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Fostering healthy, equitable, resilient, and sustainable agri-food value chains

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Abstract

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1. Introduction

The agri-food system (AFS) is the only economic sector that touches every human on Earth each day, mainly through regular food consumption. But AFSs are also a key source of livelihood. The FAO estimates that 1.23 billion people were employed in the world's AFSs in 2019, and that almost half the world's population lives in a household that earns income within the AFS (Davis et a. 2023). A large share of those individuals works on the world's approximately 600 hundred million farms, roughly 80% of them family farms that produce nearly 80% of the world's food commodities by value (Lowder et al. 2021). These two groups – primary producers (i.e., farmers, fisherfolk, etc.) and final consumers – comprise the two most populous ends of the agri-food value chain (AVC).

A great deal of economic theorizing therefore focuses on these two subpopulations, relying on the often-useful oversimplification that agricultural primary producers and final food consumers directly transact through markets, that no one intermediates between them. Economists' workhorse models of economic structural transformation have long relied heavily on that assumption (Lewis 1954, Johnston and Mellor 1961, Ranis and Fei 1961). National data collection systems are built to look at those two ends of the AVC – through household and

agricultural surveys and censi – but are rarely well-suited to capture the full population of midstream intermediaries (Barrett et al. 2022a). Even the international System of National Accounts does not recognize the AVC as an economic sector, with the result that national accounts cannot directly estimate value addition in AVCs; that requires innovative manipulation of input-output and supply-and-use tables (Yi et al. 2021; Schneider et al. 2024).

The longstanding oversight of the midstream of the AVC matters as a rising chorus of policymakers, scholars, and thought leaders call for AFS transformation, in the 2021 World Food Summit and other high-level fora (von Braun et al. 2021; Barrett et al. 2022b). AFSs directly facilitated the emergence and flourishing of human civilization, indeed our very survival (Fogel 2004). But AFSs also contribute significantly to rising environmental concerns around climate change, air and water pollution, biodiversity loss, etc. And AFSs account for a large share of health problems, including those related to antimicrobial resistance, foodborne pathogens, zoonoses, and especially to non-communicable diseases associated with obesity or with insufficient intake of essential minerals and vitamins. Another growing concern is equity; a disproportionately large share of the 1.2 billion AFS workers also earn incomes below the global poverty line and they bear unusually great occupational risks – of injury, slavery, etc. (ILO 2024). We must consider the whole AVC if AFSs are to become healthy, equitable, resilient, and sustainable (HERS) (Barrett et al. 2022b).

The sheer headcount dominance of food consumers and primary producers naturally focuses researchers' and policymakers' attention on these two groups of actors in the struggle to promote HERS AFS transformation. Considerable attention therefore gets paid to organic, regenerative, and other agricultural practices thought to improve various environmental, health, animal welfare, or social justice outcomes on farm and likewise to nutrition education, product labeling, and other interventions believed effective in nudging consumer food choice towards more sustainable, healthy, or equitable products. The logic of focusing on farmers and consumers is compelling and attractive.

A foundational claim of this paper, however, is that a focus on the two populous ends of the AVC is manifestly not working well enough to rely primarily on interventions that target the ends of the AVC. For example, despite decades of studies and promotion of regenerative agriculture among US farmers by extension services, researchers and even corporate buyers, according to the 2017 US Census of Agriculture (Tables 1 and 41), just 3.9% and 24.6% of US cropland was planted in cover crops or used no-till practices, respectively, with much of the former likely on the latter (USDA 2019). Likewise, although decades of dietary guidelines, nutrition education programs, nutritional labeling requirements, and other consumer, consumption of obesogenic foods and obesity prevalence have grown steadily worldwide. HERS AFS transformation will be driven ultimately by changes in consumer dietary choices that favor healthier, more sustainable and affordable foods produced on more equitable terms, and in producer practices that deliver those product attributes. But those changes might be most cost-effectively and rapidly induced not through interventions directed at farmers or consumers but rather by targeting the AVC midstream.

The central claim of this paper is that success in transitioning to HERS AFSs will require more concerted attention on midstream AVC actors, especially the larger, corporate actors and

emergent market disrupters (see section 2). Because we economists generally assume away the intermediation between primary agricultural producer and final food consumer, we are less well equipped than we ought to be, both theoretically and empirically, to tackle the challenge of fostering HERS AVCs through midstream AVC innovations. That makes this topic exceptionally fertile ground for policy-relevant research (see section 3).

2. Mind the Neck!

The familiar phrase "Mind the gap!" calls attention to the hazards of neglecting the space between two prominent features: the train and the platform in the case of the London Underground where this audible and visual warning to passengers was first popularized. An analogous caution applies to AFSs, where one must pay careful attention to the midstream actors that connect the populous upstream primary producers to the even-more-numerous downstream consumers. But in the AVC case, the space in between isn't a dangerous void but rather a powerful connector, a neck. The AVC exhibits the shape of a decanter. Although the relative dimensions vary among AFSs worldwide, a standard qualitative pattern holds: a wide top (the hundreds of millions of upstream AFS primary producers), an even-broader base (the >8 billion downstream consumers), with the thinnest part being the long neck between the two. For example, in the U.S., in that midstream neck one finds about 23,000 manufacturing firms and nearly 31,000 grocery and related product merchant wholesalers . whereas there are nearly 3.4 million farmers and over 300 million consumers (US Census Bureau 2017). The narrowness of the neck regulates the flow between the upper and lower parts. Hence the need to focus on the less-well-populated middle of AVCs, the neck of the AVC decanter. Mind the neck!

More substantively, there are (at least) three compelling reasons to focus on the neck of the AVC. First, coordination is far simpler and heterogeneity far less among orders-of-magnitude fewer midstream AVC intermediaries than among the primary producers or consumers on either end of the hourglass (Tirole, 1988). High concentration (i.e., the share of sales held by the largest firms in the midstream AVC) can sometimes result from leadership in innovation or from realizing scale or scope economies that improve productivity and reduce costs and prices (MacDonald et al. 2023). This can give midstream intermediaries superior ability to effectively foster HERS AVCs. High market concentration and coordination, however, can also lead to the exercise of market power with firms setting higher consumer prices, lower prices for suppliers, or lower wages to workers in comparison to competitive markets (Azar, Berry and Marinescu 2022; Bresnahan 1989). Moreover, fewer large AVC intermediaries can more easily engage in collective action to influence AFS policies and regulations (Olson 1965, Knoke 2019). Such initiatives may or may not promote the broader social good, depending on their impact on the firms' profit-maximization objectives. Hence the importance of harnessing firms' profit motives to promote HERS objectives in AFS transformation

Second, the midstream of AVCs enjoys far faster growth than upstream primary production, thus has the greatest opportunity for change. Over the course of structural transformation, populations have steadily urbanized around the world, AVC intermediation inevitably expands (Barrett et al. 2022a). So too as agricultural technological advances generate

greater marketable surpluses on more farms, AVC midstream growth follows automatically from the surpluses that need transport, processing, storage and preservation services on their way to distant dinner tables. Per capita income growth creates similar pressures, rapidly boosting demand for convenience, quality, safety, variety and other features of diets that appear luxuries, in the economic sense that demand for them increases at a rate faster than income growth. The net result has been astonishingly fast – but often under-the-radar –transformation of AVCs' midstream, a pattern that will almost surely continue as urbanization, income, population and productivity growth (hopefully) continue (Yi et al. 2021; Barrett et al. 2022a, Bellemare et al. 2022).

Third, midstream market actors make deliberate decisions, heavily influenced by economic and financial analysis. They demonstrably respond to changing market and policy incentives. Changing consumer behavior is far harder than changing firm behavior. That is because each human makes scores – often hundreds – of food-related decisions each day (Wansink and Sobal 2007), most of which are non-deliberative, based instead on sensory and sociocultural signals that correspond with slow-evolving heuristics based on genetic and sociocultural predispositions (Yang et al. 2024). Organizations – restaurants, supermarkets, manufacturers, schools – design and adapt food environments — the interfaces between consumers and foods that frame consumers' food purchase and consumption choices (Fanzo and Davis 2021) — to serve organizational interests, not consumers' nor societal ones. Get the midstream actors to position HERS foods in ways that induce more desirable consumer behaviors and one makes faster progress than purely by providing consumers or farmers more, or better, information (Yang et al. 2024).

This suggests another way in which the AVC midstream resembles a neck. While visual, taste and olfactory sensation, as well as deliberation, all takes place in the head, the neck orients the head's attention. Midstream actors (often guided by public policies) structure food environments explicitly to influence consumer behaviors. And as primary producers move beyond semi-subsistence production towards commercial production for downstream buyers, they too increasingly take cues from downstream buyers, whether in the form of market signals or contract terms (Barrett et al. 2012; 2022a, Bellemare et al. 2022). Indeed, with increased digitization of production agriculture, midstream actors are increasingly able to customize producers' choice architecture much in the way they structure consumers' food environments. The midstream AVC neck turns producers' and consumers' heads as it wishes. Therefore, mind the neck!

The central challenge of AFS transformation is how to influence midstream AVC actors to change practices and products so as to guide consumers, primary producers, and whole societies to HERS AFSs. Indeed, efforts to adapt consumer or primary producer behavior that are not reinforced by midstream actors almost inevitably prove futile. So we agricultural economists need to provide greater analytical and empirical support to help guide HERS transitions by 'minding the neck'. What natural processes are likely to induce better or worse midstream actor behaviors and outcomes? What tools available to governments, civil society advocacy organizations, investors, employees can cost-effectively induce changed midstream behaviors that get multiplied manifold by subsequent, predictable consumer and primary

producer responses? Developing analytically and empirically rigorous answers to those questions is perhaps the most pressing research agenda for agricultural economists in the years ahead.

3. Research priorities

If agricultural economists and our collaborators are to focus more intently and productively on inducing midstream AVC actors to help achieve HERS AFS, what are the key research priorities to advance that audacious goal?

3.1 Measurement. We focus first on measurement issues because private and public sector leaders manage to what gets measured. Policy reforms get undertaken and evaluated based on target indicators. Historically, the dominant indicators have been firm and farm profits, consumer expenditures, calorie or protein intake, and farm yields. Unfortunately, those measures necessarily ignore externalities. Managing to those metrics has predictably led to adverse outcomes in the less-commonly measured HERS domains. Our conceptual understanding of the complexities of AFSs, and of the importance of externality effects and feedbacks has advanced impressively, but measurement has not kept pace. Right now we have inadequate empirical foundations on which to build analytically-and-empirically-sound policy guidance. We must develop and mainstream better measures of agri-food system performance beyond productivity and profitability in order to induce better AFS management (Fanzo et al. 2021).

Historically, agricultural economists have been pace setters within the broader social sciences in pushing careful measurement, perhaps especially of total factor productivity and technology diffusion (Griliches 1957, Leontief 1971), estimation of multi-output, multi-input systems to capture (dis)economies of scale and scope (Shumway et al. 1984, Chambers 1988), and in thinking about more holistic measures of the true cost of foods (Hendriks et al. 2023). The agricultural economics research community can better help AFS managers and policymakers guide HERS transformation the faster we offer reliable, timely measures that move beyond yield, profits, and calories as key performance indicators.

One key area is to track better concerns the association of environmental, health, and labor indicators with changes in AVC activity. Seminal work by Canning (2011) uses input-output and supply-and-use tables to answer the question “For what do consumers’ food dollar pay?” in the United States. This work generated data series that estimate the distribution of the average dollar consumers spend on food between farm and AVC intermediaries; the distribution of the food dollar among 16 distinct AVC industry groups; and the distribution of the food dollar among U.S. worker salaries and benefits, rents to food industry property owners, net taxes, and imports. This approach has been extended to material flow measures (e.g., water, greenhouse gas emissions, employment) and the economic and environmental impacts of changing diets (Canning et al. 2010; Rehkamp and Canning 2018; Hitaj et al. 2019; Canning et al. 2019). To date, this work has focused primarily on the U.S. in spite this method’s prospective value to inform interventions that can foster healthy, equitable, resilient, and sustainable AFSs globally.

Recent research efforts extending the U.S. food dollar methodology have demonstrated how analysts can track the food dollar and the material flows in AFSs at a global scale (Yi et al. 2021; Canning et al. 2022; Yi et al. 2024). More such work is sorely needed to characterize AFSs, particularly in low- and lower-middle-income countries, where input-output and supply-and-use data are often scarce.

Innovation has historically been the main engine of AFS improvements of all sorts (Ruttan 1960; Schultz 1964; Ruttan 2000; Fogel 2004; Alston and Pardey 2021; Barrett et al. 2022b; Alston et al. 2023). Agricultural economists have pioneered methods for identifying and tracking diffusion of promising science, technology and innovations (Griliches 1957; Alston and Pardey 2021, 2023), although to date diffusion studies have focused heavily on primary production and desperately need extension downstream within AVCs (FAO 2022). At present we have little effective tracking of emergent innovations within firms, especially not midstream actors. Partly that reflects firms‘ protection of proprietary data that may confer competitive advantage in the marketplace. But it is feasible to offer firms the same privacy protections around sensitive, individually-identifiable information as is standard practice in farm and household surveys that track of the diffusion of improved agricultural inputs among smallholder farmers (Sheahan and Barrett 2017) or of shifting consumption of specific products by consumers. The dearth of data arises mainly from lack of investment in standardized, high quality enterprise surveys that cut across traditional sectors to encompass the whole AVC.

3.2 Natural market inducements to HERS innovations. Once we start measuring more carefully and routinely, we suspect that researchers will corroborate longstanding hypotheses that private firms‘ incentives to meet societal HERS goals turn in large part on consumers‘ willingness to pay (WTP) for such product attributes and firms‘ ability to monetize that WTP. There have been many studies on the consumer value of credence attributes of food products, including those related to social responsibility, environmental and health (Van Loo et al. 2014; Grebitus et al. 2015, etc.). This literature often uses experimental approaches to show that consumers‘ WTP for these attributes in food products increases with income and with their trust in the information source that claims such properties. As real incomes continue to grow in the years ahead, this should naturally create added latent consumer WTP for HERS attributes.

But will the latent growth in consumer WTP translate into real market opportunities for midstream firms? There remain several relevant unexplored research areas which agricultural economists can tackle. First, little research has explored whether HERS multiple attributes are complements or substitutes among themselves and with other non-credence attributes such as convenience, packaging and food products‘ organoleptic properties (Janßen and Langen 2017). Are there specific bundles of properties that synergistically multiply consumers‘ WTP, making it attractive to profit-seeking firms to prioritize those properties?

Second, because credence attributes cannot be assessed by consumers themselves, even post-purchase, certification schemes, labels and other means of conveying information are important to turn such attributes into WTP (Darby and Karni 1973; Grebitus et al. 2015). But such signaling only boosts consumer WTP if additional information is salient (i.e., noticed by a casual consumer, trusted and clear), else consumers ignore them (Grunert et al. 2013; Reisch et al. 2021; Sunstein 2021). Hence the very mixed evidence to date on the effectiveness of labels in

changing consumer preferences at scale (Crockett et al. 2018; Meemken et al. 2021; Roberto et al. 2021; *Sunstein 2021*). Firms need firmer evidence on how best to effectively communicate to consumers the credence benefits for which they might be willing to pay, in particular what options exist beyond certifications and labels. For example, we know relatively little still about the relative returns to emergent (e.g., blockchain) or even established (e.g., radio frequency identification, RFID) traceability technologies for conveying credence benefits. Without reliable traceability, it remains unclear whether certified products routinely deliver what they claim or merely create "greenwashing" profiteering opportunities.

Furthermore, certification schemes and labeling imply additional costs. Research has concentrated primarily on the value of HERS attributes captured by the final seller (e.g. retailer, restaurant) and less on the accrual of costs or net benefits among actors along the AVC. It remains unclear to what degree the net benefits of retail price premiums from certification or labeling get passed upstream through the AVC, including ultimately to primary producers and workers.

Inducing heightened consumer willingness to pay for HERS attributes is not the only, and likely not even the most promising path, to market-based induced innovation in the HERS direction. Historically, technological innovation has been the biggest driver of AFS change. Agricultural economists' attention commonly focuses on technological change in primary production, from the first domestication of plants and animals roughly 10,000 years ago through the discovery and use of Mendelian genetics, the Haber-Bosch process for manufacturing ammonia from atmospheric nitrogen, mechanization of time-consuming repetitive tasks, the Green Revolution, the rise of transgenic and now gene-edited organisms, bio-fortification to boost crops' micronutrient content, etc. These have all been hugely impactful, to be sure. But technological change is equally crucial midstream, both in facilitating new post-harvest processes and products, and perhaps especially by changing relative prices, thereby inducing rapid midstream (e.g., in food and beverage manufacturing) and downstream (e.g., in food service) substitution of now-cheaper inputs from those growing relatively scarce.

Why does this matter? Because cost-saving and risk-reducing innovation can induce profit-seeking midstream firms to adjust inputs quickly in response to relative prices and risk exposure. Of course, such innovations can either advance or impede HERS objectives. Hence the importance of focusing on inducing HERS-oriented cost-saving and risk-reducing innovations for midstream intermediaries. We hypothesize that midstream-oriented innovations that develop low-cost substitutes for current ingredients that run counter to HERS objectives can have larger-scale and faster effects than efforts to capture consumer WTP for credence attributes or to nudge consumer preferences or farmer practices in HERS directions.

History shows this repeatedly. For example, as it became commercially appealing to fortify foods with essential minerals and vitamins (e.g., iodized salt, flour enriched with folic acid, vitamin D-fortified milk), food and beverage manufacturers have done so, improving public health, even in the absence of regulatory requirements to do so. Conversely, when innovations have made unsustainable, unhealthy ingredients cheaper, food manufacturers have reformulated processed foods and food service have switched to recipes that have adverse environmental, equity or health externalities. This was true in the emergence of high fructose

corn syrup and of trans-fatty acids arising from the hydrogenation of vegetable oils (Carman 1982; Barry 1983; Skeaff 2009). Of course, firms can just as easily reformulate foods to improve HERS attributes when it serves the company's interests and consumers will scarcely notice (Unnevehr and Jagmanaite 2008; Jensen and Sommer 2017). That is precisely what happened in the North American cheese industry in the 1980s–90s when natural rennet extracted from calf stomachs was almost completely replaced – over the span of less than a decade – by transgenic rennet produced through industrial-scale fermentation processes, generating considerable animal welfare benefits (Johnson 2017). As rising real incomes and the higher opportunity cost of people's time inexorably increases the share of consumer food expenditures on food away from home and on processed and prepared foods, investing in innovation that reduces the cost of healthy ingredients relative to less healthy, sustainable and equitably sourced ones has considerable potential to advance HERS objectives.

As the world increasingly pays attention to HERS concerns in AFSs, investment in potentially disruptive technologies has accelerated dramatically. This is simply induced innovation on display (Hicks 1932; Ruttan 2000). As the returns to HERS attributes rise and the costs of greenhouse gas emissions, pollution, and other environmentally damaging practices likewise increase, changing relative prices induce innovation in a HERS direction. We see this in a massive pipeline of AFS innovations at various stages of development and deployment around the world today (Barrett et al. 2022b). It is exceedingly difficult to predict accurately which technologies will ultimately prove disruptive. But it isn't hard to predict that some will, given the huge volume of innovations in the AFS science and technology pipeline (Barrett et al. 2022b, FAO 2022). Alternative proteins, indoor farming, improved reformulation, precision nutrition, biodegradable packaging, methane-reducing livestock feeds, the list goes on and on. Some of these technologies – e.g., cellular agriculture, indoor farming, precision fermentation – may dampen natural comparative advantage based on geographic features, like the temperate climate and rich soils of the North and South American interior plains. On balance, this would be good news for regions in Africa and Asia expecting rapid food demand growth in the decades ahead and where water, soils, and pests presently limit relative productivity.

HERS innovations may also have general equilibrium – capital and labor market – effects on midstream AVC firms. For example, cost and access to capital may be cheaper and more readily available for firms with high Environmental, Social and Governance (ESG) ratings. Some recent evidence suggests that higher ESG reporting and ratings are associated with improved financial performance in the European food industry (Sandberg, Alnoor and Tiberius 2023) and that firms with higher ESG scores enjoy lower costs of capital (Apergis et al. 2022). HERS innovations may also impact the attractiveness of firms to prospective and current workers, thereby improving employee recruitment and retention rates as well as labor productivity (Barrymore and Sampson 2021). Younger generations state that corporations are not doing enough to improve society or protect/improve the environment, and that these are two critical aspects guiding their decision to work for a firm (Deloitte 2019). An interesting empirical question is whether firms that embrace HERS innovations benefit from more productive workers given the alignment between corporate and employee goals. Does doing good help a firm to do well financially in AVCs?

Civil Society Organizations (CSOs) can play an important role in incentivizing midstream firms to foster HERS AVCs (Hutter and O'Mahony 2004). Research on collaboration initiatives between CSOs and corporations (including the food industry firms) suggests that such collaborations often fail to achieve the expected impacts, except for those related to business interests such as employment generation and improved education (Ashman 2001; Meemken et al. 2021). Most research focuses on denouncing the corporate food industry's poor performance in fostering HERS AVCs – and in documenting corporate malfeasance and misfeasance that demonstrably causes harm – and on implementing rigorous policies to rein in food industry market power (e.g., Jacques 2015; Nestle 2019; Howard 2021). This research, and perhaps especially popular literature and media (e.g., Pollan 2009; Nestle 2019) have generated high levels of mistrust between food firms, CSOs, and the public. While the outrage is understandable, there remains scant evidence that CSO pressure has appreciably changed corporate behaviors at scale in ways that alter the current trajectory of AFSs around the world. Comparatively little applied economics research has explored how best to incentivize midstream AVC firms to meaningfully reduce negative externalities and boost positive ones. In addition, it remains unclear whether the ESG movement spurred, even championed, in large part by CSOs proves helpful or just amounts to "greenwashing", and thus ultimately a distraction on the path towards HERS AVCs (Cohen 2023; Sandberg et al. 2023; Conca et al. 2021). Research is needed to measure the impacts of the ESG reporting on environmental and health outcomes in ASFs globally, especially controlling for the direct or indirect financial benefits firms enjoy from ESG programs; i.e., is ESG just instrumentally important, as a means of reducing costs or boosting revenues, or do they intrinsically matter to improving HERS outcomes within AVCs?

3.3 Public policies to induce HERS innovations. Firms need incentives to change practices and products to promote HERS objectives. As just discussed, rising incomes, induced innovation, and heightened civil society activism will naturally induce some progress. But only slowly. Given the growing urgency of calls for AFS transformation, public policies aimed at the AVC midstream will be essential to accelerate progress, in reinforcing market-driven change processes. Much like one can use the natural flow of a river to carry products but may sometimes need to intervene strategically to alter the river's flow and provide safe navigation around its rougher stretches, so can (must!) public policy help shape powerful market forces in the direction of HERS AFS transformation. What are the most cost-effective actions that governments can take to induce midstream firm actions that measurably improve AFS' HERS outcomes? Considerably more research is needed on this topic, especially research explicitly comparing among different candidate policyi interventions to establish which generates the biggest bang for the taxpayer buck.

Taxes and reliably-enforced statutory or regulatory restrictions can provide effective means of changing firms' behaviors. Food safety and fortification regulatory requirements, and occupational safety and minimum wage laws, for example, have been widely effective in high- and upper-middle-income countries in improving health and equity outcomes. Regulations are harder to implement and enforce, however, in lower-income economies where informality is high and state capacity low. Similarly, effective antitrust enforcement is crucial to guard against excessive concentration that obstructs equity goals while still reaping the real gains of economies of scale and/or scope (Crespi and MacDonald 2022) but is largely absent in lower-

income countries (Barrett et al. 2022a). We have little evidence, however, to answer the question: at what stage of development do regulatory mechanisms become effective in helping shape AFS transformation?

Taxes on unhealthy or environmentally ingredients typically induce consumer substitution away from such foods (Andreyeva et al. 2010; Cawley and Frisvold 2023; Pineda et al. 2024). Front-of-pack labels and warnings do likewise, albeit to a much lesser degree (Roberto et al. 2021; Fanzo et al. 2023). These policy instruments may induce even greater effects among firms as they adjust the sourcing of ingredients and/or foods' formulation to avoid taxation and to gain or maintain market share (Reyes et al. 2020; Bauner & Rahman 2024). Considerably more research is needed to establish how best to use food taxes and warning labels to induce firms to change product formulation and offerings enough to make measurable HERS improvements at scale.

In principle regulatory "sticks" are efficient because they serve as a coordination mechanism that rarely requires costly enforcement and – unlike many "carrots" based on subsidies – are less prone to unintended distributional consequences (DeGeest and Dari-Mattiacci 2013). But sticks are typically politically harder to implement, as firms likely affected by proposed rules can organized and lobby effectively to resist (Olson 1965; Resnick and Swinnen 2023). Thus "carrots" have become increasingly widespread, especially when policymakers seek to induce disproportionate effort from specific actors (DeGeest and Dari-Mattiacci 2013). Examples of carrots that have grown increasingly popular to induce socially desirable innovations include prizes, advanced market commitments, and prospectively benevolent patent extensions (Masters 2005; Kremer et al. 2020; Barrett 2023). Such inducements can prove transformative, as when Napoleon offered a cash prize of FF12,000 for a discovery that would enable reliable and cost-effective food preservation to help feed his armies while on the move, which 15 years later yielded the method of heating, boiling and sealing food in airtight containers that introduced the canning of food (Wright 1983). We need more research to identify which public policy "carrots" that work best in inducing better midstream firm behaviors regarding HERS outcomes.

The most commonplace – and perhaps high return – public policy for inducing innovation has historically been public investment in research and development (R&D). The reason is simple; public R&D yields basic discoveries over an extended period that private investors can adapt or combine to develop profitable new products or practices over shorter time horizons. Hence the 'slow magic' of public agricultural R&D investment (Alston et al. 2023). Yet public agricultural R&D has been in decline in most of the world, by one-third in the US since 2002 (Nelson and Fuglie 2022). Furthermore, agricultural R&D has historically focused on staple cereals, oilseeds, roots and tubers, not on the fruits, legumes, nuts and vegetables that are under-consumed relative to most dietary guidelines. And to date, governments have offered little support for R&D into protein transitions (Mylan et al. 2023), although that may be changing, as the $523 million in newly announced global public funding for alternative proteins in 2023 was nearly one-third of the all-time cumulative total of $1.67 billion (Good Food Institute 2024). There is widespread belief that expanded, and redirected public R&D is needed to uncover better ways to generate higher quality products at lower cost, greater convenience,

and yielding improved HERS outcomes. But how does one solve the political economy problem of mobilizing public resources for R&D investment?

In several jurisdictions within high-income countries, governments are experimenting with public food procurement policies intended to improve the environmental and/or health profile of the foods they purchase for schools, prisons, hospitals, etc. Much of this is"values-based" procurement that imposes quotas based on often-vague standards. In principle, however, governments could instead adjust vendors' bid prices for the known health, environmental or economic externalities associated with procuring particular foods – e.g., for fiscal revenue multipliers associated with local procurement, the public costs of environmental remediation associated with pollution or of health care to cope with life cycle effects. One can readily imagine the lure of large, repeatable institutional contracts inducing midstream firms to improve practices and products, much as labels or taxes can in retail markets. This would imply not only reduced total life cycle costs for government agencies that buy food, but also spillover gains in private wholesale and retail markets. But how best to implement such an idea – ensuring a lean enough process that it does not inadvertently discourage competition – and its impacts remain key research topics for agricultural economists.

3.4 Monitoring and impact evaluation. New technologies, policies and institutional arrangements require monitoring and impact evaluation (M&E) for the simple reason that unintended effects are commonplace (Herrero et al. 2021). Agricultural economists have a long and distinguished tradition of designing and conducting rigorous M&E of HERS outcomes to inform learning, adaptation and diffusion of promising innovations, partly because of the field's predisposition to cross-disciplinary collaboration and traditional role in evaluating AFS innovations. Such research will be as needed as ever in the coming decades.

But more such work needs to focus on midstream actors. Recent work on markets and contracting with AVCs in the Global South, in particular, has focused heavily on the upstream links between primary producers and the traders or processors to whom they sell (Macchavello and Morjaria 2015, 2021; Meemken and Bellemare 2020; Bergquist and Dinerstein 2020; Bergquist et al. 2024), with relatively little credible causal infrerence on the impacts of innovations by midstream actors (Barrett et al. 2022a). More such research will be needed as midstream actors' importance only grows with increasing urbanization and incomes.

We cannot rely exclusively on modern econometric methods of causal identification alone, however.It is exceedingly difficult to run experiments that offer rigorous *ex post* impact assessment of mid-stream interventions at scale and there are both ethical and logical limits to randomization (Barrett and Carter; Harrison 2011; Teele 2014; Deaton & Cartwright 2018; Ravallion 2020). And relying on non-randomized interventions to generate credible quasi-experimental causal identification is wishful thinking.

Moreover, the design of policy interventions ought to be informed by credible model-based *ex ante* impact assessment. Historically, agricultural economists engaged in considerable such research. But while some prominent modeling exercises remain – e.g., the Agricultural

Model Intercomparison and Improvement Project (AgMIP), the Global Trade Analysis Project (GTAP), and IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model, such work has fallen somewhat out of favor over the past couple of decades, largely disappearing from graduate curricula. The balance between *ex ante* and *ex post* impact assessment has shifted dramatically towards the latter since the turn of the millenium. Agricultural economists might usefully address that imblanace and invest more in rigorous integrated modeling to identify how best to induce midstream AVC actors to deliver on HERS objectives. For example, econometric estimates can calibrate key parameters for multicriteria optimization models commonly used in operations research to unpack complex interdependencies across economic, environmental, and social outcomes of AVCs interventions (Gómez and Lee 2023). Econometric parameter estimates can likewise be leveraged in systems dynamics and agent-based modeling frameworks to conduct *ex ante* impact evaluation of public and private initiatives designed to improve the HERS performance of midstream AVCs (Nicholson et al. 2021; Axtell and Farmer forthcoming). Advances in empirical industrial organization, especially the use of structural econometric models to shed light on market structures, behaviors and policies will likewise be important to guide interventions that target AVCs' midstream (Reiss and Wolak 2007; Pakes 2021).

4. Conclusions

As the global community increasingly turns its attention to the central importance of agrifood systems to first-order concerns about the climate, economy, environment and health, agricultural economists have an extraordinary opportunity to have a real impact through rigorous research. Toward that end, we urge our colleagues to 'mind the neck', to turn greater attention to careful study of midstream AVC actors and how public policy and natural market processes can increase, even accelerate, the uptake of practices, processes and products that advance not just firm profitability goals, but equally societal health, equity, resilience and sustainability objectives. Appropriate public policy design can help more AVC businesses do well by doing good. Agricultural economists for help that cause through our research, teaching and extension activities.

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