as a test bed, and on the basis of emerging roadmaps that set achievable objectives over a 1- to 3-year horizon, we introduce this special feature with convergence thinking and practice at its core. Specifically, we discuss academic papers structured around four themes: (1) evidence for a need for convergence and underlying mechanisms at the individual and societal levels; (2) strategy for mainstreaming convergence as a driver of business engagement and innovation; (3) convergence in policy and governance; (4) convergence in metrics and methods. Academic papers under each theme are accompanied by a roadmap paper reporting on the current status of concrete transformative convergence-building projects associated with that theme. We believe that the insights provided by these papers have the potential to enable all actors throughout society to singly and collectively work to build supply and demand for nutritious food, in both traditional and modern food systems, while placing the burdens of malnutrition and ill health on their core strategic agendas.

**Keywords:** convergence innovation; roadmap; food

## Background and introduction

It is well known that the causes of many vexing challenges facing 21st-century society are at the nexus of systems involved in agriculture, health and wealth production, consumption, and distribution, be it for stemming biodiversity loss,<sup>1–3</sup> stopping climate change,<sup>4,5</sup> reducing poverty,<sup>6–8</sup> ensuring food security,<sup>9–11</sup> or containing healthcare costs driven to ever higher heights, largely by diseases tied to modern diet, lifestyle, and environment.<sup>12–17</sup> These problems are complex, multilevel, multisectoral, and heterogeneous;<sup>2,18</sup> they are woven into the everyday lives of individuals and families and into traditional and modern societies around the world.<sup>18,19</sup> Bringing solutions at scale to such complex challenges requires both behavioral change and ecosystem transformation. Food, being common to all

systems involved in causes and solutions, may potentially be a key lever for changing the well-entrenched industrialization patterns where the rest of the world converges with the West on income, lifestyle, and diseases.<sup>20–22</sup> Using food as a test bed, we could potentially redefine a new 21st-century convergence that better bridges traditional villages and siloed modern systems to reduce the collateral damages listed above, while continuing to accelerate human and economic development.

An earlier special feature of the *Proceedings of the National Academy of Sciences* (PNAS) on Agriculture Development and Nutrition Security called for forward thinking around paths of convergence for agriculture, health, and wealth, with a focus on a richer integration of smallholder farmers into state, national, and global agricultural and food systems, health systems, value chains, and markets.<sup>21</sup>

The outline of a roadmap was proposed for a full-fledged, transdisciplinary approach to support real-world change of sufficient scale and scope. Suggestions were made concerning research avenues for an actionable understanding of decision making that accounts for individual and contextual diversity, and intertemporal development effects; for health systems that improve service access and quality for the most vulnerable; for new approaches to innovation that build bridges across agricultural, health, and wealth production–consumption systems; for scaling up of business engagement in multilevel collaborations with civil society and public organizations centered on the needs of the poorest and most vulnerable; for policy convergence and novel models of governance that break down state–market bipolarity in ways that enable both cooperation and competition across sectors and levels of jurisdiction; and finally, for the development of metrics and models to support integrated, near real-time decision making by all actors involved.

At the time of publication, we were challenged by supporting philanthropies, funding agencies, and other partners to give a solution orientation to this roadmap and to anchor its development and deployment into concrete actions on the ground and over the full spectrum of development (i.e., from low- and middle-income countries to emerging economies and industrialized nations). Such a whole-world perspective is clearly motivated since changes in both traditional and modern societies are needed in order to meet the agriculture, health, and wealth needs of an expected 9.7 billion people by 2050 (an increase of around 37% beyond the 7.1 billion in 2013; [http://www.prb.org/pdf13/2013-WPDS-infographic\\_MED.pdf](http://www.prb.org/pdf13/2013-WPDS-infographic_MED.pdf)).<sup>23</sup> With a global urban population crossing the 50% mark,<sup>24</sup> maintaining the status quo would call for the world producing 70% more food by this timeline<sup>23,24</sup> and for ensuring universal access to a healthcare system whose demand is fueled largely by the present pattern of industrial development.<sup>25</sup> In a country such as the United States, for instances, where a substantial percent of uninsured individuals represent over 15% of GDP cost and is rising,<sup>26</sup> healthcare costs are the most significant threat to future public finance.<sup>12–14</sup>

Pragmatically moving away from such an alarming future scenario and aiming to tweak the many natural and man-made systems at play,<sup>27</sup> the con-

ference “Paths of Convergence for Agriculture, Health, and Wealth,” hosted in New Delhi in June 2012, and the follow-up week-long workshop at the Rockefeller Foundation’s Bellagio Resident Fellows program in November 2012, presented concrete roadmaps for change on the ground, enlisting the knowledge, capability, and eagerness to act of participants from academia, civil society, and the private and public sectors. The emerging roadmaps and their project portfolio rally strategic consortia around concrete and time-bound problems in either or both developed and developing world contexts and where convergence can add value and scale. These roadmaps set achievable objectives to be implemented over a 1- to 3-year horizon and generate intellectual leadership, policy direction, and product and program innovation through novel collaborations at local, national, and global levels. This convergence thinking and practice formed the core substance of the present issue of *Annals of the New York Academy of Sciences*, with academic papers being structured around four themes: (1) evidence for a need for convergence and underlying mechanisms at the individual and societal levels; (2) strategy for mainstreaming convergence as a driver of business engagement and innovation; (3) convergence in policy and governance; and (4) convergence in metrics and methods. Papers under each theme are accompanied by a roadmap paper reporting on the current status of concrete transformative convergence-building projects associated with that theme. In this introduction, we first explore the relevance of each theme. Second, we review the perspective brought by each paper, and finally, we discuss the challenges and possibilities in pursuing the journey toward a full-fledged transdisciplinary science for the 21st century convergence.

### Convergence needs and mechanisms

As per the definition of the 1996 Rome Declaration,<sup>28</sup> food security that would eradicate the triple burden of undernourishment, micronutrient deficiency, and overnutrition around the world and reduce that of ill health is a condition “when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life.” Over the last few decades, although the scale remains insufficient, significant progress has been made in reducing the food-related burdens

of resource-poor contexts (i.e., undernourishment and micronutrient deficiency).<sup>29</sup> In contrast, an overall regression is observed at the population level in resource-rich contexts (i.e., overnutrition),<sup>15–17</sup> with the exception of a handful of countries that show a reverse trend in overnutrition and the spread of noncommunicable chronic diseases (NCDs),<sup>30–32</sup> sometimes due to a rise in GDP.<sup>33</sup> The multiplicity of mechanisms involved in causes and solutions underscores a major challenge in articulating paths of convergence that go beyond what has been possible thus far. These mechanisms range from biological and behavioral processes influencing food choice, nutrition, and health, to the diverse social influences that frame individual and collective decision making, to the unique pathways through which agriculture affects nutrition in traditional systems, and the complex dynamics involved as modern value chains and markets evolve. The papers in this issue in turn address these diverse but interrelated mechanisms, while the roadmap papers provide an early illustration of how such complexity can be better harnessed to improve child nutrition and health.

Developments in brain,<sup>34,35</sup> economic,<sup>36</sup> and marketing<sup>37</sup> sciences, primarily conducted in modern contexts, have provided a rich understanding of individual-level mechanisms underlying consumption choice and behavior. In fact, informing demand-building strategies to absorb an ever-growing innovation and production capacity and diversity has been one of the thrusts of many disciplinary sciences in the last century.<sup>20,21</sup> This has been blamed as a key driver of overnutrition in the resource-rich contexts of Western societies and emerging economies.<sup>15–17</sup> In contrast, such deep knowledge of human decision making and behavior has been relatively ignored with respect to bringing solutions to all facets of malnutrition and ill health, which as of yet still rely almost exclusively on education, prescription, or restraining environmental policy.<sup>36</sup> However, because the human being is, in turn, a consumer, producer, patient, and citizen, such knowledge, in particular for food, may be critical to achieve impact and scale in both resource-poor and resource-rich contexts. For instance, Portella and Silveira<sup>38</sup> examine the determinants of food choice and eating behavior in the especially vulnerable population of children born with fetal growth restrictions. This early adversity induces a series of adaptive physiological responses

aimed at improving survival, but imposes increased risk for developing chronic nontransmittable diseases (i.e., obesity, type II diabetes, cardiovascular disease) in the long term.<sup>39,40</sup> Recently, mounting evidence has shown that fetal growth impairment is related to altered feeding behavior and preferences through the life course.<sup>41</sup> When living in countries undergoing nutritional transition, individuals experience the coexistence of underweight and overweight problems (the double burden of malnutrition). In this context, fetal growth—restricted children can be simultaneously growth restricted and overweight—a double burden of malnutrition at the individual level.<sup>42,43</sup> Considering food preferences as an important aspect of food security, the authors of this paper summarize the putative neurobiological mechanisms at the core of the relationship between fetal growth, eating behavior, and nutrition over the life course, as well as the evidence linking early life adversity to later food preferences. Such research on the full array of motives driving food and other consumption behaviors is critical, as eating is the single human behavior common across all three facets of malnutrition.

Human communities and man-made systems emphasize information, technology, and social organization, with cognition, information, and communication flow as powerful variables affecting how individuals and societies interact with their environments and define their priorities.<sup>27</sup> Scientific advances in simulating the physical and economic processes and outcomes of traditional and modern food systems are clearly more advanced than the modeling of social responses to that change.<sup>44,45</sup> Without downplaying the importance of science and modeling, social processes need equal attention in informing new transformative paths. For instance, Timmer<sup>11</sup> documented the role of herd behavior by rice farmers and market intermediaries in recent food price crises, where exchanges between rural and urban locations were enabled by social media through electronic and mobile technologies. Delving further into the underlying mechanisms of such social influences, Hammond and Ornstein<sup>46</sup> examine overconsumption in modern societies to develop an agent-based model of social influence on body weight. This paper develops a better theoretical understanding of how one particular social influence mechanism, such as body-type norms, can independently support the development and persistence

of obesity.<sup>47</sup> The mathematical model demonstrates that a simple desire on the part of an individual actor to conform to the average weight of his/her peers could in fact produce an increase in obesity at the population level. The model shows that the network structure (i.e., homophily and local conformity) further shapes the dynamics of the results. The model is tested against longitudinal data from American youth.

Turning to the unique pathways through which agriculture impacts nutrition in traditional systems,<sup>48</sup> Kadiyala *et al.*<sup>49</sup> take India as an example to comprehensively map existing evidence along agriculture–nutrition pathways, and assess both the quality and coverage of the existing literature. The paper presents a conceptual framework delineating six key pathways between agriculture and nutrition. Three pathways pertain to the nutritional impacts of farm production, farm incomes, and food prices. The other three pertain to agriculture–gender linkages. The literature suggests that Indian agriculture has a range of important influences on nutrition.<sup>50,51</sup> Agriculture seems to influence diets even when controlling for income, and relative food prices could only partly explain observed dietary changes in recent decades.<sup>52</sup> The evidence on agriculture–gender linkages to nutrition is relatively weak, and sizeable knowledge gaps remain. The root causes of these gaps include an interdisciplinary disconnect between nutrition and economics/agriculture, inadequate survey data, and limited policy-driven experimentation.<sup>49</sup> Closing these gaps is essential to strengthening the agriculture sector's contribution to reducing undernourishment and micronutrient deficiency in India and other developing countries. Furthermore, work by Webb and Block<sup>53</sup> points to the need to consider pathways and outcomes of agriculture related to all three facets of malnutrition in order to better account for the complex dynamics between investments being made in agricultural and other economic sectors over the course of industrial development. This work, based on empirical data from 22 countries, shows that a focus on agriculture is more effective in addressing stunting, a clinical indicator of undernourishment. However, both agricultural and industrial paths to economic development thus far have resulted in overnutrition.

Classic accounts of the Industrial Revolution suggest a process in which small farms and artisanal

entrepreneurs are displaced over time by large-scale enterprises, owing to innovations in mechanized production and the increasing capital intensity of business, which in turn gives rise to urbanization and rural migration, and devitalization.<sup>20–22</sup> In fact, much of the present research and practice still takes for granted the archetypal linear pattern of industrial development, where traditional small-farm agriculture moves inexorably toward integration within global food systems. Traditional food systems are typically natural, local, small-scale, and low-tech, with short farm-to-plate value chains. Their modern counterparts are typically characterized as processed, national/global, large-scale, and high-tech, with long farm-to-plate value chains. We believe that this polarized notion reduces the possibility for better balance and increased reciprocity and synergy between traditional and modern livelihoods and lifestyles, between farm and nonfarm activities, between social and commercial SMEs, between these and national and global businesses, as well as between organizational practices and policies that shape environments. This traditional-versus-modern food system dichotomy also leads to failed anticipation of challenges at the individual and country levels, as modern Western foods often contain high levels of sugar, fat, and salt. It also neglects the possibility of modernizing traditional food, while keeping or making it nutritious, affordable, appealing, and convenient, and redistributing the points of value creation (preservation or addition) closer to the farm.<sup>54</sup> In fact, some countries in Europe, such as France and Italy, have not followed the model from small-farm agricultural to industrial food systems, continuing to maintain a small entrepreneur-oriented food retail system even as they achieved high-income status. To what extent agricultural subsidies keep this system viable is an open question. It is therefore critical to develop a richer and more rigorous knowledge of the complex mechanisms underlying the formation and transformation of traditional and modern food markets and their convergent outcomes from all of agriculture, nutrition, and economic perspectives.<sup>55,56</sup>

As a first step in this direction and focusing on modern markets in Canada, Struben *et al.*<sup>57</sup> develop a system dynamics model of nutritional food market transformation, tracing over-time interactions between the nutritional quality of supply, consumer

food choice, population health, and governmental policy. With body mass index as the primary outcome, they examine policy portfolios for obesity prevention, including (1) industry self-regulation efforts; (2) health- and nutrition-sensitive governmental policy; and (3) efforts to foster health- and nutrition-sensitive innovation. This work provides novel theoretical and practical insights on drivers of nutritional market transformation, highlighting the importance of integrative policy portfolios to simultaneously shift food demand and supply for successful and self-sustaining nutrition and health. Extending this work to use deeper and more comprehensive linkages of nutritional food market transformation with supply, demand, and policy in agrifood and health will provide significant insights for system design and policy. While the model is calibrated for industrialized countries (Canada), there is a need for extension and adaptation to countries at different stages of structural transformation. At the high end of the transformation process, the demand for higher quality, nutrition, and food safety leads to innovations in food supply systems that respond to the new demands. The rising demand for organic agriculture and the local food movements are examples of changing demands on food systems at high-income levels. Anticipating such complex spatial and temporal dynamics and proactively integrating these findings into sectoral and cross-sectoral system design, strategy, and policy will not only have greater impact, scale, and resilience, but also will address single as well as double malnutrition burdens in varying country settings.

In the roadmap paper under this theme, Ghosh *et al.*<sup>58</sup> report a business-led collaboration around the development and testing of a high-nutrient value complementary food supplement, called KOKO Plus<sup>TM</sup>. With feeding practices starting from birth being crucial to immediate and long-term nutritional status, the project brings in two elements of innovation in the area of infant and young child feeding, targeting the needs and preferences of vulnerable rural populations in Ghana. A public-private partnership spearheaded by a Japan-based multinational food corporation (MNC) aims to develop and test the efficacy of marketing and delivering KOKO Plus<sup>TM</sup> so as to further the common goal of improving access and availability of Ghanaian households to good nutrition. A second aim of the Japan-based corporation is to test the concepts

of social entrepreneurship and social business models in the distribution and delivery of its product against traditional marketing models. This paper shares information on the ongoing activities in the testing of concepts of public-private partnerships, social business, social marketing, and demand creation, using different delivery platforms to achieve optimal nutrition in Ghanaian infants and young children in the first 2 years of life.

### **Mainstreaming convergence as a driver of business engagement and innovation**

Achieving paths of convergence across agriculture, health, and wealth will require the emergence of novel forms of innovation, organization, and partnership that can foster changes throughout the whole of society (WoS) at local, national, and global levels. A fuller convergence of human and economic outcomes needs to be placed front and center as an end goal and core driver of innovation, practice, strategy, and policy within and across the private sector, civil society, and public organizations in the farm, food, and health sectors.<sup>25,31,32,59,60</sup> Reaching such changes at scale calls not only for scaling up, but also for extending private-sector engagement down to the root of technological innovation and related entrepreneurship and business strategies, since innovation has been the lifeblood of economic growth and associated human development from the onset of the Industrial Revolution. It also requires capitalizing on the many avenues taken by social innovation to transform society in ways that improve human development outcomes. These can be, for example, at the level of organizations and value chains, in social processes and entrepreneurship, in financial investments at scale, and in policy and other facets of institutional design.

The first paper under this theme, by London and Esper,<sup>61</sup> assesses poverty-alleviation outcomes of an enterprise-led base of the pyramid (BoP) initiative to improve the basic necessity of sanitation. Inadequate sanitation negatively affects the lives of billions of people in the developing world and has a particularly significant impact on the well-being of millions of young children.<sup>62</sup> Given the magnitude of the challenge and the limitations of existing approaches,<sup>63–65</sup> enterprise-led initiatives to provide public goods are generating a growing interest. Specifically, enterprises targeting the BoP are presented as potentially sustainable and scalable

interventions that generate positive poverty-alleviation effects.<sup>66</sup> Yet an understanding of who is affected, and how, remains limited. To begin to address this gap, the paper applies a multidimensional framework to an urban-based, sanitation-oriented BoP enterprise, focusing its poverty-alleviation effects on young children. The analysis indicates that the enterprise's effects include changes in capability, economic, and relationship well-being,<sup>67</sup> and that these changes can be positive or negative. Furthermore, the impact varies depending on the role of the stakeholder in the business model and the age of the child. These results contribute to a better understanding of how to assess the effectiveness of a sanitation intervention and how to evaluate the poverty-alleviation implications of an enterprise-led approach. These results also provide further insights into how collaborative interdependence<sup>68</sup> between business and development actors can enhance the connection between profits and the alleviation of poverty.

The second paper, by Reardon *et al.*,<sup>69</sup> goes one step further in convergence outcomes to report about the mainstream agricultural and economic activities. This article talks about a “quiet revolution” in Asia's rice value chains, specifically in countries such as India, China, and Bangladesh. In these countries, rapid transformation is occurring with the upstream changing quickly and shifting from subsistence to small commercialized farmers. For instance, farmers are undertaking capital-led intensification<sup>70</sup> and participating in burgeoning markets for land rental, fertilizer and pesticides, water irrigation, and seed. Midstream, in wholesale and milling, there is a quiet revolution underway with thousands of entrepreneurs investing in equipment, increasing scale, and diversifying into higher quality, with segments undergoing consolidation and vertical coordination and integration.<sup>71</sup> Mills, especially in China, are packaging, branding, and building agent networks in wholesale markets with large mills building direct relations with supermarkets. The downstream retail segment is undergoing a “supermarket revolution,” again with China leading the change.<sup>72</sup> In most cases the government is not playing a direct role in the market, but is instead enabling this transformation through infrastructural investment. The transformation appears to be improving food security for cities by reducing margins, offering lower consumer rice prices, and

increasing quality and diversity of rice. The paper discusses findings derived from unique stacked surveys of all value chain segments in seven zones, more and less developed. This pattern of development is very different from the “supermarket revolution” documented earlier by the same research team over the preceding two or three decades,<sup>72</sup> where Asia's supermarket revolution exhibited unique one-way pathways of Western retail diffusion, with accompanying procurement system change and valuable, although limited, effort to connect small farmers. Instead, the reported emerging quiet revolution, alongside the development of more robust rural–urban food value chains and systems, gives rise to rural small- and medium-scale enterprises in trucking, wholesale, warehousing, cold storage, first- and second-stage processing, alongside social enterprises, BoP ventures, and corporate shared value creation programs that support villages, communities, and emerging small and mid-size towns in driving local and regional activities. This more dynamic view of farm and nonfarm activities and rural–urban development reflects possibilities for novel forms of decentralized urbanization, addressing key humanitarian problems while spreading wealth to surrounding rural areas that find smaller cities and towns to be more accessible markets than large cities. This produces more spin-off effects to surrounding rural areas for rural non-farm employment generation, growing markets for local traditional food, and the possibility of industrialized value-addition that remains closer to the farm.

The third paper by Dubé *et al.*<sup>25</sup> introduces convergent innovation (CI) as a form of conceptual meta-innovation—an innovation in the way people innovate. CI goes further in the way society has innovated in the past,<sup>73</sup> viewing individual, community, market, and state organizations as part of the same complex dynamic adaptive system, purposefully targeting human and economic development in single and collective decision making, investment, and public policy. Convergent innovation requires assembling bundles of technological innovations that combine farming and food distribution and transportation into appropriate solutions that provide value to specific clientele. It also requires organizational, social, financial, and institutional innovations to transform the ecosystem, improving accessibility, affordability, and price, toward

positive human and economic outcomes, specifically for the most underserved populations. As a solution-oriented paradigm, CI goes beyond the current strategies addressing complex nutrition-related societal challenges, defining new paths of convergence for agriculture, health, and wealth production and distribution that better balance tradition with modernity, farm with nonfarm activities, and rural and urban development. Aiming for behavioral and ecosystem transformations at scale, CI encourages sustainable prosperity and affordable universal health care within a WoS paradigm.<sup>21,74</sup> CI takes a modular approach that convenes a complementary portfolio of partners from the business community, civil society, and public sector, all loosely coupled around roadmaps. Roadmaps serve as collaborative platforms for focused, achievable, and time-bound projects to provide scalable, sustainable, and resilient solutions to complex challenges, with benefits both to participating partners and to society. The paper provides a brief review of the literature on technological innovation that sets the foundations of CI and motivates its feasibility. The paper then describes CI, its building blocks, and enabling conditions for its deployment and scaling up, illustrating its operational forms through examples of existing CI-sensitive innovation.

The roadmap paper under this theme, by Jha *et al.*,<sup>75</sup> reports on early-stage design, development, and implementation of a collaborative CI roadmap promoting pulse production and consumption, with the potential to contribute to all three facets of malnutrition while also being one of the most environment-friendly agricultural commodities. Partners in the pulse roadmap at the global level have spearheaded the long policy process of getting 2016 to be declared by the United Nations (UN) as the International Year of Pulses (IYOP), with a core component of the roadmap being the formation of a global pulse innovation platform (PIP) to be the food innovation platform. PIP is a platform where global organizations (businesses from along the pulse value chain as well as research and development organizations) work with their global counterparts in the food sector (MNCs) and at the country level. With MNCs, PIP aims to enrich their present efforts in food product technologies by other facets of CI that build supply, demand, and institutional capacity for superior commercial and societal return on investment. At the country level, PIP works

with and for micro, small, medium, and national businesses, and other actors to scale up pulse consumption and foster CI through behavioral change and ecosystem transformation, in order to create both human and economic development outcomes for partners and for society.

### **Convergence in policy and governance**

Scaling up business engagement as a catalyst for new paths of convergence for agriculture, health, and wealth requires that changes be made to the institutional framework that has been in place since the onset of the Industrial Revolution, which posits a clear divide between private and public goods and between market and state responsibility.<sup>21</sup> Existing institutional restrictions, which scale down actions on the ground, have many components. These include limited resources and funding, conflicting functional, philosophical, and/or political beliefs and goals, concerns of confidentiality, issues of territoriality and lack of trust, as well as differences in decision-making styles and performance metrics.<sup>76</sup> Current policy approaches do not completely account for the progressive misalignment between biological, human, and social dynamics as development unfolds.<sup>53,77,78</sup> A disconnect exists between policy making in economic sectors on the one hand, (i.e., agriculture, trade, industry, finances) and human development sectors on the other (i.e., education, health, family, and other social domains). The result of this disconnect is that consideration of immediate and intertemporal adverse nutrition, health, or social effects are only now beginning to be factored into policy making and investment decisions. The disconnect between health systems and agriculture and wealth production and consumption systems is also manifested in the observation that early health systems capacity building and policy remain focused on infectious diseases and other health problems tied to extreme poverty, remaining relatively blind to, or unable to anticipate, prevent, and manage, the rising burden of obesity and NCDs. These diseases arise from present development patterns emerging from other sectoral policies and investments, and are doing so at even lower GDP thresholds. Present policy approaches in neither health nor industrial and economic sectors consider the central role that agriculture may play over the full development spectrum. Considering a sustained and central role for agriculture can ensure

a smoother transition into industrial value chains and urban societies, and more balance between traditional low-income agrarian structures and emerging farm and nonfarm activities in rural and urban communities and economies.

The first paper under this theme, by Arora *et al.*,<sup>79</sup> examines the agricultural, industrial, and trade policies that relate to sugar, salt, and fat production and consumption in India. As mentioned previously, India is still struggling against undernourishment and micronutrient deficiency while concurrently gaining recognition as the diabetes capital of the world. In this country diabetes spreads as much in rural areas and urban slums as it does in higher socioeconomic strata of society.<sup>80</sup> The paper, written by lead medical experts in the field, recognizes the limited governance of health policy on the social, developmental, and economic determinants of these diet-related health problems when drivers and incentive structures are outside of formal health policy purview and where health and economic outcomes are still being perceived as conflicting objectives by many. Arora *et al.*<sup>79</sup> call for cross-sectoral policy making where synergies and trade-offs among these objectives are fully acknowledged and take a more central place in policy dialog and investment decisions. They also call for transformation throughout society to make the production and consumption of healthy food and diet as simple, convenient, and appealing as possible.

The second paper<sup>81</sup> explores such institutional design in the context of standards and label systems targeted to consumer and actors along farm-to-plate value chains, with the objective of improving the nutritional quality of choices made at all levels. These can be developed and managed under private, governmental, or civil society leadership.<sup>81</sup> Research in both traditional<sup>82</sup> and modern<sup>83</sup> food systems has shown that standards and labels can be a crucial factor in local knowledge building for upgrading small producers and improving their market competitiveness and livelihoods. Such informational support also aims to empower consumers to make healthier food choices to help fight the epidemic of obesity and associated diseases. Helfer and Shultz<sup>81</sup> report a series of experiments on how four different nutritional labeling schemes, varying in information richness and usability, can affect the speed and nutritional value of food choices. The psychology experiment shows that quantitative, single-attribute

labeling schemes have greater usability than multiattribute and binary ones, and that they remain effective under moderate time pressure. Applying decision field theory, a leading computational model of human decision making,<sup>84</sup> the authors simulate these psychological results and provide explanatory insights, which can importantly enrich the scientific basis that informs the design and improvement of such standards and labels. Still too often, labeling scheme decisions are made on the basis of consensus among nutrition and public health experts to expense of theoretical frameworks, models, and data of other types that can improve their sustainable use and integration into everyday activities by all involved.

The third paper, by Kirton *et al.*,<sup>85</sup> turns to political science methods, an approach that is necessary to examine how policy makers and political leaders can embrace the complexity of the societal transformation.<sup>86</sup> This research tradition also enables the examination of how grassroots and market-driven bottom up initiatives can be further scaled up and brought into policy and investment decisions made by national governments and global agencies and summits, such as the Group of Eight (G8), G20, BRICS (Brazil, Russia, India, China, and South Africa), UN, and Food and Agriculture Organization (FAO) summits. This paper examines how and why informal, multilateral summit institutions, such as the G8 major market democracies succeed in advancing costly public health priorities even when the formal, multilateral UN system fails to meet such goals. This paper finds that the Muskoka Summit succeeded in mobilizing major money and momentum for maternal, newborn, and child health (MNCH). This success was due to the initiative and influence of children-focused non-governmental organizations (NGOs) working with committed individuals and agencies within the host Canadian government, as well as supportive public opinion and the help of those in the UN responsible for realizing its Millennium Development Goals. Also relevant were the democratic like-mindedness of G8 leaders and their African partners, the deference of G8 members to the host's priority, with Premier Stephen Harper endorsing this initiative as one of the flagship programs to define his political leadership, as well as the need of the G8 to demonstrate its relevance through a division of labor between it and the new G20 summit. This



study shows that G8 summits can succeed in advancing key global health issues without a global shock on the same subject. The need to improve the accompanying accountability mechanisms to improve implementation thus remains.

The last paper in this theme by Dubé *et al.*<sup>74</sup> offers the WoS paradigm of human and economic development<sup>21</sup> as a broad institutional framework to move beyond the well-entrenched market-state bipolarity underlying Western-centric development and past and present efforts at cross-sectoral policy coherence. The paper takes as an anchor the well-established model of polycentric governance<sup>87</sup> that views individuals, as well as state, market, and community-forming society as part of the same complex adaptive system, self-organized into nested hierarchies operating at multiple scales and able to move toward 21st century convergence of human and economic development. Decades of work in environmental sustainability of socioecological systems by Ostrom<sup>87–89</sup> and other leaders in the field<sup>90,91</sup> have demonstrated the added value of formally linking local communities to market and states as core structuring institutions in society. Locals have accurate understandings of how the systems to be affected operate and of appropriate behavioral norms. Local communities are also the point of convergence for various programs targeting individuals and families, increasing the probability of having trustworthy stakeholders involved. In addition, community-level knowledge enables more specific tailoring to local needs and allows for a diversity of context-specific applications, thus facilitating experimentation and adaptive learning. Finally, local communities often play a front and center role in helping the poorest segments of the population access basic necessities and employment, acting as key intermediaries for higher-level state and market actors. In both research and action in socioecological systems, the local community is taken as a central entry point, where emerging processes and outcomes are being linked down to household and individual levels and up to higher-order actors in the ecosystem.<sup>92,93</sup> This broad governance framework bears particular promise in bridging modern and traditional food systems and societies in a novel way, exploring more synergy and reciprocity.

The roadmap paper by Addy *et al.*<sup>94</sup> provides further operational insights on how a WoS paradigm

of human and economic development can be deployed. The paper draws upon empirical evidence of policy design processes in Quebec, where this framework serves as the lens through which the authors observe the multiplicity of state and non-state actors involved over time in a comprehensive effort to promote healthy lifestyles to fight obesity and associated NCDs. These actors, in a somewhat experimental and organic manner, develop rules and other institutional arrangements to solve public health problems, on the basis of their expertise and perspectives from the diverse sectors and levels that they inhabit. The concepts of polycentricity that have been developed outside of public health are discussed, noting that it represents a paradigm shift in the social sciences, as, rather than promoting research that is generalizable, there is an acknowledgment that governance structures are context-specific and that micro-situational analysis of the processes by which the governance structures emerge is key. A process analysis is provided on the emergence of the social, economic, and political context of Quebec's public health system, noting the interactions between global, national, and local-level actors and structures in the emergence of multisectoral and whole-of-governance approaches. The paper, in conclusion, discusses how to address challenges faced in the Quebec case, as well as a research agenda for the WoS approach moving forward.

### Convergence in metrics and methods

Convergence efforts deployed throughout the whole of society to alleviate the burden of ill health and malnutrition are hampered by the current state of sectoral data and decision support in population health, human development, media, agriculture, industrial, and other economic sectors. These data are generally fragmented, out of date, unrepresentative, and typically unavailable at the local level. Bridges must be built between knowledge systems and models in health, and those used in policy making by agricultural, social, and economic actors at local, national, and global levels. Public health, agriculture, business, and economic researchers and practitioners have proposed and implemented various sectoral surveillance systems and models to monitor processes and outcomes, each in their respective spheres. None of them, though, fully link the available data from one sector to other relevant

data from other sectors that support decision and policy making across various actors in society who determine the level of direct and indirect risk factors of diseases. Also required is complementary research and technological development in fostering convergence into analytical, statistical, and computational modeling as well as in research methods. Simultaneously, materials assembled may be particularly timely on the eve of the post-2015 Development Agenda, which calls more than ever to reach beyond efforts thus far predominantly deployed by governments, development agencies, and donors, to scale up what individuals, communities, and businesses can contribute. Data, models, and decision-support tools that bridge human and economic development outcomes and processes within and across scales and sectors may carry especially high promises since information is key to transformation in such complex systems, be they traditional, modern, or a combination of both.<sup>18</sup>

The first paper, by Cafiero *et al.*,<sup>95</sup> reviews some of the existing food security indicators used in development work.<sup>96–98</sup> It discusses the validity of the underlying concept and the expected reliability of measures under reasonably feasible conditions. The main objective of the paper is to raise awareness about the trade-offs between different qualities of possibility measurement tools that must be taken into account when such tools are proposed for practical application, especially for use within an international monitoring framework.<sup>99</sup> The hope is to provide a useful contribution to the process, leading to the definition of a more nuanced food security goal and the associated monitoring framework.

The second paper, by Pingali and Ricketts,<sup>100</sup> goes one step further in moving toward a multidisciplinary convergence of data systems. The work, remaining focused on the development context, is motivated by a particular emphasis on agricultural pathways toward improved nutrition since the 2008 food price crisis placed food and nutrition security back on the global development agenda.<sup>101–103</sup> Parallel efforts are being promoted to improve the data and metrics for monitoring progress toward positive nutritional outcomes, especially for women and children.<sup>104</sup> The data investments, while rising, are still made in silos with very little interaction and communication among them. This paper proposes a minimum set of nutrition indicators to be included in nationally representative agricultural (and mul-

titopic) household surveys. Building multisectoral convergence across existing surveys will allow for better identification of priority interventions and improved monitoring of progress toward superior nutrition targets.

The third paper, by Masters *et al.*,<sup>105</sup> offers a typology and associated metrics for integrated interventions and research targeting agriculture, nutrition, and health in global development. The authors argue that, despite rhetoric claiming that enhanced agriculture leads to improved nutrition and health, there is scant empirical evidence about potential synergies across sectors or about the mix of actions that best supports all three sectors. The geographic scale and socioeconomic nature of these interventions require integration of previously separate research methods.<sup>106</sup> This paper proposes a typology of interventions and a metric of integration among them to help researchers build on each other's results, facilitating integration in methods to inform the design of multisector interventions. The typology recognizes the importance of regional effect modifiers that are not themselves subject to randomized assignment, and trade-offs in how policies and programs are implemented, evaluated, and scaled. Using this typology could facilitate methodological pluralism, helping researchers in one field use knowledge generated elsewhere, each using the most appropriate method for their situation.

The fourth paper, by Buckridge *et al.*,<sup>107</sup> pushes the boundaries of metrics and analytics research design further, to support integration among sectors and geographic scales, and target population segments of varying socioeconomic backgrounds, taking this time as a laboratory the rich-country context (more specifically, Canada). The authors introduce a method for neighborhood-level surveillance of food purchasing, motivated by the increasing share worldwide of caloric intake represented by sugar-rich, nutrient-poor food, such as carbonated soft drinks (CSDs).<sup>108</sup> Interventions to decrease the intake of added sugar have been proposed,<sup>109</sup> but monitoring their effectiveness can be difficult because of the costs and limitations of dietary surveys. The authors develop, assess the accuracy of, and take an initial step toward validating an indicator of neighborhood-level purchases of CSDs, using automatically captured store scanner data in Montreal, Canada, between 2008 and 2010, and census data describing neighborhood socioeconomic

characteristics. The indicator predicted total monthly neighborhood sales on the basis of historical sales and promotions, and store and neighborhood characteristics. The prediction error for monthly sales in sampled stores was low (2.2%), and a negative association is shown between predicted total sales and median personal income. For each \$10,000 decrease in median personal income, a fivefold increase in predicted monthly sales of CSDs is observed. This indicator can be used by public health agencies to implement automated systems for neighborhood-level monitoring of an important upstream determinant of health. Future refinement of this indicator is possible to account for factors such as store catchment areas and to incorporate nutritional information about products.

The roadmap paper by Dubé *et al.*<sup>110</sup> proposes to capitalize on 21st-century Big Data and advanced analytics, such as those used by Buckridge *et al.*<sup>107</sup> above to set the foundations for an integrative knowledge platform that bridges sectoral practices and disciplinary theories, as well as metrics and models to better inform and monitor behavioral change and ecosystem transformation. Building upon the science and practice of the four Ps of industrial marketing (product, price, place, and promotion), the authors examine digital commercial marketing data through the lenses of the four As of food security (availability, accessibility, affordability, and appeal), applicable to both traditional and modern systems. Applying advanced consumer choice analytics to archetype traditional (i.e., fresh fruits and vegetables) and modern (i.e., soft drinks) product categories, it is demonstrated that business practices typically associated with the latter also have important effects on the former. While the overall consumer responses tend to be more intense for modern products, certain practices, such as product assortment and point-of-sale promotion, have more impact for fresh products than for soft drinks. Discussion bears on the potential of Big Data as a convergence enabler by facilitating greater reciprocity between traditional and modern food systems, both within and across developing and industrialized countries, enabling the production and consumption of accessible, affordable, and appealing nutritious food for all, and scaling up convergence in their single and combined human and economic development outcomes.

## Conclusions

On the eve of the Millennium Development Goals for the target year 2015, the series of papers assembled in this issue articulate concrete paths of convergence for agriculture, health, and wealth, and may pave the way to redefine and better distribute points of value creation from farm to plate, as well as the type of novel public–private partnerships that have had timid results thus far. Instead, insights provided have the potential to enable all actors throughout society to singly and collectively work to build supply and demand for nutritious food, in both traditional and modern food systems, while placing the burdens of malnutrition and ill health on their core strategic agendas.

## Acknowledgments

The authors would like to thank the Bill & Melinda Gates Foundation for sponsoring the “Paths of Convergence for Agriculture, Health, and Wealth” conference in New Delhi in June 2012 as well as the production of this volume. The authors would also like to thank the Rockefeller Foundation’s Bellagio Resident Fellows program for hosting the follow-up week-long workshop in November 2012. Dr. Dubé acknowledges financial support from a Fonds de Recherche Société et Culture Québec (FQRSC; #230130) Team Grant and Social Sciences and Humanities Research Council (SSHRC) Insight Grant (#219822). A special thank you is extended to Gabriela Heslop for her research assistance provided for this article.

## Conflicts of interest

The authors declare no conflicts of interest.

## References

1. Barrett, C., A. Travis & P. Dasgupta. 2001. On biodiversity and poverty traps. *Proc. Natl. Acad. Sci. USA* **108**: 12907–12912.
2. Barrett, C., T. Reardon & P. Webb. 2011. Nonfarm income diversification and household Livelihood strategies in rural Africa: concepts, dynamics and policy implications. *Food Policy* **26**: 315–332.
3. Terborgh, J. *et al.* 2001. Ecological meltdown in predator-free forest fragments. *Science* **294**: 1923–1926.
4. MacDonald, G. 2010. Water, climate change, and sustainability in the southwest. *Proc. Natl. Acad. Sci. USA* **107**: 21256–21262.
5. Seager, R. & G. Vecchi. 2010. Greenhouse warming and the 21st century hydroclimate of southwestern North America. *Proc. Natl. Acad. Sci. USA* **107**: 21277–21282.

6. Barrett, C. & B. Swallow. 2006. Fractal poverty traps. *World Dev.* **34**: 1–15.
7. Coomes, O., Y. Takasaki & J. Rhemtulla. 2011. Land-use poverty traps identified in shifting cultivation systems shape long-term tropical coverage. *Proc. Natl. Acad. Sci. USA* **108**: 13925–13930.
8. Jalan, J. & M. Ravallion. 2002. Geographic poverty traps? A micromodel of consumption growth in rural china. *J. Appl. Econ.* **17**: 329–346.
9. Barrett, C. 2010. Measuring food security. *Science* **327**: 825–828.
10. Timmer, C.P. 2010. Preventing food crisis using a food policy approach. *J. Nutr.* **140**: 224S–228S.
11. Timmer, C.P. 2012. Behavioral dimensions of food security. *Proc. Natl. Acad. Sci. USA* **109**: 12315–12320.
12. Cutler, D., K. Davis & K. Stremekis. 2010. The impact of health reform on health system spending. Issue Brief, Center for American Progress. [http://mail.nescso.org/files/33-1405\\_Cutler\\_impact\\_hlt\\_reform\\_on\\_hlt\\_sys\\_spending\\_ib\\_v4%5B1%5D.pdf](http://mail.nescso.org/files/33-1405_Cutler_impact_hlt_reform_on_hlt_sys_spending_ib_v4%5B1%5D.pdf). Accessed October 12, 2014.
13. Cutler, D.M., A.B. Rosen & S. Vijan. 2006. The value of medical spending in the United States, 1960–2000. *N. Engl. J. Med.* **355**: 920–927.
14. Deaton, A. 2013. *The Great Escape: Health, Wealth, and the Origins of Inequality*. Princeton, NJ: Princeton University Press.
15. Moodie, R. *et al.* 2013. Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *Lancet* **381**: 670–679.
16. Swinburn, B.A. *et al.* 2011. The global obesity pandemic: shaped by global drivers and local environments. *Lancet* **378**: 804–814.
17. Thomas, B. & L. Gostin. 2013. Tackling the global NCD crises: innovations in law and governance. *J. Law, Med. Ethics* **41**: 16–27.
18. Hammond, R.A. & L. Dubé. 2012. A systems science perspective and transdisciplinary models for food and nutrition security. *Proc. Natl. Acad. Sci. USA* **109**: 12356–12363.
19. Gomez, M. & K. Ricketts. 2013. Food value chain transformation in developing countries: selected hypothesis on nutritional implications. *Food Policy* **42**: 139–150.
20. Acemoglu, D. & J. Robinson. 2012. *Why Nations Fail: The Origins of Power, Prosperity, and Poverty*. New York, NY: Crown Business.
21. Dubé, L., P. Pingali & P. Webb. 2012. Paths of convergence for agriculture, health, and wealth. *Proc. Natl. Acad. Sci. USA* **109**: 12294–12301.
22. Ferguson, N. 2011. *Civilization: The West and the Rest*. New York, NY: Penguin.
23. Sjauw-Koen-Fa, A. 2012. *Framework for an Inclusive Food Strategy*. The Netherlands, Utrecht: Rabobank.
24. FAO. 2014. Food for the cities. <ftp://ftp.fao.org/docrep/fao/012/ak824e/ak824e00.pdf>. Rome, Italy.
25. Dubé, L. *et al.* 2014. Convergent innovation for sustainable economic growth and affordable universal health care: innovating the way we innovate. *Ann. N.Y. Acad. Sci.* **1331**: 119–141.
26. Nambiar, D. 2013. India's "tryst" with universal health coverage: reflections on ethnography in Indian health policy-making. *Soc. Sci. Med.* **99**: 135–142.
27. Butzer, K. & G. Endfield. 2012. Critical perspectives on historical collapse. *Proc. Natl. Acad. Sci. USA* **109**: 3629–3631.
28. FAO. 1996. Rome declaration on world food security. World Food Summit. <http://www.fao.org/docrep/003/W3613E/W3613E00.HTM>. Accessed October 12, 2014.
29. Black, R. *et al.* 2013. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **382**: 427–451.
30. Cunningham, S., M. Kramer & K. Narayan. 2014. Incidence of childhood obesity in the United States. *N. Engl. J. Med.* **370**: 403–411.
31. Slining, M.M., S.W. Ng & B.M. Popkin. 2013. Food companies' calorie-reduction pledges to improve US diet. *Am. J. Prev. Med.* **44**: 174–184.
32. Slining, M.M. *et al.* 2013. *Complexities of Monitoring Food and Nutrition From Factory to Fork: the University of North Carolina at Chapel Hill Crosswalk Approach*. Chapel Hill, NC: University of North Carolina.
33. Finucane, M. *et al.* 2011. National, regional and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 millions participants. *Lancet* **377**: 557–567.
34. Dagher, A. 2010. The neurobiology of appetite: hunger as addiction. In *Obesity Prevention: The Role of Brain and Society on Individual Behavior*. L. Dubé, *et al.*, Eds. Amsterdam: Elsevier/Academic Press.
35. Xiao, L., L. Dubé & A. Bechara. 2010. Resisting temptation: impulse control and trade-offs between immediate rewards and long-term consequences. In *Obesity Prevention: The Role of Brain and Society on Individual Behavior*. L. Dubé, *et al.*, Eds.: 105–114. Amsterdam: Elsevier/Academic Press.
36. Kahneman, D. 2010. The human agent, behavioral changes and policy implications. In *Obesity Prevention: The Role of Brain and Society on Individual Behavior*. L. Dubé, *et al.*, Eds. Amsterdam: Elsevier/Academic Press.
37. LeBel, J. 2010. Aligning pleasures and profits: restaurants as healthier lifestyle enablers. In *Obesity Prevention: The Role of Brain and Society on Individual Behavior*. L. Dubé, *et al.*, Eds. Amsterdam: Elsevier/Academic Press.
38. Portella, A.K. & P.P. Silveira. 2014. Neurobehavioral determinants of nutritional security in fetal growth-restricted individuals. *Ann. N.Y. Acad. Sci.* **1331**: 15–33.
39. Lithell, H. *et al.* 1996. Relation of size at birth to non-insulin dependent diabetes and insulin concentrations in men aged 50–60 years. *BMJ* **312**: 406–410.
40. Rich-Edwards, J. *et al.* 1997. Birth weight and risk of cardiovascular disease in a cohort of women followed up since 1976. *BMJ* **315**: 396–400.
41. Gluckman, P. *et al.* 2008. Effect of in utero and early-life conditions on adult health and disease. *N. Engl. J. Med.* **359**: 61–73.
42. Popkin, B., M. Richards & C. Montiero. 1996. Stunting us associated with overweight in children of four nations

- that are undergoing the nutrition transition. *J. Nutr.* **126**: 3009–3016.
43. Varela-Silva, M. *et al.* 2012. The nutritional dual-burden in developing countries—how is it assessed and what are the health implications? *Collegium Antropol.* **36**: 39–45.
  44. Costanza, R. *et al.* 2007. Sustainability on collapse: what can we learn from integrating the history of humans and the rest of nature? *Ambio* **36**: 522–527.
  45. Wainwright, J. 2010. Climate change, capitalism, and the challenges of transdisciplinarity. *Ann. Assoc. Am. Geographers* **100**: 983–991.
  46. Hammond, R.A. & J.T. Ornstein. 2014. A model of social influence on body mass index. *Ann. N.Y. Acad. Sci.* **1331**: 34–42.
  47. Mueller, A. *et al.* 2010. Sizing up peers: adolescent girls' weight control and social comparison in the school context. *J. Health Social Behav.* **51**: 64–78.
  48. Ruel, M., H. Alderman & t. M. a. C. N. S. Group. 2013. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *Lancet* **382**: 536–551.
  49. Kadiyala, S. *et al.* 2014. Agriculture and nutrition in India: mapping evidence to pathways. *Ann. N.Y. Acad. Sci.* **1331**: 43–56.
  50. Deaton, A. & J. Dreze. 2009. Food and nutrition in India: facts and interpretations. *Econ. Politics Weekly* **44**: 42–65.
  51. Headey, D., A. Chiu & S. Kadiyala. 2012. Agriculture's role in the Indian enigma: help or hindrance to the crisis of undernutrition? *Food Security* **4**: 87–102.
  52. Headey, D. 2013. Developmental drivers of nutritional change: a cross-country analysis. *World Dev.* **42**: 76–88.
  53. Webb, P. & S. Block. 2012. Support for agriculture during economic transformation: impacts on poverty and undernutrition. *Proc. Natl. Acad. Sci. USA* **109**: 12309–12314.
  54. Pingali, P. 2007. Westernization of Asian diets and the transformation of food systems: implications for research and policy. *Food Policy* **32**: 281–298.
  55. Timmer, C.P. 1995. Getting agriculture moving: do markets provide the right signals? *Food Policy* **20**: 455–472.
  56. Timmer, C.P. 2009. Do supermarket change the food policy agenda? *World Dev.* **37**: 1812–1819.
  57. Struben, J., D. Chan & L. Dubé. 2014. Policy insights from the nutritional food market transformation model: the case of obesity prevention. *Ann. N. Y. Acad. Sci.* **1331**: 57–75.
  58. Ghosh, S. *et al.* 2014. Improving complementary feeding in Ghana: reaching the vulnerable through innovative business—the case of KOKO Plus. *Ann. N. Y. Acad. Sci.* **1331**: 76–89.
  59. Astrup, A. *et al.* 2008. Nutrition transition and its relationship to the development of obesity and related chronic diseases. *Obes. Rev.* **9**: 48–52.
  60. Popkin, B. 2004. The nutrition transition and the global shift towards obesity. *Diab. Voice* **49**: 38–40.
  61. London, T. & H. Esper. 2014. Assessing poverty-alleviation outcomes of an enterprise-led approach to sanitation. *Ann. N.Y. Acad. Sci.* **1331**: 90–105.
  62. Spears, D. & S. Lamba. 2013. *Effects of Early-Life Exposure to Sanitation on Childhood Cognitive Skills: Evidence from India's Total Sanitation Campaign*. Houston, Texas: Rice Institute.
  63. Duflo, E., S. Galiani & M. Mobarak. 2012. Improving access to urban services for the poor: open issues and a framework for a future research agenda. Cambridge, MA: Abdul Latif Jameel Poverty Action Lab. <http://www.povertyactionlab.org/publication/improving-access-urban-services-poor>. Accessed November 16, 2014.
  64. WaterAid. 2007. *Water, Environmental Sanitation and Hygiene Programme for Urban Poor*. Kuponole: WaterAid, UN Habitat.
  65. World Health Organization & UNICEF. 2012. *Progress on Drinking Water and Sanitation*: p. 1–58. New York: WHO/UNICEF.
  66. Prahalad, C.K. 2004. *The Fortune at the Bottom of the Pyramid: Eradicating Poverty with Profits*. Philadelphia: Wharton Business Publishing.
  67. London, T. 2009. Making better investments at the base of the pyramid. *Harv. Bus. Rev.* **87**: 106–113.
  68. London, T. & R. Anupindi. 2012. Using the base-of-the-pyramid perspective to catalyze interdependence-based collaborations. *Proc. Natl. Acad. Sci. USA* **109**: 12338–12343.
  69. Reardon, T. *et al.* 2014. The quiet revolution in Asia's rice value chains. *Ann. N.Y. Acad. Sci.* **1331**: 106–118.
  70. Yang, J. *et al.* 2013. The rapid rise of cross-regional agricultural mechanization services in China. *Am. J. Agric. Econ.* **95**: 7.
  71. Reardon, T. *et al.* 2012b. The Quiet revolution in staple food value chains in Asia: enter the dragon, the elephant, and the tiger. City of Mandaluyong, Philippines: Asian Development Bank.
  72. Reardon, T., C.P. Timmer & B. Minten. 2012. Supermarket revolution in Asia and emerging development strategies to include small farmers. *Proc. Natl. Acad. Sci. USA* **109**: 12332–12337.
  73. von Hippel, E.A., S. Ogawa & J. Pj de Jong. 2011. The age of the consumer-innovator. *MIT Sloan Manage. Rev.* **53**: 27–35.
  74. Dubé, L., N.A. Addy, C. Blouin & N. Drager. 2014. From policy coherence to 21st century convergence: a whole-of-society paradigm of human and economic development. *Ann. N. Y. Acad. Sci.* **1331**: 201–215.
  75. Jha, S.K. *et al.* 2014. Convergent innovation for affordable nutrition, health, and health care: the global pulse roadmap. *Ann. N. Y. Acad. Sci.* **1331**: 142–156.
  76. Bond, B. & J. Gittel. 2010. Cross-agency coordination of offender reentry: testing collaboration outcomes. *Crim. Justice J.* **38**: 118–129.
  77. Kevane. 2012. Gendered production and consumption in rural Africa. *Proc. Natl. Acad. Sci. USA* **109**: 12350–12355.
  78. Pingali, P.L. 2012. Green Revolution: impacts, limits, and the path ahead. *Proc. Natl. Acad. Sci. USA* **109**: 12302–12308.
  79. Arora, N.K. *et al.* 2014. Whole-of-society monitoring framework for sugar, salt, and fat consumption and non-communicable diseases in India. *Ann. N.Y. Acad. Sci.* **1331**: 157–173.

80. Anchala, R. *et al.* 2014. Hypertension in India: a systematic review and meta-analysis of prevalence, awareness and control of hypertension. *J. Hypertens.* **32**: 1170–1177.
81. Helfer, P. & T.R. Shultz. 2014. The effects of nutrition labeling on consumer food choice: a psychological experiment and computational model. *Ann. N.Y. Acad. Sci.* **1331**: 174–185.
82. Perez-Aleman, P. 2012. Global standards and local knowledge building: upgrading small producers in developing countries. *Proc. Natl. Acad. Sci. USA* **109**: 12344–12349.
83. Lee, J., G. Gereffi & J. Beauvais. 2012. Global value chains and agrifood standards: challenges and possibilities for smallholders in developing countries. *Proc. Natl. Acad. Sci. USA* **109**: 12326–12331.
84. Busemeyer, J. & J. Townsend. 1993. Decision field theory: a dynamic-cognitive approach to decision making in an uncertain environment. *Psychol. Rev.* **100**: 432–459.
85. Kirton, J., J. Kulik & C. Bracht. 2014. The political process in global health and nutrition governance: the G8's 2010 Muskoka Initiative on Maternal, Child, and Newborn Health. *Ann. N. Y. Acad. Sci.* **1331**: 186–200.
86. Gillespie, S. *et al.* 2013. The politics of reducing malnutrition: building commitment and accelerating progress. *Lancet* **382**: 552–569.
87. Ostrom, E. 2010. Beyond markets and states: polycentric governance of complex economic systems. *Am. Econ. Rev.* **100**: 641–672.
88. Ostrom, E. 2005. *Understanding Institutional Diversity*. Princeton, NJ: Princeton University Press.
89. Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge, UK: Cambridge University Press.
90. Heckathorn, D.D. 1996. The dynamics and dilemmas of collective action. *Am. Sociol. Rev.* **61**: 250–277.
91. Oliver, P.E. 1993. Formal models of collective action. *Ann. Rev. Sociol.* **19**: 271–300.
92. Futtema, C. *et al.* 2002. The emergence and outcomes of collective action: an institutional and ecosystem approach. *Ambiente Sociedade* **15**: 107–127.
93. Rout, S. 2010. Collective action for sustainable forestry: institutional dynamics in community management of forest in Orissa. *Social Change* **40**: 479–502.
94. Addy, N.A. *et al.* 2014. Whole-of-society approach for public health policymaking: a case study of polycentric governance from Quebec, Canada. *Ann. N. Y. Acad. Sci.* **1331**: 216–229.
95. Cafiero, C., H.R. Melgar-Quiñonez, T.J. Ballard & A.W. Kepple. 2014. Validity and reliability of food security measures. *Ann. N.Y. Acad. Sci.* **1331**: 230–248.
96. FAO. 1996b. The sixth world food survey. <http://www.fao.org/docrep/012/w0931e/w0931e00.htm>. Accessed October 17, 2014.
97. Hoddinott, J. 1999. *Choosing Outcome Indicators of Household Food Security, Vol. Technical Guide No 7*. Washington, DC: International Food Policy Research Institute.
98. UNICEF. 2014. The State of World Children. <http://www.unicef.org/sowc/>. Accessed October 17, 2014.
99. Maxwell, D., J. Coates & B. Vaitla. 2013. How do different indicators of household food security compare? Empirical evidence from Tigray. <http://fic.tufts.edu/assets/Different-Indicators-of-HFS.pdf>. Accessed October 17, 2014.
100. Pingali, P.L. & K.D. Ricketts. 2014. Mainstreaming nutrition metrics in household surveys—toward a multidisciplinary convergence of data systems. *Ann. N.Y. Acad. Sci.* **1331**: 249–257.
101. Brinkman, H. *et al.* 2010. High food prices and the global financial crisis have reduced access to nutritious food and worsened nutritional status and health. *J. Nutr.* **140**: 153S–161S.
102. Ruel, M. *et al.* 2010. The food, fuel, and financial crises affect the urban and rural poor disproportionately: a review of the evidence. *J. Nutr.* **140**: 170S–178S.
103. Webb, P. 2010. Medium to long run implications of high food prices for global nutrition. *J. Nutr.* **140**: 143S–147S.
104. Black, R. *et al.* 2008. Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* **371**: 243–260.
105. Masters, W.A. *et al.* 2014. Agriculture, nutrition, and health in global development: typology and metrics for integrated interventions and research. *Ann. N.Y. Acad. Sci.* **1331**: 258–269.
106. G8 (Group of Eight Forum Countries). 2009. L'Aquila Joint Statement on Global Food Security.
107. Buckeridge, D.L. *et al.* 2014. A method for neighborhood-level surveillance of food purchasing. *Ann. N.Y. Acad. Sci.* **1331**: 270–277.
108. USDA. 2010. Report of the dietary guidelines advisory committee on the dietary guidelines for Americans.
109. Ebbeling, C. *et al.* 2012. A randomized trial of sugar-sweetened beverages and adolescent body weight. *N. Engl. J. Med.* **367**: 1407–1416.
110. Dubé, L. *et al.* 2014. A nutrition/health mindset on commercial Big Data and drivers of food demand in modern and traditional systems. *Ann. N.Y. Acad. Sci.* **1331**: 278–295.