Structural Transformation and Economic Development: Insights from the Agri-food Value Chain Revolution[*]

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1. Introduction

One key empirical regularity of the economic development process involves the structural transformation from a low-income economy in which low productivity agriculture employs most workers and generates most output, to a higher-income, more industrialized, service-oriented and diversified economy with a far more productive, but relatively much smaller agricultural sector (Timmer 1988, 2002, 2009). During this transformation agriculture releases labor to work in other sectors, provides plentiful raw materials for secondary processing and manufacturing, and farmer income growth stimulates demand for non-food goods, especially non-tradables that generate especially big local multiplier effects (Mellor 2017). This pattern is strongly associated with economic growth, poverty reduction, urbanization, and increasingly efficient spatial integration of factor (e.g., financial and labor) and output (e.g., food) markets. The bidirectional linkages between rural agricultural and urban industrial economies have long been recognized as essential to structural transformation (Lewis 1954; Johnston and Mellor 1961). Indeed, the Nobel Laureate W. Arthur Lewis famously wrote: "industrial and agrarian revolutions always go together, and … economies in which agriculture is stagnant do not show industrial development" (Lewis 1954, p. 433).

Lewis and others have commonly overlooked, however, the central role played by the simultaneous revolution in the agri-food value chain that intermediates between the shrinking pool of predominantly rural agricultural producers and the rising population of urban food consumers with evolving demand for food products. Dual economy models and other useful simplifications of complex development processes almost always abstract from the crucial intermediation roles played by aggregators, food processors, wholesalers, retailers, third party logistics firms, and restaurants and other food service providers. The analytically convenient simplification of assuming that primary agricultural producers directly supply consumers through complete and competitive markets necessarily assumes away these intermediaries. Economists have therefore naturally focused on technological change in farm-level production (Feder et al. 1985; Foster and Rosenzweig 2010), on smallholder farmer market participation (Barrett 2008), and on the competitive performance of agricultural commodity markets (Dillon and Dambro 2017) to describe the supply side of the food economy in developing countries. In this paper, we synthesize largely unintegrated literatures from agricultural economics, development economics, industrial organization, and trade so as to tell the story of the agri-food value chain revolution and its oft-overlooked role in the structural transformation of developing economies.

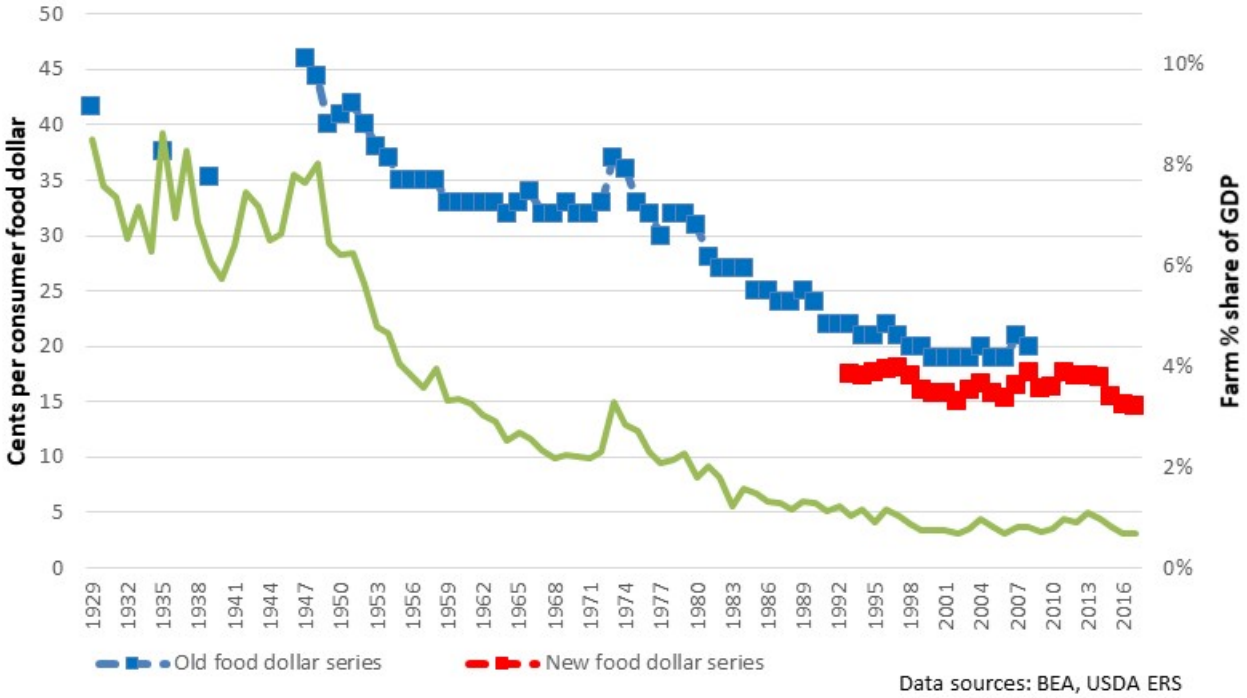
Data from the United States illustrate nicely how the value chain comes to play a dominant but overlooked role in the agri-food economy. Most readers will be familiar with the story of how rapid technological change led to a dramatic rise in United States (US) agricultural productivity over the course of the 20th century, leading to sharp contraction in the sector's share of aggregate employment and output, even as American farms became among the world's most productive.[1] The solid green line in Figure 1 – read against the righthand vertical axis – depicts the shrinking share of gross farm production relative to gross domestic product. At the start of the time series displayed, in 1929, the US had real disposable annual personal income per capita of $7,361 in real 2012 dollars (FRBSL 2019); thus it was a middle-income country (MIC) by today's standards.[2] Gross farm production as a share of annual US gross domestic product

[1] See Gardner (2009) for an excellent overview.

[2] The World Bank defines low income countries (LICs) as having gross national income (GNI) per capita of US$1,005 or less and middle income countries (MICs) as those with GNI per capita between US$1,006-$12,235. Together, the LICs

(GDP) was 8.5%, quite similar to middle-income countries today such as China, Ecuador, Sri Lanka, Thailand, and Zimbabwe (World Bank 2019). Over the ensuing 87 years, real per capita income increased roughly eight-fold and agricultural total factor productivity grew roughly three-fold[3], so that by 2017 the gross farm value added share of US GDP was just 0.7%. This is the familiar story of structural transformation in its mid-to-later stages.

Figure 1: US Farm Share of Consumer Food Expenditures and Gross Farm Value Added Share of GDP, 1929-2017



Perhaps more remarkably but far less well recognized, over the same period, the farm share of total consumer food expenditures fell by an even larger magnitude. The marker series, read against the lefthand vertical axis in Figure 1, depicts the dramatic reduction in the gross farm share of consumer food expenditures, from 40-50 percent to less than 15 percent over the same 1929-2017 period.[4] If US history is any guide, by the time countries reach middle-income status, post-farmgate value addition already accounts for roughly half of total consumer food expenditures and increases rapidly as economic growth proceeds. Not only does overall economic activity migrate off the farm, but so does value addition within the food system itself.

Over the past decades, such structural changes in agri-food value chains have been transforming the lives and economic fortunes of billions of poor people in low and middle income countries (LMICs). What is possibly even more impressive than the number and the poverty of the people affected by these changes, is the speed of the process. It took a century to

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and MICs encompass more than 85 percent of the world's population and a far greater share of the poor. We use the terms 'developing countries' and low- and middle-income countries (LMICs) interchangeably for the LICs and MICs together.

[3] See ERS' national tables available at https://www.ers.usda.gov/webdocs/DataFiles/47679/table01.xlsx?v=2945.1.

[4] The United States seems to be the only economy for which consistent time series exist on the farm share of consumer food expenditures. See the USDA Economic Research Service (ERS)'s 'food dollar' series. See Canning (2011) for technical details on the construction of the old series and the new one introduced in 2008. The new series is, on average, 3.5 cents/dollar lower than the old series over the 16 years of overlapping coverage.

transform the food supply chains in North America and Western Europe; comparable change is now taking place at a much faster pace and through a more encompassing process in many LMICs.[5] In this long-term perspective, the current changes are dramatic and non-linear. As such they provide a modern example of how major changes in economic systems and growth can occur from the confluence of a set of factors (Durlauf 1993) – similar to the "sudden, eruptive" industrialization of England and the "catching up" in other countries (Gerschenkron 1962) or the 20th century globalization processes and rapid industrial development in East Asia (Rodrik 1995).

This phenomenon was first documented as part of the so-called "supermarket revolution" where large-scale retailers and agribusinesses took the lead in transforming food systems in Latin America, Central and Eastern Europe, and Asia, especially in the transition from state-organized economic systems to market-based systems (Reardon et al, 2003; Rozelle and Swinnen, 2004). More recent studies show that even staple food markets and production systems in many poorer African and Asian countries are being transformed by a "quiet revolution", a fundamental transformation in the mid-stream intermediaries (e.g., transporters, cold storage providers, millers, etc.) that has largely gone unrecognized (Reardon, 2015). There is also a dramatic, and under-researched "food service revolution" underway in the provision of food away from home to consumers. These agri-food value chain changes are an oft-overlooked feature of the broader process of structural transformation of developing economies (Timmer 1988, 2009).

These changes have major implications for food consumers, farmers, and the middlemen (e.g., wholesalers, processors, third party logistics service providers, retailers) who transform and move product among them. They have been accompanied by rapid changes in the types of food offered to urban consumers, upgrading of processing and trading systems, changing forms of vertical coordination and integration among firms, and in major opportunities and challenges for small and poor farmers. Farmers increasingly have the opportunity to access higher value markets, both domestically and globally, but at the cost of higher standards demanded in terms of the quality, reliability, and volume of the products they supply. This commonly necessitates technology upgrading by producers and marketing intermediaries alike. And as part of these changes, the institutional organization of the agri-food value chains has been transformed to address changes in demand from consumers, trade and investment liberalization, urbanization, and continued rural market imperfections arising from weak physical and institutional infrastructure.

Although this dramatic shift in the industrial organization of food, the most essential of consumer goods in any economy, has substantive implications for the economic development process, it has been widely overlooked by economists. The absence of cross-national data series with which one could test hypotheses also serves as a clear indication of how overlooked the agri-food value chain revolution has been. By now, there is a growing literature describing and analyzing specific aspects of this change and the processes underlying it. In this paper we pull together relevant literatures to begin to tell the story. But this review is as much a call for scholars to engage with this topic across fields as it is an integrative summary of lessons learned thus far. The research agenda on the transformation of agri-food value chains is nearer the beginning of the story than its end.

[5] The spread of modern retail ("supermarkets") in Brazil in one decade (the 1990s) was equivalent to the retail expansion over half a century in the USA (Reardon and Berdegué 2002). Similar rapid expansions of modern retail chains have since occurred in many emerging and developing countries.

In the next section we offer a conceptualization of why and how the agri-food value chain revolution happens. In section 3 we review the empirical evidence on the broad patterns evident in the agri-food value chain transformation within LMICs. Section 4 then reviews the micro-scale empirical evidence on the causes and impacts of these changes within the broader economy. Section 5 then closes by identifying key research opportunities just beyond the current frontier in this space.

2. Conceptualizing the emergence and transformation of value chains

In this section we briefly sketch out a conceptual model of the macro- and sectoral-scale drivers that help drive the agri-food value chain revolution, and of the firm behaviors that reinforce the process endogenously through innovation and integration. We eschew formality here. Developing more formal, dynamic general equilibrium models that capture the features we flag here is an important line for future research. Our present aim is far more modest: to pull together into a brief, coherent narrative the key drivers found in the existing, heavily empirical literature.

2.1 Macro- and sector-scale drivers

Economists have recently begun to return attention to old, Lewis (1954) and Johnston and Mellor (1961) era macroeconomic questions surrounding structural transformation, labor allocation, technology transfer, and agricultural productivity differences across countries (Gollin et al. 2013, Lagakos and Waugh 2013, Adamopolous and Restuccia 2014; Timmer, 2015, Tombe 2015, Restuccia and Rogerson 2017). The macro-scale drivers in these models apply equally to the value chain that intermediates between primary producers in agriculture and final food consumers. An exogenous component to technological change increases the supply of raw agri-food commodities, some of which gets directed consumed, but most of which is feedstock in food manufacturing. Exogenous technological change also lowers unit costs of communications, energy, storage, and transport, and ignites income growth independent of that endogenously induced by changes then arising within the agri-food value chain. Population steadily (and partially exogenously) shifts to urban centers where agglomeration economies further reduce costs and accelerate technological change.

The implications for the agri-food value chain are intuitive and straightforward. Growing incomes fuel increased consumer demand for food, but especially for higher-quality and more varied foods. The income elasticity of demand for non-nutritive attributes – appearance, safety, storability, taste, variety, as well as perceived environmental or social attributes associated with the production process (e.g., Fair Trade, organic) – is much higher than for nutritive attributes (Behrman and Deolalikar 1987, 1989; Bouis and Haddad 1992, Pingali 2007; Jensen and Miller 2008, 2011; Ortega et al. 2011). Indeed, the rapid growth in demand for 'higher quality', broadly defined, has been a major driver of agri-food value chain transformation, as we explain below. So too is the income elasticity of demand for more nutritious, perishable vegetables, fruits, and animal-sourced foods much higher than that for staple cereals, legumes, roots, and tubers.[6] And higher incomes – and the higher wages and salaries that generate those incomes – also increase the opportunity cost of time, fueling consumer demand for food away from home (FAFH) supplied by restaurants and other food service firms, along with prepared and processed foods,

[6] Some economists refer to the relationship between income growth and diversification of diets away from calorie-dense starchy staples as Bennett's Law, following Bennett (1941).

especially frozen and refrigerated products that spare consumers considerable preparation time (Ma et al. 2006; Senauer et al 1986). The endogenous consumer demand response to exogenous income growth thereby creates opportunities for firms to profit through processing, product differentiation, and services provision, as well as by seizing prospective economies of scale and scope. This growth in consumer demand for food in general, and especially for higher value food and food away from home, has been a fundamental growth stimulus for agri-food value chains.

This happens even in rural areas, as farm income growth drives agricultural households to buy an increasing share of the food they consume. For example, rapid real income growth in rural Vietnam drove the median share of agricultural household food expenditures coming from own production (i.e., autoconsumption) down from 53.5 to just 19.7 percent from 1992-2016, as farm output diversification could not keep pace with growth in farm household dietary diversity (Liu et al. 2019). Similarly, in the LMICs of eastern and southern Africa, Tschirley et al.. (2015) show rural households bought 44% (in value terms) of the food they consumed. The share of rural food consumption in value terms that was purchased was found by Reardon (2015) to be 52% in Nepal, 80% in Indonesia and Bangladesh, and 72% in Vietnam.

Urbanization reinforces the effects of exogenous income growth. As the agricultural sector sheds workers and people increasingly move to towns and cities, consumers necessarily live further from the farms that produce most of their food. Spatial intermediation involving long-distance transport, cold storage, preservation, processing, wholesaling and retailing functions grows more important as a result. Urbanization perhaps plays a greater role than many researchers recognize because LMICs are amassing far more and larger urban centers than one finds in today's high-income countries. For example, among the member states of the OECD, only Korea (three), Australia, Japan and the United States (two each) have multiple cities with populations of three million or more people. By contrast, China has more than 30, India 10, Pakistan 5, and Brazil, Egypt, and Nigeria have 3 each. Rural-urban intermediation becomes an especially complex and important task in economies with multiple large concentrations of consumers, which are demonstrably more commonplace in today's LMICs than in high-income economies.

Indeed, because urban incomes typically exceed rural incomes, the center of economic mass in the food industry shifts to urban spaces even while rural areas retain a majority of the population. For example, in Indonesia and Vietnam, 40% of people lived in urban areas, representing 50% of total food consumption and 60% of total market value in 2010 (Reardon and Timmer, 2014). This drives a rise in retail and in food service to meet FAFH demand. Urban populations' higher incomes and greater distance from farmgate also drive far higher demand for processed foods. In east and southern African LMIC countries, urban households dedicate 56% of food expenditures to processed foods, versus just 29% among rural households (Tschirley et al. 2015). In a multi-country study of Asia, Reardon et al. (2015) likewise find that urban households dedicate 73% of food expenditures to processed foods, rural areas, just 60%.

Economic policy naturally plays an important role in the evolution of agri-food value chains. Beginning in the colonial era, many states controlled the purchase and/or sale of agri-food commodities through state-run marketing boards (Barrett and Mutambatsere 2008). Marketing boards with state-sanctioned monopsony or monopoly powers enabled governments to maintain control over the marketing of strategic commodities, such as the food staples and important export crops. Governments typically fixed official producer prices for all controlled commodities, often uniformly across seasons and regions, thereby discouraging, if not expressly prohibiting, private sector investment in agri-food value chain development. Beginning in the

1970s, government throughout the developing world began to relax their control over food marketing systems. Both the extent of liberalization and the effects of the liberalization policies have differed strongly between countries and regions and commodities. Market-oriented reforms are widely believed to have caused some economies to grow rapidly afterwards (e.g., China, Vietnam), other to collapse (e.g., some states of the former Soviet Union), and in others they had mixed effects (Timmer 1986; Barrett 1997; Kherallah et al 2002; Rozelle and Swinnen 2004; Barrett 2008). But everywhere the shift to a market-led agri-food economy created both disruptions and opportunities in agri-food value chains, in particular by intensifying competitive pressures and creating new incentives for firms to improve quality so as to satisfy growing consumer demand. But the cessation of state-sanctioned market power has typically not been replaced with explicit, enforced competition policy in LMIC agri-food value chains, leading to widespread questions about whether private firms now establish and exercise market power that squeezes farmers, consumers, or both (Moser et al. 2009; Dillon and Dambro 2017; Berquist 2017; Casaburi and Reed 2017).

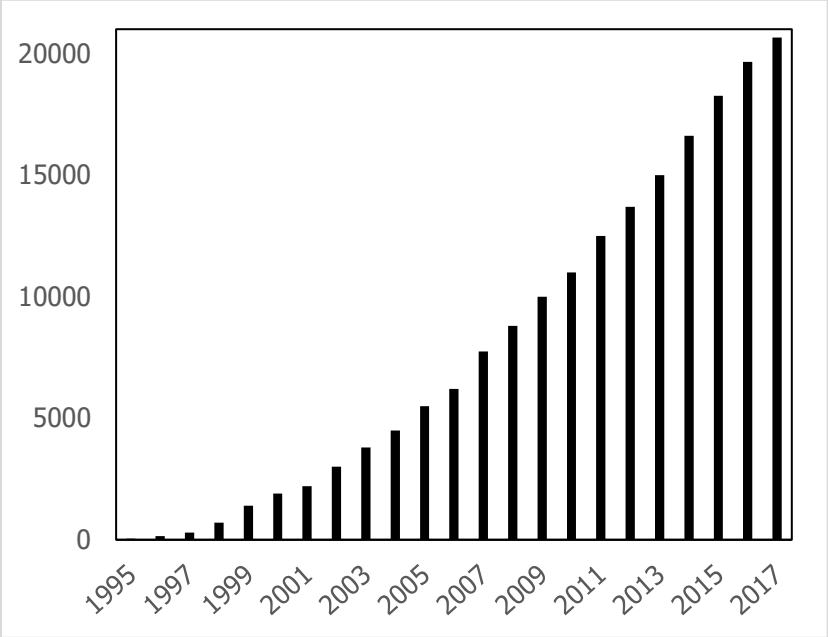
In many countries, market liberalization also entailed opening the economy to foreign investment. Countries such as Argentina, Brazil, Korea, Mexico, and Taiwan nearly completely opened up to foreign investment in the 1980s-90s while other large LMICs, such as China, Indonesia, and South Africa were much slower and others, like India, remain resistant to foreign majority ownership of firms in the agri-food sector. As we describe in the next section, in those places that permitted it, foreign direct investment (FDI) often helped ignite the supermarket revolution by facilitating the inflow not only of scarce financial capital, but perhaps especially importantly, of logistical expertise, successful, proprietary business practices, and agricultural and food processing technologies. The far slower emergence of supermarkets in countries like India, where government regulation has prevented foreign entry into the sector, is at least partly attributable to policy choices around FDI.

The extent of economic integration within the domestic economy and with global markets, through infrastructure, trade, and cross-border financial policies, has especially large impacts by enabling spatial market integration and foreign direct investment, which commonly comes with the transfer of technologies and business practices. As we detail below, domestic value chains are considerably large than global value chains in most LMICs. As a result, infrastructure investments have comparatively large impacts on agri-food value chain development. Whether railroads in India or Malawi (Donaldson 2018; Zant 2018), or roads and bridges in Ethiopia or Mozambique (Minten et al. 2016; Zant 2017), reducing the remoteness of farmers from markets has more of an impact on agricultural commercialization than do macroeconomic or trade policies (Barrett 2008; Stifel et al. 2016).

Accessing increasingly prosperous markets domestically and globally has invariably meant raising product quality and standards. Exporting to high-income countries, in particular, has typically required LMICs to import those markets' food product grades and standards. In the European Union (EU), for example, rising incomes coupled with a series of food scandals in the later 1990s triggered the introduction of the EU Food Safety Law, which imposed much more stringent regulations of food value chains serving EU consumers. In recent years public food standards have also tightened in LMICs such as China and India, especially as new food laws have been enacted to try to enhance food safety, in some cases in response to scandals involving deaths from adulterated or contaminated foods. Food safety and similar laws inevitably have trade implications, some of them reflected in states' use of sanitary and phytosanitary standards (SPS) as nontariff barriers to trade. Figure 2 illustrates the rapid growth of public standards in

global food trade as reflected in SPS notifications at the World Trade Organization, from a few hundred per year in the mid-1990s to around 20,000 by 2017. While such standards were dominated by high-income countries earlier, in recent years they come increasingly from LMICs (Zezza et al 2018).

Figure 2: SPS notifications at the WTO (total) 1995-2017



Source: WTO SPS Information Management System

Food safety laws typically evolve relatively slowly, most commonly reactively in response to high-profile scandals or scares. As we discuss below, private standards typically evolve faster and bind before public standards, responding to and creating profit opportunities for suppliers of standards-compliant products. These market segments can also, however, entail considerable risk of catastrophic market loss due to exogenous changes in standards, trade disputes, or an unanticipated shift in distant consumers' tastes (Ashraf et al. 2009; Maertens and Swinnen 2009; Harou et al. 2017). These opportunities underscore the need to understand agri-food value chain firms' strategies, to which we now turn.

2.2 Microeconomics of agri-food value chain transformation: Innovation in pursuit of profits

Schultz (1975) distinguished between traditional rural societies which are in equilibrium with low rates of technological change and low levels of agricultural productivity, and modern societies characterized by high rates of technological change and productivity, which therefore frequently find themselves in disequilibrium. The agri-food value chain transformation is characterized by high rates of innovation and considerable disequilibrium as the macro- and sector-scale drivers just discussed expand agri-food production and exchange beyond the farming household (Polopolus, 1982) and spark the emergence of agribusinesses serving producers and food industries serving consumers, each characterized and connected by complex value chains (Boehlje, 1999). The key engine of this transformation is a constellation of private firms seeking profits through innovation based on new technologies, new business practices, and

new markets. Shifting competitive pressures induce dynamism as firms seek at least temporary competitive advantage and, if possible, market power to maximize profits.

In this sub-section we aim to conceptually connect several literatures that offer useful insights on the transformation of the industrial organization of the agri-food system over the development process. We first introduce a schematic framework of the supply chain, rooting it in the process of innovation, and conclude with consumer choice among evolving alternative goods and services. Along the way, we will consider three distinct bodies of work. First comes the economics of innovation and technology transfer that characterizes the value chain transformation. Second, the economics of supply chains that implement innovations covers issues of market structure, institutional arrangements including vertical integration and contracting, and the impact of various policies on the evolution and performance of supply chains. Third, we get to the literature on the diffusion of innovations. We necessarily move briskly and informally as we use this conceptual framework to lay out several key, empirically testable hypotheses about the process of agri-food value chain transformation that will guide our review of empirical findings in the next section.

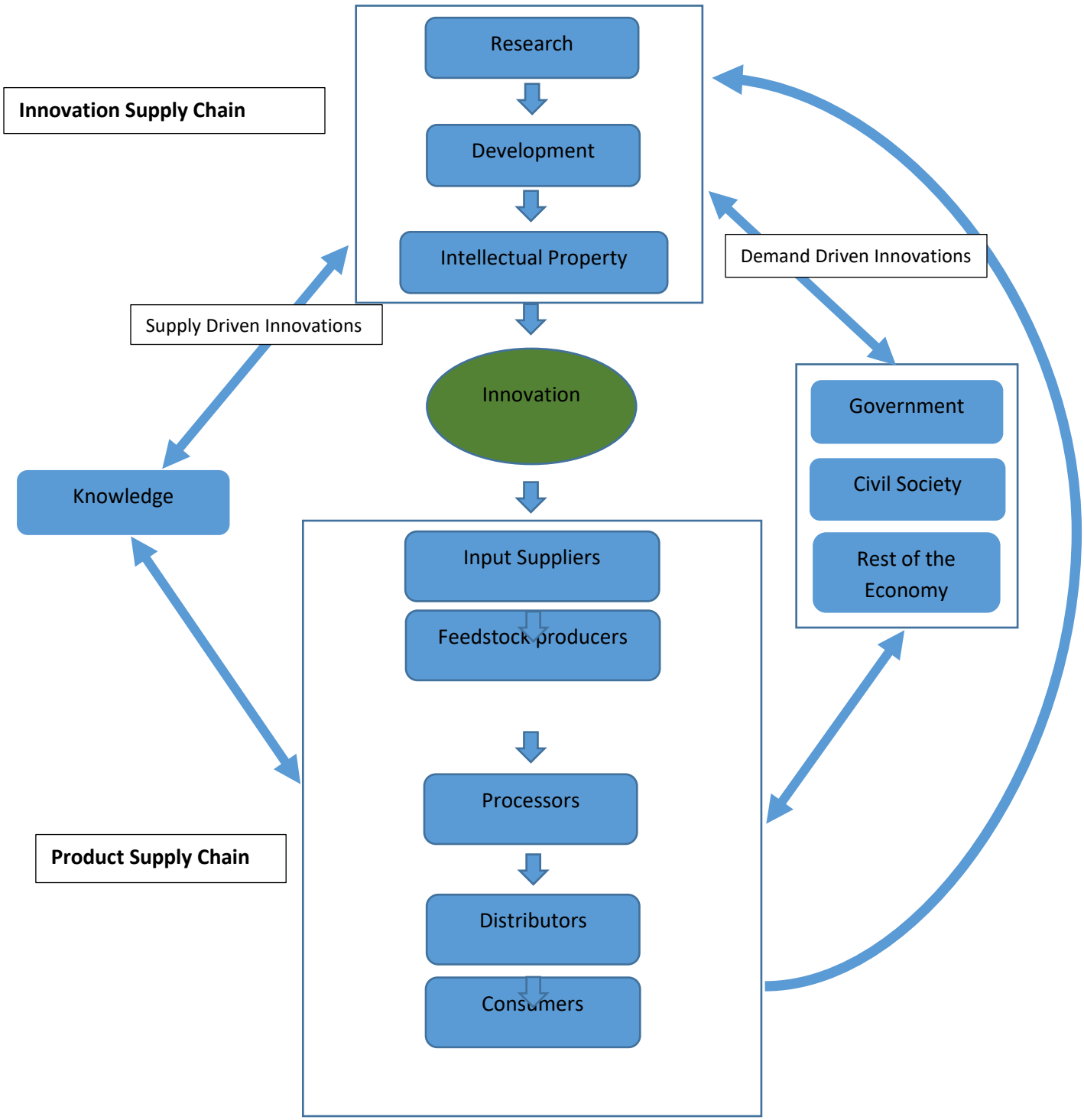
2.2.1 Innovation and product supply chains

Schumpeter viewed innovations as new ways of doing things, which may include new products or services, new technologies or locations of production, new uses of existing products or services, and new modes of organizing people or groups of people (i.e., management practices and institutional arrangements). The literature on innovations distinguishes between innovations embodied in products versus disembodied innovations that may include management practices or even institutions (Sunding and Zilberman, 2001). The literature recognizes multiple stages of evolution, from the basic concepts and ideas that lead to innovation, then to the utilization of the manifestation of the innovation, whether in a product or a service. This evolution from innovation to product may be the result of interactions – e.g., nested feedback loops (Etzkowitz and Zhou 2017) – between the public sector (e.g., multilateral organizations and governments, including public universities and national agricultural research organizations), private and public not-for-profits (e.g., universities), and the for-profit private sector. While acknowledging the important role played by motives other than profit, financial gains indisputably play an important role in guiding the innovation process and thus in the transformation of agri-food value chains. Public and private research in agri-food systems are commonly complementary and thus co-evolve (Alston et al. 2009). Especially given the symbiotic relationship between private firm and public researchers, the interests of private sector actors within the agri-food value chain – input suppliers, farmers, processors, grocers, restaurant chains, etc. – will commonly dominate in public policy deliberations as the sector develops, and innovation proceeds. This is an important mechanism behind the 'development paradox', the observation that low-income agrarian nations commonly impose net taxes on agriculture while higher-income, post-agrarian nations commonly provide net subsidies (Krueger et al. 1988; Anderson 2009; Timmer 2015).

Figure 3 offers a simple schematic flow of the evolution of innovation and products for agri-food systems. This is one among multiple plausible and similar forms of evolution. The key is that we distinguish between the innovation supply chain, which creates innovations through processes of research and development that generate new intellectual property – and thus influenced by policies and practices related to intellectual property rights (IPR), such as patenting, trademarks, trade secrets, etc. – and the transformation of basic ideas into implementable innovations within the product supply chain. Frequently, innovation arises

through basic and applied science that involves combinations of public research and private development activities. In the high-income countries, this is commonly the "educational-industrial complex"; in LMICs the university sector has only occasionally been a locus of such discovery. But once an innovation is well-defined, it is most commonly implemented through a

Figure 3: Innovation and Product Supply Chain and Innovation Creation



product or service supply chain operated by a for-profit private sector organization. This is no less true in the agri-food value chain than in manufacturing, services, or other sectors, like information and communications technologies or pharmaceuticals and biomedical services, on which so much of the innovation and IPR literatures focus.

The stylized product supply chain includes several stages. First, input suppliers who provide seed, fertilizers, etc., then feedstock producers which may include heterogeneous farmers, who produce raw agricultural products that are feedstock for processors and distributors, which provide products to the final consumers, who are as or more heterogeneous than feedstock producers. This heterogeneity becomes important in thinking about selection mechanisms that lead to non-random participation in agri-food value chains, adoption of new technologies, purchase of specific commodities, etc. The activities of both the innovation and product supply chains are affected by government and civil society's policies and actions, signals from the rest of the economy, and general knowledge. Many, although certainly not all, technological and institutional innovations are induced by changing economic incentives (Hayami and Ruttan, 1971; Ruttan, 2000). Here, we distinguish between supply-driven innovations that are the result of application of new knowledge or utilization of new technology (e.g., computers, gene sequencing, standardized shipping containers) versus various forms of demand-driven technologies that may result from initiatives by government, civil society, the changing needs of farmers and other players in the product supply chain, or shifts in final consumer demand in response to income growth, urbanization, changing work patterns, etc. Obviously, the product supply chain is affected by knowledge, as well as the actions of government, civil society, and the rest of the economy. Much of the literature that we survey below is built on the interaction between policy, the economy, technology, and the product and innovation supply chains.

In traditional societies, most innovations were developed by practitioners and the input supply, feedstock production, processing and distribution functions were commonly collapsed with consumption in home-based, autarkic production. In modern societies, as actors specialize and begin to integrate through exchange mechanisms as market participation frictions decline (Gollin et al. 2004), a growing share of the innovations derive from scientific knowledge and may be induced by demand or supply factors (Hayami and Ruttan, 1971; Ruttan, 2000). The evolving literature on innovation in agriculture suggests that many economic factors influence the direction of the innovation, in terms of whether it reduces costs by saving inputs such as capital, land, or labor, or if it expands output holding inputs constant, or enhances a certain product quality: prices of final outputs, scarcity of inputs, cost of alternative lines of research, uncertainties about prices, costs, and technological feasibility, political economy considerations that influence public research spending, etc. (Sunding and Zilberman, 2001; Alston et al. 2009; Rausser et al. 2011). Schultz (1964) emphasized the importance of research leading to innovation as a key element of improved productivity in agriculture, and Jorgenson (2011) provides an overview of recent methods and findings on the contributions of innovations to overall productivity of agriculture. This is no less true of the post-harvest value chain than it is of production agriculture.

In LMICs, where capital access limits investment, the private sector share in overall research is relatively small, thus the public sector tends to carry the lion's share of research, development, and extension. These public institutions often established innovation supply chains, conducting much of the research to develop new agricultural technologies, including post-harvest processing methods, most visibly manifest in the Green Revolution (Evenson and Gollin 2003). National agricultural research organizations and pubic extension services are

typically responsible for adaptive research and the transfer of technologies to farmers and to small-and-medium-sized enterprises (SMEs) within LMICs. Foreign donors and multilateral organizations are key investors in innovation in developing countries. Political economy considerations suggest that their preferences have a strong impact on the evolution of value chains in these countries, for example leading to restricted research on development of transgenic crops varieties in Africa (Herring and Paarlberg, 2016). However, as economies grow, investible capital emerges, and a critical mass of commercial consumers emerge, private sector research and extension increases, slowly at first and then sharply as economies move through the middle-income range, especially with adequate complementary government investments, as has occurred in Brazil, China, or India, for example (Pardey et al, 2016). The growing importance of the private sector in agricultural innovation in developing countries almost surely affects the innovation mix within the agri-food value chain. Once the innovations are established, SMEs and large firms implement the innovations by establishing a supply chain.

2.2.2 The economics of supply chains

A supply chain is a system of organizations that produces and distributes goods and services.[7] Supply chains are commonly established precisely to implement innovations, broadly defined to include entering new markets. The innovation may be mechanical (e.g., a new tractor), biological (a new type of crop), agronomic (starting to produce roses in Kenya), or economic (entering a new market for an established product). A supply chain to produce final food products may consist of multiple stages and may be controlled by one firm or many firms. Coase (1937) argued that the extent to which firms decide to control certain stages of production processes within the firm or to rely on markets turns on economic considerations, especially transaction costs. Williamson (1979) expanded the range of institutions that govern the transactions associated with implementations of various tasks and a supply chain to include contracts and other mechanisms that allow to address multiple contingencies. While there has been a rich literature on designing contracts between parties within a supply chain, the literature on designing agri-food supply chains that determine the scale of operations and to what extent it relies on external or internal supply of inputs, as well as its implications for market structure has been rather recent.

Zilberman et al. (2017) argue that entrepreneurs that control innovation design the supply chain to maximize their expected economic benefits (profits, expected utility, or net present value). A key feature of supply chain design is that it may require introducing new markets, so innovative firms do not necessarily take markets as given but instead create new ones if profitable opportunities exist. For example, innovators that introduce a new type of food (e.g., pre-cut, pre-washed salad) establish a market for this product and for the feedstocks (various types of vegetables) needed to produce the salad. The innovator may decide to vertically integrate and produce the vegetables directly, or may vertically coordinate by contracting with a feedstock producer instead, or simply buy from feedstock producers on the spot market. But the innovator has significant, if likely transitory, market power in this new market.

Supply chains may have multiple components, but a minimal supply chain has two segments: upstream (production of feedstock, e.g., raw agricultural commodities) and downstream (processing and marketing to generate a final product for consumers). Consider innovators that specialize in agri-food processing and marketing, for example, entrepreneurs that

[7] Frequently, "supply chain" and "value chain" are used interchangeably. According to Tan (2001), the supply chain is the entire system, and the value chain is the portion of the supply chain that adds value to the organization.

start to produce biofuels from sugarcane or to produce and market flowers from Kenya to Europe. As formalized by Du et al (2016), the decision-making framework for a firm that controls a simple two-stage supply chain to implement an innovation. Their analysis reduces the complexity in Figure 3 to two elements: feedstock production (e.g., farmers) and downstream processing (e.g., distributors) who sell to consumers. The firm then solves a supply chain optimization problem by choosing the optimal scale of operation, and the extent to which it makes or buys the feedstock. i.e., the extent it vertically integrate upstream or coordinate through contract farming or similar arrangements. This analysis can be extended to determine the extent a firm makes or buys processing and retailing – i.e., to vertically integrate manufacturing and distribution or to outsource or contract downstream. In this approach, a firm may choose a mix of internal production of feedstock and external contracting based on variation in the costs of production among prospective suppliers and on its market power, if any rather than a corner solution of complete vertical integration or of pure contracting – e.g., a franchise-only model such as that of Subway, the largest global restaurant chain by store fronts. The analysis shows that the relative reliance on outside suppliers of feedstocks is increasing when the firm has a relative disadvantage in producing the feedstock, when outside suppliers are reliable, and when the firm encounters credit constraints. The importance of vertical integration is likely to increase when suppliers may cause IPR or reliability risks. When credit constraints are significant, firms' reliance on an external provider of feedstock is likely to increase the scale of operation. The scale of operation may be smaller if the firm faces inelastic demand in the final product market or among the suppliers, and an innovative firm will take advantage of their market power in both the input and output markets.

The demand for and the cost of processing the feedstock downstream and producing it upstream affect the overall volume and quality of final output. Thus, as demand grows – due to exogenous income growth, reduced trade frictions domestically or internationally, etc. – so does both the output and quality of the final product increase. Similar quantity expansion arises from changes that reduce the cost of activities downstream (e.g., infrastructure that reduces processing or transport costs) or of production upstream (e.g., new crop or livestock production technologies, the introduction of irrigation). But it is also true that enterprises that introduce new innovations and enjoy temporary market power initially produce less output overall than would occur under perfect competition and/or use fewer inputs overall, reflecting profit maximization in the presence of sell- and/or buy-side market power. This extra profit is the compensation for the entrepreneurial effort.

Zilberman et al. (2017) also emphasize the role of dynamics and learning. A firm may begin a supply chain under one format, but subject to uncertainty about the innovation, and then may change as it learns by doing, as others learn by observation, or in response to exogenous changes to key macro- or sectoral drivers of the supply chain optimization solution. For example, if external producers lack sufficient knowledge to produce it in reliable volume and quality innovators may be compelled to produce feedstock in house initially, or rely on traditional suppliers if it is a multinational firm investing in a developing country, but as employees of local firms learn the method, they become external producers under contract. Along these lines, one popular type of structure between processors and external providers of feedstock is a nucleus-plasma structure (D'Silva et al, 2009), where the relatively large facility that processes feedstocks produces some of it, but also provides guidance and support to external producers.

Zilberman et al (2017) also argue that over time, innovations diffuse through networks and other companies enter the spaces associated with the new innovations, thereby dissipating

profits and transitioning the market to more perfectly or monopolistically competitive states. Profit-seeking firms look for new innovations to gain cost or quality advantages or to seize temporary market power so as to restore extraordinary profits. Altogether, the process of innovation leads to market structure that evolves over time.

More generally, supply chains tend to have multiple levels of operations (upstream, midstream, downstream), not just the simple two stages enumerated above. So firms have to determine not only decisions about the diversification of sources of feedstock, but also diversification of output delivery. The result is that the structure of the agri-food value chain depends on context-specific factors, that a satisfactorily general theory generates no clear prediction of a sequence of supply chain organizational forms.

This conceptual framework can be expanded to incorporate many of the insights of the literature on organizations and supply chains. Williamson (1981) emphasized the cognitive limitations of decision makers and the importance of bounded rationality and simplifying arrangements in the design of supply chains. He also emphasized that supply chains have to be designed to protect against opportunistic behavior, and in particular, the nature of transaction. For example, if introduction of new technology requires a feedstock producer to invest in specialized assets that can only be used for products that benefit the processor, then the arrangement between the two may be a long term contract or vertical integration so as to obviate hold up problems. On the other hand, when a feedstock supplier is using exchangeable products, then it can rely on markets. Uncertainty about opportunistic behavior on the one hand leads to the establishment of collaborative networks for repeated transactions that are based on trust, as well as monitoring and enforcement mechanisms, taking into account specifics of the technologies of different segments of the supply chain and sources of uncertainty it faces (Platteau 1994a,b, Fafchamps 2003, Greif 2006, Gereffi et al 2005) develop a systematic framework to assess global supply chains, identifying distinguishing features between supply- and demand-led supply chains, distinguishing between different elements of transaction costs, and their impact on system design. They find that the complexity of transactions, the transparency of information, and the capability of different segments of the supply chain will affect its design, resulting in several different types of supply chains, from market-based supply chains with very low switching costs for all parties to a vertically integrated system.

Swinnen and Kuijpers (2017) argue that especially in the context of agriculture, the design of supply chains depends on the nature of innovation (whether it is a new product or a new process), who the entrepreneur behind it is, and credit conditions. They also emphasize that analysis of supply chains has to study in parallel the transaction of real products from upstream to downstream, as well as monetary transactions across a system, since credit constraints are a crucial consideration that affect supply chain design. They also emphasize the importance of supply chain structure in adoption of new technologies, especially at the farm level. A key element of any supply chain is that it evolves over time and expands in terms of product differentiation and in particular to take into account heterogeneity in upstream producers and downstream consumers, in terms of both socioeconomic variables as well as location. The economic literature on diffusion can help us to address the evolution of supply chain over space and time.

Some value chain arrangements are rather loose arrangements while others involve intensive vertical coordination that come very close to complete ownership integration with subcontractors operating more as workers than as independent entrepreneurs. Some contracts are initiated by downstream buyers such as processing companies, slaughterhouses, or supermarkets,

while others are initiated by upstream suppliers such as feed milling companies, or by farmers themselves, perhaps organized in farmer groups or cooperatives. Some contracting arrangements are rather basic, involving two contracting parties at successive stages in the chain, while other value chain structures are more complex, linking multiple stages in the chain and involving multi-stakeholder agreements and partnerships.

2.2.3 Diffusion and spread of innovation over space and time

Successful innovations – and even some unsuccessful ones – may start in one location, or with one or a small group of agents, but over time will spread to new agents and places. One way to understand this spread is to incorporate it within a threshold model of diffusion. Traditionally, the diffusion of innovations was modelled as an imitation process (Rogers 1995). But this approach lacks an economic mechanism, so an alternative, perhaps complementary, threshold approach has emerged (Zilberman et al. 2012). This model has three components: individual adoption behaviors, heterogeneity among individuals, and dynamic learning processes. Individual adoption decision making may have several stages – e.g., awareness, assessment, and decision re-evaluation – with learning from the behaviors and experiences of peers or of technology promoters (e.g., extension or marketing agents) major contributors to awareness (Foster and Rosenzweig 1995; Conley and Udry 2010). The assessment and decision re-evaluation phases of learning may also benefit from learning by doing among those who choose to adopt; learning may differ among these distinct objects (Hanna et al. 2014; Nourani 2019; Barrett et al. 2019). Individual decision makers follow a decision rule subject to their information and constraints, including fixed, nontradable factors of production (e.g., distance from a market center, availability of water, climate). Adoption rates vary over each period of time because of the multi-dimensional heterogeneity among prospective adopters of the innovation. For example, adoption of irrigation technology is more likely in regions that have high water prices and by farmers that are better off. Network externalities and social influences, beyond just learning about the returns to the innovation, may influence adoption over time as well (Rogers 1995; Moser and Barrett 2006; Young 2009; Maertens 2017; BenYishay and Mobarak 2018).

This all leads to an S-shaped diffusion curve, thus to some periods during which there is rapid behavioral change during which system transformation becomes more readily observable. For example, because of heterogeneity, introduction of new equipment (e.g., tractors) may be slow in the beginning, but during a period of takeoff, suddenly the diffusion rate increases drastically, which results in observable transformation, as has been seen in China and Vietnam in recent years (Zhang et al. 2017, Liu et al. 2019). Olmstead and Rhode (1995) recognized that when technologies are embodied in a product and are indivisible, part of the adoption will be by larger units that have sufficient scale, while others will adopt the services provided by the technology through rental services. Lu et al. (2016) suggest that in this case, marketing of the technology may change through the diffusion process, with emphasis on rental services in the beginning and sale of equipment later on. Furthermore, part of the innovation is developing different products for different scales of operations, and the introduction of the technology itself may affect the farm size distribution, perhaps driving out some small farmers.

Much of the empirical literature on adoption aims to identify the sources of heterogeneity among individuals and key factors that affect adoption in different times. The early survey of Feder et al. (1985) emphasized the important roles of risk, risk aversion, and access to credit. The more recent survey by Foster and Rosenzweig (2010) presents findings on the importance of

finance, insurance, social learning, economics of scale, and social norms and behavioral anomalies. Acemoglu et al. (2007) show the importance of contract design in affecting adoption of technologies, with significant implications for the management of supply chains. So the literature on the economics of supply chain design borrowed from the marketing literature (Mahajan et al, 1990) and emphasized that firms that introduce innovations take into account adoption behaviour of their potential customers, be them consumers or producers. Firms determine their expansion plan over space and time, accounting for heterogeneity among locations, as well as dynamic processes of learning (Zilberman et al., 2017). They may introduce a technology and build a supply chain to implement it in locations where it is most beneficial initially, then expand to other locations over time, as they refine and adapt the innovation. Furthermore, heterogeneity among consumers may lead firms to develop differentiated products that target different market segments.

Lu and Reardon (2018) develop a modeling framework that demonstrates how the introduction of new forms of food retail may spread over space and time, moving from locations where the technology is most favorable to other locations. This literature suggests that technology may also evolve at locations where it started, but over time, the main change is the diffusion of innovations over space and among the population within the initial location(s). Introduction of a new technology in developing countries through foreign direct investment or establishing a franchise is a gradual process. Zilberman et al. (2017) suggest that the firms that control a technology may initially export feedstock to the new market and rely on existing suppliers while at the same time developing local producers that will allow further expansion. The capacity to transfer feedstock production and processing depends on the availability of human capital, infrastructure, and incentives to invest in the development of local capacity or to restrict local ownership.

2.2.4 The welfare implications of value chain transformation

This conceptual microeconomic framework of firm decisions around innovation, supply chain design, and the resulting diffusion of innovations – involving the introduction of new production or processing technologies, new forms of organizing the supply chain, and entry into new markets – provides a starting point for empirical analysis of the agri-food value chain transformation occurring throughout the developing world. Key hypotheses revolve around the emergence and spread of modern supply chains – with greater value addition to turn raw commodities into final consumer products, increased attention to the logistics of intermediation between feedstock suppliers and food consumers, more firms tapping into economies of scope and scale where they exist, increased product differentiation and quality upgrading, and rapid change in the competitiveness (or, conversely, market power) of markets over time.

Firms continuously search for new innovations to generate new sources of profit as product and process innovations diffuse to competitors, squeezing margins for the original innovators. The evolution of technology over time through continuous innovation and research and the expansion of demand through marketing, word of mouth, learning by using, and macro factors like increased income lead to patterns of behavior that are consistent and expand Vernon's (1992) international product life cycle theory. Innovations commonly launch in niche markets where consumer demand suffices to cover the higher unit costs of initial production. As the technology improves and becomes less costly and as the capacity to absorb the output of the supply chain improves, the market expands. Food and agricultural supply chains enter LMICs in

response to changes in economic policy (e.g., reduction of trade barriers), as their economy grows, and as urbanization drives consumers further from commodity growers.

The diffusion of technologies over space increases when communications, transport and other costs of intermediation fall – often themselves due to innovations in third party logistics (e.g., cooling or storage technologies) – integration into the broader economy accelerates and competitive pressures grow (Atkin and Donaldson 2015). The introduction of innovations thereby prompts endogenous reorganization of supply chains.

Much of the gain from introducing innovations to developing countries will accrue to users of products based on the innovation, be they farmers or consumers (Just, Hueth, and Schmitz 2008). Some of the gains may accrue to feedstock suppliers (i.e., farmers), but farmers not integrated into the supply chain for the innovation may lose out. The introduction of an innovation may increase labor demand, either in production of feedstocks or processes, which can stimulate earnings gains for workers. Final consumers typically gain as innovations in food products expand aggregate supply in the face of relatively price inelastic food demand, thereby generating lower real food prices (Cochrane 1958; Evenson and Gollin 2003).

Another thread of predictions from this conceptual framework revolves around the gains from participation in emergent agri-food value chains and the challenges of cleanly identifying those gains empirically. The considerable heterogeneity in the conditional returns to adoption of a new technology, entry into a new market, or purchase of a new product, means that selection and placement effects exist at each stage of the supply chain. The non-random nature of participation in value chain innovations makes it important both to understand the sources of this heterogeneity, as a way of targeting likely beneficiaries from new innovations, and to control for those non-random effects in estimating the returns to new technologies, contracting opportunities, etc. (Barrett et al. 2012, Bellemare and Bloem 2018). It also puts a premium on existing networks of exchange that facilitate the diffusion of innovations, whether through vertical integration or long-term contracting relationships, especially given the inevitably incomplete nature of contracts (Antràs 2003, 2005; Acemoglu et al. 2007).

Finally, the importance of disequilibrium periods of transition loom large (Schultz 1975). Firms routinely seek extraordinary profit opportunities that come from even transitory market power. And not all suppliers, workers, or consumers are equally adept at dealing with the disequilibrium that routinely arises from an increasing pace of innovation. But disequilibrium poses considerable analytical challenges, as workhorse models tend to rely on competitive market closure rules. Even building in nonconvexities associated with nontrivial fixed costs of market entry poses challenges, although these can have first-order effects in economies characterized by a range of market imperfections (Romer 1994), as is typically true of LMIC agri-food systems.

3. Challenges and approaches in empirical agri-food value chain transformation research

Before summarizing the empirical literature on the agri-food value chain transformation, we offer a few general observations on the general state of this body of research. The literature has appeared primarily in agricultural economics journals thus far. But important, recent contributions exist in development economics and more mainstream economics journals. But the latter papers have typically focused very narrowly on specific phenomena and not linked to the broader sweep of the literature. So there is a need for integration; hence this review paper.

We must also emphasize that this literature has faced multiple challenges in documenting the patterns and testing the hypotheses just described conceptually. As a result, opportunities abound to firm up our empirical understanding of agri-food value chain transformations and their broader economic – and environmental, health, and other – implications.

The first challenge is a formidable one: the dearth of suitable micro-scale data. The large-scale, nationally-representative household data sets – such as those from the World Bank's Living Standards Measurement Study (LSMS) or the Demographic and Health Surveys (DHS) – that have become workhorses in empirical development economics research are ill-suited to explore the agri-food value chain transformation for one fundamental reason. The primary reason? They miss commercial enterprises, by design, picking up only household-based, largely informal enterprises. And even the household data typically lack detailed information on contracting, much less linked data between buyers and sellers. So large chunks of the value chain are omitted and the links that connect agents in the value chain are routinely unobservable.

So too do national enterprise surveys suffer fatal lacunae. Because of the sampling frame construction, enterprise surveys typically miss much of the informal sector, which can be massive in LMIC agri-food value chains. For those countries where large enterprise surveys are available, farms and households that are included are typically strongly biased towards larger enterprises as they are the only ones with formal accounting, and such surveys are often limited to higher-income economies.[8] So high quality, large-scale, nationally representative micro data have severely limited researchers' ability to study this phenomenon.

Meanwhile, national aggregate data, such as those routinely made available through the Food and Agriculture Organization of the United Nations (FAO), rely on official data of often questionable quality (Jerven 2013), and typically lack essential indicators and control variables. The macro-scale data really only lend themselves to description of broad patterns.

For these reasons, the early literature was mostly empirical and observational, based on business and value chain case studies. This was then complemented with specifically designed surveys. These studies focused on specific commodity supply chains, commodities, countries and/or specific aspects of the value chain (e.g., the emergence, the restructuring, the impact, etc.), making comparative analyses difficult because of the variation of multiple variables across value chains. Examples include Reardon et al. (2003) from Latin America; Demmler et al (2017) and Minten et al (2009) from Africa; Dries et al (2009) and Gow et al (2000) from Eastern Europe; Minten et al (2012) and Reardon et al (2012) from Asia; and Barrett et al (2012) across multiple continents.

Moreover, these special purpose surveys were typically built on purposively sampled units prone to biases due to placement and selection effects. For example, many empirical papers in this literature rely on surveys of just the region where a supermarket contracts for produce – thereby subject to non-random placement effects – or just the participants in a value chain, as compared to the (non-random) non-participants, with limited or no credible strategy for resolving selection effects, especially where these are based on unobservables such as social network connections, reputation, skill, or charisma. Such surveys also typically look at just a single sub-sector chain (i.e., one commodity) within the broader agri-food sector, raising important questions of external validity even within that country's agri-food sector. The multi-sub-sector study by Narayanan (2014), for example, establishes how much the contracting arrangements

[8] See, for example, Garrone and Swinnen (2018) who use Bureau van Dijck company-level data to measure the distribution and volatility of mark-ups along the agri-food value chains for EU countries.

and average treatment effects on farmer incomes, etc. can vary across commodities even within the same region of a single country.

Most of these surveys are simple cross-sectional surveys, with recall data at best. The combination of cross-section surveys and case studies has yielded important descriptive documentation but with obvious limits in terms of causal inference. In recent years a series of attempts have been made to improve the methodologies for identifying causality. One approach was the use of panel data and of stacked surveys that sample each segment of a value chain so as to explicitly capture the links among distinct agents (e.g., Michelson 2013; Van Herck and Swinnen 2015; Van den Broeck et al 2018; Burkitbayeva et al 2019). These are important innovations, but still uncommon and rely entirely on observational data subject to lots of statistical endogeneity.

Less commonly and more recently, studies using randomized controlled trials (RCTs) – a methodology which has swept through development economics over the past generation – and exploiting natural experiments have provided new insights on the causal impacts of modern value chains in developing countries (e.g., Ashraf et al. 2009, Saenger et al. 2014, Bergquist 2017, Casaburi and Reed 2017, Burke et al. 2018). These studies have typically focused on specific aspects of value chain development but it is very difficult, if not impossible, to use RCTs to address "the bigger questions" occurring at sectoral level. Further, natural worries arise about the representativeness of the (very few) firms or NGOs willing to implement (and fully comply with) an RCT design in a real value chain (Barrett and Carter 2010, Usmani et al. 2018). A related literature has exploited natural experiments to identify how changes in agri-food value chains affect behavior and welfare (e.g., Jensen 2007, Aker 2010, Goyal 2010, Saenger et al. 2014, Casaburi and Macchiavello 2015, Macchiavello and Morjaria 2015, Atkin et al. 2018). This more recent literature has stronger claims to credible causal identification but has largely been narrowly focused on establishing the relevance of particular value chain mechanisms (e.g., reputation, trust, information, credit) or the veracity of specific outcomes (e.g., farmer income gains from contracting). The identification-oriented literature remains silent on the crucial connections between changes in the macro- and sector-scale drivers enumerated above to shifts in firm behaviors, labor conditions within the value chain, or the well-being of farmers upstream or consumers downstream. The recent literature accretes useful observations of very specific links within the value chain. But empirically well-identified, integrative perspectives have thus far remained elusive.

Much as in the broader development economics literature, a few countries have had influence in the literature far beyond their relative population or market size. The agri-food value chains literature has been especially concentrated in places like China, Ethiopia, Ghana, India, Indonesia, Kenya, Madagascar, Malawi, and Senegal, where good research infrastructure has facilitated much useful work. The generalizability of patterns revealed from specific places remains an open question.

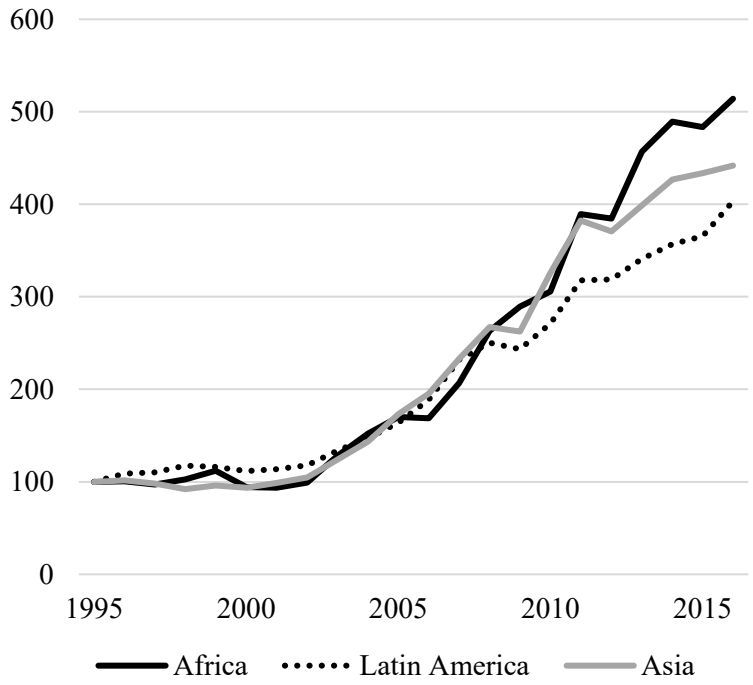
In summary, the empirical literature has clearly evolved, from being dominated by case studies, to cross-section surveys, to a combination of panel data, RCTs and natural experiments-based studies. The combination of these has yielded increasingly better and detailed insights on the processes and effects of value chain developments. But there remains much room for improvement in empirical research in this field to enhance our insights, especially around key impacts we detail below.

4. Empirical observations on patterns of agri-food value chain transformation

4.1 Global and domestic value chains transformation

A broader literature on global value chains (GVCs) and its relationship with trade and productivity has developed in parallel to the agri-food value chain literature on which we focus, with important insights for agri-food value chains (e.g. Antras and Helpman, 2004; Gereffi et al. 2005; Goldberg et al 2010; Antras et al 2017). GVCs increasingly matter because of rapid growth of agricultural trade over the past few decades, especially since the 1994 conclusion of the Uruguay Round Agreement on Agriculture under the World Trade Organization (WTO). Agri-food sector participation in GVCs has increased as a share of agricultural output, with growing diversity of suppliers, especially from LMICs, and the rise of China as a key GVC hub within the sector (Greenville et al. 2019b). That growth has been strongest in sub-sectors where product standards are most important, i.e., in higher value sectors such as fruits, vegetables, seafood, fish, meat and dairy products. In Asia and Latin America, such high-value exports increased from around 20% of agricultural exports in the 1980s to around 40% in more recent years (Maertens and Swinnen 2015). As an example, Figure 4 illustrates the rapid growth of fruit and vegetable exports from LMICs. The value of exports increased four-to-five-fold, in current value terms, in twenty years. The increased trade in fresh food products such as fruits, vegetables, meat and dairy products – which require cold chains and are both prone to food safety risks and subject to specific quality demands by consumers – have increased the need to regulate trade through standards.

Figure 4: Fruit and Vegetable Exports from Africa, Asia and Latin America, 1995-2016 (Current USD value, Indexed 1995=100)



Source: FAOStat

The rapid export growth of some commodities notwithstanding, domestic value chains still represent the dominant share of agricultural output for most LMICs. Globally, 23% of the food produced for human consumption is traded (d'Odorico et al. 2014). Relative to most manufactured goods and non-food commodities, most food is low value-to-weight and perishable, so localized, intra-national value chains are more important in terms of throughput volumes, even if international trade provides a reference price that stabilizes domestic markets against volatility. Even the great majority of processed foods are not internationally traded, but manufactured in the country in which they are consumed. Storable grains are more widely traded than commodities further up the value ladder because grains can be shipped relatively cheaply in bulk without refrigeration. The internationally traded shares of total output can be high for particular products such as cocoa, coffee, rubber, or tea. But agricultural exports via global value chains are quite concentrated in several countries within each region, and in the countries in which agricultural exports are concentrated, those exports are further quite concentrated in only several products (e.g., oranges or soy in Brazil, bananas or coffee in Colombia). For those products and within those sub-sectors global trade is very important. However, even for the countries in which most of the exports are concentrated, the share of exports in total output is still quite modest, especially for low-income countries. But domestic value chains supply the great majority (usually around 80-90%) of food in developing countries.

Reardon et al. (2019) show several very interesting points. First, in the 43 years from 1970-2013, total food supply in Africa, Asia and Latin America and the Caribbean (LAC) grew almost four-fold, from about 1.3 to 5 billion tons. This far outpaced population growth, which grew roughly 2.5-fold, from 2.6 to 6.5 billion. The trends did not differ much over the three regions.

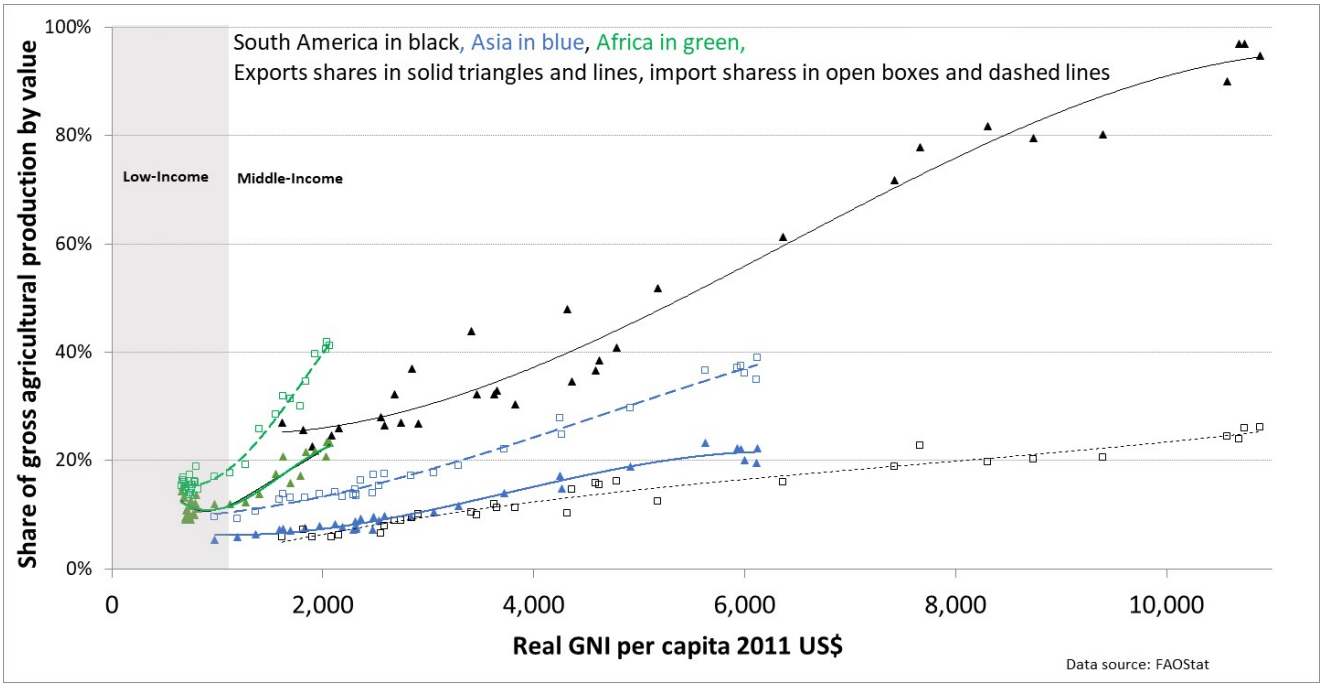
Second, imports as a share of food supply (net of exports) has risen, but still represents a small share. In Africa, tons of imports rose 11 times over the 43 years – and constituted from 7% to 21% of consumption by disappearance. In Asia, imports grew 7 times and went from 9% to 18% of total consumed tons. In LAC, imports rose 7 times but again remain a small share, increasing only from 3% to 9%.

Third, agricultural exports, while often important in policy debates, are relatively small compared with the domestic food system. In Africa, these reached only about 7% of the level of domestic consumption; in Asia, 10%; in Latin America, 22%. Indeed, the common narrative of LMICs as agricultural exporters is largely incorrect. Of the three continent-scale LMIC regions, only South America is a net exporter of agri-food products. As shown in Figure 5, within the (shaded) low-income range, gross imports and exports are consistently less than 20% of domestic agricultural production, even in value terms. It is therefore important to focus not just on global value chains and trade but also on domestic chains when studying the agri-food value chain.

Global value chains in the agrifood sector typically involve important cross-border movements of investment capital (through direct and portfolio investment), and business practices/skills (contracting, logistics expertise, etc.). Capital market integration has stimulated substantive foreign direct investment (FDI) in agri-food value chains as well. Arguably the most extreme case has been in the food chains of Eastern Europe in the 1990s where a vast share of agribusiness, food processing and retail companies were taken over by western companies through FDI after economic liberalizations and privatization (Gow and Swinnen, 1998). For example, in just a few years, from 1995-2000, 80% of the Czech retail sector was owned by foreign companies. As we discuss in the sub-section below on the supermarket revolution, FDI undergirds the rise in retail chain sales and in food processing firms in LMICs.

We therefore emphasize both domestic and global value chain transformation, including the role of cross-border flows of finance, expertise, and technologies over the role of global value chains structured around exports to or imports from high-income regions such as Australia, Europe, and North America. We now describe three distinct waves of transformation that have occurred in LMICs in the past two or three decades, albeit at different pace and to differing degrees across countries and regions. Whereas conventional wisdom and common perception might have it that economic dynamism and modernization and growth mainly are concentrated in GVCs, we show dynamic growth in modern segments of DVCs. We illustrate this with evidence on rapid growth sales of the leading supermarket chains in Africa, Asia and LAC. We note for the illustration of horticulture, that sales of fruits and vegetables by just leading supermarket chains far exceed exports of those products from the region. In LAC they are about equal. We also show that FDI in retail is important to the sales of supermarkets as an important share of the sales of leading chains is from FDI-origin chains in developing regions. We also note that SMEs in DVCs are also proliferating and growing rapidly.

Figure 5: Agricultural exports and import shares of production, by region, 1985-2016



4.2 Three stages of agri-food value chain transformations

The speed of agri-food value chain transformation in today's LMICs is astonishing. It took roughly a century to transform the food supply chains of North America and Western Europe from spot market-based exchange with limited food processing or consumption outside the home; comparable change is now taking place in the space of just a couple of decades. For example, Reardon and Berdegue (2002) argue that the spread of modern retail (in particular, supermarkets) in Brazil in one decade (the 1990s) was equivalent to the retail expansion over half a century in the USA.

The broad sweep of rapid and dramatic agri-food value chain transformation can perhaps be best represented descriptively as occurring in roughly three stages, following the macro- and

sector-scale drivers and endogenous firm behavioural responses we outlined in section 2. Despite heterogeneous conditions across and within countries and sub-sectors, these patterns appear fairly general.

4.2.1 Traditional stage

The first stage of transformation is the traditional stage. Traditional value chains are spatially short because the urban share of the population is low. They are also intermediationally short because much of a producer's market is in the rural area, even in the same village. The share of grains and other staples in the food economy is very high. Output of non-grain products is low and hence there are few supply chains for them, except for some traditional cash crops, such as coffee, spices, or sugar. The share of value added in post-harvest segments of the VCs is quite small as home processing reigns, and the wholesale and logistic sectors are small because food does not move far. Segments are fragmented among many small-scale agents, with the exception of government parastatal organizations, if they exist. Exchange relies heavily on spot market sales and on reputational mechanisms to enforce contracts (Platteau 1994a,b; Fafchamps and Minten 2001, 2002; Fafchamps 2003; Greif 2006). Limited transport and communications infrastructure restricts spatial and intertemporal arbitrage and can create localized market power (Moser et al. 2009; Berquist 2017; Burke et al. 2018). There is little quality differentiation, explicit grades or standards, nor economies of scope or scale (Barrett 1997; Fafchamps et al. 2005). Technologies in production, processing, transport and distribution are labor intensive per unit of output, with low labor productivity.

4.2.2 Transitional stage

The second, transitional stage features the following patterns. Value chains elongate spatially in response to increasing urbanization and the associated emergence of concentrated purchasing power distant from the main regions of primary agricultural production. Income growth meanwhile drives rapid growth in demand for higher-value, more perishable animal and horticultural products and for processed foods that save consumers food preparation time. This begins to drive the emergence of public grades and standards for quality, including around food safety. Some product quality differentiation arises based on private firm standards, especially in processed foods. In highly perishable products, such as green leafy vegetables, farmed fish and dairy, short but lucrative peri-urban supply chains emerge and quickly dominate the market because preservation and transport technologies disfavor more distant regions that might possess comparative advantage in primary production. Value chains become longer intermediationally as many SMEs enter midstream – between feedstock producers and final consumers – to add value and to move food from rural areas to urban areas. The share of value added in post-harvest segments grows rapidly as moderately large wholesale, processing, and logistics sectors develop. Especially in places where government parastatals previously exercised state-sanctioned market power, one commonly sees what Reardon (2015) calls a "J-curve of concentration", with concentration initially falling with the dismantling of parastatals and the entry of many SMEs, especially in low barriers-to-entry parts of the chain, such as farm-level aggregation, or informal retailing. But mobility barriers (Caves and Porter 1977) arising from lack of access to finance, entrepreneurial skill, or perhaps social networks with political influence impede most SMEs from scaling up (Barrett 1997). After some time, economies of scale and scope in long-haul transport, capital access, etc. begin to drive re-concentration in the hands of private actors, albeit often with strong state connections. Market intermediation and processing (e.g., grain milling)

activities become more capital-intensive, even if farming remains relatively labor-intensive, but with rapid spread of modern inputs (Sheahan and Barrett 2017). Spot markets still play a major role, but vertical integration and especially vertical coordination through contracting begin to emerge at significant scale.

4.2.3 Modern stage

In the third, modern stage, agri-food value chains become organized almost entirely around serving urban demand. The growth in urban consumer demand compels sourcing from greater distances and thus increased investment in cold chains, packing, preservation, storage, bulk transport and other logistics. The share of grains and other staples in the food economy has shrunk to a quarter or less or gross food sales. Non-grain supply chains and processed food VCs dominate the total food sector. Even perishable products such as dairy, poultry and vegetables are by this stage produced far from cities and shipped frozen, chilled, packed, and so on. High-end consumer demand can nonetheless sustain niche peri-urban and urban (e.g., vertical horticulture) production of some perishables products. Consumer demand increasingly favors non-nutritive characteristics of foods, driving down the farm share of consumer food expenditures and in particular fueling a rapid rise in demand for food away from home, met by rapid growth in the food service sector (e.g., restaurants). Product differentiation thus becomes key, reliant primarily on private standards that evolve far faster than public food regulations or laws (Farina et al. 2005). Agri-food value chains become intermediationally shorter as supermarkets and large processors increasingly vertically integrate or establish long-term contracting relationships, often directly with primary producers, out of a concern for maintaining rising private standards in order to reap more lucrative market niches. This leads to the rising right-hand side of the J-curve of concentration in most segments of the value chain, especially immediately upstream and downstream from farms. The SMEs that remain stay competitive through product differentiation or a shield of high transaction costs (such as those in more remote regions). FDI liberalization started in the transition stage has by the modern stage caused widespread multi-nationalization within multiple segments, especially third-party logistics, processing, supermarkets, and food services. The capital-intensity of all links in the agri-food value chain grows appreciably, leading to significant increases in labor productivity in everything from farm-level production to retail services (Lagakos 2016; Liu et al. 2019). Spot markets become niche means of exchange, in farmer markets and similar settings, with contractual arrangements and vertical integration completely dominating the value chain across all sub-sectors.

In the second and third stages, product standards emerge as an important concern. Product standards represent a very specific type of innovation and are an important part of firm strategy. Private companies set most agri-food grades and standards in response to consumer demand for food safety and quality, as well as for particular environmental and social characteristics of food production and processing (e.g., dolphin-safe tuna, fairtrade). These private standards typically evolve more quickly, and are far more strictly enforced, than public regulatory standards in LMICs. Public standards rarely bind. New private standards typically require new investments and practices for farmers and firms. These can easily exceed the investment capacity of small, asset-poor farms and firms, such as occurred among small dairy farms and SME processors in Argentina and Brazil (Reardon et al. 1999; Henson and Reardon 2005; Farina et al. 2005). Increased product and process standards commonly necessitate technology upgrading by producers and marketing intermediaries alike. The entry of large multinational retailers and the

growth of modern retail chains building on new processes introduced by the multinationals has accelerated the proliferation of increasingly stringent private standards (Fulponi 2007; Vandemoortele and Deconinck 2013).[9]

Predictably, countries – and regions within countries – have moved through these stages in waves that correspond roughly with their level of economic development, as reflected by per capita incomes and economic openness. The first wave were countries that enjoyed rapid economic growth, urbanization, and industrialization somewhat earlier than others of today's LMICs – in particular, South American countries, East Asia outside China, and South Africa. They moved from the first stage into the second in the 1960s and 1970s, and then into the modern stage especially with FDI liberalization and the various market-oriented policy reforms of the 1980s and early 1990s. The second wave occurred in countries that began their economic growth and urbanization spurts later and/or had prolonged internal socio-political pressure to limit FDI. In Central America, Mexico, and South-East Asia, agri-food processing transformation took off in the 1980s but the food retail transformation did not start until the mid-to-late 1990s. The third wave has occurred in countries that started onto a sustained rapid growth and urbanization path mainly in the 1990s/2000s, and/or had ongoing heavy state presence in domestic agri-food value chains into the 1990s, places such as in China, India, Vietnam, and most recently, and incipiently, pockets of sub-Saharan Africa. Once again, processing transformation occurred somewhat before retail and food service.

4.3 Three revolutions in the transformation

4.3.1 The supermarket revolution

Across these three stages of transformation and waves among and within countries, three distinct transformations stand out especially prominently as empirical regularities. The first is the rise of modern retail, what Reardon et al. (2003) dubbed 'the supermarket revolution'), where large-scale retailers and agribusinesses took the lead in transforming food systems in Latin America, Central and Eastern Europe, and Asia, especially in the transition from state-organized economic systems to market-based systems There was an incredibly rapid expansion of modern supermarkets over just a few years in the 1990s and early 2000s in China and Central and Eastern Europe. (Reardon et al, 2003; Dries et al, 2004; Atkin et al., 2018). A similar process occurred in food processing and agribusiness companies in many countries.

Table 1 shows the dramatic growth in food sales, from 2002-2018, of the leading supermarket chains in Africa, Asia and LAC, respectively. We use data on the sales of edible groceries by the top retailers in 35 countries (14 in Africa, 9 in Asia, 12 in LAC), as compiled by Planet Retail.[10] We break the data into distinct waves of countries based on 1990 per capita income and urbanization rates, following Reardon et al. (2003). The first wave experienced the emergence of supermarkets before the later waves did. We also distinguish by the chain's source of capital (local, regional FDI, or global FDI such as Walmart or Carrefour). Although Planet Retail has information on most of the main retailers, they do not cover the many smaller and independent local and

[9] An illustration of the spread of private standards is the number of producers that are GlobalGAP certified. This number increased six-fold over a decade and a half, from around 20,000 in the mid-1990s to around 120,000 in 2011 (Maertens and Swinnen 2015)

[10] Planet Retail's data service tracks at least 7,000 retail companies in 211 countries. We separately researched and identified each retailer's origin to determine, for each country, if that retailer was Local (from the same country), Regional (from that region: Asia, Latin America, or Africa), or International (anything outside Africa). For example, Fruit & Veg City, would be classified as Local for South Africa, and Regional for Namibia, but Walmart would be considered International for all countries. Our analysis is based off 222 and 305 country/chain pairs in 2002 and 2018, respectively (98/144 in Asia, 82/89 in LAC and 42/72 in Africa in 2002/2018).

Table 1: Total edible grocery sales of the leading retail chains, 2002-2018 (nominal USD mn)

	GDP/capita (2010 US$) 2016	Urban % 2016	Sales 2002	Market share 2002	Sales 2018	Market share 2018	Avg Growth 2002-2018	Total Growth 2002-2018
ASIA								
First Wave	**25484**	**80**	**12.435**	**100%**	**52.014**	**100%**	**20%**	**318%**
Local			7.99	64%	37.248	72%	23%	366%
Regional			1.281	10%	11.119	21%	48%	768%
International			3.163	25%	3.646	7%	1%	15%
Second Wave	**5874**	**56**	**5.012**	**100%**	**39.632**	**100%**	**43%**	**691%**
Local			1.122	22%	19.916	50%	105%	1675%
Regional			0.37	7%	14.17	36%	233%	3730%
International			3.521	70%	5.546	14%	4%	58%
Third Wave	**3497**	**42**	**6.738**	**100%**	**76.831**	**100%**	**65%**	**1040%**
Local			3.88	58%	50.098	65%	74%	1191%
Regional			1.126	17%	14.443	19%	74%	1183%
International			1.732	26%	12.289	16%	38%	610%
LATIN AMERICA & CARIBBEAN								
First Wave	**11706**	**91**	**12.956**	**100%**	**43.382**	**100%**	**15%**	**235%**
Local			3.283	25%	10.225	24%	13%	211%
Regional			0.231	2%	3.486	8%	88%	1409%
International			9.442	73%	29.671	68%	13%	214%
Second Wave	**8029**	**73**	**18.758**	**100%**	**56.785**	**100%**	**13%**	**203%**
Local			10.444	56%	28.242	50%	11%	170%
Regional			0	0%	1.081	2%		
International			8.314	44%	27.462	48%	14%	230%
Third Wave	**3499**	**68**	**0.325**	**100%**	**3.778**	**100%**	**66%**	**1062%**
Local			0.28	9%	1.248	33%	22%	346%
Regional			0.41	13%	1.729	46%	20%	322%
International			0.255	79%	0.802	21%	13%	215%
AFRICA								
First Wave	**7219**	**60**	**6,719**	**100%**	**25,576**	**100%**	**18%**	**281%**
Local			4,375	65%	13,453	53%	13%	207%
Regional			117	2%	946	4%	44%	709%
International			2,227	33%	11,176	44%	25%	402%
Second Wave	**909**	**32**	**581**	**100%**	**3,011**	**100%**	**26%**	**418%**
Local			160	28%	1,505	50%	53%	841%
Regional			161	28%	858	28%		
International			260	45%	648	22%	9%	149%
Third Wave	**2265**	**54**	**23.4**	**100%**	**683**	**100%**	**176%**	**2819%**
Local			-		298	44%		
Regional			4.18	18%	228	33%	335%	5355%
International			19.4	82%	157	23%	44%	709%

Source: Authors' analysis of raw data from www.Planetretail.net, supplemented by GDP per capita and urbanization data from World Bank (2019). First wave countries are South Korea and Taiwan (Asia), Argentina, Brazil and Uruguay (LAC), Bostwana, Namibia and South Africa (Africa). Second wave countries are Indonesia, Malaysia, Philippines and Thailand (Asia), Chile, Colombia, Costa Rica, Ecuador, Guatemala and Mexico (LAC), and Kenya, Madagascar, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (Africa). Third wave countries include China, India and Vietnam (Asia), Bolivia, Nicaragua and Peru (LAC), and Angola, Ghana, Nigeria and Senegal (Africa).

regional supermarket chains. Thus, the data underestimate total supermarket penetration and local-capital-funded supermarket sales. With that in mind, a number of interesting trends clearly appear. First, in just the 16 years represented in the data, sales of leading grocery chains increased dramatically, 2-to-6 fold in first and second wave countries, more than 10-fold in third wave countries. In all regions, supermarket sales increased faster in the third wave countries than in the first or second wave countries, a form of "catch up."

Second, global multinational FDI was important in the early stages, especially dominant in the first wave countries in LAC, such as Walmart in Brazil. But outside of those few countries, local chains have come to dominate the supermarket sector, especially in Asia but even in parts of Africa and LAC. Global multinational FDI has been important in several countries, especially in the early stages, but domestic chain investments have caught up quickly.

Third, there has been a sharp rise in the share of Asian regional multinational supermarket chains, such as Thai investments in China and in Malaysia. Regional chains have not emerged the same way in LAC, outside of the poorer third wave countries where, for example, Costa Rican supermarket chains possess significant market share in Nicaragua. In LAC, competition now is primarily between local and global chains, such as Soriana competing with Walmart in Mexico.

4.3.2 *The food services revolution*

Just as the supermarket revolution emerged in response to growing urban demand to reshape domestic agri-food value chains delivering food to consumers' homes, so has the food services sector (i.e., fast-food chains, street vendors, restaurants, cafés, institutional food service providers, etc.) undergone rapid, dramatic change in recent decades. As with the supermarket sector, the food service revolution occurred slowly in the US, over roughly a century starting in the late 1800's, and much faster in Asia and Latin America over the past 20-30 years, and, most recently, in Africa. Rising consumer incomes and opportunity costs of time have driven a rapid rise in the food away from home share of consumer food expenditures. In the US, food away from home increased as a share of consumption, from negligible in 1940, to 40% in 1980, and 51% in 2014. The share of calories from food away from home purchases was 17% in 1977, but 34% by 2011, and higher still in urban areas (Effland 2018; Elitzak and Okrent 2018). Moreover, food away from home shifted from slow, dine-in full meal formats to fast food, and from traditional foods to easy-to-prepare, serve, and take-away meals and snacks. The latter led to the diffusion of non-traditional foods such as sandwiches, hot dogs, snacks, and hamburgers. And food preparation in food service outlets shifted from traditional cookery, to use of a range of new equipment that substituted capital for labor (e.g., steamers, fryers, dishwashers, refrigerators).

Thus the food services sector transformed along a path similar to retail and processing, from traditional, fragmented, small-scale, and labor-intensive, to large-scale (especially based on franchising and large chains of small outlets), consolidated, and capital-intensive, relying heavily and increasingly on branding and product differentiation. Early entrants to markets – or market niches – commonly enjoyed extraordinary profits for short periods of time before new entrants boosted competition, reducing real consumer prices and raising product and service quality.

The food services transformation involves the shift from small-scale independent restaurant outlets to fast-food, restaurant, and café chains. Pioneers such as McDonalds gained cost advantages and reputation for a reliable quality standard through centralized sourcing and either vertically integrated or sourced first-stage food processing (such as frozen burger patties and French fries to then rapidly heat at the outlet), streamlined management and instituted private standards and branding. That still holds true today. As these companies out-compete

traditional food service outlets, they expand nationally, then often internationally. In the US, fast food restaurants expanded from a tiny share of total food services revenues in the 1940s to 40% of the food away from home budget (and number of food service outlets) by the early 1980s (Effland 2018 and Elitzak and Okrent 2018). As the US market began to saturate in the 1970s and 1980s, the leading US fast food chains began extensive FDI in other regions to seek new, less competitive markets. For example, McDonalds began franchise operations in 1954, but by 2018 it had nearly 14,000 outlets in the US and 25,000 outlets internationally. The spread of (mainly US-based) chains has been a driver of the food services revolution in LMICs.

Changes in the wholesale and processing segments of the agri-food value chain were important factors in the transformation of the food services sector in the US, and again later in developing regions. Just as with supermarkets, the larger fast food chains developed centralized procurement and distribution centers, allowing economies of scale and scope, in part through improved bargaining power, and thus lower unit costs than the traditional restaurant sector with which they compete. Even chains that purely follow a franchise model – like Subway, which now has the most restaurants of any single restaurant brand in the world but does not own and operate a single store – organize franchisees into marketing cooperatives to seize the gains from scale and scope.

Starting in the 1970s, specialized and dedicated wholesalers emerged in larger markets and globally to handle sourcing and distribution on contract for food services firms, thereby allowing smaller chains and independents to achieve economies of scale and scope and access specific collective assets they could not obtain on their own. The most prominent example is Sysco, now the largest wholesaler of food products in the world, serves restaurants, hotels, educational and healthcare facilities, prisons, etc. in 90 different countries globally. Similarly, processing firms emerged to meet the demands of restaurant chains and other food services retailers. These processors have introduced key innovations to fast food chains, such as the frozen beef patty technology introduced for McDonalds in the early 1970s by OSI, a large custom food processor that now operates in a range of high- and middle-income countries. Wholesalers and processors have commonly developed new products and business processes in high-income markets (especially the US) and then diffused those into LMIC markets via FDI. These operations commonly followed existing multinational supermarket and fast food clients into LMIC markets (see Reardon et al. 2007 for details on the retail case), and then, once established locally, expand to supply domestic chains in these new markets. For example, OSI took its product and business model innovations to Brazil and Mexico in the 1980s and 1990s to supply the rapidly emerging fast food chains and restaurants sector. Domestic firms with the same structure and aim of OSI, rising in their own context of growing fast food chains, then bought the beef, chicken and pork operations of OSI in Brazil and Europe in 2008 (Popkin and Reardon, 2018).

The food services revolution in LMICs has proceeded much faster than it did in today's high-income countries. Mainly, this is because product and process innovations initially developed for high-income markets diffused relatively easily as multinational firms undertook FDI in search of profitable new markets. Fast food restaurants thus began appearing in secondary cities at a far earlier stage of urbanization in LMICs than they did in the high-income world. This includes not just modern fast food chains diffusing from North America and Europe, but also South-South FDI from markets in earlier waves of food services transformation (e.g., Philippine fast food hamburger chain "Jollibee" into Malaysia, or the spread of fast food spicy chicken chain Nando's from South Africa to more than two dozen countries, especially in Africa and

Asia). For similar reasons, new technologies (such as oil pressure cookers for French fries) similarly diffused faster and earlier in the urbanization and economic growth process, many of them introduced by multinational wholesale and processing firms (such as Sysco or OSI) that few diners would recognize by name.

As the business practices and products emerged, largely imported via FDI, local food services chains emerged and proliferated to serve poorer and emerging middle-class markets. For example, the Brazilian fast food chain Giraffas, founded in 1981 had expanded to 130 cities with 410 outlets nationwide by 2017 and into neighboring Paraguay. Similarly, Brazil's Marfrig Global Foods began by supplying processed beef (e.g., frozen patties) to multinational food service companies in Brazil, Chile, and Argentina in the 2000s, then by acquiring the Latin American operations of US firms, including the US-based multinationals OSI and Keystone (Popkin and Reardon 2018).

Rapid growth and economies of scope and scale in the food services sector have led to a raft of acquisitions in LMIC markets. Large multinational or regional processors and food services firms have acquired multiple chains, building product differentiated portfolios of restaurant brands much like food manufacturers have diversified branded product offerings. For example, Yum! Brands, a 1997 spin-off from PepsiCo – which had itself acquired fast food restaurant chains over the 1980s/90s – now has over 48,000 restaurants in more than 145 countries, with especially heavy concentrations in Asia and Latin America. In 2016 Yum! itself spun off YumChina, a publicly-traded holding company now operating nearly 9,000 restaurants in over 1,300 cities and towns in every province and autonomous region of China. Similarly, in 2014 of the Colombian hamburger chain El Corral was bought by the giant Colombian food processing company Nutresa (Popkin and Reardon 2018). Remarkably, the rapid expansion and subsequent consolidation of the food services sector in LMICs has gone largely unnoticed by economists.

Table 2 shows the sales growth of leading multinational food services companies in Asia and Latin America. As with Table 1, these data come from Planet Retail and necessarily underestimate food services company market share and growth, as the data only are available for multinational chains, covering 33 countries in the three regions. [11] But the growth patterns clearly illustrate the dramatic growth of the food services sector, with major implications for the agri-food value chains of these LMICs. Gross sales in Asia tripled in just 10 years (from US$12 to 35 billion). Growth in Latin America was less rapid, likely because the main markets (Brazil, Mexico) experienced earlier multinational entry and because of the earlier rapid development of local competition, as well as slower economic growth in the region. Unlike in the case of supermarkets, sales growth rates have been reasonably similar across waves, as food services markets saturate at far higher levels of sales due to the far more limited offerings – and greater product differentiation – across retail outlets.

4.3.3 The 'quiet revolution' in value chain intermediation

As the prior two sub-sections emphasized, the supermarket and food services revolutions have emerged symbiotically with a no-less-radical transformation in the array of intermediation services that occur between farmgate and processor or processor and retailers. Although these changes are often lost behind the more-visible changes occurring at the final consumer end of the agri-food value chain serviced by supermarkets and restaurants, changes in the food at home

[11] Our analysis is based off 185 and 232 country/chain pairs in 2008 and 2018, respectively (85/102 in Asia, 87/105 in LAC and 13/25 in Africa in 2008/2018).

Table 2: Gross sales of leading café, fast food, and restaurant chains, 2008-2018 (nominal USD mn)

	GDP/capita (2010 US$) 2016	Urban % 2016	Sales 2008	Sales 2018	Avg Growth 2008-2018	Total Growth 2008-2018
ASIA						
First Wave						
South Korea	25.484	82	1511	3391	12%	124%
Taiwan	NA	77	1065	1694	6%	59%
Second Wave						
Indonesia	3795	54	902	1735	9%	92%
Malaysia	11.039	75	1000	2250	13%	125%
Philippines	2752	46	899	2116	14%	135%
Thailand	5911	48	745	1720	13%	131%
Third Wave						
China	6895	57	5128	18092	25%	253%
India	1862	33	579	3023	42%	422%
Vietnam	1735	35	62	335	44%	440%
LATIN AMERICA AND CARIBBEAN						
First Wave						
Argentina	10.206	92	475	369	-2%	-22%
Brazil	10.869	86	1892	3106	6%	64%
Uruguay	14.043	95	60	62	0%	3%
Second Wave						
Chile	14.959	87	306	520	7%	70%
Colombia	5441	80	151	542	26%	259%
Costa Rica	9592	78	200	282	4%	41%
Ecuador	5210	64	207	357	7%	72%
Guatemala	3101	50	446	398	-1%	-11%
Mexico	9868	80	2939	3465	2%	18%
Third Wave						
Bolivia*	2458	69	25	62	15%	148%
Nicaragua	1944	58	43	46	1%	7%
Peru	6095	78	170	363	11%	114%
AFRICA						
First Wave						
Botswana	7797	68	6.4	23	25%	255%
Namibia	6365	48	14.8	25	7%	72%
South Africa	7495	65	791	1678	11%	112%
Second Wave						
Kenya	1130	26		39		
Malawi	506	17		1		
Mozambique	533	35	4.4	13	20%	204%
Tanzania	904	32	1.6	6	30%	302%
Zambia	1652	42	6.1	39	54%	541%
Zimbabwe	1224	32		2		
Third Wave						
Angola	3530	64	0.55	20	356%	3557%
Ghana	1643	55		2		
Nigeria	2456	49		33		

Source: Authors' analysis of raw data for ### total retail food service chain-country pairs in Asia, LAC and Africa from www.Planetretail.net, supplemented by GDP per capita and urbanization data from World Bank (2019). Firms represented: *Fast Food Restaurants*: A&W All American Food; Baskin-Robbins; Burger King; California; Cold Stone Creamery; Domino's; Doña Tota; East Dawning; Harajuku Delights; KFC; Long John Silver's; McDonald's; Pizza Hut; Seaport; Subway; Taco Bell; Taco Bell Grande; Wendy's. *Cafés*: 85 degrees C; Au Bon Pain; Cafe Brio; Dunkin' Donuts; Pacific Coffee; Sanborns Café; Starbucks; Restaurants: Afternoon Tea; Applebee's; BHG Kitchen; Chili´s; IHOP; KAZOKUTEI; Little Sheep; LongHorn Steakhouse; Maxim's; Olive Garden; Red Lobster; Rock and Roll; S&R QSR; SHUN-NO-MAI; Super Quick; The Capital Grille; Vips.

(supermarket) and food away from home (food services) retail sectors could not have proceeded without simultaneous advances in less glamorous logistics and processing sectors. Moreover, even staple food markets and production systems in many poorer African and Asian countries have been transformed by this "*quiet revolution*" among the mid-stream intermediaries such as transporters, cold storage providers, millers, etc. (Reardon, 2015). These agri-food value chain changes are an oft-overlooked feature of the broader process of structural transformation of developing economies (Timmer 1988, 2009).

The observation that higher-income countries make significantly greater use of services in agri-food production than do LMICs (Greenville et al. 2019a) – consistent with the US transformation reflected in Figure 1 – signals that logistical and business services play a growing role in the sector as it evolves. These changes have major implications for food consumers, farmers, and the middlemen (e.g., wholesalers, processors, third party logistics service providers, retailers) who move product among them. They have been accompanied by rapid changes in the types of food offered to urban consumers, upgrading of processing and trading systems, changing forms of vertical coordination and integration among firms, and in major opportunities and challenges for small and poor farmers. Farmers increasingly have the opportunity to access higher value markets, both domestically and globally, but at the cost of higher standards demanded in terms of the quality, reliability, and volume of the products they supply (Aksoy and Beghin 2005; Jaffee and Henson 2004).

A nice illustration of the dramatic transformations occurring midstream in food supply chains is the rapid rise of cold storages in south Asia (Das Gupta et al. 2010; Reardon et al. 2012; Minten et al. 2014). The confluence of several factors led to very rapid and deep change in the cold storage sector – especially for potatoes – and, in turn, in the seasonality of price and availability in cities and intermediation patterns in the rural areas. The big driver was the rapid development of vegetable demand and of investible capital in cities arising from urban income growth. Improved transport links from rural areas and regional towns to the major cities improved arbitrage opportunities to meet that demand. And the introduction of a disease-resistant and long-shelf-life potato variety by the national agricultural research systems and of an electricity grid by the state or local government, as well as state (partial) subsidies for irrigation pumps and cold storage equipment facilitated a rural supply response – often financed by urban investors, or by financial institutions recirculating urban savings – to meet the emergent urban demand. In the early 1990s relatively few farmers grew potatoes for bulk commercial sale in places like Agra or Bihar and there were almost no modern cold storage facilities. By the late 1990s cold storages had risen to store 40% of the vastly larger potato output, and by 2009 had grown further to account for 80% of the supply (DasGupta et al. 2010). Traditional on-farm storage went from ubiquitous to 1% of the potato harvest over the same period. Delhi went from sharply seasonal potato consumption (all supplied from fresh harvest) to multi-season availability with 65% of consumption supplied from cold-storage potatoes, mainly from Agra. Rural brokers were sidelined as the cold storage service providers became the main locus of intermediation with urban wholesalers coming to buy potatoes directly from farmers at the storages. The cold storages also resolved idiosyncratic credit market failures for small farmers, becoming a main source of credit using stored potatoes as collateral.

Such changes are even occurring in staples cereals value chains. Minten et al. (2016) describe the sharp growth of logistics firms, processors, and wholesalers in the teff value chain supplying Addis Ababa. Teff is the leading staple cereal in Ethiopia, with marketed surplus to domestic markets in 2013/14 of $750 million, significantly higher than that of coffee ($560 million), the

country's most important export. As with the potato value chain in south Asia, the teff value chain transformation in Ethiopia traces its origins to multiple factors, principally rapid income and population growth in Addis, along with the increased opportunity cost of women's time, major improvements in national road and cell phone networks, and the government's expansion of extension services to teff growers. The result has been a shift toward higher quality and cost teff flour and enjera (a popular, spongy flatbread) produced from white varieties, rather than the sale of unmilled, cheaper red teff that households (usually women) then clean and mill themselves. This has stimulated a proliferation of small and medium-sized mills-cum-retailers and *enjera*-making enterprises in urban and peri-urban areas, which has sparked rapid growth in demand for trucking services – replacing human- or animal-powered transport – to deliver higher value product in greater volume to more distant cities. Similar changes have taken place in the maize value chain in Nigeria, where dramatic wholesale sector growth to supply feed and flour mills has sparked sharp growth in third party logistics services, in particular transport, warehousing, and handling (Liverpool-Tasie et al. 2017). Traders have partially dis-intermediated the supply chain by reducing their past reliance on rural brokers and buying directly from farmers, while increasingly hiring transport and storage services rather than investing in capital equipment and self-provisioning in logistical support.

5. Micro-scale empirical evidence on impacts

So what impacts does agri-food value chain transformation have? There is widespread interest in this question, both around private initiatives led by firms within the value chains, and for public or donor interventions as part of "inclusive value chain development strategies" that have become popular within broader agricultural and rural development programs (Swinnen and Kuijpers, 2018). These involve either or both of two types of interventions: *selective* interventions targeted at specific value chains or specific actors within those value chains, and/or *general* interventions that target the (business) environment in which value chains operate, including infrastructure, property rights, contract enforcement, corruption and the administrative burden of doing business. The general objective is to improve the functioning of value chains by lowering transaction costs and reducing holdup problems.

The impacts of these strategies, and associated interventions, have attracted considerable attention, but have been unevenly evaluated. As indicated in section 3, the micro-scale empirical evidence relies overwhelmingly on observational data and commonly lacks strong causal identification. Thus the opportunities for further, more rigorous exploration of the various hypothesized impacts remain legion.

A fundamental challenge to rigorous causal identification of the causes and impacts of changes in agri-food value chains is the endogeneity of the specific institutional arrangement in play. Any of the forms – e.g., contract farming, vertically integrated plantations with outgrower schemes – that commonly replace the smallholder production and spot market exchange that typifies traditional value chains emerge endogenously to overcome context-specific information asymmetries, capacity constraints and market failures. For example, contract farming arrangements are commonly developed to resolve coordination problems around timing of deliveries and product characteristics. But some contracts, like vertical integration schemes, also aim to address financial (e.g., credit, insurance) or other input market imperfections that might otherwise prevent farms from producing the agricultural feedstock. In the absence of the right institutional design for a specific context, input providers cannot sell their inputs, processors do

not get the raw material they need for producing consumer products, retailers cannot sell, and consumers do not get the products they desire. All these agents therefore have an incentive to assist the farm in its production and "make the value chain work". But as the optimal contracting literature has long demonstrated (Stiglitz 1974, Eswaran and Kotwal 1985), the right design behind the value chain depends on whether and which agents have comparative advantage in one or another domain (e.g., bearing price risk, accessing seasonal credit, labor supervision). As a result, the very object of study – even if randomized across participating subjects – is typically a purposively-selected product of non-random selection effects that can sharply constrain external validity but even compromise the internal validity of causal estimates (Barrett and Carter 2010; Usmani et al. 2018).

5.1 Technology transfer and diffusion

If technological change is a fundamental driver of economic development and firms' innovations in products, practices and markets serve as the main engine of agri-food value chain transformation, then we should see clear evidence of diffusion of technologies caused by exogenous changes in the value chain. Indeed, since one of the main tasks of value chain improvements is to reduce costs and frictions in exchange, and given that input costs and marketing frictions are a major impediment to uptake of improved technologies at farm and SME level (Feder et al. 1985; Foster and Rosenzweig 2010), a natural hypothesis is that value chain transformation accelerates the diffusion of modern innovations. Those frictions can be great. For example, Aggarwal et al. (2019), using exceptionally detailed data on farmer decisions in every village across two regions of Tanzania, show dramatic village-level variation in the travel-adjusted prices of inputs and outputs and that this has a sizeable reduced form effect on adoption of modern inputs.

The obvious challenge to causal identification of technological diffusion impacts again comes from (i) the multi-level selection effects that guide firms' geographical and product choices, the suppliers and clients with whom they engage in exchange (Barrett et al. 2012), and (ii) the endogeneity of the innovation process itself, as described in section 2. Adoption of agricultural technologies by liquidity-constrained farmers is affected significantly by the value chains where the farmer is located and by the nature of the technology (Kuijpers and Swinnen 2016; Swinnen and Kuijpers 2017). But the nature of the innovation behind the supply chain and the driver of the innovation affect adoption patterns. For example, if the new innovation is a new higher quality food, and its production requires adoption of new technology (e.g., climate control of output), one plausible arrangement is a contract between the farmer and the processor, where the processor provides the finance for the fixed input associated with the new technology. But if the innovation is a new farm input, for example better irrigation technology, and the entrepreneur behind the innovation is an input manufacturer, they may use a marketing strategy that may include guarantees, technical support, and provision of credit to overcome uncertain about product fit, durability, as well as credit constraints (Heiman and Hildebrandt, 2018). Furthermore, some innovations might require the establishment of new organizations, perhaps jointly owned by banks, input suppliers, processors, or others able and willing to share the risk of credit provision to farmers. The literature is necessarily restricted to piecemeal understandings of impacts within very specific contexts without sufficient general understanding yet of what type of intervention most effectively promotes technology diffusion in which contexts.

The literature nonetheless offers some important and largely encouraging insights on the question of technology diffusion and associated productivity growth. Several empirical studies

specifically document technology transfers through value chain innovations: see, for example, Dries and Swinnen (2010, 2004), Gow et al. (2000), Maertens and Swinnen (2009), Minten et al. (2009), Negash and Swinnen (2013). These studies consistently find that technology (and management) transfer through value chains generates significant productivity increases both for the product itself and for other production activities at the farm level. For example, Minten et al. (2009) also find that the better technology and management practices related to contract-farming spill over to other crops, generating large productivity increases in rice production, and further improving the food security situation of rural households.

Further upstream in the value chain, technology transfer becomes more obvious as completely new products and processes emerge and diffuse. Technologies long familiar in now-high-income countries come over with multinational FDI. An example is the diffusion of tetrapak packaging and UHT milk processing in Brazil in the late 1980s and 1990s, lengthening dairy VCs and leading to rapid consolidation within the sub-sector (Farina et al. 2005).

5.2 Competition, concentration and market power

Traditional spot markets are commonly extremely competitive, with many agents competing on price, volume and observable quality terms. Fafchamps (2003) refers to this as a "flea market economy" so as to convey the uncoordinated, somewhat chaotic nature of small-scale traditional agricultural markets. Within very localized areas, competition typically reigns, although remoteness, financial liquidity constraints, and associated credibility and reputation issues can confer considerable market power in niches that require significant capital or characterized by non-trivial economies of scale or scope, especially long-haul, large-scale trading (Barrett 1997; Moser et al. 2009; Bergquist 2017; Casaburi and Reed 2017; Dillon and Dambro 2017; Casaburi and Macchiavello 2019). But as value chains move to the transitional stage described above, we commonly see increased inter-firm competition in both upstream (i.e., commodity procurement) and downstream (e.g., retailing) segments of the value chain, increasing the pressure on firms to reduce costs and to coordinate with suppliers to provide feedstocks and products with the differentiated traits more highly valued in the target market. Then, as the value chain moves to the more modern stage, one commonly observes re-concentration downstream among a shrinking number of large firms in the more capital-intensive segments that have become ever more important in the value chain (Swinnen and Vandeplas 2010). Re-concentration can emerge at the farm input supply level as well if intellectual property rights confer market power, as is evident in the global seed industry today.

This pattern is nicely illustrated by Jensen and Miller (2018), who study the artisanal boat building industry that services fisherfolk in Kerala, India. They show how improved market integration brought about by the spread of mobile telephones transformed the formerly atomistic market in which fishermen traditionally bought their boats from the nearest builder. An exogenous market integration shock exposed fishermen to new prospective boat suppliers. This sharply increased competition based on cost and quality, leading to significant expansion of the most efficient producers, loss of market share or even exit among the least efficient, lowest quality producers. The end result is a sharp fall in the real, quality-adjusted price of boats and increased concentration in the industry, as well as significant shedding and specialization of labor.

Beyond these broad patterns, one should expect the routine emergence of market power in particular locations since value chain transformation is driven by innovation that typically confers temporary market power. Empirical testing of the hypothesis of spatiotemporal variation

in the presence or absence of market conditions approaching perfect competition within agricultural markets remains extremely underdeveloped, however. Perhaps the closest is the rather specialized literature that employs parity bounds models to estimation the frequencies with which markets violate spatial equilibrium conditions, and that literature relies on very strong econometric assumptions (Baulch 1997; Negassa and Myers 2007; Moser et al. 2009; Butler and Moser 2010; Zant 2012).

One indicator of the degree of competition that exists within markets is the frequency of side selling of contracted products. In theory, suppliers or purchasers only renege on a contract – e.g., fail to deliver or purchase the agreed volume – when they expect both to earn higher profit from the renegade transaction and to find alternative counterparties for future contracts on comparable terms. The scant empirical evidence on side-selling suggests it is widespread in transitional LMIC agri-food value chains. Upton and Lentz (2017) find that the median rate of farmer default on procurement contracts with the World Food Programme in Ethiopia, Kenya, and Tanzania was 28 percent, with default fully explained econometrically by side-selling in moments of spot market prices exceeding the contract price. Narayanan (2012) reports that 44 percent of farmers in one of several different contract farming schemes in southern India acknowledged defaulting on a contract. So the indirect evidence on competition is consistent with the idea of vigorous competition in at least the transitional stage of agri-food value chains.

This raises a much deeper question as to whether competition is necessarily preferable to market power. In environments with multiple market failures, as typifies most rural LMIC settings (Dillon and Barrett 2017), market power can actually help resolve problems related to financing, contract enforcement, etc. and thus prove optimal in second-best contexts (Fafchamps 2003). Studying the contracts between coffee farmers and processing mills in Rwanda, Macchiavello and Morjaria (2019) find intriguing evidence consistent with that hypothesis. They find that additional competition from an extra mill within her marketshed makes a farmer worse off, seemingly because it increases the temptation to default on an existing contract, thereby costing the grower relational contracts designed to resolve various market failures. Machiavello and Morjaria (2019)'s upstream, producer level results from Rwanda stand in stark contrast, however, with the downstream, consumer-level impacts Busso and Galiani (2019) document in the Dominican Republic when they randomly induced entry of small retail shops, leading to lower real consumer prices due to increased competition.

5.3 Smallholder inclusion in value chains

Whether or not smallholder farmers share in the benefits from value chains depends importantly on whether they are included in contract-farming arrangement and the impact that participation in contract-farming has on their incomes and well-being. There is widespread concern that structural changes may lead to the exclusion of smallholder farmers from contract farming schemes and other linkages to modern value chains. This might occur because small farmers have a harder time satisfying tightening product standards, poorer access to irrigation or all-season roads, or because of the comparatively high transaction costs of buying smaller quantities from many smallholder suppliers (Key and Runsten 1999). On the other hand, standards are themselves instruments for harmonizing product and process attributes over suppliers, and can as such also reduce transaction costs in dealing with a large number of small suppliers. Moreover, well-specified contracts that include farm extension and assistance programs can alleviate the financial and technical constraints small farmers often face in meeting stringent standards. In addition, firms might prefer to contract with smaller farms possessing a

cost advantage in more labor-intensive production with relatively small economies of scale, such as in fresh fruit and vegetable production. Thus the impact of value chain modernization on smallholder participation is theoretically ambiguous and ripe for empirical hypothesis testing.

The empirical evidence is mixed (Reardon et al. 2009; Barrett et al. 2012; Maertens et al. 2012). Several empirical studies have documented that with increasing standards, a decreasing share of export produce is sourced from small farmers, including in Kenya (Dolan and Humphrey 2000; Gibbon 2003; Jaffee 2003) and Cote d'Ivoire (Minot and Ngigi 2004; Unnevehr 2000). Subervie and Vagneron (2013) describe the rise of large exporter-owned lychee plantations in Madagascar in response to rising private standards. Maertens and Swinnen (2009) document a shift from smallholder contract farming to vertically integrated farming on large-scale plantations in the vegetable export sector in Senegal with the increased importance of private standards, especially GlobalGAP. Schuster and Maertens (2013) conclude that the spread of private standards, especially production standards such as GlobalGAP, in the Peruvian asparagus export sector led to decreased sourcing from smallholders and that certified companies sourced significantly less from smallholders than non-certified companies. Some value chains are completely based on vertically integrated agro-industrial farming, without any inclusion of smallholder suppliers, e.g., the tomato export sector in Senegal (Maertens, Colen, and Swinnen 2011). In Indian dairy chains, suppliers include both small and large farms, but emerging contracting systems are concentrated on large modern farms (Burkitbayeva et al 2019).

Yet, other studies show that smallholders continue to be included in modern value chains, sometimes exclusively. For example, several studies from Eastern Europe document that small farmers were integrated in modern agricultural value chains (e.g., Dries et al. 2009, 2009; Noev, Dries, and Swinnen 2009). Minten et al. (2009) find that the vegetable export sector in Madagascar includes 10,000 smallholder farms and is based entirely on an intensive contract farming systems, as has likewise proved true in the fruit and vegetable sectors in Zimbabwe (Henson, Masakure, and Boselie 2005), Chile (Handschuch, Wollni, and Villalobos 2013), and Thailand (Kersting and Wollni 2012), in export horticulture chains in China (Wang et al. 2009) and domestic chains in India (Gulati et al. 2007).[12]

To explain these different patterns of smallholder inclusion Vandemoortele et al. (2012) developed a formal theoretical model of the emergence of the demand for high quality and safe food, which they use to analyze which small producers are most likely to be included. They show that conditional on the initial production structure in the economy, the nature of transaction costs, and the possibility of contracting between producers and processors, certain producers are included in the high quality economy, and others are not. Their model predicts that in a mixed production structure, with both smallholder farms and larger farm enterprises, smallholders are more likely to be excluded. When the farm sector is more homogeneous and dominated by small farms, it is likely that the emergence of high value production will be slower but more inclusive. So the mixed evidence seems entirely consistent with the context-dependence of firms' optimal contract design.

[12] Many examples of smallholder inclusion in high value chains come from the horticulture sector. One potential explanation for this is the high labor input requirements for crop protection and harvesting of vegetables and fruits, and the competitive advantage that smallholders have in accessing cheap labor compared to large estate farming. Whereas large farmers have to hire labor to produce these type of crops, smallholders can use family or community labor. As is well known, the comparative advantage of family labor over hired labor arises from avoidance of principal-agent problems in labor supervision (Stiglitz 1974; Eswaran and Kotwal 1985). Consequently, smallholders might have a comparative advantage in supplying more labor-intensive commodities.

5.4 Employment and labor market impacts

Since farmer participation in modernizing value chains is necessarily limited, broader economywide gains arise largely through labor market effects or food market (i.e., price, quality, variety) effects in general equilibrium. We address employment and wage effects in this sub-section, real income effects in the next.

Much of the literature has looked at farm-level employment and wage effects. This could be labor demand induced among smallholder suppliers. Neven et al (2009) found substantial employment creation for local farm workers by medium farmers directly supplying fruit and vegetables to supermarkets in Kenya. Meemken and Bellemare (2019) find that contract farming is strongly associated with higher on-farm labor demand in five of six countries they study using nationally representative survey data, although they do not find evidence that added employment has significantly favourable earnings impacts on non-contract households. This could well reflect insufficient scale, i.e., despite significant labor demand impacts on participating farms, the number of participating farmers is insufficient to generate an effect that impacts wages and overall employment in general equilibrium at even village level.

Alternatively, a shift from smallholder contract farming to vertical integrated estate farming also entails a shift from production based on family labor to production based on hired labor. Favorable employment effects have been shown in many studies of export market value chains that use both vertical coordination via contract farming and vertical integration, for example in the vegetable export sector in Senegal (Colen, Maertens, and Swinnen 2012; Maertens and Swinnen 2009) and in the cut flower industry in Ethiopia (Mano et al. 2011). According to the nation's horticulture export association (EPHEA), the Ethiopian horticulture industry now employs 180,000 people, 85% of them women. [13] Webber and Labaste (2010) report that the approximately 7,000 smallholders involved in fresh vegetable exports in Kenya were dwarfed in number by the 40,000-60,000 persons employed as farm workers or in the processing industry.

An important – and largely overlooked – issue in the welfare analyses of agri-food value chain modernization is that poor households may benefit through employment effects in the post-harvest segments of the value chain. High-standards trade can create new employment opportunities in labor-intensive processing and handling of produce post-harvest and in more capital-intensive segments, boosts to labor productivity might drive wage rates higher, boosting earnings among workers. Hence, there might be additional benefits from agri-food trade through employment effects beyond the farmgate. The empirical evidence on this issue is scarce, however. Dolislager et al. (2019) analysed LSMS data for several African countries and found that only about 40% of total labor supply in rural households was devoted to households' own farms, with 20-25% supplied to non-farm activities (e.g., milling, transport) within the agri-food system. Only about 5% was spent in farm wage employment. So the labor market effects of agri-food system transformation can be substantial, even in low-income rural areas.

Lagakos (2016) observes that labor productivity within the retail sector differences across countries can be accounted for largely by compositional differences. As the share of 'modern' establishments, such as supermarkets, grows, so does labor productivity within the sector, and thus workers' incomes as well as firm profits. Consistent with the conceptual framework advanced in section 2, Lagakos (2016) argues that technology choices largely drive productivity, and that 'low' technology choices appear optimal in LMICs given low incomes. Low incomes both reduce the likelihood of consumers owning automobiles that make bulk purchases feasible

[13] http://www.ehpea.org/GeneralInfo.aspx#medialink, accessed 10 December 2016.

and efficient, and lower consumers' willingness to pay for higher quality products. Further, informality may confer advantages, especially tax avoidance, creating another motive to remain small and informal. These findings suggest sizeable labor productivity gains from value chain modernization, but merit further exploration in other data sets.

The increase in standards in export and domestic market value chains may also create improved employment conditions for workers. Ethical or fair trade standards may generate positive effects on working conditions. Barrientos et al. (2003) find that labor standards and codes-of-conduct can improve workers' well-being, although Meemken et al. (2019) find that Fairtrade certification in Cote d'Ivoire leads to more and better compensated employment for workers within cocoa cooperatives, where labor standards are regularly monitored, and for smallholder farmers who supply the cooperatives, but not farmworkers, who have the worst working conditions in the sector. Yet, even food quality and safety standards may generate benefits for workers. Colen et al. (2012) similarly find evidence of increased employment periods and higher wages for workers, following companies' certification to private standards in the horticulture export sector in Senegal.

A related concern is whether labor market effects are shared effectively with traditionally disadvantaged subpopulations. In the vegetable export sector in Senegal, employment in agro-industrial production and exporting companies has proved especially accessible for the poor and this employment has a large positive effect on household incomes and on poverty reduction (Van den Broeck, Swinnen, and Maertens 2017). There is also some suggestive evidence of differentially higher labor demand for female workers in many value chains (Maertens and Swinnen 2012). For example, Liverpool-Tasie et al. (2016) found in Nigeria that 80% of the agrifood wholesale and processing employment in rural areas was done by women. Besides helping to close labor market participation and wage rate gaps that persist globally, if there really are pro-female employment effects of value chain modernization, this could general other, indirect welfare benefits, such as increased child schooling (Maertens and Verhofstadt 2013).

5.5 Real incomes, poverty and food security

Because the vast majority of the world's poor (typically estimated at around 70%) depend on agriculture as a primary source of income, whether as farmers or farm workers, the impacts of value chain transformation on farmer and farmworkers incomes matters enormously to poverty reduction objectives. And for virtually all the poor, food is among the primary expenditure categories. The poor consistently spend a far larger budget share on food than do wealthier households. So any reductions in real, quality-adjusted food costs likewise disproportionately benefit the poor.

Perhaps the most common, and most widely evaluated, innovation in agri-food value chains has been the rise of contract farming, arrangements under which firms vertically coordinate upstream with farmers to deliver particular commodities, often to specific quality standards, and sometimes linked to other (e.g., credit, input supply) transactions (Little and Watts 1994), Barrett et al. 2012, Bellemare 2018). Some scholars have argued that the gains from high-standards agricultural trade are captured by foreign investors, large food companies and developing country elites (Little and Watts 1994; Dolan and Humphrey 2000). Some have hypothesized that vertical coordination mechanisms and consolidation at the buyer end of export chains might amplify the bargaining power of large agro-industrial firms and food multinationals downstream, and thereby strengthen the capacity of these companies to extract rents, to the disadvantage of contracted smallholder suppliers in the chains (Warning and Key 2002).

On the other hand, Swinnen and Vandeplas (2011) develop a theoretical model to show why buyers may pay suppliers an extra "efficiency premium" in high value chains, even with very unequal bargaining power in the contract relationship. The demand for higher quality products requires buyers to assist farmers in order to improve the quality of production, for example by providing the farmer with inputs on credit. In a context of weak contract enforcement, which is likely in many developing countries, this creates holdup opportunities for the farmer, who can decide to use the inputs but sell the high-value product to another buyer without paying back the credit that the first buyer offered him. In order to prevent this, buyers are forced to offer attractive contract terms in order to secure their returns to investment, for example by offering the farmer a price premium. Hence, poor suppliers can benefit from the introduction of quality standards in a weak contract enforcement context, even if all bargaining power lies with the buyer.

The lack of a clear theoretical prediction of the impacts of modern value chains on farmers' well-being has prompted a sizeable literature on contract farming aiming to answer that question. Most studies' findings suggest that various forms of pre-harvest coordination between growers and downstream intermediaries indeed boost smallholder incomes and related food security or wealth-based measures of well-being. Bellemare and Bloem (2018) and Ton et al. (2018) offer recent, nice reviews of the contract farming literature. Ton et al. (2018)'s meta-analysis of 26 distinct published estimates of the relationship between contract farming and income or food security measures found a pooled average effect size of 28% gains, although they note that estimate is inflated by both publication and survivor biases. The best of the contract farming impact studies (e.g., Schipmann and Qaim 2010, Michelson 2013, Narayanan 2014; Bellemare and Novak 2017; Meemken and Bellemare 2019) consistently find real gains to growers from contract farming, so the qualitative conclusion that contract farming has favorable development effects finds consistent support. But these studies often struggle for credible causal identification of the estimated effects. At least as importantly, they offer relatively little useful guidance on how firms might best structure contracts so as to generate maximal gains at minimal costs, nor as to what governments, development agencies, or other actors might most usefully do to stimulate expanded, impactful vertical coordination within the agri-food value chain. And surely the benefits vary structurally among farmers and farm worker communities, much as they do for agricultural inputs (Marenya and Barrett 2009, Suri 2011), yet we understand little about the structural heterogeneity in returns to contract farming from the existing literature.

Some studies report positive effects of participation in high-value contract schemes on food security, nutritional adequacy of diets, and health. Bellemare and Novak (Bellemare and Novak 2017) find that participation in contract farming schemes in more than ten different crops in Madagascar reduces the duration of the hunger season by an average of 8 days. Chege et al. (2015) show that participation by Kenyan vegetable farmers in supermarket value chains is associated with a significant increase in intake of calories (by 19%), vitamin A (by 96%) , iron (by 18%) and zinc (by 15%). The positive nutrition effect is explained by increased income and an increased share of land under vegetables. However, these positive effects are partially suppressed (i.e. not as high as they could have been) by a higher likelihood of male control of revenues as a result of further commercialization of vegetable production. Asfaw et al. (2010) find improved health outcomes among farmers as a result of the use of less toxic pesticides and improved farmers' pesticide management as specified in GlobalGAP requirements.

Xiang et al. (2012) simulate the general equilibrium effects of the growth in high standards food on rural and urban household welfare. Their simulation results show that an increase in the

demand for high standard food leads to an increase in the production of high standard products and to a reduction of poverty and inequality. However they also find that export-led growth is more likely to benefit the poor than domestic growth since import competition may increase with domestic demand growth for high-value products.

These general equilibrium effects raise questions about whether modern agri-food value chains benefit people, especially the poor, who are not direct participants in the supply chain, either as feedstock growers or as workers. The evidence on spillover gains to non-participating households is far more limited. Meemken and Bellemare (2019) find no convincing evidence that contract farming schemes in six countries generate either spillover benefits within the value chain or employment or wage gains that result in significant income gains for non-contract farmers. But at more aggregated scale, Edwards (2019) does find strong evidence of agglomeration externalities further downstream, in agricultural processing. Studying a natural experiment in Indonesia - the spread of palm oil factories across outer islands – he finds strong evidence of favorable impacts on incomes and non-agricultural employment in villages where the factories open.

The biggest welfare impacts from the agri-food value chain revolution have likely accrued to food consumers. This was true of the Green Revolution that introduced improved crop varieties, inorganic fertilizers, and irrigation to much of the developing world, multiplying crop yields, averting predicted famines, and earning Norman Borlaug the 1970 Nobel Peace Prize (Evenson and Gollin 2003). And the same logic suggests the same will ultimately prove true of the agri-food value chain revolution as well. The basic logic is straightforward. Food demand is typically relatively price inelastic, owing to humans' limited metabolic range, and thus aggregate supply expansion tends to drive food prices down, leading to welfare gains for consumers, with ambiguous welfare effects for producers.[14]

Testing this prediction rigorously is nonetheless challenging. Atkin et al. (2018) perhaps come closest to generating credible causal estimates of the impacts of agri-food value chain transformation on consumer welfare. Using detailed micro-data, they study how the quadrpuling of foreign supermarkets impacted Mexican households from 2002-2014.They find that the average Mexican household gained equivalent to 6% of initial household income from the entry of a foreign supermarket into its municipality. Most of the gains come through price effects that reduce the cost of living, much as occurred in the Green Revolution. Lower prices arise mainly through the efficiencies introduced by the foreign supermarket entrants, but partly through procompetitive effects, i.e., lower prices in pre-existing domestic stores. All households appear to gain, but the effects are regressive, with the richest households gaining about half again as much as the poorest ones. But keeping in mind that these estimates reflect just the cost of entry of a foreign supermarket, omitting the gains that arise through all of the other innovations occurring throughout agri-food value chains in low- and middle-income countries, Atkin et al. (2018)'s estimates are strikingly large.

A key caution about the impressive Atkin et al. (2018) findings is that they arise in the context of new entry into markets. The authors report adverse welfare effects on consumer prices from domestic firms exiting the market in response to foreign supermarket entry. This underscores the crucial role of competition in conditioning the benefits from value chain transformation. Busso and Galiani (2019) likewise find significant (2-6 percent) consumer price reductions (and significant improvements in reported service quality) in response to 26 percent randomized expansion in the number of small retail shops in conjunction with a conditional cash

[14] Cochrane (1958) first developed this analysis as part of his theory of the agricultural 'technology treadmill".

transfer program in the Dominican Republic. In places where value chain modernization leads to increased concentration, rather than heightened competition, one might reasonably expect quite different impacts.

One might likewise look for welfare impacts in consumer dietary and health data. Value chain transformation has radically reshaped the food environments for all consumers. One often hears casual claims about the rise of food away from home –especially fast food – causing a rise in obesity, hypertension, or other adverse health outcomes. And rates of diet-related noncommunicable diseases have indeed increased contemporaneously with the supermarket and food services revolutions (Popkin and Reardon 2018). Is this causal, however? Khonje and Qaim (2018) show that use of modern retailers in Zambia has been shown to be associated with greater consumption of less healthy, ultra-processed foods. They show that the same is true, however, of the use of traditional grocery stores and kiosks, underscoring that modern agri-food firms might not be causal drivers behind dietary transitions that raise public health concerns. Solid causal evidence tying adverse dietary and health changes to changes in domestic and global value chains is, as best as we can tell non-existent.

Moreover, those same value chain transformations have facilitated lower cost access to food overall, and perhaps especially to micronutrient-rich fruits, vegetables, and animal source foods for a broader population. Given that the most prevalent form of malnutrition worldwide arises from mineral and vitamin deficiencies, not from insufficient energy (i.e., calorie) intake nor from obesity, food processing industries in LMICs play an important role through commercial fortification. Mineral-or-vitamin fortified processed foods (e.g., iodized salt, vitamin D-enriched milk, bread and pasta flour enriched with folic acid and niacin) have become widely and inexpensively available to poor populations worldwide, with salutary health benefits. The sharp worldwide reduction in iodine deficiency disorder – the single largest cause of preventable mental retardation globally – follows primarily from nations' widespread enactment of regulations requiring food processors to iodize salt and the rise of value chains producing and distributing industrial salt. But to the best of our knowledge, no systematic literature has yet emerged that convincingly causally links agri-food value chain changes to dietary and health outcomes.

6. A research agenda on agri-food value chains

This review has highlighted the dramatic changes taking place in the industrial organization of the agri-food sectors of low- and middle-income countries, as well as the multiple apparent drivers and the far-reaching implications of those changes. These issues have caught the attention of agricultural economists, of some development economists, and of somewhat fewer researchers within industrial organization and international macroeconomics. These literatures generally remain unintegrated, however. Abundant opportunities exist for fruitful research on this topic with real impact on private and public sector decision-makers. Major multinational companies are making public commitments to increase the incomes of smallholder farmer suppliers, while governments worldwide are exploring how best to nudge food manufacturers and retailers to provide healthier foods to increasingly overweight consumers. In this closing section, we outline a few key areas most in need of attention, in the hopes of sketching the broad contours of a research agenda in this fascinating space.

Formal modeling

As indicated at the beginning of section 2, and hopefully demonstrated in the subsequent sections, the literature on the agri-food value chain revolution is heavily empirical and descriptive. There exist models of the industrial organization of the value chain. But thus far these remain detached from broader macroeconomic models. The intermediation activities of the value chain are notably absent from theoretical models that help us to isolate deductively the mechanisms behind the structural transformation of developing economies and the predictable consequences for different stakeholder populations. One important line of advance in the literature will involve integrating the theory of the agri-food value chain revolution into broader economic growth processes. That will require more formal dynamic general equilibrium models that allow for endogenous product and/or process innovation, imperfect competition, frictions in exchange, and consumer valuation of both the nutritional and non-nutritive attributes of food.

Impact evaluation allowing for heterogeneous effects

Serious limitations exist on robust causal inference within the value chain, as discussed above. Nonetheless, there is considerable scope for more rigorous impact evaluation, especially if researchers work closely with firms and donor or government agencies working actively to build out modern value chain linkages. Randomized roll-out or simply clear (and confirmed) control for firms' explicit selection mechanisms in recruiting workers, suppliers, or both, can generate more robust estimates of the impacts of value chain transformation, both on average and on participants. Real advances will require explicit attention to the heterogeneous responses and returns intrinsic to the process. Concern naturally focuses on the welfare effects on small farmers, (especially landless) workers, and poor consumers, moreso than on average effects across the population.

Relatedly, what firms most want and need to know is the lowest cost way to generate the supply and quality response from growers – and the grower or worker benefits they seek, for example if adhering to Fairtrade protocols – among the range of contract parameters at their disposal: price guarantees, seasonal credit, extension services, transport services, etc. Arouna et al. (2019) offer a first step in this direction by working with a rice processor in Benin to randomize contract terms offered rice growers. They find that an output price guarantee suffices to deliver virtually everything provided by more expensive, complex contracts that also offer seasonal credit and/or extension training. Such research not only provides actionable findings to firms, it also helps the broader development community identify which are most important among the many market failures afflicting growers and workers in LMICs.

Innovation and technology diffusion through the value chain

The agri-food value chain revolution ultimately revolves around innovations, in the products firms sell to consumers, the markets companies enter, the business practices they employ, and the biophysical, digital, mechanical, and other technologies they develop, adapt, and diffuse. Economists have paid considerable attention to farm-level adoption of production technologies, and for good reason. But the bulk of the welfare effects of revolutions within the agri-food system likely accrue to consumers through reduced quality-adjusted food costs, and a steadily rising share of consumer food expenditures go to value addition beyond the farmgate. So economists need to begin paying far more attention to the emergence and diffusion of innovations through the broader agri-food value chain, not just to changes taking place on farms, as important as those may be.

Dynamics of competition and market power

Because firms innovate seeking at least temporary competitive advantage, even market power, and because the degree of competition matters to the welfare impacts of value chain transformation, we need to study the dynamics of competition and market power more explicitly. Where in the value chain, and geographically, are firms most likely to successfully establish market power, how, and for how long does that market power commonly last? When does the market power induce the development and diffusion of new technologies or resolve pre-existing market failures, providing a second-best solution that advances well-being indicators, even for poorer farmers, workers and consumers? And when does market power merely lead to regressive outcomes within the value chain and rent-seeking by firms in the complex political economy of agri-food policies (Swinnen 2018)? These and other questions beg exploration as the agri-food value chain revolution continues apace in today's low- and middle-income countries.

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