Agri-food Value Chain Revolutions in Low-and Middle-Income Countries[*]

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1. Introduction

The economic development process invariably involves structural transformation. The narrative is familiar. A low-income agrarian economy, in which low productivity agriculture employs most workers and generates most output – much of it for subsistence consumption – transitions to a higher-income, more industrialized, service-oriented and diversified economy with a far more productive, but relatively much smaller agricultural sector (Lewis 1954; Johnston and Mellor 1961; Timmer 1988, 2002, 2009). Agricultural technological change often sparks the transformative process, releasing farm labor to work in other sectors and to migrate to cities, and providing plentiful raw materials for secondary processing and manufacturing. Given an income elasticity of demand greater for non-farm goods and services than for food, per Engel's Law, the resulting farm and non-farm income growth disproportionately stimulates demand for non-food goods, including non-tradable services that generate especially big local multiplier effects and rapid economic growth (Mellor 2017). In the face of price inelastic demand for food, increased agricultural productivity also drives down real food prices, thereby raising real incomes and reducing poverty and undernutrition among the rapidly growing non-agricultural population (Evenson and Gollin 2003). The bidirectional linkages between rural agricultural and urban industrial and service economies spark increasingly efficient spatial integration of factor (e.g., financial and labor) and output (e.g., food) markets, shrinking intersectoral productivity gaps and igniting balanced growth (Lewis 1954; Johnston and Mellor 1961; Gollin et al. 2013; Lagakos and Waugh 2013; Timmer 2015; Tombe 2015). As 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).

This empirically and theoretically compelling story largely overlooks, however, the role of the agri-food value chain (AVC) that intermediates between agricultural producers and the rising population of urban food consumers. The vast AVC encompasses the whole post-farmgate range of processing, storage, transport, wholesaling, retailing, food service, and other functions that transform the agricultural outputs that farms produce into the foods humans consume multiple times every day.[1] Dual economy models and other useful simplifications of complex development processes typically abstract from crucial intermediation roles and implicitly assume that primary agricultural producers directly supply consumers through complete and competitive markets. 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.

There has been far less focus on the dramatic transformations occurring within AVCs, on the agri-food value chain revolutions that always go together with industrial and agrarian revolutions, to adapt the earlier quote from Lewis (1954). The discovery and diffusion of new products, equipment or management practices typically reduces the quality-adjusted unit costs of

[1] We favor the modifier 'agri-food' over either 'agricultural' or 'food' because the value chain transforms the agricultural feedstocks produced by farms into the foods humans eat. Since many farms cultivate both food and non-food (e.g., cotton, sisal, tobacco) products, and people consume little food that has not been packaged, prepared, processed or transported off-farm, both the 'agricultural' and 'food' modifiers are too narrow on their own. Upstream input suppliers – e.g., seed, fertilizer, or agricultural machinery manufacturers – are often included in the AVC. In this paper, however, we focus mainly on post-farmgate intermediation between farmers and consumers.

processing, storage, transport, retailing and food service, driving down quality-adjusted consumer prices for food, permitting entry into new markets, and sparking increased investment, off-farm employment, and economic growth. Indeed, as we explain below, innovations in the AVC often induce the adoption and diffusion of agricultural technologies, sometimes initiating the familiar processes of structural transformation.

The role of the AVC in the process of structural transformation remains largely unexplored, however. A key reason for this is the absence of an integrated, structured empirical narrative on AVC revolutions. This paper aims to help fill that gap. We expressly do not attempt to modify established theories of structural transformation to account explicitly for AVCs. As our closing section emphasizes, that is a key research frontier as this literature progresses. We concentrate here on the initial step of integrating extant empirical understandings of how and why AVC revolutions occur in developing countries, and the impacts of those changes.

As we show below, AVCs represent a larger and more rapidly growing share of most low- and middle-income countries' (LMIC) economies[2] than most non-specialists recognize. AVCs are a source of tremendous dynamism in rapidly growing LMICs, an entry point for foreign direct investment (FDI) and technology transfer, a generator of scarce foreign exchange, and a far larger employer than the farm sector as economies grow. Structural changes in AVCs have been transforming the lives and economic fortunes of billions of people in LMICs for decades. But many observers have paid little attention to those changes.

What is possibly even more impressive than the number and poverty of the people affected by these changes is the speed of the process. It took a century to transform AVCs 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. For example, the spread of modern retail (supermarkets, etc.) in Brazil in just one decade (the 1990s) was equivalent to the retail expansion over half a century in the USA (Reardon and Berdegué 2002). Such rapid transformations 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). A dramatic, parallel "food service revolution" has likewise been underway to meet rapidly growing consumer demand for food away from home (FAFH). This has been evidenced in studies showing rapid growth in consumer FAFH expenditures in places like China (Liu et al. 2015 and Tian et al. 2016), as well as from the supply side by studies showing the meteoric rise of fast-food chains, domestic and international, in Latin America (Popkin and Reardon, 2018) and in

[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 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.

Asia (Pingali, 2007), as well as an explosion of street food vendors in rapidly growing cities of the global South (Crush and Young, 2019). More recent studies show that even staple food markets and production systems in 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).

These changes have major implications for food consumers, farmers, and the intermediaries(e.g., wholesalers, processors, third party logistics service providers, retailers) and their workers who transform and move product between them. The AVC revolutions have been accompanied by rapid changes in the types of food offered to urban consumers, forms of vertical coordination among and integration within firms, and in the opportunities and challenges farmers face. For example, farmers can increasingly access distant, 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 often necessitates technological upgrades by producers and marketing intermediaries alike. The industrial organization of the AVC necessarily evolves to attend both to new issues arising from changing consumer demand patterns and to continuing rural market imperfections arising from weak physical and institutional infrastructure.

The AVC revolutions have also introduced new systemic risks, as the COVID-19 pandemic has made clear. Elongated supply chains have brought product differentiation to satisfy the varied needs of both retailers selling small volumes to individual consumers and restaurants and other food service providers that need bulk supplies of products meeting specific, often idiosyncratic standards. Processing and packing customized to the needs of specific channels (or even large individual clients) bring high average returns but also increased costs of switching to a different format. Channel-specific shocks due to the pandemic, especially within labor-intensive nodes, have had quite varied impacts within AVCs as shocks propagate quickly to other markets through backward or forward linkages. The FAFH channel has been especially heavily affected, as restaurants, schools, factory canteens, and stadium concessions have shuttered. This generated negative income and labor demand shocks beyond the food service sector as farmers linked into the food service channel have struggled to find new markets for their commodities. Many farms have been forced to dump perishables such as eggs or milk into waste lagoons, or to leave crops to spoil in the field or plow them under so as to avoid attracting pests that damage plants the next season. Meanwhile, farmers in some countries and sub-sectors have faced interruptions in harvest labor availability due to travel restrictions on farmworkers or social distancing requirements that compel sub-optimal density of farmhands on fields and in orchards where workers typically operate side-by-side. Public health concerns and associated labor restrictions have likewise forced closures or slowdowns in processing plants, driving up retail meat prices even as the prices farmers receive for live animal collapse. Meanwhile, the pandemic induced a rapid surge in retail consumer demand that has led to stock-outs and temporary price surges for some staple food products (e.g., eggs, flour), and an uptick in labor demand in food retail supply chains globally. The recent spectacle of food price spikes occurring at the same time as farmers dump the same product as waste can only be properly understood through the lens of AVC evolution. The COVID-19 experience reinforces the importance of analyzing AVCs so as to better understand the economic implications of real economy shocks.

In this paper we synthesize largely unintegrated literatures on the AVC that can be found in in agricultural economics, development economics, industrial organization, and international economics – as well as multidisciplinary development studies and agricultural sciences – journals. Each field has told only part of the story of the AVC revolutions that has been taking place now for decades. We call attention to the massive and rapidly evolving, but largely underappreciated, role that AVCs play in the economic transformation of LMICs, especially in rural areas that comprise so much more than simply a space for farm production. Although the evidence on AVCs has been hiding in plain sight for years, the many interesting economic phenomena found therein have been insufficiently studied by economists.

Section 2 describes some broad empirical patterns evident in AVC transformation. This provides a basic conceptual framing of the AVC revolution in LMICs, emphasizing its roots in exogenous income growth and technological change, urbanization, economic liberalization, and globalization. We then briefly enumerate some key challenges to empirical work in this space in section 3. The many shortcomings in this literature have limited its integration into the broader study of economic development and growth, but also open up important research opportunities. Section 4 chronicles three remarkable revolutions within AVCs, with special attention to the consumer-facing supermarket retail and food service sub-sectors, and the mid-stream sub-sectors that quietly intermediate between farm-level producers and consumer-facing retailers and food service providers. Section 5 summarizes the predominantly micro-scale empirical evidence on the impacts of AVC changes on various outcomes of interest, such as poverty, nutrition, labor, and the environment. Section 6 then closes by identifying key research opportunities in this space.

Ours is largely an empirical narrative. But opportunities abound for richer theorizing about AVCs' role in the structural transformation process. These can usefully inform empirical study. For example, no good empirical evidence presently exists on the relative size and importance of productivity growth on farm versus in the post-farmgate AVC. These presumably complement each other, as efficiency gains in either should spill over into price changes in the other, potentially inducing correlated investment and productivity growth. In order to explore these and other interesting questions, however, we first need to pay greater attention to AVCs, a large, growing and rapidly evolving part of the economy. The research literature on AVC transformation in LMICs is far nearer the beginning of the story than its end.

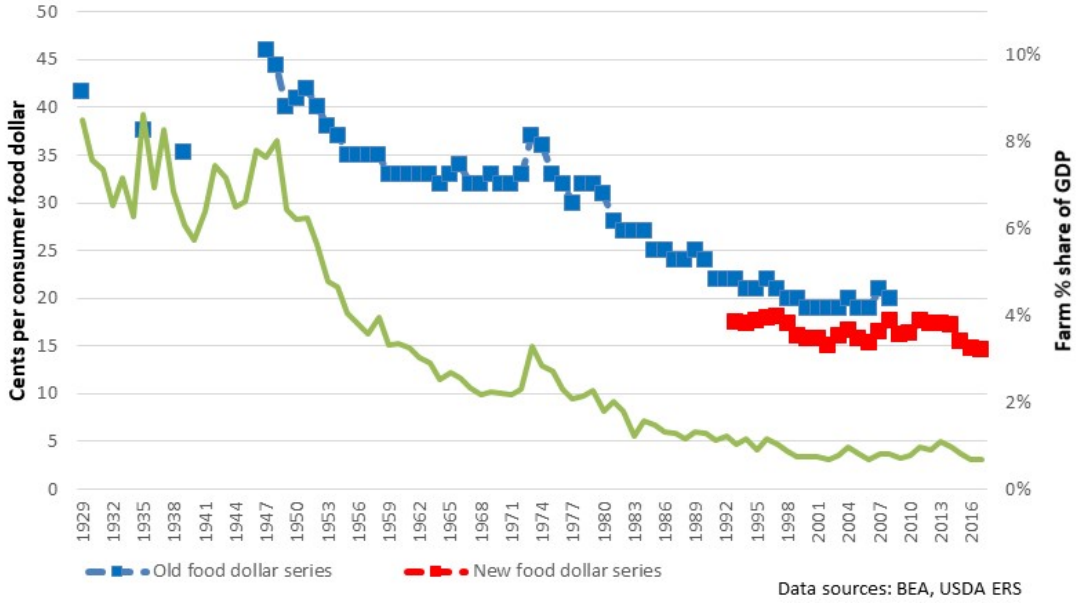
2. Key stylized facts and drivers

Data from the United States illustrate 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.[3] 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 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.

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

Gross farm production as a share of annual US gross domestic product (GDP) was 8.5%, quite similar to MICs today such as China, Ecuador, Sri Lanka, Thailand, or 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,[4] 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 left-hand 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.[5] Yi et al. (2020) apply the same method to harmonized annual national input-output and use tables over the 2005-15 period for 61 middle- and high-income countries, with real gross national incomes per capita ranging from $1,969 to $85,422 per year, that together represented about 90 percent of the global economy in 2017. Their data include all the large LMICs – e.g., Brazil, China, India, Indonesia, Mexico, Russia, South Africa -- and a few poorer countries as well – e.g., Cambodia, Vietnam. They show very similar patterns, albeit over a much shorter time period, with mean (standard deviation) farm share of food expenditures at home of 0.27 (0.09) in 2015 and varying across countries only between 0.16 and 0.38 over the whole 2005-15 period. Post-farmgate AVC actors clearly capture the overwhelming majority—

[4] See ERS' national tables available at https://www.ers.usda.gov/webdocs/DataFiles/47679/table01.xlsx?v=2945.1.
[5] 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 2011. The new series is, on average, 3.5 cents/dollar lower than the old series over the 16 years of overlapping coverage.

typically two-thirds to three-quarters or more—of the revenue generated by domestic consumer food expenditures throughout most of the world today, including the LMICs.

So what factors are most strongly associated with this transformation? We briefly enumerate these in the rest of this section, setting the stage for more detailed discussion of the three key AVC revolutions that have occurred in LMICs in recent decades and of the growing microeconomic evidence on the causes and impacts of AVC transformation.

2.1 Income

The growth of AVCs and broader macroeconomies have coevolved. The reasons for the growth of the post-farmgate AVC are intuitive and straightforward. Not only does overall economic activity migrate off the farm as economies develop, but so does value addition within the food system itself. Yi et al. (2020) find that a doubling of per capita real income is associated with a 5.4 percentage point shrinkage in the farm share of domestic consumer food expenditures even as absolute farm revenue increases.

The reason is that growing incomes fuel increased consumer demand for food, but especially for higher-quality, more processed and varied foods. The income elasticity of demand for non-nutritive quality 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 macronutrients such as calories (Behrman and Deolalikar 1987, 1989; Bouis and Haddad 1992, Pingali 2007; Jensen and Miller 2008, 2011; Ortega et al. 2011). 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] But perishables require more and faster processing and transport so as to avoid spoilage and losses. Meanwhile, 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 time-conserving prepared and processed foods, especially frozen and refrigerated products (Ma et al. 2006; Senauer et al. 1986).

The endogenous consumer demand response to exogenous income growth and technological change – e.g., the emergence of low-cost refrigerators and microwave ovens affordable to the working class – 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, but especially for the non-nutritive attributes of higher value food and food away from home, is 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, using nationally representative household survey panel data, Liu et al. (2020) find that rapid real income growth in rural Vietnam drove the median share of farm (not just rural) 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

[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).

diversity. Similarly, in the LMICs of eastern and southern Africa, Tschirley, Reardon, et al. (2015) show rural households bought 44% (in value terms) of the food they consumed. In Asia, Reardon (2015) found that the share of rural food consumption in value terms that was purchased was 52% in Nepal, 80% in Indonesia and Bangladesh, and 72% in Vietnam.[7]

2.2 Urbanization

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. Furthermore, patterns of urbanization differ in today's LMICs, that have more high-density megalopolis than today's high-income countries of Europe and North America, that evolved more spatially distributed networks of medium and large cities and far fewer mega-cities. 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. Industry executives tell us that economies of scale and scope feature more prominently when intermediaries serve an urban population concentrated in mega-cities than when serving an urban population more distributed across many mid-sized ones, although we find scant research that explores this hypothesis. This suggests more opportunities for the emergence and exercise of market power 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 urban food 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 households just 60%.

2.3 Market-oriented policy reforms

Economic policy naturally plays an important role in AVC evolution. Beginning in the colonial era, many states controlled the purchase and/or sale of agri-food commodities through

[7] Computing the value of autoconsumed food necessarily requires contestable assumptions about the shadow price of those foods. Careful studies use the seasonal-average local purchase price of the same commodities, not the price of the same commodity sold by local households, which may differ in timing, quality, and volume. Even then, autoconsumed foods typically require more costly preparation than purchased foods and survey data rarely if ever report food preparation time in a way that enables incorporating it into the valuation of autoconsumed foods. While level estimates may therefore be treated with healthy suspicion, changes over time computed using the same data series and methods should provide a reasonably accurate representation.

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, governments 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), others 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 (Swinnen et al 2011). 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; Bergquist 2017; Casaburi and Reed 2017). In places without institutions supportive of private investment in AVC innovations, these transformations have been notably slower (World Bank 2005).

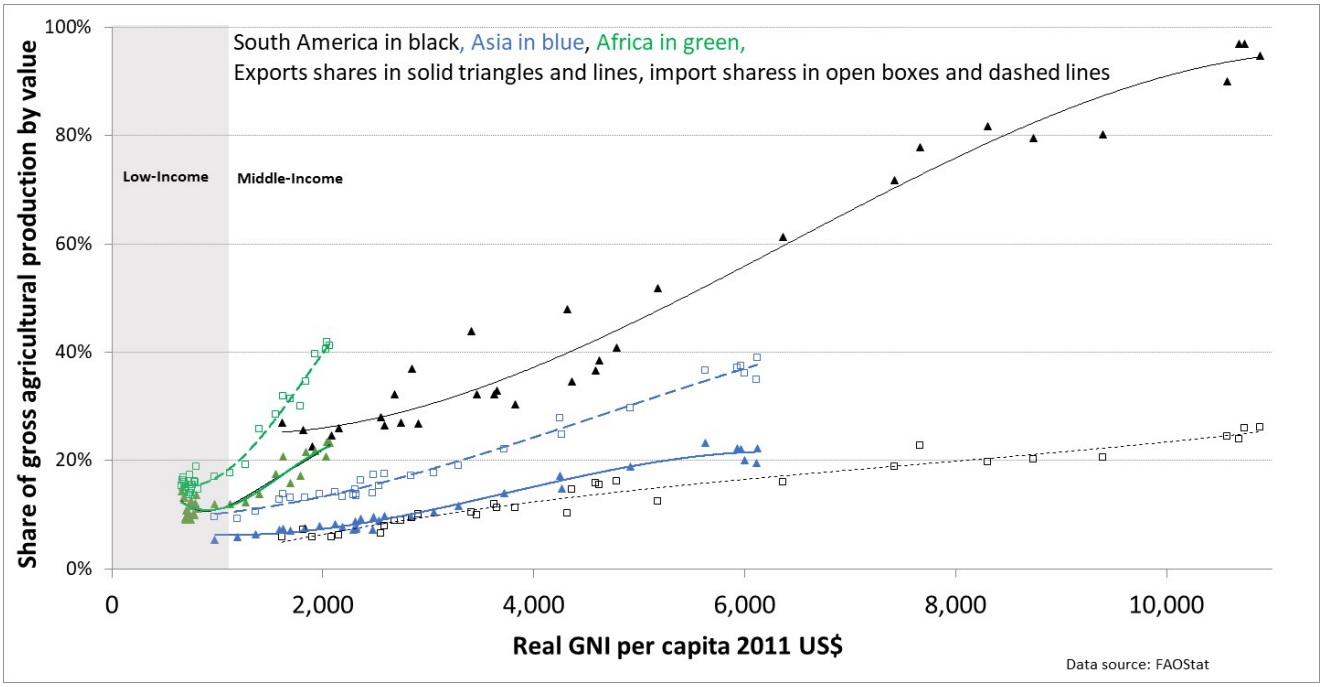
2.4 Globalization: global and domestic AVCs

In many countries, market-oriented policy reforms also entailed opening to international trade and foreign investment. Both have had an important impact on AVCs in LMICs. Global value chains (GVCs),[8] within which products cross international borders to supply foreign markets, increasingly matter due to the 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).

The share of agricultural exports and imports in domestic production for Africa, Asia and Latin America provides an important indicator of AVC globalization. Figure 2 shows how over the 1985-2016 period, in (shaded) LIC range, gross imports and exports comprise less than 20% of domestic agricultural production. In the MIC region, food imports increased to around 40% in Africa and Asia and to around 25% in South America. Food exports are significantly less, varying from around 5-10% to around 25% in Africa and Asia. Only agricultural exports from Latin America are significantly higher.

[8] A broader literature on global value chains (GVCs) and their relationship with trade and productivity has developed parallel to the AVC literature on which we focus (e.g. Gereffi 1994; Antras and Helpman, 2004; Gereffi et al. 2005; Goldberg et al 2010; Antras et al 2017, World Bank 2020). We do not attempt to summarize that rich literature here, only to draw on a few key insights directly relevant to the AVC transformations that have been underway in LMICs for decades.

Figure 2: Agricultural exports and import shares of production, by region, 1985-2016



There are obviously large differences among commodities. The internationally traded shares of total output can be high for particular products, such as cocoa, coffee, or tea. Traditionally, these products and storable commodities, such as grains, were more widely traded than commodities further up the value ladder because they can be shipped relatively cheaply in bulk without refrigeration. In recent years exports of higher value products in sub-sectors such as dairy, fruits, meat, seafood, and vegetables have increased with significant GVC investments in logistical capacity. 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).

Global value chains in the agri-food sector typically also involve important cross-border movements of investment capital (through direct and portfolio investment), and business practices/skills (contracting, logistics expertise, etc.), perhaps even more than the flow of goods through trade. Capital market integration has stimulated substantive foreign direct investment (FDI) in agri-food value chains as well. Countries such as Argentina, Brazil, Korea, Mexico, and Taiwan nearly completely opened up to foreign investment in the 1980s-90s. Arguably the most extreme case has been in Eastern Europe where a huge share of agribusiness, food processing and retail companies were taken over by western companies through FDI after economic liberalization and privatization in the 1990s (Gow and Swinnen, 1998). The likelihood and magnitude of FDI have tended to increase the more the domestic economy is integrated with global markets through infrastructure, trade, and cross-border financial policies. FDI tends to enhance private sector investments to integrate markets, complementing – occasionally even replacing – public sector efforts (Timmer 1997).

Some large LMICs, such as China, Indonesia, South Africa were much slower and others, like India, remain resistant to foreign majority ownership of firms in the agri-food sector. In those places that permit it, FDI often helped ignite the supermarket and food service revolutions

we describe below 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.

Yet, despite significant integration of LMICs in international markets, most food products are still consumed inside the country that produced the source agricultural feedstocks. Globally, only 23% of the food produced is traded across borders (d'Odorico et al. 2014). Relative to non-food manufactured goods and non-agricultural commodities such as metals or oil, 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 rather manufactured in the country in which they are consumed.

It is therefore important to focus not just on GVCs but also on domestic value chains (DVCs), which continue to play a very important role in LMICs. DVCs – product supply chains that begin and end within a single country - still represent the dominant share of agricultural output for most LMICs. DVCs can be operated by both domestic and multinational firms. Many AVCs link the two, as when a locally-owned farm sells its produce to a multinational processor or trader (e.g., Cargill, Danone, Heinz, Mars) that sells its products (e.g., chocolate, flour, ketchup, yogurt) to either multinational or domestic retail chains and food service outlets. The rate of 'multinationalization' of domestic AVCs – i.e., the share of foreign capital in a given function, sub-sector, or supply chain remains notably underresearched (Dries et al. 2004). While data on foreign investments in AVCs are not systematically available, we document in Section 4 how local small and medium enterprise (SME) retailers continue to occupy a large share of the domestic food market in most LMICs. Even in modern supermarkets, locally-owned chains' share of supermarket food sales varies from 38% in Latin America, to 52% in Africa to 64% in Asia (see section 4.2 below).

DVCs maybe especially, and differentially, affected by specific policy interventions. For example, public infrastructure investments have comparatively large impacts on DVC 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), investments that reduce the remoteness of farmers from markets seems to have more of an impact on agricultural commercialization than do macroeconomic or trade policies, mostly within the DVC (Barrett 2008; Stifel et al. 2016).

There may be spillovers between GVCs and DVCs (Feyaerts et al. 2019). These spillovers are mostly positive, with growth in one channel benefitting expansion in the other. Some of this involves technological spillovers, for example, when improved practices introduced by firms exporting to high income markets help growers learn and satisfy more stringent international standards (e.g., GlobalGAP certification) and the same growers' then enter domestic supply chains (Masakure and Henson 2005; Maertens 2009; Krishnan 2018; Van den Broeck et al. 2018). Similarly, improved soil and water management practices introduced by a fresh vegetables exporter's extension agents were used by farmers in Madagascar to boost livestock and rice production for local markets (Minten et al. 2007; Bellemare 2012). Infrastructure directed towards facilitating foreign exchange earning exports – e.g., rural feeder roads and aggregation marketplaces – can also accelerate the evolution of DVCs (Theriault and Tschirley

2014). And because most LMIC farms produce multiple agricultural commodities, increased earnings by growers supplying a contracted commodity to one channel often provide the revenue needed to invest in boosting productivity in another product supplied to the other value chain.

Of course, there can also be competition between GVCs and DVCs for labor, land, water, and other inputs. An important concern during the large-scale land acquisitions that occurred in many LMICs in the 2008-15 period was that foreign investors aiming to secure a reliable source of food for the investing country would divert scarce resources away from DVCs. Most of the limited available descriptive evidence suggests little competition for labor, land or water in places such as Senegal (Maertens 2009, Van den Broeck et al. 2018), although intrahousehold competition for water and for labor allocated between men's export crops and women's domestic food crops has been found in Kenya (e.g., Dolan 2001, Zaehringer et al. 2018). Overall, globalization appears a key stimulus to AVC transformation, even if much of the resulting change occurs in DVCs, not just in GVCs.

2.5 Endogenous evolution of practices, standards and technologies

Increased access to increasingly prosperous markets domestically and globally, as well as increased trade in perishable fresh food products that require cold chains and are both prone to food safety risks and subject to specific quality demands by consumers, have 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 safety scandals in the later 1990s triggered the introduction of the EU Food Safety Law, which imposed much more stringent regulations of AVCs 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. The emergence of commodity exchanges to facilitate the management of financial risk, especially through forward contracting, also inevitably compels standardization of quality and measures to facilitate larger scale transactions among anonymous agents.[9]

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. SPS notifications at the World Trade Organization have increased rapidly. While SPS notifications were once dominated by high-income countries' filings, in recent years they come increasingly from LMICs; and the same holds for other food standards (Zezza et al. 2018).

Although food safety laws and regulations typically evolve relatively slowly and in response to high-profile scandals or scares, 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; Harou et al. 2017). Standards can help differentiate

[9] The track record of commodity exchanges in LMICs is checkered at best for a range of reasons related to contract enforcement, liquidity and regulatory problems (Sitko and Jayne 2012; Meijerink et al. 2014; Rashid 2015).

a product, obviating the need to compete on price, perhaps especially for standards satisfying product attributes, like safety, with high income elasticity of demand (Barrett and Yang 2001).

Firms continuously search for new markets, more efficient management practices, higher quality inputs and new ways to differentiate their products so as to generate new sources of profit as their past innovations diffuse to competitors, increasing competition that squeezes profit margins for the original innovators. Continuous innovation both drives and is driven by income growth, urbanization, integration with distant markets, and rising standards, leading to patterns that appear broadly consistent with Vernon's (1992) international product life cycle theory. Innovators take advantage of heterogeneity of potential adopters and commonly launch new products 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. AVCs 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.

AVC entry into new markets, adoption of new product standards and management practices follow patterns quite similar to the technology development, adoption, adaptation, and diffusion processes so widely studied in agricultural and development economics.[10] The processes are commonly intertwined, as private AVCs invest in research and development and upstream extension services, as has occurred in Brazil, China, or India (Pardey et al, 2016). The growing importance of the private sector in agricultural innovation in developing countries is both cause and consequence of the growing importance of AVCs that both propagate and adapt farm-level innovations to suit downstream demand.

The logistics and management of AVCs are also typically designed to optimize the economic returns to entrepreneurs entering new markets or introducing new products or practices to established markets, as we detail below (Zilberman et al. 2017; Swinnen and Kuipers 2019). For example, innovators that introduce a new type of food (e.g., pre-cut, pre-washed salad) establish a market for this product with a customer base they already reach and simultaneously build the supply chain for the feedstocks (e.g., various types of vegetables) needed to produce the salad. Depending on its financial resources, human capital, risk considerations and legal constraints, the innovating firm might vertically integrate and produce the crops directly, contract with feedstock producers, or simply buy from feedstock producers on the spot market, as local conditions dictate. Often, the innovator enjoys significant, if perhaps transitory, market power in the new market channel.

The diffusion of production and processing 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). Innovations prompt endogenous reorganization of supply chains. For example, AVC organization often evolves as firms and their clients and suppliers learn by doing and by observing others. As we describe below, it has therefore been common to see firms initially produce feedstock in house initially, until external producers develop sufficient skill to produce in reliable volume and quality – or former employees develop spin-off firms to meet the firm's

[10] Feder et al. (1985) and Foster and Rosenzweig (2010) offer good surveys of different eras' literatures on technology adoption.

demand under contracts. The modern cut flower industry in Kenya started when a Danish organization opened a vertically integrated operation producing and shipping flowers, but over time most of the production shifted to local farmers (Whitaker and Kolavalli 2006). Pre-cut, pre-washed salad was initiated by a large, vertically operated organization in California, which gradually transitioned to processing throughout North America, relying on contract farmers for feedstock, and was later taken over by a multinational that took the product global (Lugg et al 2017). Change is the greatest constant in AVCs once transformation is underway.

The broad story of the AVC revolutions sweeping the developing world is thus one of endogenous technological change and product differentiation as incomes grow, people migrate to cities, consumer food demand changes endogenously, and AVC firms emerge and expand by serving new markets that might give them at least temporary market power and (often transitory) higher profits. This process induces market integration, investment, changing labor demand, and the diffusion of new practices and products. Monopolistic competition often emerges, and increased opportunities for hold up problems associated with customized supply chains. One of the major challenges in this literature is to describe these changes accurately and to test the hypotheses that naturally emerge, especially around the distribution of gains from AVC transformation. These challenges have their origins in data and methods issues to which we now turn.

3. Data and methods challenges in empirical AVC transformation research

Before we summarize the empirical literature on the AVC revolutions in LMICs in section 4, we first offer a few observations on the general state of this body of research. Most AVC scholarship has appeared in agricultural economics journals thus far, although important, recent contributions exist in development economics and general economics journals. The latter papers have typically focused very narrowly on specific phenomena, however, and have not linked to the broader sweep of the literature. Multiple challenges exist to documenting patterns and cleanly testing hypotheses, especially about causal mechanisms driving AVC transformation and the impacts of those changes. As a result, opportunities abound to firm up our empirical understanding of AVC transformations and their broader impacts through intellectual arbitrage across fields. Hence this review paper.

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 is that 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 unobserved. This largely limits study of AVCs in large household surveys to coarse descriptions of participation in marketing channels.

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. 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. Even those have not been widely used. The national harmonized input-output and supply-and-use tables available through UN Stats, for example, have rarely been used to try to decompose food value chains in a comparable, cross-country way (Yi et al. 2020).

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., its emergence, restructuring, 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.

Those special purpose surveys are prone to important biases, however. 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). For example, most 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 and average treatment effects on farmer incomes, etc. can vary across commodities even within the same region of a single country, in her case, south India.

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, attempts have been made to use panel data and stacked surveys that repeatedly sample each segment of a value chain so as to explicitly capture the links among distinct agents and prospectively control for time invariant unobservables that almost surely confound inference (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 statistical endogeneity.

Less commonly and more recently, studies using randomized controlled trials (RCTs) 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; Arouna et al. 2019; Burke et al. 2019). As we describe in more detail below, these studies have typically focused on specific aspects of value chain development. 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 the emergent RCT-based literature has largely focused narrowly 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 and 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. And for many important AVC questions, standard RCT designs aimed at uncovering average treatment effects can be irrelevant due to structural heterogeneity (Barrett and Carter 2020). It may be more fruitful to work directly with firms to explicitly and precisely document and control for their actual placement and selection mechanisms than to randomize across a subpopulation of farmers differentially likely to ever be offered a contract.

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 agricultural 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. Bellemare and Bloem (2018) graphically document this spatial bias in the special case of the contract farming literature. The generalizability of patterns revealed from specific places remains an open question.

Finally, there is a related but somewhat distant literature using computable general equilibrium (CGE) models based on input-output tables and social accounting matrices that model the value chain explicitly. While these remain exceptions within the broader CGE literature, a few country-specific CGE models have explicitly modelled segments of the AVC. Roe and Diao (2004), for example, model the Moroccan economy, using a Ramsey growth framework assuming higher capital intensity of the retail sector and of modern agriculture as compared to traditional agriculture. Simulating growth dynamics over 30 periods, they find increased income growth accompanies an increase in the capital-intensity of the food sector, a contraction of traditional agriculture, and a decline in the overall share of food expenditures, matching the broad patterns of most economies. Dorosh and Thurlow (2018) developed CGEs

for five African countries to investigate alternative strategies to reduce poverty. They found that a diversified strategy, including investments in small farms as well as in manufacturing and agro-processing sectors, may dominate strategies that mostly invest in smallholder agriculture. Recent applications of these models have been useful in simulating the impacts of COVID-19 and the economywide impacts of lock-down policies propagated through AVCs (Thurlow 2020, Zhang et al 2020). Their disaggregated models allow them to disentangle the strong effects originating in the food service sector from lesser effects prompted by direct shocks to food processing and farming.

Of course, CGE models take a structural rather than a design-based or descriptive approach to empirical analysis. The emphasis within economics over the past generation on design-based (perhaps especially RCT-based) empirical work has disfavored these structural model-based approaches to empirical exploration of AVCs. That might help explain why there has been relatively little integration of the CGE-based literature with the rest of the empirical research on AVCs. Renewed, current interest in shocks and the resilience of AVCs, triggered by the COVID-19 pandemic, may increase interest in model-based approaches to study AVCs and and their role in broader economic phenomena and policy.

In summary, the empirical literature has clearly evolved, from being dominated by case studies, to cross-sectional surveys of firms and households, to a combination of panel data, RCTs and natural experiments-based studies, with a few CGE modelling efforts on the fringes of this literature. The growing diversity and rigor of methods in use 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 clean causal identification of the gains generated by AVC transformation and the distribution of those gains, as we detail in section 5.

4. Patterns of agri-food value chain transformation

We now provide a more in-depth discussion of the AVC transformation by identifying, first, three distinct waves of transformation and, second, three different AVC "revolutions" that have occurred in LMICs in the past two or three decades, albeit at different paces and to differing degrees across countries and regions.

4.1 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 away from spot market-based exchange with limited food processing or consumption outside the home; comparable change is now taking place elsewhere in the space of just a couple of decades. 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 behavioral responses we outlined in section 2. Despite heterogeneous conditions across and within countries and sub-sectors, these patterns appear fairly general, albeit impressionistic.

Table 1. The three stages of transformation of agri-food value chains

	Traditional AVC	Transitional AVC	Modern AVC
Main enterprise type in:			
Retail	Home enterprise	SMEs, wet markets	Supermarkets
Food service	None (home cooking)	Street vendors, independent restaurants	Fast-food chains
Processing	None (home-processing)	SMEs such as small mills	Large processors and food manufacturers
Wholesale	Brokers based in rural villages	Wholesaler based in urban markets	Off-market distribution companies
Logistics	Own-logistics by brokers	SMEs in third party logistics (3PLS)	Large 3PLS companies and freight forwarders
Supply chain length	Short, local	Long, rural-urban	Long, rural-urban, international
Exchange arrangements	No contracts, no standards	No contracts, public standards, some vertical integration	Emerging contracts, private standards, vertical integration
Technology	Labor-intensive	Labor-intensive	Capital-intensive
Foreign direct investment	None	Emerging	Significant

Table 1 provides an overview of the discussion of the three stages of evolution in AVCs that we explore empirically below. Table 1 shows as rows distinct axes of AVC transformation. The shifts depicted in the table are empirical regularities consistent with the broad patterns described in section 2. As a market grows with rising incomes, urbanization and globalization, firms grow in scale, shifts occur from technologies intensive in labor to intensive in capital, from spot markets to coordinated markets with contracts and standards and more vertical integration, from short local supply chains to longer supply chains with a larger share of post-harvest segments, and from sourcing investment capital locally to sourcing it internationally through FDI. The following subsections discuss these three stylized stages in more depth.

The first is the traditional stage of low-income agrarian nations with large semi-subsistence agricultural sectors. In these settings, traditional value chains are spatially short because the urban share of the population is low. 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. Hence there are few supply chains for specialty crops, except for some traditional export commodities, 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 nor undergo much physical transformation by commercial firms. 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; Bergquist 2017; Burke et al. 2019). 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. This is the agricultural sector in the background of the 'backward' agricultural sector in conventional dual economy models.

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.

Many SMEs enter midstream – between feedstock producers and final consumers – to add value through canning, milling, packaging and other services 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, as Barrett (1997) documents in multiple AVCs in post-liberalization Madagascar. 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 those 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, especially to farms connected to commercial AVCs (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.

In the third, modern stage, agri-food value chains become organized almost entirely around serving urban demand through commercial intermediaries. 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 perishable 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).

AVCs exhibit fewer transactions between farm and fork as supermarkets, restaurant chains, 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 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 or catering to a distinct ethnic group through social networks. FDI liberalization that started in the transition stage now brings widespread multi-nationalization within multiple segments, especially third-party logistics, processing, supermarkets, and food service. 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. 2020). 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, fair trade, Meemken 2020; Sellare et al. 2020), or for status-signaling or health-oriented commodities, such as quinoa (Bellemare et al. 2018). These private standards typically evolve more quickly, and are far more strictly enforced, than public regulatory standards in LMICs. Public standards rarely bind once the AVC reaches the modern stage. 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).

Countries – and regions within countries – have moved through these stages in broad 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 of 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 only 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. And a host of low-income agrarian countries that have yet to enjoy any significant, sustained improvement in standards of living remain mired in the traditional stage today.

4.2 Three revolutions in the transformation

Across these three stages of transformation, three distinct revolutionary changes in AVCs stand out especially prominently as empirical regularities. Although we describe them as distinct revolutions, they are closely intertwined, sharing common drivers and feeding off one another. Because national accounting systems are not organized to group data by both function and product, these broad patterns have gone largely unnoticed outside the specialized literatures we briefly describe here. As we describe in section 6, these may be fodder for useful extensions of existing general equilibrium models.

4.2.1 The supermarket revolution

The first revolution, both to appear in the literature and to occur in most AVC transformations, 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 (Dries et al, 2004; Atkin et al., 2018). Supermarkets emerged recently in Africa, as we show below. A process similar and parallel to that of supermarkets occurred in food processing and agribusiness companies in many countries.

We use 2002 and 2018 data from the retail data service Edge by Ascential (www.ascentialedge.com), formerly PlanetRetail, to analyze food sales by modern retail chains in Africa, Asia, and Latin America. In Africa, Asia, and Latin America and the Caribbean (LAC), Edge assembles and standardizes data for food sales by modern retailers in 35 countries in the three regions (14 in Africa, 9 in Asia, and 12 in LAC). The data cover 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). Edge covers leading retailers; the rising number of retailers followed in the base indicates retail chains starting in the countries. The sales data represent a conservative estimate of modern chain food sales in the regions because the service only covers leading chains, not smaller chains and independent supermarkets. The full list of retailers followed per country and region, classified by country into of local, regional, or international origin for that country's market, is provided in Appendix Table 1.

Table 2: Three waves of transformation per region

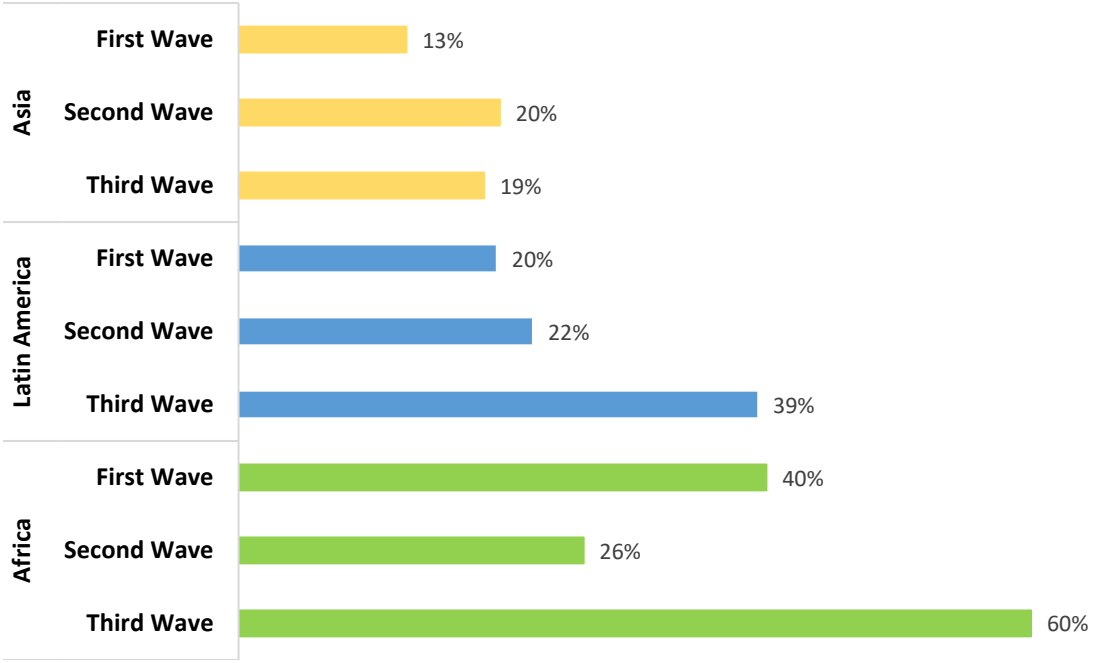
Regions and Waves	GDPpc 2016	% Urban 2016	Countries
ASIA			
First Wave	**25,098**	**80**	South Korea, Taiwan
Second Wave	**6,179**	**56**	Indonesia, Malaysia, Philippines, Thailand
Third Wave	**4,000**	**42**	China, India and Vietnam
LATIN AMERICA			
First Wave	**12,295**	**91**	Argentina, Brazil, Uruguay
Second Wave	**8,371**	**73**	Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico
Third Wave	**3,796**	**68**	Bolivia, Nicaragua, Peru
AFRICA			
First Wave	**7,303**	**60**	Botswana, Namibia, South Africa
Second Wave	**906**	**32**	Kenya, Madagascar*, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe
Third Wave	**2,221**	**54**	Angola, Ghana, Nigeria, Senegal*

Source: 2010 real US$ GDP/capita and share of urban population from World Bank Open Data (https://data.worldbank.org/). The per wave estimate is the arithmetic mean over the countries. These variables are used to classify countries into the three waves. They are correlated with the degree of current supermarket penetration in the countries as well as the vintage of supermarket expansions in the country.
*We exclude Madagascar and Senegal from the food service analysis due to insufficient data.

As there was substantial heterogeneity in the start of modern retail diffusion over countries per region, we categorize the countries in each region into a sequence of three waves of diffusion (following Reardon et al. 2003), for early, middle, and late adopters. Table 2 shows the categorization of countries into waves using two explicit criteria (the 2016 per capita GDP and the share of urban in total population) and implicit criterion (the approximate "take-off" year of supermarkets in the countries. Not surprisingly, supermarkets tended to take off earlier in places with greater per capita incomes and urbanization. The exception is in Africa where the third wave has higher incomes and urbanization than the second wave due mainly to supermarkets from South Africa and Kenya investing in proximate Eastern and Southern African countries (in the second wave) before investing in better-off West African countries such as Ghana, Nigeria, and Senegal.

Figure 3 shows the dramatic growth of food sales in real terms of modern retailers in the three regions from 2002 to 2018. Even the most mature supermarket sectors that had undergone take-off of their modern retail mainly in the 1990s, i.e., the Asian region and the first and second wave countries of Latin America, averaged 19% real sales growth per year over the 16 years. The "newcomers", i.e., the third wave of Latin America and the Africa region, averaged 41% per year growth in sales, albeit from a low base at the start of the 2000s. In all three regions the first wave's sales growth is well below the third wave's growth. Hence, both the inter-regional and inter-wave patterns per region indicate a form of "catch up" and convergence.

Figure 3: Leading grocery chains' edible sales, average real annual growth, 2002-18

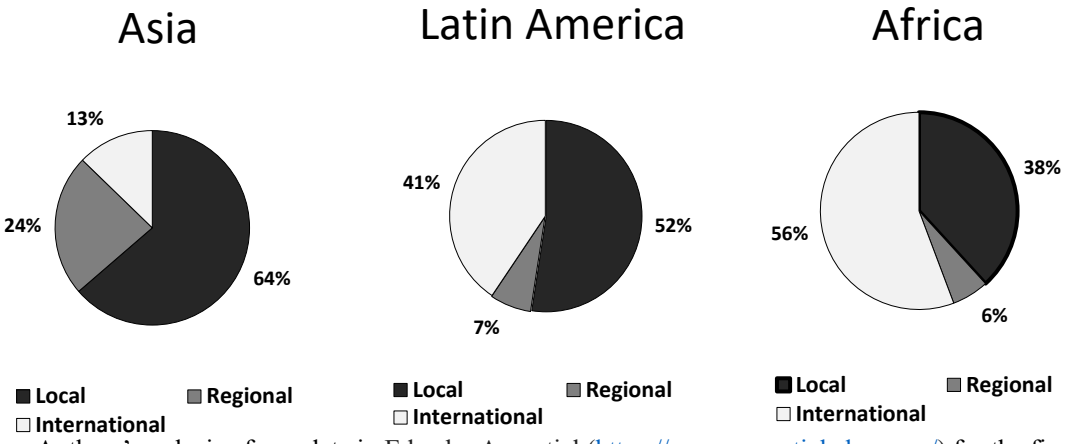


Source: Authors' analysis of raw data from Edge by Ascential (https://www.ascentialedge.com/)
The countries and firms in each wave are given in Appendix Table 1. To convert the raw, nominal, US dollar-denominated data into real 2018 terms we: 1) converted dollar sales value for each firm and country in 2002 into local currency (LC) units using the 2002 average LC/dollar exchange rate (XR). 2) Then converted the 2002 LC estimates to 2018 real terms based on national CPI. 3) Then converted back into 2018 dollars using the 2018 average XR in order to sum over all countries in the wave. CPI and XR data taken from World Bank *World Development Indicators* (https://datacatalog.worldbank.org/dataset/world-development-indicators).

Figure 4 disaggregates 2018 modern retail food sales by chain ownership, distinguishing among local firms (firms based in that country), regional (headquartered in another country in that region but with FDI in that country, such as Japanese retailers in China), and international (those based outside the region but with FDI in that country, such as Walmart in Mexico), aggregated over countries per region.[11] Leading local chains were dominant in Asia and Africa, at 64% and 52% respectively averaged over the regions and years. This shows that domestic capital has been an important determinant of retail transformation. International chains only controlled about 13% of market share in Asia and 41% in Africa. Over the past two decades, the share of international chains in Asia fell strongly (from 34% in 2002) as regional chains rose from 12 to 24%. The rise of regional multinational chains, especially Japanese, South Korean and Thai chains in the Asian region, displacing global firms in food retail, was a manifestation of a broader trend noted by Rugman (2005). By contrast, international chains' investments played a larger role in Latin America, at about 56%. Western European and US chains have invested heavily in Latin American retail since the 1990s, while regional chains had little presence. In Mexico, for example, the main competition is between a local chain, Soriana, and Walmart.

[11] The list of firms by these categories is provided in Appendix Table 1 per country.

Figure 4: Supermarket food sales shares by chain ownership, 2018



Source: Authors' analysis of raw data in Edge by Ascential (https://www.ascentialedge.com/) for the firms by type (local, regional, or international for that country) per country listed in Appendix Table 1.

The supermarket revolution underscores several key features of the broader AVC transformations taking place throughout LMICs. These new forms of food retailing emerged in direct response to urbanization with accompanying employment change. As women increasingly worked outside the home, their opportunity cost of time to home-process food and to shop increased. They increasingly sought processed foods and supermarkets to save time with one-stop shopping, as well as larger, cleaner markets with greater assurance of hygiene and food safety as well as product variety. The trend started earliest with higher income households but then over the decades has gone well beyond the middle class into the shopping habits of the poor. The latter occurred as supermarkets spread over the country, beyond the middle class areas and large cities into smaller towns and into poorer urban and peri-urban neighbourhoods. Eventually the poor were attracted to supermarkets because basic staple foods were sold cheaper in supermarkets than in traditional shops because supermarkets could procure with economies of scale (Minten and Reardon 2008). The rise of supermarkets was catalyzed by FDI initially, not just the inflow of financial capital to build stores, warehouses and vehicle fleets, but equally by the transfer of management practices from high-income markets. Improved practices and lower cost of capital sometimes enable multinational entrants to undercut the prices of incumbent national firms, as Walmart did in Mexico (Atkin et al. 2018). But local and regional chains have also invested and imitated practices of global multinationals in marketing and procurement systems and in Asia and Africa have more than 50% of supermarket food sales. They have been successful as they also draw on superior social and political connections, and a deeper understanding of local consumer tastes.

The localization and regionalization of retailing occurs in part because although trade liberalization helped spur the rise of supermarkets, modern food retail chains rely far more heavily on DVCs than on imported products. When a multinational chain enters a developing country, it typically sources some (but not most) of its food from imports. As it builds its domestic networks, the chain then increasingly sources from traditional DVCs and develops its own modernized DVCs. The latter is often assisted by a growing cadre of local "specialized dedicated wholesalers" and "follow sourcing" wherein its home country partner firms in wholesale, logistics, and processing follow (via FDI) the retailer to the host market to "fast track" the development of its local supply chains (for examples in Latin

America and Central and Eastern Europe, see Reardon et al. 2007; Dries et al. 2004). These patterns emerge as well in the next two AVC revolutions we describe.

4.2.2 *The food service revolution*

Just as the supermarket revolution emerged in response to growing urban demand for variety, quality, and convenience in procuring food to prepare at home, so has the food service sector (i.e., fast-food chains, street vendors, restaurants, cafés, institutional food service providers, etc.) undergone rapid, dramatic change in recent decades. Many of the patterns mirror those of the supermarket revolution, driven largely by changes in urban consumer demand patterns. Rising incomes and opportunity cost of consumer time have stimulated demand for both food preparation away from home and for convenience, packaging, processing and quality in retail food outlets. AVC intermediaries adapt processing channels to address one or the other sort of demand, but are constantly learning and borrowing from the other channel. 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.

Moreover, as the COVID-19 pandemic has made clear, the food service and retail sectors are inextricably linked through post-farmgate processing and packaging operations tailored to specific end-user groups. We describe those patterns in more detail in the next sub-section. Ultimately, these parallel and sometimes-intersecting value chains back up to farms from which they source agricultural feedstocks. Shifts in consumer demand between the retail and food service sub-sectors induce reallocation of throughput volumes between retail and food service channels. But the machinery, materials, and management processes of each channel grow increasingly differentiated to meet the varied volume and standards requirements of different clientele. For example, individual shoppers rarely buy more than one dozen eggs at a time while institutional food service providers often prefer shelled, liquid whole eggs in 10 or 20 kg packages. The process of moving eggs from layer farms to the end user is increasingly customized to the needs of the downstream consumer. In normal times, cross-channel adjustments to throughput volumes are marginal, and can occur reasonably fluidly and inexpensively. But the efficiency gains of channel- (or even buyer-) specific specialization come at a cost of reduced flexibility in adjusting to large demand shocks of the sort that occurred in early 2020 as the food service sector largely shut down across many countries in the public health response to the pandemic. Hence the spectacle of empty grocery shelves for perishables while relatively nearby farmers simultaneously plow vegetables underground or pour eggs and milk into waste lagoons, all because food service outlets were suddenly shuttered during the pandemic and the throughput directed toward them could not be affordably and quickly diverted to retail channels.

Throughout the world 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 service 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 service 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 service 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 into other regions to seek new, less competitive markets. For example, McDonalds began franchise operations in 1954; 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 service 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 service sector in the US and Europe, 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 service 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 service 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.

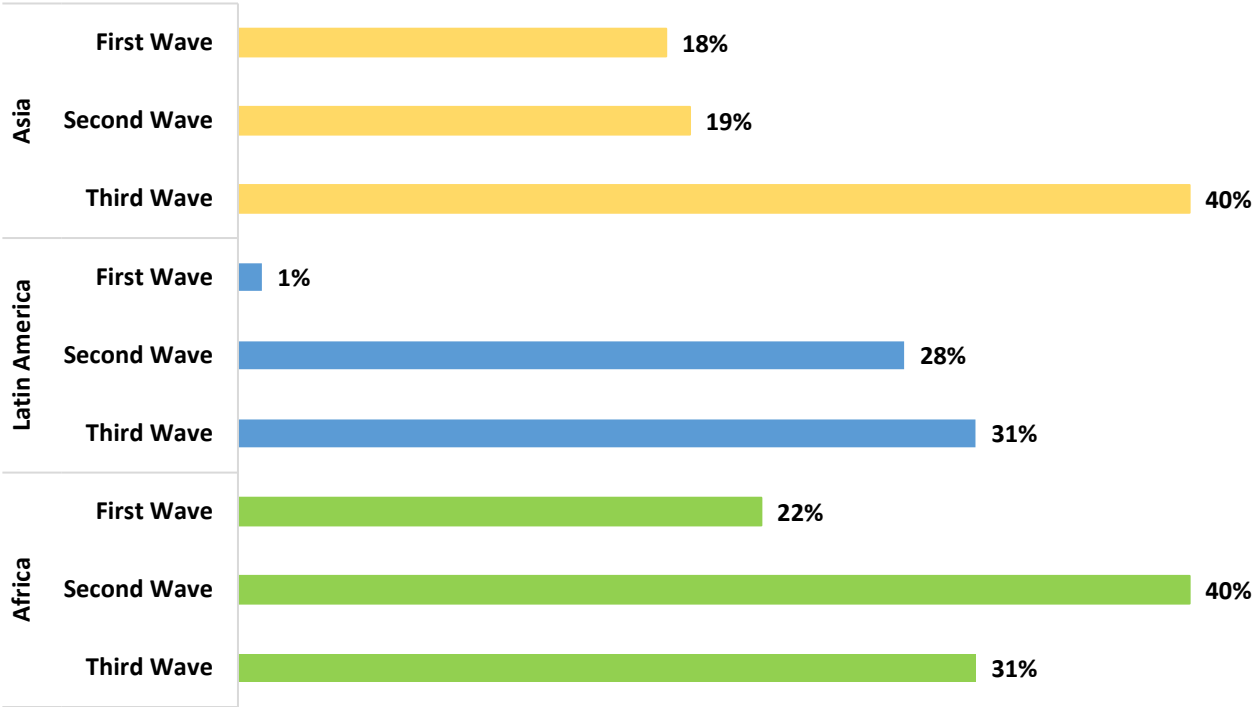
Wholesalers and processors have commonly developed new products and business processes in high-income markets (especially the US) and then diffused those into LMIC markets via FDI. These operations commonly followed existing multinational supermarket and fast food clients into LMIC markets (see Reardon et al. 2007 for details), 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).

As with the supermarket revolution, the food service 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 service transformation. Examples include the Philippine fast food hamburger chain "Jollibee" entering the Malaysia market, 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 service 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 service sector have led to a raft of acquisitions in LMIC markets. Large multinational or regional processors and food service 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 service sector in LMICs has gone largely unnoticed by economists.

Figure 5: Multinational food service chains real annual sales growth, 2008-2018



Source: Authors' analysis of raw data in Edge by Ascential (https://www.ascentialedge.com/) for selected countries shown in Table 2. Raw data processed following the same protocol explained in the note to Figure 3.

Figure 5 shows the average annual real sales growth of leading multinational food service companies in LMICs. As with the preceding two figures, these data come from Edge by Ascential and necessarily underestimate food service company market share and growth, as the data only are available for multinational chains, covering 33 countries in the three regions.[12] The growth patterns clearly illustrate the dramatic growth of the food service sector, with major implications for the agri-food value chains of these LMICs. The average annual growth of sales was around 30% in Africa and Asia (averaging over waves and regions), compared with 20% in Latin America. Growth in Latin America was less rapid on average because of low growth in the First Wave countries (such as Brazil and Mexico) which experienced earlier multinational entry and because of the earlier rapid development of local competition, as well as slower economic growth. Overall, as with food retail, growth rates in the second and third wave countries are higher with same "catching up" or inter-wave convergence process in food service as in retail.

4.2.3 The 'quiet revolution' in value chain intermediation

As the prior two sub-sections emphasized, the supermarket and food service 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

[12] 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). The list of chains is provided in Appendix Table 2. Countries are grouped by waves based on income and urbanization levels justn as we did previously for retail.

changes are often lost behind the more-visible changes occurring at the final consumer end of the AVC serviced by supermarkets and restaurants, changes in the food at home retail (supermarket) and FAFH (food service) sectors could not have proceeded without simultaneous advances in less glamorous third party logistics services (3PLS) 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).

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 storage had risen to intermediate 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 just 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 3PLS 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 the impacts of AVC transformation

So what impacts do agri-food value chain transformation or efforts to stimulate such transformations 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" or "inclusive food systems strategies" that have become popular within broader agricultural and rural development programs (IFPRI, 2020; Swinnen and Kuijpers, 2019). 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. Opportunities for further, more rigorous exploration of the various hypothesized impacts remain legion. Here we describe the mass of evidence, such as it is. We flag studies we find especially compelling and briefly highlight features that make them stand out. Since most of this literature is descriptive rather than causal – albeit littered with somewhat misleading language about 'drivers' and 'impacts' – readers should interpret an absence of direct commentary as the implied suggestion that the study's results should be interpreted only as suggestive, not as compelling.

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, 2020; 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 new market entry serve as a main engine of AVC transformation, then we should see clear evidence of diffusion of technologies caused by exogenous changes in the AVC. Indeed, an important subset of value chain improvements aim to reduce costs and frictions in exchange, and input costs and marketing frictions are major impediments to uptake of improved technologies at farm and SME level (Feder et al. 1985; Foster and Rosenzweig 2010), so a natural hypothesis is that AVC transformation accelerates the diffusion of modern innovations on farms, linking the AVC transformation to the more traditional, farm-based perspective on structural transformation. The value chain-based frictions to farmer adoption of new technologies can be great in low-income rural areas. 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 such as fertilizers.

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. 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). 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 higher quality food, which requires adoption of new technology (e.g., climate control in post-harvest handling), then one plausible arrangement is a contract between the farmer and the processor, where the processor finances the fixed cost of the input specifically associated with the new technology. Minten et al. (2014), using observational

data from stacked surveys to study potato supply chain evolution in Bihar in northern India, find precisely such effects, leading to rapid diffusion of cold storage to enhance preservation and quality control.

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). In some cases, a retailer might work with development organizations to promote small farmer uptake of an input such as irrigation in order to facilitate more reliable throughput volume and quality needed in their value chain. As Walmart expanded its retail network in Nicaragua, NGOs worked with small farmers to introduce irrigation necessary to grow vegetables to the giant retailers' specifications; the panel data Michelson (2013) collected and analyzed show a clear difference in pre-contracting trends in irrigation uptake among supply chain participants as compared to non-participants. The data do not permit testing for a causal effect of AVC participation driving on-farm irrigation adoption, but the case study evidence strongly suggests a strong linkage between AVC transformation and farm-level technological advance. 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. For example, Dries and Swinnen (2004, 2010), Gow et al. (2000), Maertens and Swinnen (2009), Minten et al. (2009), Bellemare (2012) and Negash and Swinnen (2013) all find that technology (and management) transferred 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 vegetable contract farming in Madagascar 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 often 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).

A specific, but important, form of technology adoption comes from quality upgrading. This might arise from the use of improved inputs, from better management practices, or some combination. But when AVCs offer non-trivial quality premia – which rarely exist in spot markets, especially with unreliable enforcement of grades and standards (Reardon et al. 1999; Fafchamps 2003) – incentives emerge to exert effort to boost quality. Macchiavello and Miquel-Florensa (2019) exploit the variation across space and time in the roll out of a quality upgrading program introduced by a multinational coffee buyer in Colombia to generate difference-in-differences estimates of the program's impacts on farmer uptake of more disease-resistant trees,

generating a significant gain in coffee quality that brough almost 10 percent higher prices and measurable welfare gains for farmers.

5.2 Competition, concentration and market power

The degree to which perfect competition or market power prevails has been one of the longstanding preoccupations of the empirical literature on developing country AVCs. Traditional spot markets are commonly extremely competitive, with many agents competing on price, volume and observable quality terms. Fafchamps and Minten (2001) and 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 high search, storage and contracting costs can sharply limit competition over longer distances and across seasons, limiting spatial and interseasonal competition (Barrett 1997; Moser et al. 2009). Throughout history and across many different countries, food marketing intermediaries have therefore been distrusted and often vilified as predatory agents rather than celebrated for facilitating welfare-enhancing transactions. State-run marketing boards were a direct response to such sentiments (Barrett and Mutambatsere 2008). And the low quality of infrastructure and long distances in many LMIC markets can indeed foster market power. Kopp (2019) shows that Indonesian rubber farmers incur non-trivial switching costs of moving to new buyers, which leads to oligopsonistic market power that allows buyers to mark down feedstock purchase prices. This downstream market power results in a more than 20 percent reduction in the prices farmers receive (Kopp and Sexton 2019).

Atkin and Donaldson (2015) generate precise estimates of the relative scale of intra-national trade frictions in developing countries and show their implications for market power. Using data from Ethiopia, Nigeria and the US, Atkin and Donaldson (2015) analyze barcode-level price data – including for many processed food items – in order to control for unobservable product quality differences, and identify the exact point of origin of each product they match with observed consumer retail prices in spatially varied markets, so as to control precisely for the distance each product travelled to where its price was observed. They estimate that the effect of log-distance on trade costs is 4-5 times larger in Africa than in the United States. These frictions lead to intermediary market power such that traders capture most of the gains from reduced costs of imports in the wake of reduced international trade barriers.

Market power appears on the upstream side of the AVC as well in low-income rural areas. Dhingra and Tenreyro (2017) use variation in farmers' exposure to large agribusiness buyers to estimate the impact on pass through of global crop price increases to farmers. They find that farmers more likely to sell through larger firms with more market power see a 30 percent lower income increase in response to exogenous global market price increases – and now greater insurance against global market price decreases – as compared to those more likely to sell through a small local trader. In a related, subsequent paper, Dhingra and Tenreyro (2020) cleverly use a 2004 national policy change intended to promote agribusiness-mediated exports of

particular crops to test for differential income gains across farmers in villages with ex ante comparative advantage in those versus other crops. They find that farmers growing the policy-affected crops suffered relative to those growing other crops, both in terms of income and consumption, especially of durable assets. Large agribusinesses appear to have been able to extract most of the rents accruing from a policy intended to stimulate small farmer income growth.

As value chains move from the traditional stage to the transitional stage, communications and transport infrastructure – and legal contract enforcement mechanisms – typically improve and inter-firm competition commonly increases in both upstream (i.e., commodity procurement) and downstream (e.g., retailing) segments of the value chain. This enables – but also pressures – 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. Competition becomes less about relationship-based advantages in trade costs than about quality differentiation.

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 grown more important in the value chain (Swinnen and Vandeplas 2010). Re-concentration can emerge at the farm input supply level as well, especially if intellectual property rights confer market power, as is evident in the global seed industry today (Deconinck 2019). Indeed, as one of the leading scholars of the industrial organization of agricultural markets observes, "[a]lthough microeconomics textbook writers continue to point to agricultural markets as examples of competitive markets, in reality probably none are, especially in light of dramatically increased concentration in food manufacturing … and grocery retailing" (Sexton 2013, p. 209). Market power seems one of the defining feature of the modern AVC.

Jensen and Miller (2018) demonstrate this pattern nicely in their study of the artisanal boat building industry that services fisherfolk in Kerala, India. They use the exogenous rollout of mobile telephone service to show how improved market integration transformed the formerly atomistic market in which fishermen traditionally bought their boats from the nearest builder. The 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 result was 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 (often transitory) 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. A vast literature relies excessively on testing hypotheses about the time series properties of price data from spatially distinct markets, subject to overly strong assumptions about the stationarity of trade costs and the continuity of trade flows (Barrett 1996; Fackler and Goodwin 2001; Stephens et al. 2012). A rather specialized literature employs parity bounds models to estimate directly the frequencies with which markets violate spatial equilibrium conditions, although that literature likewise relies on very strong econometric assumptions (Baulch 1997; Negassa and Myers 2007; Moser et al. 2009; Butler and Moser 2010; Zant 2012).

An important, indirect 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.[13] In low-income rural environments with multiple market failures, as typifies most rural LMIC settings (Dillon and Barrett 2017), market power may help resolve problems related to financing, contract enforcement, etc. and thus prove optimal in a second-best sense (Fafchamps 2003). Studying the contracts between coffee farmers and processing mills in Rwanda, Macchiavello and Morjaria (2019) find intriguing evidence consistent with that hypothesis. Using a clever instrument to generate plausible causal identification, 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 -i.e., side sell – thereby costing the grower relational contracts designed to resolve various market failures. Oligopsonistic middlemen may also benefit small-scale primary producers in systems that rely on open access or common property resources, such as fisheries. Thuy et al. (2019) show, for example, that oligopsony power exercised by middlemen in Vietnam's skipjack tuna fishery effectively prevents overexploitation of the fishery as compared to that nation's far more competitive inshore anchovy fishery.

These impacts in rural upstream markets 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. Their powerful observation was that the nation's conditional cash transfer program issues participating households debit cards that can be used only in grocery stores affiliated with the program. This restriction creates an opportunity for groceries to exercise local market power. By experimentally varying the number of new stores authorized to accept the debit card payment, Busso and Galiani (2019) find that incumbent stores

[13] Most studies on market power in AVCs have focused on developed economies. Sexton and Xia (2018) argue that today's market characteristics are not consistent with standard economic model assumptions and "likely cause market power to be less than would be predicted based on the highly concentrated structures of many modern agricultural and food markets." Reviews by Sheldon (2017, 2018) conclude that there is little robust empirical evidence for food processing firms exerting buyer power. Other studies by McCorriston (2015) also provide no clear evidence of concentration on market power abuse in price transmission in value chains. Wohlgenant (2013), in a study of the US meat industry, finds that concentration in procurement of livestock has not adversely affected prices received by producers or prices paid by consumers, possibly because its effect on technical innovations.

– i.e., authorized vendors before the intervention – reduced prices from 2-6 percent and exhibit a statistically significant improvement in customer-reported service quality, with greater effects in places with (randomly) more new entrants.

5.3 Smallholder inclusion in value chains

One of the most widespread aspirations for AVC modernization is that commercial market participation will boost the living standards of poor agricultural households. Of course, whether or not smallholder farmers share in the benefits from value chains depends importantly on whether they participate at all, and conditional on participation, on the impact that AVC participation has on their incomes and well-being. There is widespread concern that structural changes may exclude 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. The rapid growth of dairy consumption with income growth in India has improved food safety and technology (better feed and cows) across all dairy farms, but the most important response in dairy supply in more developed regions is coming from a new class of modern dairy farms which are larger, located closer to the urban consumer areas, use more advanced technology, are managed by well educated people and have extensive vertical interactions with dairy processors (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. 2004, 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).[14]

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.

How smallholders integrate into AVCs also matters. Fafchamps (2003) describes the rise of vertical integration and formal contracting as one of the defining features of the transition from traditional to transitional and then to modern stages of AVCs. AVC firms' choice of organizational structure will likewise impact smallholder participation in modern value chains.

As incomes grow and consumers become more responsive to product quality, the price premium to higher quality typically rises. Given difficulties in contracting over imperfectly observable quality – perhaps especially in perishable commodities or for credence attributes related to, for example, environmentally sustainable production methods – one might expect firms to become more likely to integrate vertically as the quality premium rises, so as to maintain greater control (Holmstrom and Milgrom 1994; Baker et al. 2002). This results in reduced grower independence as contract suppliers become (explicit or de facto) employees of vertically integrated AVCs.

Hansman et al. (forthcoming) harness unusually detailed data on within-firm as well as inter-firm transactions and direct observations of product quality from Peru's fishmeal industry to test this hypothesis directly. Taking advantage of regulatory fishing quota-driven variation in the supply of fishmeal of different quality grades in other countries, Hansman et al. (forthcoming) construct a credible instrument for the quality premium, which varies considerably across seasons, and show that the firms with greater opportunities for quality upgrading are far more

[14] 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 such crops, smallholders can use family or community labor. The comparative advantage of family labor over hired labor often 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.

likely to integrate vertically in response to increasing quality premia. Firms do not integrate in response to higher average prices; the observed response is not simply a scaling effect. As quality-sensitive markets for perishable products and credence attributes grow, one might reasonably expect to see more vertical integration of AVCs.

5.4 Employment and labor market impacts

Since farmer participation in modernizing AVCs is necessarily limited, and may even shrink as AVC firms vertically integrate upstream, 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 include labor demand induced among smallholder suppliers. Neven et al (2009) found substantial employment creation for local farm workers by medium-scale farmers directly supplying fruit and vegetables to supermarkets in Kenya, far more so than for comparable farmers not in the supermarket supply chain. Meemken and Bellemare (2020) 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 favorable 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. Although both of these studies rely, however, on observational data and are vulnerable to bias through any of several mechanisms, they provide rich descriptions and are admirably careful not to overstate their inferential findings.

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. Several studies show that favorable employment growth has been associated with the emergence 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. [15] Webber and Labaste (2009) 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.

There may also be labor supply effects. Bellemare (2018), for example, uses a credible instrumental variables estimation strategy to control for non-random selection into contract farming to show that entry into that modern AVC induces vegetable growers in Madagascar to sharply reallocate labor out of both unskilled casual labor off-farm and non-farm enterprise activities, most of which are likewise unskilled. The clear implication is that the returns to labor

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

allocated to the modern value chain dominate the reservation wages set by unskilled wage or self-employment.

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. (2020) analysed LSMS data for 188,996 households in Africa, Asia, and Latin America and found that only 17-37% of adult full time equivalents in rural households was devoted to households' own farms, with another 17-24% allocated to non-farm activities (e.g., milling, transport) within the agri-food system, and only 3-13% to farm wage employment. So the labor market effects of agri-food system transformation can be substantial, even in low-income rural areas. For example, Christiaensen (2020) showed that AVC employment was especially important for poor women in the Lebanese potato value chain.

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. 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 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. And workers commonly are poorer than firm owners, so the labor market effects of AVC transformation (discussed in section 5.4) have broader distributional impacts. The distribution of gains from the emergence of a more specialized, elongated, and encompassing AVCs in analytically ambiguous. In principle, gains can accrue to both farmers, workers, consumers or any combination of the three. Feedstock suppliers (i.e., farmers) benefit if their productivity gains outpace any fall they experience in output prices. But farmers not integrated into the AVC may lose out. AVC innovations often increase labor demand, either in production of feedstocks on farm or in downstream processes – for example, kitchen and serving staff in food service establishments – which can stimulate employment and wage growth. 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).

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 2012, 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) model 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 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, Bellemare 2012, Michelson 2013, Narayanan 2014; Bellemare and Novak 2017; Meemken and Bellemare 2020; Ogutu et al. forthcoming) 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 agricultural 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. Using three rounds of household panel data from smallholder vegetable farmers in Kenya and credible controls for a host of prospective confounders, Ogutu et al. (forthcoming) find that securing a supermarket contract is associated with significant reductions in multidimensional poverty indicators, with the strongest reductions occurring among the poorest households. 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. They also find, however, 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 (2020) 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.[16]

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 quadrupling 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 transfer program in the Dominican Republic. In places where value chain modernization leads to

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

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 service revolutions (Popkin and Reardon 2018). Is this causal, however? The evidence base thus far appears to thin and inconclusive to reach and firm conclusions. Khonje and Qaim (2019) show that use of modern retailers in Zambia has been associated with greater consumption of less healthy, ultra-processed foods. They also show, however, that the same is true of the use of traditional grocery stores and kiosks, underscoring that modern agri-food firms might not be causal drivers – certainly not the sole causal drivers – behind dietary transitions that raise public health concerns. Solid causal evidence tying changes in domestic and global value chains to adverse (or favorable) dietary and health changes 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 LMICs, 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. The environmental impacts of agri-food systems draw increasing attention in high-level policy circles, and the fragility of AVCs manifest during the pandemic of 2020 has heightened public awareness of how important the 'missing middle' between farm and fork is to everyday economic phenomena. 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.

6.1 Formal modeling

The literature on the agri-food value chain revolution is heavily empirical and descriptive. A few applied theory papers exist, including several by Sexton (e.g., Saitone and Sexton 2017; Merel and Sexton 2019), Reardon (Du et al. 2016; Zilberman et al 2017; Lu and Reardon 2018), or Swinnen (e.g., Swinnen and Vandeplas 2010, 2011; Swinnen et al 2015) that model the welfare implications of AVCs; see also the review by Hamilton et al (2020).

A quite distinct emergent literature models value chains using network theory. Many of the papers most directly relevant to AVCs trace back to Kranton's seminal work on reciprocal exchange and buyer-seller networks (Kranton 1996; Kranton and Minehart 2001) and Kremer's (2003) on the role of positive assortative matching in determining the productivity and vulnerability of production systems. This rapidly growing literature explores how supply chains form as heterogeneous suppliers, intermediaries and downstream clients match, how frictions or shocks might disrupt equilibrium supply chain configurations, render competitive equilibria unstable and imperfectly competitive market power stable, and the implications for the distribution of earnings through the value chain (Condorelli et al. 2017; Fleiner et al. 2019; Carvalho et al. 2020; Elliott et al. 2020). While conceptually these models apply to AVCs, to date, the few empirical applications have largely been to formal sector firms, mainly outside the AVC. Much of that empirical work builds on longstanding spatial general equilibrium models (Samuelson 1952; Takayama and Judge 1971), focusing on trade (Allen and Arkolakis 2014; Donaldson 2018; Porteus 2019; Allen et al. 2020).

Thus far, however, these threads of the literature remain detached from broader models of economic growth and from rigorous estimation of either the causes or the causal impacts of AVC change. AVC intermediation activities are notably absent from most theoretical models that help researchers to isolate deductively the mechanisms behind the structural transformation of developing economies and to pose testable hypotheses about the consequences of these transitions for different stakeholder populations and other economic phenomena of interest, such as employment, wages, or land use.

One important future line of advance will involve integrating stylized facts about AVC revolutions into broader economic growth processes, for example by allowing for food to be consumed either from a labor-intensive food service subsector or from a more capital-intensive retail network, each supported by services sub-sectors with convex adjustment costs as throughput varies between sub-sectors. That will require more formal models of value chain emergence and transformation that allow for endogenous product and/or process information (Dixit and Stiglitz 1977), imperfect competition and scale economies (Krugman 1991; Helpman 1998), frictions in exchange, and consumer valuation of both the nutritional and non-nutritive attributes of food (Unnevehr et al. 2010). Developing more formal, dynamic general equilibrium models that capture the features such is an important line for future research.

There exists a small literature of empirical general equilibrium models that introduces services sub-sectors, including a few that tailor these to interactions with primary agricultural production and consumer retail sectors such as CGE models by Roe and Diao (2004) of Morocco and Dorosh and Thurlow (2018) of several African countries. The latter disaggregate the AVC in farming, agro-processing and retailing. The current interest in shocks and resilience of AVCs, triggered by COVID-19, is increasing demand for such models in order to simulate how AVCs

are affected by shocks and policy responses and how those effects impact the broader economy. For example, Zhang et al (2020) for China and Thurlow (2020) for African countries show significant differences in impacts on the food service sector compared to food processing and farming.

We can envision a fruitful line of research that uses observations about AVC revolutions to develop models that might help analysts pose more nuanced, well-theorized, policy-relevant questions than the traditional juxtaposition of investments in agriculture versus industry or services. Which service and manufacturing sectors generate the greatest multiplier effects, given their connections upstream to primary producers and downstream to consumers, and given non-homothetic consumer preferences with respect to many food attributes?

6.2 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 (as in Arouna et al. 2019) 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. But more attention needs to be paid to the broader process of AVC transformation and less on specific phenomena amenable to micro-scale manipulation. We need more experiments designed to tease out market-level general equilibrium effects, as in Bergquist (2017) and Burke et al. (2019).

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 to 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.

Both of these developments will require more data sets that explicitly capture both parties to transactions, i.e., linked buyer-seller data. This raises a raft of sampling challenges analogous to those found in the networks literature (Chandrasekar 2016; Heckathorn and Cameron 2017). That will be especially true for studies that seek to demonstrate the impact on AVC structure and performance rather than the impact of AVCs on outcome variables of interest.

6.3 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. 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. One of the potentially most important questions concerns the relative importance – even to farmers and farmworkers – of innovations in the post-farmgate AVC as compared to on the farm.

6.4 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.

Careful study of these questions will require improved time series data on prices, the costs of market intermediation (e.g., transport), and directional trade flows (Barrett 1996), with careful controls for product quality and origins (Atkin and Donaldson 2015). This will likely also require methodological innovations to get beyond the limitations posed by conventional spatial price analysis methods that aim to test how shocks to demand or supply propagate through markets, as compared against the strong null posed by the law of one price (Fackler and Goodwin 2001). Trace how interventions – especially ones that are randomized, or generated by natural experiments such as policies implemented differentially across space and time or the unanticipated loss of critical infrastructure (e.g., bridges)[17] – affect intermarket price spreads and trade flows as a way of testing for the presence of excess profits (Moser et al. 2009; Stephens et al. 2012).

The evidence in this paper suggests that traditional economic analysis needs to be expanded. Agriculture and the food sector are supposedly the embodiment of the competitive paradigm, but even in developing countries their structures evolve to favor some degree of market concentration. Much of the economic activity is determined beyond markets by value chains that evolve over time- introducing new products, new exchange arrangements, and new markets. We

[17] We emphasize the unanticipated loss of critical infrastructure rather than the installation of new infrastructure (as in Zant 2017, 2018), which necessarily suffers from non-random placement effects and potential anticipatory that confound identification of the causal effects of new infrastructure.

need to further develop our conceptual understanding of what gives rise to value chains and shapes their structure and evolution.

There is a vast need for empirical work that will assist the developing theories on supply chains. It may require better documenting and understanding of the behavior of large organizations and the evolution of linkages between them. Analysis of these patterns can be quite challenging. The number of observations is small, and the data are not well organized or easily available. We may need to adopt methods from history and business to analyse case studies and narratives. We may need to interact with engineers and system analysts to understand their perspectives in designing value chains and the data sources they use. We may need to learn about the political economy that enables the establishment of infrastructure and regulations that empower supply chains. To understand the behaviour of agri-food value chains it will be necessary to expand the reach and scope of economics, but doing so will contribute to the discipline beyond the implications for agriculture and food systems.

Although economists have not always been paying close attention, the AVC revolutions that have been underway throughout the developing world for the past three decades raise a range of interesting questions about the evolution of developing economies, spatial and intersectoral dynamical relationships, and the distribution of gains from innovations throughout the value chain. Opportunities abound for rigorous, impactful, creative research as agri-food value chains continue to undergo rapid transformations.

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Appendix Table 1. Food retailers covered by Edge by Ascential

Region and Wave	Local	Regional	International
Asia			
First Wave			
South Korea	BGF Retail; Buy The Way; ELAND; GS Retail; Haitai Stores; Hanwha Stores; Homeplus; Lotte Shopping; Mega Mart; New Core; Seowon; Shinsegae	AEON; FamilyMart UNY; Seven & I; Valor	Carrefour; Costco; Tesco; Walmart
Taiwan	Far Eastern, Hi-Life; Matsusei; OK Mart; Pxmart; President Chain Store	Dairy Farm; FamilyMart UNY; Seven & I; Valor	Auchan; Carrefour; Casino; Costco; Couche-Tard; SHV Makro; Tesco
Second Wave			
Indonesia	Alfa Retailindo; Alfamart; Indomaret; Matahari Putra Prima; Ramayana	AEON; Dairy Farm; FamilyMart UNY; GS Retail; LAWSON; Lotte Shopping; Seven & I	Ahold Delhaize; Carrefour; Couche-Tard; Delhaize Group; Lulu Group; SHV Makro; Spar International; Total
Malaysia	Econsave; The Store Corp	AEON; Dairy Farm; FamilyMart UNY; Seven & I;	Ahold Delhaize; Carrefour; Couche-Tard; Delhaize Group; Lulu Group; SHV Makro;Tesco
Philippines	Benison Group of Companies; Puregold; Rustan; SM Retail; Uniwide	AEON; Alfamart; Dairy Farm; FamilyMart UNY; LAWSON; President Chain Store; Seven & I	Couche-Tard; Metro Retail Stores Group; Pricesmart; SHV Makro; Spar International; Total
Thailand	Berli Jucker; CP All; Central Retail; Foodland; Villa Market	AEON; Dairy Farm; FamilyMart UNY; LAWSON; Seven & I	Ahold Delhaize; Carrefour; Casino; Delhaize Group; SHV Makro; Spar International; Tesco
Third Wave			
China	A. Best; AS Watson; Beijing Hualian; Better Life; China Resources Vanguard; Chongqing Shangshe; Dairy Farm; Dalian Dashang; Hefei Baida Group; Hualian Supermarket; Jiajiayue; Jingkelong; Kedi; Lianhua; Liqun; Lotus; Renrenle; Sanjiang; Shanghai	AEON; CP All; Daiei; FamilyMart UNY; Far Eastern; LAWSON; Lotte Shopping; Mega Mart; NTUC FairPrice; President Chain Store; Seven & I; Shinsegae; Trust-Mart; UNY	Carrefour; Ceconomy; Couche-Tard; Metro; NBTY; PriceSmart-China; SHV Makro; SPAR International; Tesco; Total; Walmart; Woolworths (AUS)

	Nonggongshang; TIMES; Wu-Mart; Wuhan Zhongbai Group; Yonghui;		
India	Adani; Aditya Birla; Avenue Super Marts; Bharti; Fu-Com; Future Group (Future Retail); Home Store (IND); K Raheja Corp; Landmark Group (India); Nilgiris; Radhakrishna Foodland; Reliance Retail; Samara Capital; Spencer's Retail; Subhiksha; Tata Retail; Trinethra	Dairy Farm	Booker; Carrefour; Ceconomy; Lulu Group; Metro; SPAR International; Tesco; Walmart
Vietnam	Citimart; Fivimart; G7; Hapro Mart; Intimex; Maximark; Ocean Retail; Saigon Co-op; Shop & Go; Vingroup	AEON; Berli Jucker; Central Retail; Dairy Farm; FamilyMart UNY; GS Retail; Lotte Shopping; President Chain Store; Seiyu; Seven & I; Shinsegae	Auchan; Casino; Ceconomy; Couche-Tard; Louis Delhaize; Total; Walmart
Latin America			
First Wave			
Argentina	Cooperativa Obrera; Coto; Eki; La Anónima; Supermercados Toledo	Cencosud; Coppel, Falabella	Ahold Delhaize; Auchan; Carrefour; Casino; Dia; SHV Makro; Walmart
Brazil	Angeloni; Atacadao; Carvalho; Condor; Coop Cooperativa de Consumo; DMA Distribuidora; G.Barbosa; Giassi; Muffato; Prezunic; Savegnago; Sendas; Sonda; Supermercados BH; Supermercados Comper; Y.Yamada; Zaffari; Zona Sul	Cencosud; Coppel, Falabella; Grupo Líder	Ahold Delhaize; Carrefour; Casino; Dia; Jerónimo Martins; SHV Makro; Walmart; Sonae; Walmart
Uruguay	Ta-Ta; Tienda Inglesa	Falabella	Casino
Second Wave			

Chile	Cencosud; D&S; Falabella; SMU; San Francisco; Supermercados del Sur	OXXO	Ahold Delhaize; Alliance Boots; Carrefour; Montserrat; Sonae; Walgreens Boots Alliance; Walmart
Colombia	Alkosto; Carulla; D1 Supermercado; Justo y Bueno; La 14; Olímpica	Cencosud; Falabella; OXXO	Carrefour; Casino; Jerónimo Martins, Pricesmart; SHV Makro
Costa Rica	Auto Mercado; Gessa	Olímpica	Ahold Delhaize; Pricesmart; Walmart
Ecuador	Corporación Favorita; El Rosado; Tia		Ahold Delhaize; Casino
Guatemala			Ahold Delhaize; Pricesmart; Walmart
Mexico	Chedraui; Comercial Mexicana; Coppel; Gigante; Modelorama; OXXO; Soriana		Alliance Boots; Auchan; Carrefour; Casino; Costco; Couche-Tard; H-E-B; Pricesmart; Safeway; Walgreens Boots Alliance; Walmart
Third Wave			
Bolivia	Hipermaxi		
Nicaragua			Ahold Delhaize; Pricesmart; Walmart
Peru	Supermercados Peruanos	Cencosud; D&S; Falabella; SMU	Ahold Delhaize; SHV Makro
Africa			
First Wave			
Botswana	Choppies	Clicks Group; Fruit & Veg City; Massmart; Pick n Pay; Shoprite	Metcash; SPAR; Walmart; Woolworths
Namibia		Clicks Group; Fruit & Veg City; Massmart; Pick n Pay; Shoprite	Metcash; SPAR; Walmart; Woolworths
South Africa	Clicks Group; Fruit & Veg City; Massmart; Pick n Pay; Shoprite	Choppies	Indomaret; Metcash; NBTY; SPAR; Walmart; Woolworths
Second Wave			
Kenya	Chandarana Foodplus; Cleanshelf; Eastmatt; Naivas; Nakumatt; Tuskys; Uchumi	Choppies	Carrefour; LuLu Group; Metcash; Walmart

Madagascar		Shoprite	Casino; Lousi Delhaize; Metcash
Malawi		Massmart; Shoprite	Metcash; SPAR; Walmart
Mozambique		Choppies; Massmart; Pick n Pay; Shoprite	Manuel Nunes; Metcash; SPAR; Walmart; Woolworths
Tanzania		Choppies; Fruit & Veg City; Massmart; Nakumatt; Pick n Pay; Shoprite; Uchumi	Walmart
Zambia		Choppies; Fruit & Veg City; Pick n Pay; Shoprite	Metcash; SPAR; Walmart; Woolworths
Zimbabwe	OK Zimbabwe	Choppies; Clicks Group; Fruit & Veg City; Massmart; Pick n Pay; Shoprite	Metcash; Spar
Third Wave			
Angola	Kero; Nosso Super	Fruit & Veg City; Shoprite	Auchan; Metcash; SPAR
Ghana		Massmart; Shoprite	Walmart
Nigeria	Addide; Prince Ebeano Supermarket	Massmart; Shoprite	SPAR International; Walmart
Senegal			Auchan; Casino

Notes. Local means that the company is based in that country; regional means it is based in a country in the region; international means it is based in a country outside the region. All retailers that sold some food and were covered by Edge by Ascential are included.

Appendix Table 2. Multinational food service companies covered by Edge by Ascential

Region and Wave	Food service companies
Asia	
First Wave	
South Korea	Baskin-Robbins; Burger King; Domino's; Dunkin' Donuts; KFC; Little Sheep; McDonald's; Pizza Hut; Starbucks; Subway; Taco Bell
Taiwan	85 degrees C; Afternoon Tea; Baskin-Robbins; Burger King; Cold Stone Creamery; Domino's; Dunkin' Donuts; KFC; Little Sheep; Long John Silver's; McDonald's; Pizza Hut; Starbucks; Subway
Second Wave	
Indonesia	A&W All American Food; Applebee's; Baskin-Robbins; Burger King; Domino's; Dunkin' Donuts; KFC; Little Sheep; McDonald's; Pizza Hut; Starbucks; Wendy's
Malaysia	A&W All American Food; Baskin-Robbins; Burger King; Domino's; Dunkin' Donuts; KFC; Long John Silver's; LongHorn Steakhouse; McDonald's; Olive Garden; Pacific Coffee; Pizza Hut; Starbucks; Subway; Wendy's
Philippines	Applebee's; Baskin-Robbins; Burger King; Domino's; Dunkin' Donuts; IHOP; KFC; McDonald's; Pizza Hut; S&R QSR; Starbucks; Subway; Taco Bell; Wendy's
Thailand	A&W All American Food; Baskin-Robbins; Burger King; Domino's; Dunkin' Donuts; IHOP; KAZOKUTEI; KFC; McDonald's; Pizza Hut; SHUN-NO-MAI; Starbucks; Subway
Third Wave	
China	85 degrees C; Afternoon Tea; Applebee's; BHG Kitchen; Baskin-Robbins; Burger King; Cold Stone Creamery; Domino's; Dunkin' Donuts; East Dawning; KAZOKUTEI; KFC; Little Sheep; McDonald's; Pacific Coffee; Pizza Hut; Seaport; Starbucks; Subway
India	Au Bon Pain; Baskin-Robbins; Burger King; Cafe Brio; Domino's; Dunkin' Donuts; Harajuku Delights; IHOP; KFC; McDonald's; Pizza Hut; Starbucks; Subway; Taco Bell; Wendy's
Vietnam	Baskin-Robbins; Burger King; Domino's; KFC; Maxim's; McDonald's; Pizza Hut; Starbucks; Subway
Latin America	
First Wave	
Argentina	Burger King; KFC; McDonald's; Starbucks; Subway; Super Quick; Wendy's
Brazil	Applebee's; Burger King; Domino's; Dunkin' Donuts; KFC; McDonald's; Olive Garden; Pizza Hut; Red Lobster; Starbucks; Subway; The Wendy's Company
Uruguay	Burger King; McDonald's; Subway
Second Wave	
Chile	Applebee's; Burger King; Domino's; Dunkin' Donuts; KFC; McDonald's; Pizza Hut; Starbucks; Subway; Taco Bell; Wendy's
Colombia	Baskin-Robbins; Burger King; Domino's; Dunkin' Donuts; KFC; McDonald's; Pizza Hut; Starbucks; Subway; Taco Bell

Costa Rica	Applebee's; Burger King; Domino's; KFC; McDonald's; Pizza Hut; Starbucks; Subway; Taco Bell; Wendy's
Ecuador	Applebee's; Burger King; Chili's; Domino's; Dunkin' Donuts; KFC; McDonald's; Pizza Hut; Rock and Roll; Subway; The Wendy's Company
Guatemala	Applebee's; Burger King; Domino's; Dunkin' Donuts; IHOP; KFC; McDonald's; Pizza Hut; Starbucks; Subway; Taco Bell; The Wendy's Company
Mexico	Applebee's; Baskin-Robbins; Burger King; California; Domino's; Doña Tota; Dunkin' Donuts; IHOP; KFC; McDonald's; Olive Garden; Pizza Hut; Starbucks; Subway; Taco Bell; The Capital Grille; Vips; Wendy's
Third Wave	
Bolivia	Burger King; KFC; Starbucks; Subway
Nicaragua	Burger King; Domino's; McDonald's; Pizza Hut; Subway
Peru	Burger King; Domino's; Dunkin' Donuts; KFC; McDonald's; Olive Garden; Pizza Hut; Starbucks; Subway
Africa	
First Wave	
Botswana	Hungry Lion; KFC
Namibia	Hungry Lion; KFC
South Africa	Burger King; Domino's Pizza; KFC; McDonald's; Pizza Hut; Starbucks; Subway
Second Wave	
Kenya	Domino's Pizza; KFC; Subway
Malawi	KFC
Mozambique	KFC
Tanzania	KFC; Subway
Zambia	Hungry Lion; KFC; Subway
Zimbabwe	OK Zimbabwe
Third Wave	
Angola	Hungry Lion; KFC
Ghana	KFC
Nigeria	Domino's Pizza; KFC

Source: Food service companies followed by Edge by Ascential (https://www.ascentialedge.com/) that were classified as cafés, quick service restaurants, and full service restaurants.