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Agrifood value chains in low-income countries

Accounting for market structure to inform policies

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Abstract

Recognizing that agrifood value chain (AFVC) are essential to ensure food security and foster structural change, Food and Agriculture Organization of the United Nations (FAO) seeks to reassess the array of policies and interventions needed to protect and strengthen agrifood value chain in low-income countries and fragile states. This paper aims to contribute to this initiative by shedding light on largely unaccounted market structures at midstream segments of agrifood value chain. Building on the field of industrial organization in economics, we develop a theoretical framework and a related simulation tool that one can inform with existing or specifically collected data. Simulation outcomes help predict how different types of shocks may affect key food security outcomes, under different levels of concentration in midstream segments of agrifood value chain. We illustrate this approach using data from the Ethiopian wheat AFVC in 2013.

Keywords: agriculture, value chains, resilience, food security, market structure.

JEL codes: L11, O13, Q13.

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1 Introduction

Agrifood value chains (AFVC) consist of all stakeholders who participate in the coordinated production and value-addition activities that are needed to make food products. This includes primary production, post-farmgate activities (processing, storage, transport, etc.), input/service providers, distribution, retail and consumers (FAO, 2021).

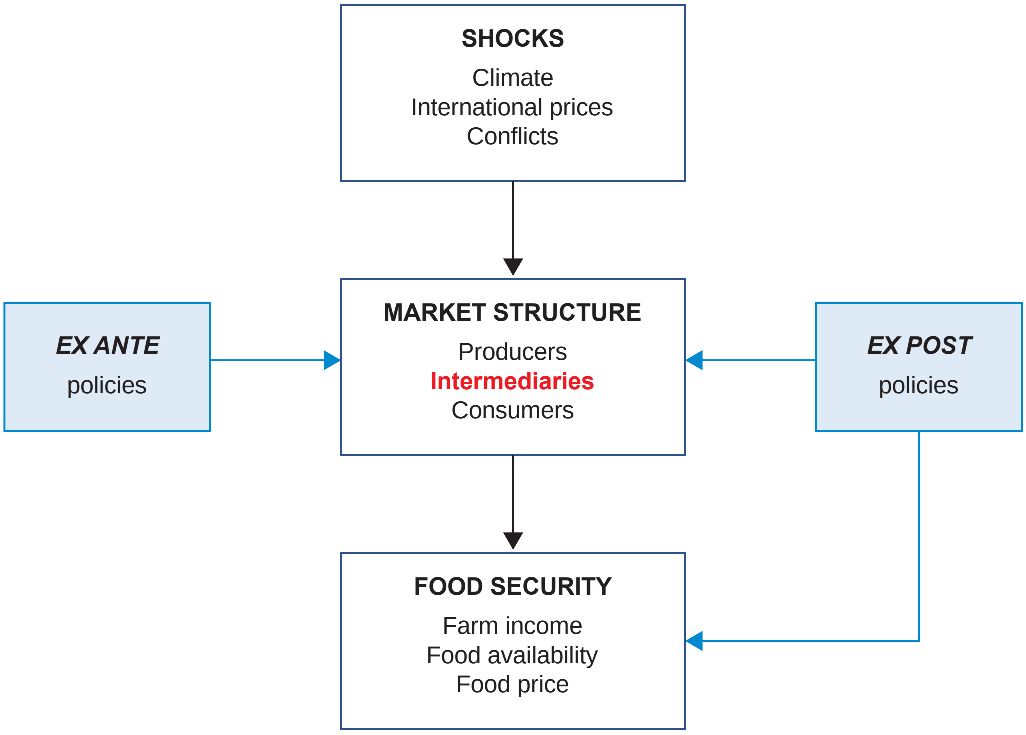
Recognizing that agrifood value chains are essential to ensure food security and foster structural change, FAO seeks to reassess the array of policies and interventions needed to protect and strengthen agrifood value chains in low-income countries and fragile states. This initiative is part of FAO's leading role in the operationalization of the Global Network Against Food Crisis at the global, regional and national levels.

This paper aims to contribute to this initiative through the development of an analytical tool to support *ex ante* diagnostics of agrifood value chains exposure to various shocks. Specifically, it hopes to shed light on largely unaccounted mechanisms related to market structure of agrifood value chains, and that can help guide policy interventions to support the resilience of agrifood value chains, and their related capacity to contribute to local food-security.

Our focus on market structure of agrifood value chains is motivated by the oftentimes concentrated nature of midstream segments of agrifood value chains. As we describe in this paper, this concentration bears consequences for an AFVC's effectiveness, its exposure to stressors and shocks, and the intensity with which shocks affect food security. Yet, midstream segments of agrifood value chains are mostly not accounted for in policy guidance for two reasons; first is the dearth of information on intermediary segments of agrifood value chains, those lying between the – often well documented – producers and consumers segments (Barrett *et al*., 2020). Second, accounting for the characteristics of these intermediary segments in policy guidance requires a dedicated set of analytical tools which, to the best of our knowledge, are currently missing. For instance, short-term analyses of the 2007–2008 surge in international food prices did not account for market structure, yielding incomplete assessment of on price transmission in low-income countries and related poverty outcomes.

Figure 1 summarizes the proposed approach, in which we seek to highlight how market structure of a given agrifood value chains (highlighted in red) affects transmission of shocks to different food security outcomes. Our aim is then to inform the role of policies in limiting these effects. We define *ex ante* policies as the type of intervention, which in the medium run seek to strengthened market structure and agrifood value chains actors in a way that enhances their resilience to such shocks. One may for instance forecast that, under current market organization, a shock of a particular nature will significantly affect an agrifood value chains and its contribution to local food security, and thus promote a policy to reinforce the identified source of weakness. In turn, *ex post* policies are understood as those policy interventions which are put in place at times of realization of a given shock, seeking to mitigate its effects on the functioning of the agrifood value chains and ultimately on food security.

Figure 1. Overview of the approach



Source: Authors' own elaboration.

In the short run, our aim is for the proposed tool to: (i) facilitate a structured analysis in situations where important data and documentation exist for a given agrifood value chain; and (ii) help target data collection to inform AFVC-related policies in combination with (possibly limited) data at hand. Specifically, we seek to develop an analytical framework:

- that can be tailored and adapted to (most) agrifood value chains setting in designated countries and/or sub-national regions within them;
- that describes the interplay of actors in agrifood value chains (from producers, through intermediaries, to consumers);
- that helps inform how various types of external shocks (e.g. climatic shocks, international price variations, political conflicts) enter and spread through agrifood value chains, and ultimately affect food security;
- whose key parameters can be documented through existing data and/or feasible data collection under time/budget/contextual constraints;
- whose outcomes can inform on the design of *ex ante* policies to support resilience of agrifood value chain, and *ex post* interventions to protect food security.

This paper proposes a first step in this direction. Its aim is to provide a proof of concept, however necessarily limited in its analytical scope. We stress that, if deemed relevant, this approach can be developed further although it is not meant to replace existing sources of information and analyses on agrifood value chain, but rather to add to the existing toolbox that currently informs AFVC-related policies.

In the following pages, we focus on the general features of the proposed tool, and provide examples of its application. Section 2 further motivates the approach, using the 2007–2008 surge in international food prices as an example. In Section 3 we discuss features of agrifood value chain in low-income and fragile countries. One key feature of most agrifood value chain lies in their “hourglass” shape: a large number of producers selling to a small number of intermediaries, catering to a large number of consumers. The size and characteristics of the intermediary level, and their consequences on the functioning of the agrifood value chain at times of shocks and policies, lies at the core of the analytical framework whose main features are presented in Section 4, while a detailed description of the underlying analytical architecture is provided in Annex 1. In Section 5 we discuss the use of this analytical framework to leverage existing or new sets of data, to derive diagnostics and simulations on agrifood value chain, their resilience to exogenous shocks, the effects of various policies, and their ultimate capacity to contribute to local food security. Section 6 illustrates the approach using the wheat value chain in Ethiopia, deriving graphically intuitive simulation outputs relating diverse type of shocks with food security outcomes under varying market structure conditions. Last, we discuss in Section 7 the limits and possible extensions of this approach.

2 The 2007–2008 international food price crisis

After decades of overall relative stability, international prices of staple grains increased sharply in 2007 and 2008.[1] These changes resulted from a wide set of factors and their unlikely combination into a "perfect storm" (Headey and Fan [2008]).[2] In low-income countries, the expected negative consequences of the surge in international prices were large, and further fuelled by media coverage of "food riots" in several countries (e.g. Berazneva and Lee, 2013).

Yet, clear assessment of the extent of these impacts on food security and poverty were missing at a time when international and national policy decisions needed to be made. Available estimates relied on partial equilibrium analyses adapted from Deaton (1989), wherein the short-term impacts of rising food prices depend on households' net consumption ratio, defined as the elasticity of the cost of living with respect to changes in prices. Accordingly, households who produce more food than they consume (net-sellers) should be positively affected, while net-buyers would be negatively affected.[3]

At the time of the international food price crisis, Ivanic and Martin (2008) applied this approach to available data from nine low-income countries, showing that the short-run impacts of higher staple food prices on poverty would differ considerably by commodity and by country, but that poverty increases would be much more frequent, and larger, than poverty reductions. Generalizing these results to other low-income countries, Ivanic and Martin (2008) derived estimates of up to 105 million additional poor generated by the rise in food prices – estimates that featured high in media coverage and international donor community arenas: on 14 April 2008, at the International Monetary Fund – World Bank spring meetings, World Bank President Robert B. Zoellick declared:

> "Based on a very rough analysis, we estimate that a doubling of food prices over the last three years could potentially push 100 million people in low-income countries deeper into poverty" (World Bank, 2008).

These predictions contrast with analyses conducted after the crisis. Using self-reported data on food security between 2005 and 2008, from over 50 000 individuals in 18 sub-Saharan countries, Verpoorten *et al.* (2013) find that 5 to 12 million individuals became more food secure over the period, albeit with significant differences across countries. They interpret the differences between these results and those predicted during the crisis (including Ivanic and Martin, 2008), by the *ceteris paribus* nature of the latter, not accounting for changes in households' adaptation to price changes in their consumption choices or their access to liquidities.

Importantly for the present study, Ivanic and Martin (2008)'s results also relied on the assumption of a pass-through rate of international price variations onto domestic prices. Accordingly, the 105 million figure corresponded to a pass-through of 66 percent, while a pass-

[1] The World Bank food price index increased from 180 to 334 between June 2007 and June 2008. Global wheat prices doubled, and rice prices tripled (Headey, 2018; Wodon and Zaman, 2010).

[2] Reviewing the various on-going explanations at the time, Headey and Fan (2008) conclude that rising oil prices, depreciation of the USD, biofuels demand, and some commodity specific explanations, were the most important drivers of the price surge.

[3] Alternative (or sometimes complementary) approaches rely on computable general equilibrium (CGE) modeling offering a more comprehensive description of the effects of prices changes (including for instance through labor market effects). However, they usually rely on specific modeling assumptions, which may drive part of the obtained predictions.

through rate of 33 percent would yield an estimated 45 million new poor.[4] *Ex post* analyses of effective changes in domestic prices provide a more nuanced picture. Using 83 monthly-price series for staple food crops in 12 sub-Saharan countries between June 2007 and June 2008 – compiled by FAO – Minot *et al*. (2010) find an overall estimate of 70 percent in the rate of pass-through of international prices to that of domestic markets, somewhat close (though significantly above) to the 66 percent upper parameter used in Ivanic and Martin (2008). Yet, this average figure hides large heterogeneity across crops, across countries, and within countries. For instance, the national-level pass-through rate reached more than 150 percent in Ethiopia and Malawi, while it was limited to 39 percent in Ghana and 53 percent in Mali. Within Ethiopia, the pass-through rate for wheat was 141 percent in Addis Ababa, and 224 percent in Mekele. For maize, it reached 236 percent in Addis Ababa.

Thus, absent information on market structures of agrifood value chains (AFVC), reliable estimates on how international short term price variations might have translated into changes in domestic prices were missing, and the predictions made during the crisis were at best imprecise. This imprecision likely affected the choice of policy instruments that were developed at the time.[5]

Following a sharp decline in 2009, global food prices rose again rapidly between June 2010 and early 2011, triggering a new set of studies to appreciate their short-term effects on poverty as a guide for policy. Accounting for the analytical constraints faced in the 2007–2008 crisis, Ivanic *et al.* (2012) wrote that: “A potentially important difference between the two episodes is in the extent to which changes in world prices of key staples have been transmitted into domestic markets – an issue on which we have much better information than in 2008.”

In fact, one of the policy outcome of the 2007–2008 was to reinforce the daily monitoring of food prices throughout the world, and the centralization of information in dedicated web repositories such as the World Bank ”Food Price Watch”, now integrated within the Food Security Update portal (available at www.worldbank.org/en/topic/agriculture/brief/food-security-update/data-and-research), and the FAO Food Price Monitoring and Analysis (FPMA) tool (available at https://fpma.fao.org/giews/fpmat4).

These support facilitate real time monitoring of international and domestic food prices, identify unusual price levels through “price warnings” at country level (FPMA), and enable on-time estimates of rate of pass-through, and more precise estimates of changes in international prices on local poverty and food security. Yet, they do not provide *ex ante* information on the extent to which surges in international food prices may translate to domestic prices, and by this, the extent to which local agrifood systems’ capacities to support local food security are exposed to future crisis.

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[4] In a similar approach, Wodon *et al*. (2008) estimated the impact of rising food prices on poverty indicators for a set of twelve West and central African countries, using a lower bound of 25 percent increase in domestic prices and an upper bound of 50 percent. Their results point to different predicted effects across and within countries (urban vs rural in particular).

[5] As reviewed in Wodon and Zaman (2010), countries differed in their choices of policy instruments to face the consequences of the predicted crisis. One set of policies aimed at stabilizing domestic prices by affecting the aggregate supply and demand balances through changes in import tariffs and sales taxes, releasing food grain reserves on local markets, or implementing export restrictions on selected items. Another set of policies revolved around the expansion of beneficiaries or benefit levels of existing safety net programs. A third type of policies aimed at supporting domestic food production through free or subsidized inputs, although the benefits would typically be observed in the medium run.

3 Agrifood value chains resilience and food security in low-income and fragile countries

Our focus on agrifood value chain starts with their contribution to food security in low-income countries. We rely on the definition of food security currently accepted by the United Nations' Committee on World Food Security. Accordingly, an area is considered food secure when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

In low-income countries where farm-households constitute the majority of poor and food-insecure families, (dis)functioning agrifood value chain may affect farmers' well-being through (un)available production means or (in)sufficient output prices. Agrifood value chain also encompass producers and consumers, as well as (sometime numerous) intermediaries, including rural traders, wholesalers, transformers and retailers, whose livelihood depend on the effective flow of goods between producers and consumers. Last, agrifood value chain contribute to determine the overall amount of food available to consumers, and the corresponding prices.

Agrifood value chain may be exposed to shocks and stressors of different nature and origins (e.g. climatic, political conflicts, international price variations), affecting their capacity to deliver on their role towards local food security. An important policy agenda is thus to strengthen AFVC's resilience to variations in their physical, economic, or political environments. Resilience itself is a broad concept. It is however commonly accepted that resilient units or systems designate those that quickly recover from an external shock, reaching their previous level of activity (Constas et al., 2014). With respect to food security outcomes, one may further add that resilient agrifood value chain contribute to guarantee some minimal standard of living, at producers, intermediaries and consumers-levels. In short, a resilient agrifood value chain is here defined as one that is able to maintain or quickly recover its food-security-related functional integrity in the event of a shock.

3.1 Traditional, transitional and modern agrifood value chains

An important challenge to the study of agrifood value chain relates to the limited (if any) data on the actors, exchanges and value additions that occur between producers and consumers. In low-income countries, studies have mostly focused on the two ends of agrifood value chain: agricultural producers or consumers.[6] And while in-depth description of agrifood value chain exist for particular crops and countries, they are selective in their country-commodity focus, built on specific questionnaires and designs, and therefore offer limited scope for systematic knowledge generation (see Barrett *et al*. [2020] for a recent review). We return to the challenges posed by the lack information below and propose possible ways to address it. Meanwhile, we rely on existing reviews to describe the functioning of agrifood value chain in low-income countries.

[6] The dearth of data on intermediary segments is not specific to low-income countries. In high-income countries, consistent data on exchanges within AFVC only exist in the United States of America through the Food Dollar Series.

Agrifood value chain are far from homogeneous and differ in their structure across geographies and commodities. Following Barrett *et al.* (2020) slightly adapted for our purpose, one can assign existing AFVC to one of three categories.

- **Traditional AFVC** exist in mostly rural and remote locations. These agrifood value chain usually relate to unprocessed staple crops, produced and consumed locally. Farm production is mainly small-scale, and transactions occur on rural spot markets. On the one hand, remoteness implies that traditional value chains do not depend on outside sources to procure or sell food (or to procure production inputs), which limits their exposure to national or international price variations, as well as conflicts. On the other hand, these agrifood value chains may be particularly exposed to climatic shocks, being unable to source food from elsewhere in cases of adverse weather conditions. In some instances, farmers in traditional agrifood value chain sell directly to end-consumers while transactions are intermediated by local traders in other cases. In the latter case, remoteness implies that if intermediation is operated by a limited number of traders – a concentrated midstream segment – the latter may exert some market power and strategically affect prices at which producers are paid and consumers are charged.
- **Transitional AFVC** usually develop in response to increased urbanization and facilitated (road) transportation. They tend to be supplied by more input intensive agriculture connected to more distant consumer markets. Operating on larger geographical scale, transitional value chains are less exposed to adverse weather affecting specific locations, but may be more exposed to variations in national or international price movements of agricultural inputs and outputs. Further, they are vulnerable to disruptions in the physical flow of goods across surplus and deficit locations, which may happen in the case of localized conflicts. Transitional agrifood value chains tend to be long, featuring several levels from upstream producers to downstream consumers: rural traders procure form farmers before selling to (oftentimes urban) wholesalers who cater to processors selling (transformed) product to retailers. Each level features different number and size of agents. Because of their important fixed costs, the number of processors (ex. flour factories) tends to be the most concentrated. Where their number is small, their possible market power increases *vis-a-vis* upstream and downstream segments of the agrifood value chain, which can be reinforced by their capacity to obtain produce from external sources (e.g. imports). At the other end of the agrifood value chain, traders are sometimes suspected of exploiting market power *vis-a-vis* the producers they source product from. While it may be true in specific crops and geographies, existing (though still limited) evidence broadly supports the notion that these crop markets are generally competitive in sub-Saharan African countries (Dillon and Dambro, 2017).
- **Modern AFVC** correspond to current high-income countries AFVC, although they have started to develop rapidly in low-income countries over the past decades (the ”agrifood value chain revolutions in low-and middle-income countries” described in Barrett *et al*., 2020). Modern agrifood value chain feature large (often international) actors and a limited number of levels. They revolve around formal contracting between large actors, and vertical integration with smaller ones. They cater to consumers through supermarkets and fast-food chains, with more processed and quality-differentiated food items, notably through a higher focus on food safety issues. From their international dimensions, modern agrifood value chain tend to be less exposed to domestic shocks (e.g. climatic or conflict) and in turn more dependent on international conditions.

As discussed in Barrett *et al.* (2020), modern agrifood value chain is still to take-off in most low-income countries, and particularly so in sub-Saharan Africa. For this reason, the rest of this paper will essentially concentrate on Traditional and Transitional AFVC.

3.2 Midstream concentration in agrifood value chains

We focus here on one particular aspect of heterogeneity across agrifood value chain: their degree of concentration in their midstream segments (see Reardon [2015] for discussion).

Concentration may occur in both traditional and transitional agrifood value chain. Concentration can be high in traditional agrifood value chain if remoteness enables few local traders to exert some level of market power *vis-a-vis* their suppliers and clients, and directly affect prices accordingly. In intermediary agrifood value chain, concentration will usually take place for those activities with the highest entry costs, such as large capital requirement for processors (e.g. flour factories in the case of grain) and possible economies of scale in their operations.

Concentration in midstream segments can imply a higher degree of overall efficiency with positive returns from upstream and downstream participants of the agrifood value chain. However, concentration also bears two possible risks for the agrifood value chain. First, a highly concentrated midstream segment means that the functioning of entire agrifood value chain depends on the economic strength of a few actors only. Accordingly, a negative shock affecting one such actor can disrupt the entire functioning of the agrifood value chain and by that, the economic well-being of many upstream producers and downstream consumers. In other words, higher concentration also means limited redundancy and greater vulnerability to shocks and stressors even if when these only affect a small number of key intermediaries.

Second, a highly concentrated midstream segment may translate in important market power for the corresponding intermediaries. Such market power implies that standard economic predictions (based on atomistic competition) may not align with observed levels of economic outcomes such as price and quantity. The more concentrated is an intermediary segment, the larger these possible discrepancies.

Concentration typically varies across the levels that compose an agrifood value chain. In simplified terms, agrifood value chains can be described through seven such levels, of which four are what we later refer to as intermediaries.

1. There are input markets, from which producers source production means including seeds, fertilizers, phyto-sanitary products or mechanized services. While a fundamental part of the functioning of an agrifood value chain, we abstract from these in the analytical framework – although later versions may delve in this direction.
2. There are producers (farmers), who can dispose of their production in three ways: consume their own production; sell directly to consumers; sell to an aggregator.
3. Aggregators (rural traders or primary cooperatives) purchase from farmers and sell to larger-scale (often urban) wholesalers.
4. Wholesalers purchase products from aggregators and sell it to processors, or retailers, depending on the transformation required before the product reaches consumers, which may differ across agrifood value chain. In some cases, wholesalers can also import product

from outside of the considered sub-national region (or country), while in other cases, this role is devolved to processors.

5. Processors purchase raw product from wholesalers or external sources, and process it for final use. Processors then sell their products to retailers.

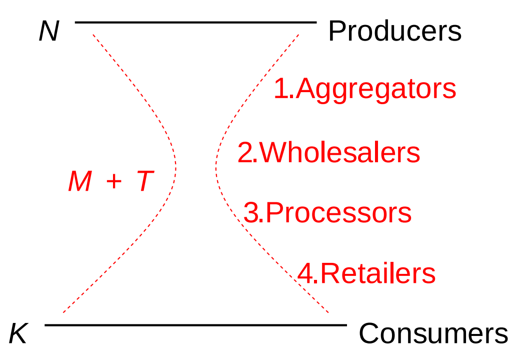
6. Retailers are in direct contact with final consumers. They may be large (supermarkets) or small (shops or booths on open-air markets). In some agrifood value chain they also apply a final transformation of product (ex. bakeries purchasing flour from mills to bake bread that they sell to consumers).

7. Consumers purchase from retailers.

Across commodity and country type, AFVC's differ with the presence/absence of particular levels. As discussed above, the most traditional agrifood value chain will essentially feature producers and consumers. As the agrifood value chain moves towards Transitional agrifood value chain, further levels are included, up to the full four levels of intermediaries that we described. As it further moves towards modern agrifood value chain, one often observes some degree of vertical integration. Thus, moving from Traditional to a Transitional agrifood value chain, one often observes and expansion in the number of intermediary levels and actors within. The opposite occurs when moving from Transitional to Modern agrifood value chain, where one tends to observe a contraction in the number of levels and actors – following a "J curve" evolution as described in Reardon (2015). The level order may also vary. For instance, in some cases, wholesaling levels appears before that of processing and sometimes after.

Abstracting from modern ones, a regular feature of most agrifood value chain is described in Figure 2, where we represent the relative number of actors at each intermediary level operating between producers and consumers. The hourglass shape illustrates the general feature where, in between large numbers of producers and consumers, a smaller number of intermediaries operate. The most concentrated level, in most cases wholesalers or processors, features the largest actors with corresponding market power on upstream and downstream segments. Among them, some may be particularly important (M), and others much smaller (T). Accounting for this midstream concentration and heterogeneity within, lies at the core of the analytical framework that we describe below. In what follows will refer as "intermediaries" those actors of the most concentrated segment of the agrifood value chain, within which M are large enough for their choice to affect the agrifood value chain, while T are not.

Figure 2. Relative number of actors in agrifood value chains



Source: Authors' own elaboration.

4 Modelling agrifood value chains: an analytical framework

Accounting for heterogeneous geographies and crops specificities when assessing the separate (or combined) effects of climatic, economic, or political changes on the resilience of agrifood value chain is in itself a significant analytical challenge. Conditioning these effects on the more or less concentrated nature of intermediary segments, while necessary, raises another level of difficulty, calling for a dedicated tool to support analyses and ensuing decision making. In this section, we take a first step in this direction, through the analytical framework that we described below.

4.1 Building blocks

Building from the field of Industrial Organization in economics, we propose a simplified model of agrifood value chain where one level of actors jointly exert some market power with upstream suppliers as well as with downstream consumers. As discussed above, this simplified approach matches with a number of agrifood value chain characterized by a large number of producers, a large number of consumers, and a much more limited number of intermediaries who, by their actions, can affect market outputs.

The model is built around three types of parameters.

1. **Structural parameters** are invariant in short/medium run. They include the number and relative size of agents at each level of the agrifood value chain.
2. **Exogenous parameters** can change in the short run, but are not influenced by agents' activities, nor policies. Exogenous parameters may relate to the evolution of external (international) prices, climatic conditions, or conflicts. We also include trade policies (e.g. import/export quotas or tariffs) as part of these exogenous parameters: although they may in part respond to (dis)functioning in the agrifood value chain, we assume that AFVC actors themselves have no control over them.
3. **Endogenous parameters** are determined by the model given the above structural, exogenous and policy parameters. We focus on a set of parameters that can be considered as key outcomes with respect to food security: farmers' income, overall food available in the country, and consumer price.

We describe below how these parameters enter the behaviour of Consumers, Farmers, and Intermediaries, before discussing the model's predictions. We concentrate below on the main intuitions of the framework, and relegate to Annex 1 the full mathematical structure underpinning these predictions.

4.1.1 Consumers

Consumers are numerous and none is large enough for one's consumption decision to affect prices: they are price takers. For simplicity, we assume that each individual seeks to consume the same amount, which one can interpret as a standard caloric requirement met by the food product of the considered agrifood value chain.

The difference between consumers lies in their effective capacity to purchase the good given their disposable income and the price of the good itself. In this model, there are K consumers, each of which has a different disposable income r, ranging from $\underline{R}$ to $\bar{R}$. Under limited assumptions, one can aggregate each consumer's demand into an overall demand function relating the overall food demand, Y, to price (p), given the distribution of consumers' income ($\bar{R} - \underline{R}$) and their overall number (K).

Doing this, one obtains a representation of consumers' behaviour which aligns with standard predictions:

- As p increases the share of consumers capable or willing to purchase the food item decreases.
- Positive or negative income shocks affect demand for the food item. Income shocks is modelled through a change in the support $[\underline{R}, \bar{R}]$ of consumer's disposable income for the good. Accordingly, a negative income shock for the poorer segments of the population corresponds to a lower $\underline{R}$.
- Policies to support consumption of the poor (e.g. through cash/in-kind transfer targeted at the poorest segments) will in turn translate into a new support $[\underline{R}', \bar{R}]$, with $\underline{R}' > \underline{R}$. Such policy will however contribute to increase the price of the product p for all individuals in the population. The real term effect of the policy on beneficiaries will thus be depreciated by the level of the price increase, and the purchasing power of non-beneficiaries will in any case be negatively affected.

4.1.2 Farmers

Consider that there are N farmers and that none is capable, through purchase or output sales activities, to affect the corresponding prices: they are price-takers. Each farmer produces a quantity of raw product, q. We assume that all farmers produce a similar quantity, although with varying level of efficiency $e \in [0,1]$. In order to sell their products, farmers must incur a fixed cost, which is higher for the less efficient farmers and lower for the more efficient ones.

Thus, a farmer will (produce and) sell q on the market if the price offered (ω_1) is greater than his costs. It can occur that not all farmers are able to supply the produce on the market for some (low) level of price. In that case, farmers' whose efficiency level e lies below a threshold calculated from the model ($\hat{e}$) will be excluded from the market.

Under these limited assumptions, the total quantity of domestic raw product available on the market, Q, can be calculated in response to the number of farmers (N), the per-farmer production level (q), and the distribution of their efficiency (e), the fixed marketing cost (G) and the producer price (ω_1).

As for consumers, this simplified representation of farmers' behaviour aligns with standard predictions.

- As producer price (ω_1) increases, so does the share of farmers that are willing or capable to supply the food item to the market. In contrast, a fall in output price will drive the least efficient (possibly smaller) farmers out of the market, with corresponding consequences on their income.
- A negative production shock (an adverse weather condition) will affect the overall per-farmer output (q) leading to greater market exclusion of the less efficient farmers for a given level of producer price.

- An input subsidy targeted at the least efficient (smaller) farmers, will in turn push the efficiency distribution to the right, enabling more farmers to sell outputs to the market, contributing to a greater overall domestic production.

4.1.3 Intermediaries

We now consider that there is a single intermediate level in the agrifood value chain, featuring M larger and T smaller intermediaries.[7] Intermediaries buy raw product upstream from farmers at price ω_1 and sell (processed) products to consumers downstream at price p. We focus on traditional and transitional value chains without vertical integration schemes: all local purchases and sales occur on spot market-types of transactions. Intermediaries can also source produce from a much larger external market at a price ω_0 that is not affected by the activity in the considered agrifood value chain.[8] Intermediaries may source any amount of produce on this external market, up to an exogenously set limit $\bar{x_0} = 0$ – representing local import constraints and/or policies. After sourcing raw products from these two markets, intermediaries sale the (possibly transformed) output to consumers.

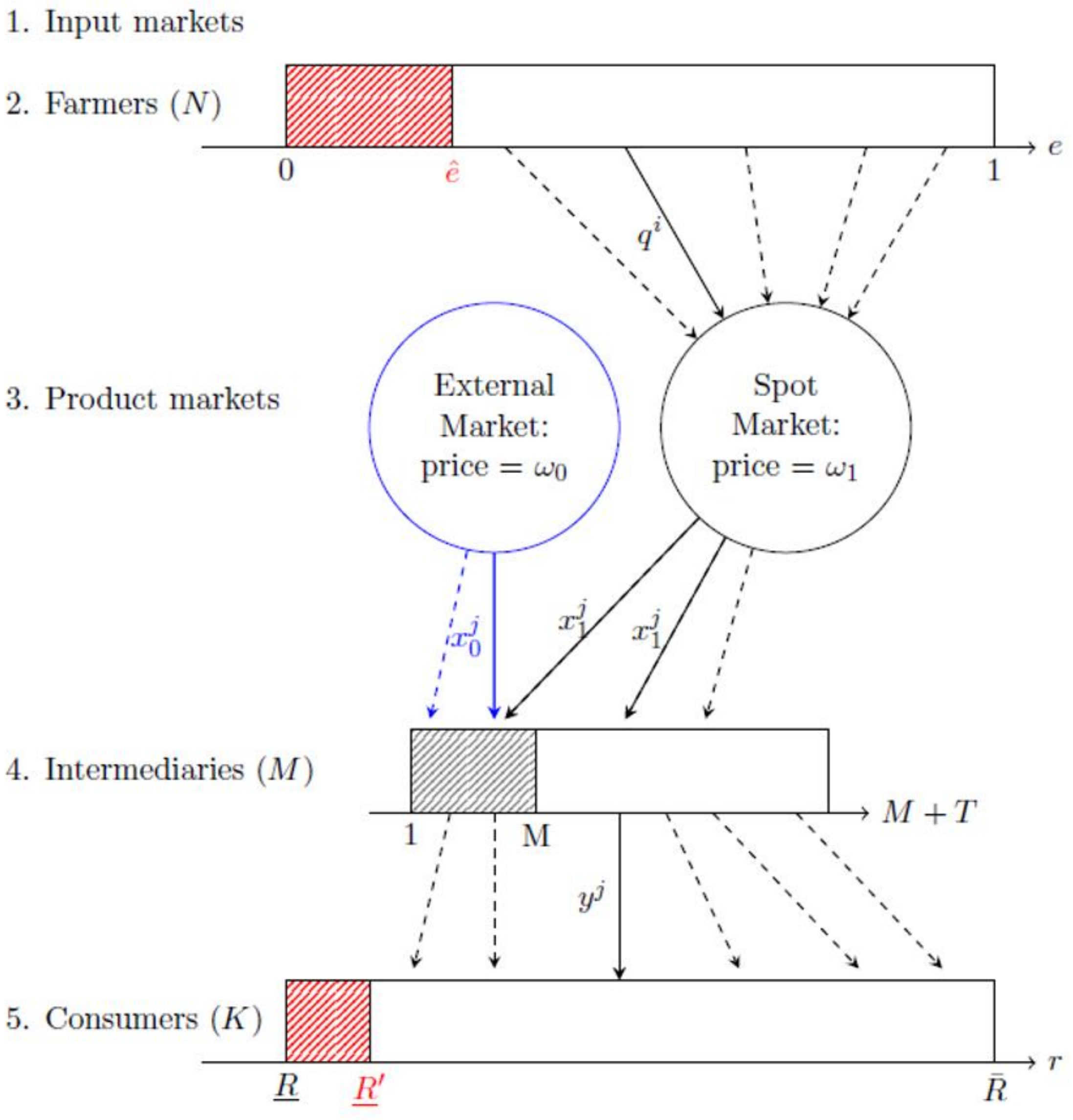
The choices and actions of small intermediaries have no effect on price-levels (they are price-takers), while those of larger ones can affect upstream producer prices (ω_1) and downstream consumer prices (p), respectively. A smaller number of large intermediaries (M) is thus associated with a correspondingly higher market power: their greater capacity to affect these prices through their choices.

The overall layout of this analytical framework is summarized in Figure 3.

[7] As discussed above, intermediaries are here defined as the most concentrated level of the agrifood value chain – whether wholesalers, processors or others.

[8] In cases of a national agrifood value chain, this external market represents the international one, from which one can import products. Conversely, if one considers sub-national AFVC, this external market represents the national market. Note that in this first step towards an analytical framework, we assume that the agrifood value chain does not export its products.

Figure 3. Five-level agricultural value chain



Notes: e captures farmers level of efficiency in production, and *r* consumers disposable income for the purchase of the food commodity. *N* and *K* are large such that individual farmers and consumers are price takers. There are *T* smaller intermediaries with no market power, and *M* intermediaries who, by their purchases and sales on upstream/downstream markets, can affect the corresponding prices.

Source: Authors' own elaboration.

4.1.4 Further blocks

The agrifood value chain structure presented here, while simplified, captures a large share of existing AFVC in low-income countries, whether *Traditional* and localized, or *Transitional* and national. Yet, AFVC are heterogeneous, and the proposed structure may insufficiently represent some AFVC of particular interest. The proposed approach relies on standard economic analysis, built on limited and transparent assumptions. Its analytical support (described in detail in Annex 1) provides foundations on which additional building blocks can be added to better align with agrifood value chain specificities.

- The current building blocks implicitly describe agrifood value chain for local food consumption. Alternative specifications may allow for the agrifood value chain to export to external buyers. In cases of cash crops (such as cocoa, cotton or coffee for instance), the external market may in fact represent the bulk of the purchases.
- As discussed in the previous section, we have thus far focused on traditional and transitional agrifood value chain, where vertical integration and contracted production remain limited. The approach may be extended to include these aspects, and explore conditions for their development over time.
- In low-income and fragile countries, the food aid sector can sometimes represent a large share of the products available in (or along) a particular value chain. Whether these products are sourced locally (and at which level) or internationally, and whether they are distributed at midstream or downstream agrifood value chain levels is not neutral to the functioning of the agrifood value chain and can constitute an important addition to the current model.
- We have explicitly concentrated on midstream segments of the agrifood value chain, ignoring other important levels such as input supply and demand. Further work would likely need to expand on this aspect.
- Further specifications may allow for a more precise account of the effects of prices changes on producer supply and consumer demand, especially for those products for which there are close substitutes in consumption and/or production.
- As of now, the analytical framework does not account for saturation in agrifood value chain actors' capacities, and in particular with respect to transport, processing and storage capacities. On the latter aspect, the extent to which time arbitrage may or not be exploited can in turn affect the formation of prices and their responsiveness to stressors and shocks.
- The functioning of agrifood value chain largely depends on what one may refer to as "enablers" related for instance to financial services (credit or insurance), transports, communications and others. The current setting can be expanded to better capture these aspects.

While outside the scope of the current paper, we believe that these and further building blocks may enrich the proposed approach. The simple and transparent features of the proposed analytical framework allow for these additions.

4.2 Outcomes and predictions

4.2.1 Solving for prices and quantities in agrifood value chains

Since no producer and no consumer can individually affect the prices of the raw product and of the final good, these depend on behaviour of those intermediaries who can exert some degree of market power. We assume that each one of them seeks to maximize profits from purchases and sales of the product, and that each has a reasonably good knowledge of the agrifood value chain in which one operates.

Thus, each large intermediary will choose the optimal amount to procure from the domestic market (x_1), and from the international market (x_0) on which he has no effect over the on-going price (ω_0). Intermediary's choices account for the anticipated effect that his purchase from local producers and his sales to local consumers, will affect the corresponding prices ω_1 and p. His choices will further account for similar and simultaneous behaviour amongst his fellow intermediaries.

Solving for this set of interactions, one can characterize the optimal behaviour of intermediaries and the corresponding Nash equilibrium that we fully describe in Annex 1.

4.2.2 First order predictions: market structure and food security

This simplified (preliminary) representation of an agrifood value chain yields a set of results that are each in-line with standard predictions, supporting its internal logic. It however enables interactions of diverse mechanisms at play, and offers a more general representation of AFVCs' capacities to contribute to food security under different sets of structural, exogenous and policy parameters. A first set of first order predictions are summarized in the first two columns of Table 1.

Consider for instance a government that is interested in an AFVC's contribution to food security. The latter is evaluated through key indicators including farmers' income, overall food availability, and consumer price. The proposed analysis suggests that, in the absence of supply constraint on the external market, farmers' output price (ω_1) depends positively on the external price (ω_0) and the number of intermediaries (M), but not on the per-farmer production (q). In contrast, the level of exclusion of less efficient (smaller) farmers from the market ($\hat{e}$) is itself negatively related to the external price (ω_0), the number of intermediaries (M), and the per-farmer production (q). Together, these predictions highlight possible trade-offs between structural, exogenous as well as policy-relevant parameters when it comes to price or quantity-relates components of farmers' food security.

Turning to the overall quantity available for domestic consumption Y, the analysis suggests that it positively depends on the number of intermediaries (M) and negatively on the external price ω_0. The share of product that is sourced locally, a value of possible interest for the resilience of agrifood value chain, also depends positively on M and ω_0, as well as on local production capacities q. Last, the consumer price, p, depends negatively on the number of intermediaries, and positively on the external price ω_0.

The analytical framework can further account for the fact that a number T of intermediaries have additional supply and/or marketing costs compared to the most influential intermediaries on the market (here in number M). These "inefficient" intermediaries will tend to increase the equilibrium price on the intermediate market and lower the one on the final market. In Table 1, we denote $H = T/M$ the corresponding ratio for a level M fixed, allowing us to conjecture these effects. These predictions are however "first order" in that they do not account for the crossed effects of market structure and the occurrence of a particular type of shock.

Table 1. Summary (first order) predictions

	Intermediaries		Sources of shocks	
	Number	Heterogeneity	Trade	Conflict
	↑ M	↑ H	↑ ω_0	↓ q
Farmers Output price: ω_1	+	+	+	+
Market participation: $s = 1 - \hat{e}$	-	+	-	-
Consumers Food availability: Y	+	+	-	-
Local supply: $s.N.q$	+	+	+	-
Consumer price: p	-	-	+	+

Source: Authors' own elaboration.

4.3 Shocks and market structure: informing policies

4.3.1 Sources of aggregate shocks

The proposed framework can be leveraged to analyse how shocks of different nature transit through the agrifood value chain and ultimately affect food security. For simplicity we consider three general types of shocks and describe the way they enter the agrifood value chain as follows:

- A climatic shock may enter the agrifood value chain through a sharp reduction in the total output that is produced locally: Nq.
- A surge in external price operates through a corresponding increase in ω_0.
- A political conflict isolating a sub-national region can take the form of a limitation in that regional AFVC's capacity to source from and deliver products to the external market: a sudden drop in $\bar{x_0}$

First order predictions of the effects of these shocks on food security-related outcomes are presented in the last two columns of Table 1.[9] Accordingly, an increase in the external price translates into higher income for producers who are net sellers (through higher price and lower market exclusion), but higher consumer prices and lower overall food availability. In comparison, an adverse weather condition has limited effects on producer prices, which translates into an overall income loss for farmers since production has itself decreased. On the consumer side, and given access to the external market, the consequences of these shocks are limited.[10]

[9] Table 1 does not display first order predictions for the occurrence of conflicts, as these are mostly non-linear. We return to the related predictions below.

[10] These broad predictions could be further refined to account for the intra-annual timing of the shock. For instance, shocks that occur after the end of the commercialization season will have limited effects on domestic producers although they will still affect consumers. Other sources of heterogeneity may relate to the logistical disruption following a shock, the magnitude of which may depend on distance between production and consumption areas and the quality of transport infrastructures in between. In this paper we abstract from these and other sources of heterogeneity to keep the model simple and tractable, although the approach be developed further to allow for the analysis of these issues.

These first order effects may however be mediated by the structure of the midstream segment of the agrifood value chain. One may for instance wish to investigate how increases in external prices transmit to domestic prices *conditional* on the number of and size of intermediaries, or the combined effects of different shocks under particular market structures.[11] Analytical solutions to these various interactions are not easily reached, however. Numerical solutions and related simulations can instead be relied upon, as describe in Section 5 and illustrate with a real-life example in Section 6.

4.3.2 Policies

The objective of the proposed framework is to provide guidance to decision making seeking to support the support the resilience of agrifood value chain in their capacity to contribute to local food security. As discussed in Section 1 we define *ex ante* policies as those geared at enhancing the overall effectiveness and resiliency of the agrifood value chain, and *ex post* policies as those seeking to mitigate the effect of a currently occurring shock on food security outcomes.

Ex ante policies

We abstract from policies supporting producers and consumers levels of the agrifood value chain (already largely documented), and instead focus on midstream intermediaries which this paper focuses on. First, the analytical framework can inform on the AFVC's vulnerability to shocks of different nature leading to the failure of individual midstream intermediaries. The objective in this case is to identify whether and how the agrifood value chain as a whole would be affected by the sudden removal of one or more intermediary, accounting for their size and geographic locations. Where the agrifood value chain is identified as highly vulnerable to these idiosyncratic shocks, *ex ante* policies will seek to strengthen existing intermediaries and/or encourage the establishment of new ones. In the proposed framework, the corresponding predictions can be obtained through second order effects of variations in midstream parameters (M,T).

Second, one may investigate the resilience of the agrifood value chain to more aggregate shocks *given* the current features of its midstream segments, simulating shocks of different natures (through large changes in Nq, ω_0 and x_0, as described above). For instance, the short-term effects of increased international price ω_0 (as in the 2007–2008 food-price crisis), would positively affect producers' income at a cost of a lower purchasing power for consumers. The net effect would thus depend on the share of net-buying and net-selling households in rural areas, considering that urban households are mostly net consumers of food items. Yet, these effects would be mediated by the rate of pass-through of ω_0 onto ω_1, itself positively depending on the number of intermediaries. Thus, the concentration of the midstream segment of the agrifood value chain partly conditions the exposure of local producers and consumers to international prices, irrespective of the level of local production q. In other words, concentrated

[11] In order to keep the approach general, we do not account for the type of intermediaries when assessing price transmission, and limit the analysis to their number and size distribution as it affects the level of competition within each level of the value chain, with consequences for price formation within and across levels. Further analyses could for instance account for different objectives functions between intermediaries: while private actors may for instance be profit oriented, parastatals such as the Ethiopian Grain Trade Enterprise may be more concerned about price stability.

intermediate segments of an agrifood value chain contributes to both higher consumer prices and lower exposure to international price variations, at least in the short run.

Such predictions may offer guidance on the current AFVC's resilience to these shocks and their level of transmission to upstream and downstream actors, and overall food security. It may further inform *ex ante* policy decisions related to midstream segments: whether and how varying the number, geographical dispersion, and relative size of key intermediaries would translates into higher or lower vulnerability to these shocks. In the proposed framework, the corresponding predictions can be obtained through second order effects of these aggregate shocks under alternative structures of midstream segments. With many dimensions involved, a finer assessment of the effects requires a dedicated simulation tool to which we turn in the next section.

Ex post policies

Last, the analytical framework allows for the consideration of various *ex post* policies at times of shocks. We list below some broad *ex post* policy options and discuss how they may be analysed through the proposed analytical framework.

- External trade policy which are often relied upon by governments seeking to limit the effects of particular shocks (international price shocks, domestic production shocks and others) can be assessed through variations in $\bar{x_0}$ (for instance when imports are limited by import quotas), or ω0 if imports are taxed or subsidized (including as a means to support intermediaries).
- Transfers which are used to support domestic consumers (in particular the poorer segments) may be included in the model as an increased in the lower bound of disposable income K. The nature of the support (e.g. in-kind or in cash transfers can further be accounted for through changes in income (cash transfers) or direct changes in disposable income for the considered food item (in-kind transfers), via r.
- Market interventions in which food stocks (or imports) are released at below-market-price on consumer market, can be thought of as an exogenous change in overall quantity available Y, and its effect on final consumer and producer prices be traced accordingly. A similar approach may be adopted to account for state agencies directly procuring food product on producer-level markets, through a floor price to mitigate issues of declining domestic prices following that of international prices.
- Support to producers can be incorporated in the analytical framework through increased producer efficiency, e(θ), where θ captures production and commercialization costs which may be affected by policies seeking to increase availability and costs of inputs, or to support small-scale commercialization. Producer support may thus take the form of an increased overall efficiency, thereby reducing market exclusion of less efficient (smaller) producers – a lower ê.

5 Contributing to the agrifood value chains policy toolbox

The overarching goal of this paper is to investigate a new set of diagnostic tools which, combined with existing ones, can contribute to guide short and medium-run policies seeking to strengthen resilience of agrifood value chain. In this section, we discuss one possible way to apply the proposed analytical framework to specific country-AFVC settings. In doing so, we first assess the extent to which current data sources can be utilized to inform the analytical framework, and propose a dedicated data-collection instrument for weakly documented midstream segments of AFVCs. We then discuss how to integrate this data in a purposefully developed computer application generating a set of graphical predictions meant to support decision-making.

5.1 Agrifood value chains data

In its current form, the analytical framework rests on a limited set of “structural” and ”exogenous” parameters which, combined, yield predictions with respect to food-security related ”endogenous parameters”. Policy variations can themselves be introduced through their implied changes in the levels either structural or exogenous parameters.

Adapting this framework to an agrifood value chain requires one to inform these parameters. Precise information naturally leads to more precise predictions. Broad and somewhat imprecise estimates are nevertheless useful, as the main objective of the framework is to understand how shocks and policies interact with the structure of an agrifood value chain, and obtain general direction and magnitude of the identified relationships. Thus, while precise and up-to-date information on each parameter is likely out-of-reach in many low-income countries (and more so in particularly fragile ones), the framework can nevertheless be informed by existing data combined with a purposefully designed data collection tool. We describe these two sources below.

5.1.1 Existing information: possibilities and limits

For many parameters, information on local agrifood value chain can be obtained from publicly available data. FAO, World Bank and other institutional portals gather data from official and survey sources throughout the world, offering one-stop data access points. Several caveats are in order: (i) information is mostly available at national-level, and thus limits analyses of sub-national-level agrifood value chain; (ii) some features of agrifood value chain lack systematic documentation, this is particularly the case for midstream segments of agrifood value chain; (iii) most information accessible through these data portals is not up-to-date, often lacking up to the five most recent years. With these caveats in mind, this information can be used to inform part of the proposed analytical framework. Table 2 lists some of these readily available data sources in relation to model parameters. For each, we propose a *Usability Index* indicating its direct, indirect, or insufficient capacity to inform the framework’s parameters.

- Product availability can be broadly informed from a series of FAOSTAT webpages. For most countries, one can obtain estimates of the overall production in several recent years, along with corresponding area cultivated and average yield, offering an idea of overall production potential. One can further obtain estimates of landholding distribution, although not specific to particular crop production. This information can be completed with field knowledge and representative survey data, assessing whether, for the considered crop, the landholding distribution can be used to infer area distribution for the crop of interest, and ultimately estimate the number of farmers.

Amongst the available pre-computed indicators, the share of farmers selling (some of) their considered crop production is rarely available. Where they exist, farm household surveys can document this important parameter, which determines the share of local production that reaches the market. Importantly however, while increasing in number, standardization and availability, such surveys may not cover the country under study.

- Midstream segments tend to be the least documented part of agrifood value chain (*Barrett et al*., 2020). While in-depth description of agrifood value chain exist for particular crops and countries, they are selective in their country-commodity focus, built on specific questionnaires and designs, and therefore offer limited scope for the kind of systematic analyses that are proposed here.

  Absent other source of information, one may seek to leverage the widely and somewhat regularly collected World Bank Enterprise surveys.[12] As we discuss below however, a key necessity for the current analysis is to document all larger actors within midstream segments of agrifood value chain if one is to assess concentration of actors at the corresponding level. This information is not available from random sampling of actors and is better documented through census – at least for the larger actors. The World Bank Enterprise Surveys usually rely on stratified random sampling from a list of firms sourced from local statistical office, government agencies or business associations. For the current purpose, the underlying census featuring information on firms' size and sector of activity is more relevant than detailed information on a random subset of them. However, the survey data and documentation seldom report this information, significantly limiting their use in the proposed analytical framework.[13] Thus, apart from isolated cases, midstream segments of agrifood value chain are unlikely to be informed by existing sources of data.

- Consumption parameters are sometimes informed, in their aggregate forms in dedicated repositories. For instance, the World Bank Poverty and Inequality Platform (PIP) proposes pre-computed indications on income deciles or overall share of food consumption. Yet, this data does not provide information on consumption of particular food items as one would need to study a particular agrifood value chain. It is therefore recommended that micro data be accessed to evaluate consumption of the product under study, and its variation across rural and urban households as well as along the local income gradient. The World Bank Living Standard Measurement Surveys (LSMS) datasets are likely the most appropriate for this, but they only cover a subset of countries and tend not to cover those

[12] Since 2005, most data collection efforts that the World Bank supports with respect to firm-level surveys are centralized in its Enterprise Analysis Unit (EAU). Surveys implemented by the EAU follow a global methodology, although country-level questionnaires also feature country-specific questions. The global coverage is large and include most low-income countries among which those listed as "fragile states" under the current World Bank classification. The manufacturing and services sectors are the primary sectors of interest, within which the Enterprise Surveys targets formal (registered) companies with 5 or more employees (note that firms with 100 percent government/state ownership are not included in the surveys).

[13] Consider for instance a World Band enterprise survey that provides information on 200 firms in a given country, of which 20 are intermediary actors of the agrifood value chain one is interested in. To inform the proposed framework, one would need to know the full number of such intermediaries and their respective market size. Without census information, the 20 firms documented in the survey will be of limited use to inform the analysis.

in conflict situations.[14] Therefore, in many instances, other sources of data need to be collected/estimated from alternative means.

- Shocks parameters are meant to inform on the likelihood and possible strength of a diverse set of shocks which may affect a given agrifood value chain. For instance, climatic shocks may affect agrifood value chain by disrupting production stages. Local conflicts, wherein particular geographical units become isolated from the rest of the country, can affect spatial inter-mediation stages in the agrifood value chain.[15] Variations in international prices of consumer food products affect agrifood value chain through their effects on domestic producer and consumer markets. The sources of data proposed here can be used as sources of early warnings with respect to climate shocks, international price variations or conflicts.

  This information, however, requires some adaptation to the crop and context under study. Climate early warning systems provide information at a somewhat large geographical scale and must be calibrated to particular crops (for instance, a drought will not affect water demanding maize the same way that it will affect drought resisting millet). When using international price data, one needs to account for their translation to local markets: CIF prices should be preferred to FOB ones, and one should account for local trade policies (such as import tariffs/subsidies or quotas). Last, likelihood of conflicts rests on somewhat soft indicators and shall also be informed by local expert opinions.

- Policy interventions can be documented from existing repositories, such as FAO's Food and Agriculture Policy Decision Analysis Tool. The information displayed is sometimes incomplete, however, it must be completed and triangulated with official sources and expert information.

Overall, for most low-income countries, data availability has significantly increased over the past two decades. As a result, several sources of information can be directly leveraged to inform the proposed analytical framework, while others require triangulation with other sources of information and/or some data analysis of available micro-data. Midstream segments of agrifood value chain are mostly undocumented, however. In the following paragraphs we propose a dedicated approach to collect this information.

[14] Over the past five years, LSMS surveys covered about 25 low-income countries.

[15] Consider for instance that for two years, the Tigray regional state of Ethiopia has been isolated from the rest of Ethiopia, with significant consequences on the in- and out-flow of food products.

Table 2. Existing sources of data, analytical parameters, and usability

	Model link	Data sources	Usability
Availability of product			
Local production (area, yields, harvest)	q	FAOSTAT	1
Number of producers (by farm-size)	N	FAOSTAT	2
Share production marketed	$s = 1 - \hat{e}$	FAO Food and Agriculture Microdata Catalogue/World Bank 50x2030 initiative	2
Imports	$\bar{x}_0$	FAOSTAT	1
Food aid shipments		FAOSTAT	1
Midstreams segments			
Number and types of intermediary levels			3
Number and size of actors at each level	M, T	World Bank Enterprise Surveys	3
Consumption			
Income deciles (rural/urban)	$\bar{R}, \underline{R}$	Living Standard Measurement Surveys	2
Total product consumption	Y	Living Standard Measurement Surveys	2
Local prices			
Producer prices	ω_1	FAOSTAT	1
Consumer / Wholesale prices	p	FAO Food Price Monitoring and Analysis tool	1
Shocks			
Climate	Δq	National Weather Service Climate Prediction Center	2
International prices	$\Delta\omega_0$	World Bank International Comparison Program	2
Conflicts	$\overline{x_0}$	Uppsala Conflict Data Program/Fund for Peace	2
Policies			
Household transfers	$\Delta \underline{R}$	FAO Food and Agriculture Policy Decision Analysis Tool	2
Use of food reserves	Δp		2
Producer/consumer price regulation	Δp, $\Delta\omega_1$		2
Import quotas/tariffs	$\Delta\overline{x_0}$, $\Delta\omega_0$		2

Notes: Usability=1: Information can, in most cases, be directly used to inform the analytical framework. Usability=2: With some computation and triangulation, information can be retrieved from existing survey data and/or further informed by other data sources/expert knowledge. Usability=3: Information is mostly missing and should be gathered using dedicated instrument. Data sources column lists the link to the specific website.

Source: Authors' own elaboration.

5.1.2 Collection of midstream segment information

As noted, information on midstream segments of agrifood value chain are seldom available in existing data sources. Further, much of the existing information discussed above is to be triangulated with independent assessments to obtain more precise estimates. Last, and as noted above, most available data is only representative at the national level and not adequate for analyses of sub-national agrifood value chain. Thus, analysis of agrifood value chain can seldom be implemented without a dedicated data collection tool.

Specifically, documenting midstream segments of agrifood value chain requires a dedicated approach, which departs from those used to document producers and consumers in at least two ways.

- One seeking to document the functioning of an agrifood value chain must collect data on all levels that compose it. Regular information on wholesalers will for instance be of limited use for the understanding the agrifood value chain unless similar information is collected from those actors, they purchase product from, and those to whom they sell it to.
- Precise documentation of the largest actors is necessary at each level of an agrifood value chain if one is to assess is concentration and related issues of price formation and transmission as well as its vulnerability to shocks affecting significant market players. In turn, this implies that any sampling frame for follow-up surveys on agrifood value chain actors themselves should depart from the regular stratified random sample approach.

As discussed in Section 1, a pre-requisite of the proposed analytical framework is that its ”key parameters be documented through existing data and/or feasible data collection under time/budget/contextual constraints”. Leveraging government or international organizations' field officers' knowledge or information collection capacities can in many contexts be sufficient to inform on these parameters using standardized information collection guidelines. We build on this assumption to propose a dedicated questionnaire supporting data collection.

To this end, we develop a specific agrifood value chain questionnaire organized in a way that supports and facilitates triangulation of information. The questionnaire can be administered to several respondents, independently or at the same time (in a focus group type of setting). When available, official or data-based information may also be included. For each information collected, its source (name of informant, official figure, etc.) should be precisely recorded.

This questionnaire, while simple in its functioning, is to be administered by senior-level enumerators or experts. Respondents themselves should be chosen amongst knowledgeable individuals with respect to the agrifood value chain studied. They may include local experts from government, NGOs or international agencies. They may also include agrifood value chain actors, such as large intermediaries who can describe the structure of agrifood value chain level from which they source product, that where they sell their products as well as features of their competitors. Respondents should also be able to inform on particular constraints faced by agrifood value chain actors, with respect to logistics, finances, or regulations for instance.

This approach bears potential to describe midstream segment agrifood value chain more comprehensively with respect to:

- Identification of key level(s) of intermediaries in the agrifood value chain, where most concentration occurs in the considered geography.

- Count (or estimate order of magnitude) of the number of actors/firms composing the identified intermediate segment(s) of the agrifood value chain.
- Collect (or estimate order of magnitude) information on the market size of larger actor/firm: share of the local raw product that they source, share of the output that they sell, share of the externally imported raw product.

Specifically, at each level of the agrifood value chain, the objective is to obtain a general estimate of the total number of actors, along with an appreciation of possible market domination by a subset of them. At each level, the questionnaire automatically computes 1 percent, 5 percent, 10 percent, 20 percent, 25 percent, 33 percent and 50 percent thresholds of the overall amount of production that is handled at the corresponding level (including commercial imports if they enter the agrifood value chain at that level). Between each threshold, one is to obtain the total number of actors. While this number may be an order of magnitude for those actors handling less than 1 percent of the total marketed product (the "*T*" intermediaries in the analytical framework), they should be increasingly precise as the market share increases. For actors handling 5 percent of the marketed production or more (the "*M*" intermediaries), one should seek to obtain names and coordinates for possible detailed follow-up interviews.

The questionnaire also supports documentation for all the other parameters of the analytical framework at the production, consumption and import stages. Where available from reliable data sources discussed above, this information can be entered directly into the questionnaire, along with the corresponding source. Where it is unavailable (for instance, in sub-national agrifood value chain), it can accommodate information obtained from expert interviews. A preliminary example of such a questionnaire is available from the authors upon request.

Once the collected data is sufficiently triangulated, yielding a stable picture of the agrifood value chain across the various expert knowledge and data contributed to it, the results may be used to:

1. Inform a simulation tool to assess how midstream concentration or dispersion affect the resilience of the agrifood value chain to aggregate climatic, price or conflict shocks.
2. Inform on the dependence of the agrifood value chain on the health of a potentially limited set of midstream actors, and the related need to either encourage entry of new intermediaries or strengthen existing ones.
3. Identify follow-up data collection on targeted actors whose activities are revealed as fundamental to the functioning of the agrifood value chain, and thereby identify their corresponding sources of strength and weakness.

5.2 A user-friendly tool to guide policies

The objective of the proposed approach is to support decision-makers in accounting for agrifood value chain market structure when designing policies and interventions. The proposed analytical framework, if standard in its economic approach, predicts complex interactions between structural and exogenous parameters, yielding predictions on endogenous food-security related outcomes. For such framework to be policy-relevant, one must delve further and assess whether more practical tools can be derived from it.

In this section we take one step in this direction, through a purposefully developed computer application with the following features:

- The tool runs on “Visual Basic Applications” which is installed by default on Microsoft Excel software. This ensures that such the proposed tool can be widely used without any specific competences or software requirements.
- By entering estimates of the main structural parameters described above, one can obtain a broad description of the agrifood value chain considered.
- Through variations in exogenous parameters, one is able to assess the vulnerability of the considered agrifood value chain to shocks and stressors of various natures and, perhaps more importantly, understand how they enter and disseminate through the agrifood value chain.
- By simulating policies of different nature and intensities, one can get a clearer picture of their likely effectiveness in addressing key sources of vulnerability in the AFVC’s ahead of shocks or upon their occurrence.

A preliminary example of this simulation tool along with underlying VBA code are available from the authors upon request.

6 An example: the Ethiopian wheat agrifood value chains

We use the proposed analytical framework to analyse a particular agrifood value chain and assess the use of its prediction to inform policies using the Microsoft Excel-based tool described previously. We take as an example the wheat agrifood value chain in Ethiopia. This choice is motivated by the somewhat complex nature of the wheat value chain in Ethiopia (falling into the "intermediate" category of agrifood value chain described above) and its strategic importance for the country – wheat being the second most important source of food in the country (14 percent caloric intake in 2013) and thus yielding significant policy involvement. Further, the country has long been chronically food insecure and has received repeated support from international agencies over several decades during which trade-offs between short-term emergency responses and long-term development strategies have featured high in the policy arena.[16]

Last, the choice of the 2013/14 year is motivated by the fairly large – although imperfect in some aspects – amount of information available, enabling to test the model's capacity to replicate real-life outcomes in this value chain. Specifically, we largely draw on the study by Minot *et al*. (2019) who provide an in-depth description of the Ethiopian wheat value chain for the year from 2012 to 2013 using various sources of data.[17] When relevant, we add parameter estimates obtained from elsewhere. Then insert the collected information in the proposed toolbox to derive predictions with respect to the resiliency of the wheat agrifood value chain in its capacity to contribute to food security and comment on the usefulness of the corresponding predictions.

6.1 Ethiopian wheat AFVC in 2013/14: key parameters

6.1.1 Wheat producers

In 2013 there were 4.7 million wheat farmers in Ethiopia, for a total of 1.6 million hectares cultivated, producing 3.9 million metric tonnes of wheat in 2013. Most production occurred on small farms of 0.34 ha on average, although 59 000 ha of wheat were cultivated by commercial farms producing a total of 206 000 tonnes.

At farmer-level, the average production per farmer was estimated at 751 kg, of which 189 kg were sold – a 25 percent average marketed surplus ratio. This share however varied significantly across households with 54 percent of the farmers selling none of their wheat production. Among the poorest quintile of farmers (mostly cultivating less than 0.5 ha for their total farm area (not limited to wheat), the marketed share was 9 percent. It reached 37 percent amongst farmers in the richest quintile (and farm size greater than 0.5 ha). Overall, 40 percent of the marketed surplus was produced by the richest 20 percent of farmers. Commercial farmers, selling 100 percent of their production, accounted for 15–20 of the marketed wheat. In what follows, we retain that 35 percent of total domestic wheat production was available for

[16] The Productive Safety Net Program (PSNP) implemented in Ethiopia since 2005 is one such outcome of these policy discussions.

[17] These include: the 2014 Agricultural Sample Survey, the 2011 Household Income, Consumption and Expenditure (HICE) Survey, the 2012 IFPRI-ATA Baseline Survey, historical AgSS production data from the Central statistical Agency, as well as data from FAOSTAT and authors' field interviews. As pointed by authors, there are some discrepancies in estimates across data sources. In particular, production and imports surpass consumption by over 1 million tonnes.

sale on the market (about 1.5 million tonnes). In 2013, producer price was estimated at ETB 6 800 per tonnes. Similarly, we assume that 40 percent of all wheat producers intend to sell some of their production, corresponding to about 2 million farmers.

6.1.2 Intermediaries

In 2013, Ethiopian farmers essentially sold their wheat to local traders operating on rural markets and oftentimes buying on the count of larger intermediaries. [18] Only 0.5 percent of wheat sales went through cooperatives. There is only limited evidence of storing (for more than a week or two) by traders to exploit time-arbitrage opportunities.[19]

Wheat production is transformed into flour through a large network of grain mills. Minot *et al*. (2019) estimate that there are close to 30 000 mills scattered throughout the country, although most are small-scale units (mostly hammer mills) mainly used by farmers to generate flour for their home consumption. Most of the commercialized wheat is ultimately processed by large-scale flour factories. These factories sell wheat flour to bakeries, retailers, and institutional buyers (such as hospitals and the army), particularly in urban areas. Flour factories are the key intermediaries in the wheat AFVC in Ethiopia. They tend to be located in urban areas and purchase domestically produced wheat from wholesalers.

We rely on the Medium and Large Scale Manufacturing and Electricity Industries (MMEI) survey conducted yearly by Ethiopia's Central Statistical Agency to assess concentration in the commercial milling sector in 2013.[20] From this data one obtains a fairly accurate account of the distribution of larger flour factories in Ethiopia at the time. There were 160 flour factories of ten employees or more in 2013.[21] Among these, seven mills had production representing more than 1 percent of the aggregate production for the 160 mills, of which four represented each more than 10 percent of the total.[22] In what follows, we assume that there are 682 flour factories, of which five are significantly large.

Some flour factories can also source wheat from imports. Since 2008 and the surge of international food prices, the Ethiopian Grain Trade Enterprise (EGTE, a parastatal) organizes wheat imports and sells it to large-scale flour mills (primarily in Addis Ababa) at subsidized price on the condition that they sell the flour to bakeries at controlled prices. The goal is to make bread more affordable to poor consumers. Although flour factories are not officially prevented from purchasing wheat from the international market, access to foreign currencies is very limited such that virtually all imported wheat is channelled through EGTE. Thus, a strategic decision faced by millers is whether and how much to buy from the domestic market and/or from EGTE at subsidized price, given constrains in the price they can charge for the imported part of their production. From their field interviews, Minot *et al*. (2019) find that millers

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[18] From a sampling survey conducted by IFPRI in 2016 on 220 wheat markets in Amhara and Oromia (main wheat producing regions), one finds an average of 1 000 farmers selling their wheat on a given market day, to an average of 50 local traders.

[19] Likely due to high storing costs and government policy preventing hoarding given the still important food insecurity.

[20] The MMEI is a census covering all industries engaging ten persons or more and use power-driven machines.

[21] For the same year, Minot *et al.* (2019) use data from the Ethiopian Bureau of Investment reporting 682 flour mills which, we assume, includes units of less than 10 employees and can then be considered as somewhat small transformation units.

[22] We abstain from reporting exact numbers, as self-reporting from millers may come with a degree of biases given the possible tax implications.

have a preference for buying EGTE wheat, though not all are able to do so. They also note that EGTE must monitor flour sales by participating mills given the latter's incentive to buy the subsidized EGTE wheat and sell the flour at the (higher) market price. This monitoring is not always feasible however.[23]

6.1.3 Imports

As mentioned above, imports are essentially organized through the EGTE. The percentage of domestic wheat consumption coming from imports varies between 25 and 35 percent, depending on the size of the harvest and other factors. In 2013, imports amounted to 863 000 tonnes.[24] The vast majority of imports take the form or grains, flour imports being negligible.

One can further disaggregate imports between commercial imports and food aid. Food aid is somewhat erratic, depending on the quality of the rainy season (there is virtually no irrigated wheat production in Ethiopia) and other sources of emergencies, as well as current level of stocks in strategic grain reserves managed by the Ethiopia Food Security Reserve Administration (EFSRA). In 2013, food aid-related imports were relatively low, at 200 000 tonnes (about one quarter of all imports), the rest of imports being for commercial use.

In 2013, cost of imported wheat was estimated at USD 360 per tonnes in Addis Ababa's main wholesale market, or ETB 6 700 per tonnes. After a 33 percent subsidy, imported wheat was available to millers at about ETB 4 500 per tonnes.[25] In comparison, with a producer price of ETB 6 800 per tonnes, the wholesale price for domestic wheat in Addis Ababa ranged between ETB 7 500 and ETB 8 000 per tonnes. Millers using imported wheat were however required to sell the corresponding flour at ETB 7 400 per tonnes to designated bakeries.

6.1.4 Consumers

Total consumption of wheat in Ethiopia amounted to 4.9 million tonnes in 2013. Wheat was consumed by most urban households with an average yearly consumption of 40 kg per capita (4.2 percent of household budget on average), but by only half of rural households who themselves consumed about 30 kg per capita (6.5 percent of household budget), reflecting higher incomes in urban areas. In fact, per capita wheat consumption followed the income gradient, with a yearly consumption of 15 kg per capita in the first (poorest) quintile (for a budget share of 7.7 percent), to 47 kg per capita in the fifth quintile (budget share of 3.5 percent). Based on HICE data, Minot *et al*. (2019) calculate an income elasticity of wheat consumption of 0.83. Assuming that farm households who produce wheat without selling it on the market do not procure additional wheat as consumers, the number of consumers who procure from the market is estimated at 40 million.

[23] For instance, more than half the imports is Durum wheat, whose high protein content makes it suitable for pasta production, while domestic wheat production is mostly bread wheat, only suitable for bread and related bakeries. It is likely that flour factories with access to imports substitute part of one into the other.

[24] Ethiopia only represents 0.6 percent of the worldwide production of wheat, such that variations in the country's production or import are unlikely to affect import prices.

[25] The rate of subsidy is taken from 2014 data and may slightly differ for the year 2013.

6.1.5 Policies and shocks

We discuss below some of main policies and shocks that the Ethiopian wheat agrifood value chain may be exposed to, in order to obtain some orders of magnitude to be included in simulations.

- **Import prices**: During the 2007–2008 international food price crisis, wholesale wheat prices in Addis Ababa increased by 83 percent between June 2007 and June 2008. This represented a 141 percent higher increase in price compared to the international price of wheat (Minot *et al.*, 2010). The market structure as well as the bad 2008 harvest likely contributed to these.
- **Imports**: In their study, Minot *et al.* (2019) attempt to evaluate the effect of the EGTE-mediated subsidy on Ethiopian consumers and producers in 2013. They rely on assumptions with respect to price elasticities of supply and demand, both of which are set at 0.3. Importantly, they assume that the effect of the subsidy is fully transmitted to retail and producer price, suggesting a market structure with perfect competition: no actor (and in particular large-scale millers) could affect producer or consumer prices by their actions. Under these assumptions, they find that the removal of the subsidy would have led to a 22 percent increase in consumer price, yielding a 6 percent decrease in corresponding demand. On the producer side, the price increase would generate a 5.5 percent increase in production and a related increase in income.
- **Climate**: Although wheat production has been steadily growing in Ethiopia over the past two decades (from about 1 million tonnes in 1997 to close to 5.5 million tonnes in 2020), limited (if any) access to irrigation exposes the wheat agrifood value chain to variations in weather conditions. According to FAO data for instance, wheat production decreased by about 10 percent in 2002 compared to 2001, 6 percent between 2007 and 2008, and 7 percent between 2009 and 2010. These variations in domestic food supplies are in part reflected in the rather erratic supply of food aid, oscillating between 0.2–0.5 (e.g. 1989, 1993, 1996, 1999, 2002, 2005, 2006, 2013) and between 0.6–1.4 (e.g. 1988, 1992, 1994, 2003, 2005, 2011) million tonnes. Findings from a recent study however suggests that despite its importance, the stream of food aid in the country, whether in-cash or in-kind, has negligible effects on food prices (Hoddinott *et al.,* 2018).
- **Conflicts**: The Federal Republic of Ethiopia is historically prone to tensions between its Regional States. For instance, since late 2020 and for two years, the northern state of Tigray (which has the highest per capita consumption of wheat) was isolated from the rest of the country. Bordered by Eritrea in the north (with which the region is in conflict) and without access to port, the Tigrayan agrifood systems has had to rely on its own systems for about two years (food aid was limited as international organization were seldom granted access to the region). In 2013, Tigray was host to a population of about 4.5 million, with a wheat production of about 205 000 tonnes for an overall consumption of close to twice as much. At the time, there were 27 large scale mills in the region. These figures can be used to assess the resilience of the Tigrayan-specific wheat agrifood value chain.

6.1.6 Parameters

We use the above descriptions to extract the key model parameters, which are summarized in Table 3 – along with some additional sources for some of them.

Table 3. Wheat value chain in Ethiopia, 2013: key parameters

Name	Parameter	Value	Remark	Source
Maximum consumer income/capita (ETB)		80 000	Maximum total expenditure	Ethiopian Statistics Service, 2023
Maximum disposable income/capita (ETB)	$\bar{R}$	30 000	Maximum food expenditure	Ethiopian Statistics Service, 2023
Aggregate demand (million tonnes)	Y	4.9		FAOSTAT, 2024
Number of consumers (million)	K	40		Calculated from Minot *et al.* (2019)
Number of farmers potentially selling wheat (million)	N	2		Calculated from Minot *et al.* (2019)
Production per farmer (kg)	Q	750		Calculated from Minot *et al.* (2019)
Overall marketable production (million tonnes)	Q	1.5		FAOSTAT, 2024
Fixed marketing cost	G			
Total number of intermediaries	$M+T$	682	All commercial flour mills	Minot *et al.*, 2019
Number of large intermediaries	M	5	Main flour factories	Ethiopian Statistics Service, 2023
International price (ETB per tonnes)	ω_0	6 700		Minot *et al.*, 2019
International price after subsidy (ETB per tonnes)	ω_0	4 500		Minot *et al.*, 2019
Consumer price (ETB/kg)	P	8.3	Consumer price in cities	FAOSTAT, 2024
Producer price (ETB per tonnes)	ω_1	6 800		Minot *et al.*, 2019
Share of producers who sale (%)	$1\text{-}\hat{e}$	65		Minot *et al.*, 2019
Domestic market supply (million tonnes)	$M.x_1$	0.975		Minot *et al.*, 2019
Imports total (million tonnes)		0.863		Minot *et al.*, 2019
Imports commercial (million tonnes)	$T.x_1$	0.663		Minot *et al.*, 2019
Imports food aid (million tonnes)		0.2		Minot *et al.*, 2019

Sources: Authors' own elaboration based on Ethiopian Statistical Service. 2023. *Ethiopian Statistical Service.* [Cited 27 May 2024]. https://www.statsethiopia.gov.et; FAO. 2024. *FAOSTAT*. [Accessed on 27 May 2024]. https://www.fao.org/faostat. Licence: CC-BY-4.0; Minot, N., Warner, J., Lemma, S., Kasa, L., Gashaw, A. & Rashid, S. 2019. The wheat supply chain in Ethiopia: Patterns, trends, and policy options. *Gates Open Res*, 3(174): 174.

6.2 Predictions and policy guidance

We use the above-described simulator to obtain a set of predictions for the Ethiopian Wheat AFVC in the year 2013. We focus here on three sets of outcomes considered directly relevant to food-security in the country. At farmer level, the producer price (ω1 in the analytical framework) and share or producers participating to the market (s) are the main components of farmers' income with respect to wheat. At consumer level, we focus on the market price of the final what-based product (p). The simulation results are based on the parameters values listed in Table 3, which gives orders of magnitude with respect to the minimum and maximum values proposed in this simulation. The model is calibrated to replicate the point values of the listed parameters.

For each of these indicators, the simulator produces a heat-map representing its level along a colour gradient, in response to midstream concentration on the horizontal axis (M), and diverse sources of shocks (international price variations (ω0), production variations such as those induced by climatic shocks (Nq), and potentially differential access to external markets in response to trade policies (import quotas, subsidies etc.) or conflicts. In Figure 4, the vertical axis measures the level of international prices, while in Figure 5 it is the overall local marketable production that is represented.[26] In both figures, the first graph features the related producer price level, while the share of farmers participating to the market is displayed in the second graph, and the consumer price in the last one. In all figures, green colours refer to lower values and red to higher ones, which does not always correlate with more desirable outcomes – for instance, a higher producer price (in red) is likely a more desirable situation than a lower (in green) one, while it is the opposite for consumers.

In the following paragraphs, we comment on these simulation outputs, and specifically discuss whether and how midstream concentration in the agrifood value chain affects the AFVC's response to variations in international prices and/or climatic conditions. We then discuss how these admittedly imprecise predictions can nevertheless contribute to inform policies.

6.2.1 Ethiopian wheat AFVC resilience to international price variations

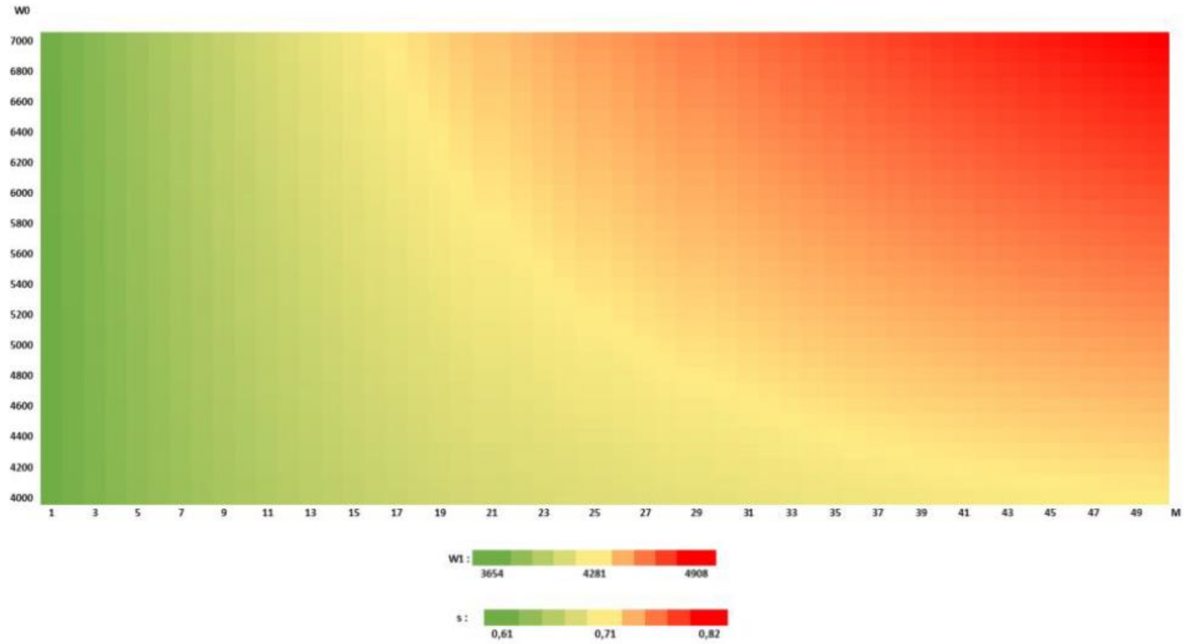
Figure 4 displays simulation outputs with respect to the Ethiopian wheat AFVC's resilience to variations in international prices. To illustrate the simulation, we choose fairly important variations in the world price (ETB 4 000–7 000 per tonnes). We vary the number of influential intermediaries from M = 1 to M = 50 – note that the number of non-influential intermediaries (who do not have access to the international market and who face somewhat higher sourcing costs (or higher inefficiencies) on the local market) is normalized and fixed to 100.

Because producers' participation is linearly related to producer price, the first two graphs of Figure 4 are similar, such that only report the corresponding legends for ω_1 and s, respectively. In the upper graph, higher (red) values of producer prices and market participation can be considered positive outcomes with respect to food security, while in the lower graph, lower (green) values correspond to lower consumer price and can thus be considered positive from the standpoint of food security. From that perspective, one can clearly see that the right part of each graph corresponds to more desirable outcomes, which also corresponds to less concentrated midstream segments – i.e. a greater number of efficient (large) intermediaries.

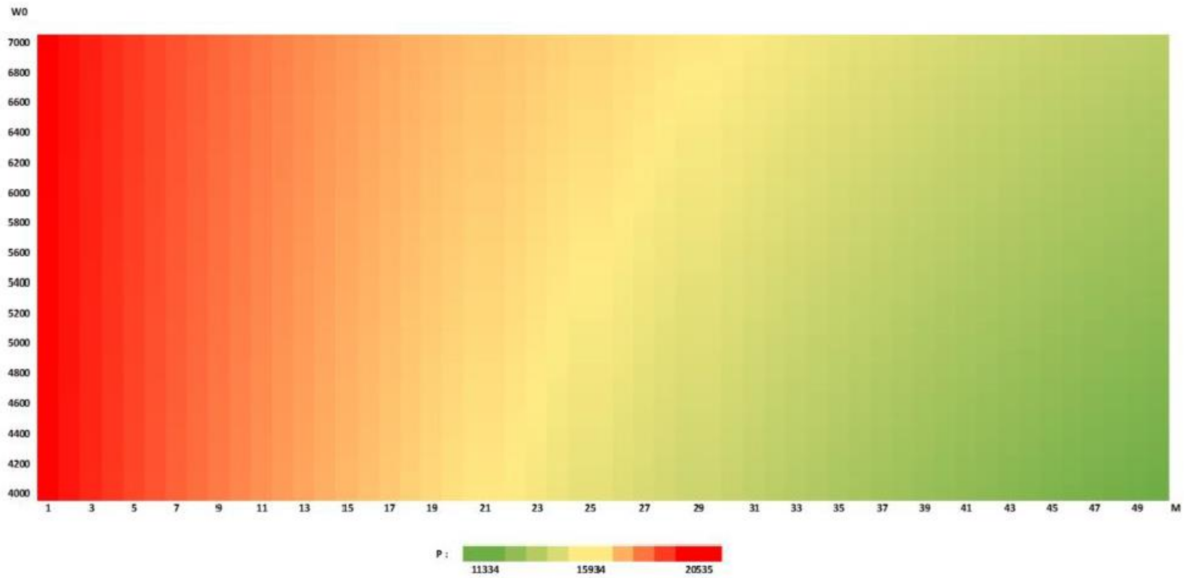
[26] Further simulations can however be generated, some of which are proposed in Annex 1.

Figure 4. Ethiopian wheat agrifood value chains' response to international price variations under varying concentration of midstream intermediaries

a. Producer price and participation in market



b. Consumer price



Source: Authors' own elaboration.

These differences can be large. Taking a mid-level international price of ETB 5 000 per tonnes and moving horizontally from left to right, one finds that:

- Producer price goes from about ETB 3 800 per tonnes if the number of large intermediaries is limited to only a handful, while they reach about ETB 4 600 per tonnes (i.e. 20 percent higher) when the midstream segment features 30 intermediaries or more.

- The share of market-oriented farmers who sell their wheat on the market moves from about 60 percent if the midstream segment of the agrifood value chain is concentrated, to about 80 percent when it is not (i.e. a 33 percent increase in overall commercialization).
- At consumer-level the price of wheat-based product reduces by about half when moving from a more concentrated midstream segments to a less concentrated one.

Thus, from a food-security perspective, a more competitive midstream segment of the wheat agrifood value chain seems to correspond to better outcomes in the face of varying international prices. These effects are not linear however, and their extent varies significantly with the level of international price. This issue is important if one considers the type of variations in international prices that have occurred in the past 15 years, when rapid increases/decreases of over 50 percent are now more frequent. Looking at the graphs in Figure 4 from a vertical angle, one finds that when the agrifood value chain is characterized by a small number of intermediaries, prices and market participation remain fairly stable despite large increases in international prices. The opposite is not true however, when the agrifood value chain features a larger number of intermediaries.

Overall, Figure 4 offers a mixed picture on the vulnerability of the wheat agrifood value chain with respect to international prices levels and variations. One the hand, more competitive midstream segments ensure that higher international prices are better transmitted to local producers. On the other hand, it also translates into transmission of the instability of international prices, which may discourage future-oriented farm investments – even if the stable prices obtained from the situation with a concentrated midstream segments remain consistently below that offered from the more competitive situation.

As a last observation, the simulations show that small differences in midstream segment concentration in the Ethiopia wheat agrifood value chain rapidly bears important consequences in terms of price levels and transmission. In these two graphs, moving from five important intermediaries to fifteen already generates significant differences in the considered dimensions.

6.2.2 Ethiopian wheat agrifood value chains resilience to adverse climatic conditions

Figure 5 reports the same set of food-security outcomes (producer price, market participation, and consumer price), this time as a function of the level of wheat production in the country on the vertical axis and midstream segment concentration on the horizontal one. An overall reading of the three graphs combined is not as straightforward as in Figure 4 as there is no clear indication that a more competitive midstream segment of the agrifood value chain leads to more desirable outcomes at both producer and consumer-levels.

In the upper graph, the effect of quantity variations (vertical axis) clearly dominates that of different levels of market concentration: starting from an intermediary level of marketable surplus of 1.5 million tonnes, one sees that corresponding prices are fairly similar across the horizontal axis measuring the number of large-scale intermediaries. In return, one can assess the effect of a large negative production shock where production would decrease by half, as would occur in a severe drought for instance. The effect on local producer price is a close to ten fold increase, here again, irrespective of the number of large intermediaries. Thus, while small variations do exist (the price variations induced by changes in the level of local production are higher when the number of large intermediaries is smaller), these are limited compared to the overall price variations generated by the production shock itself.

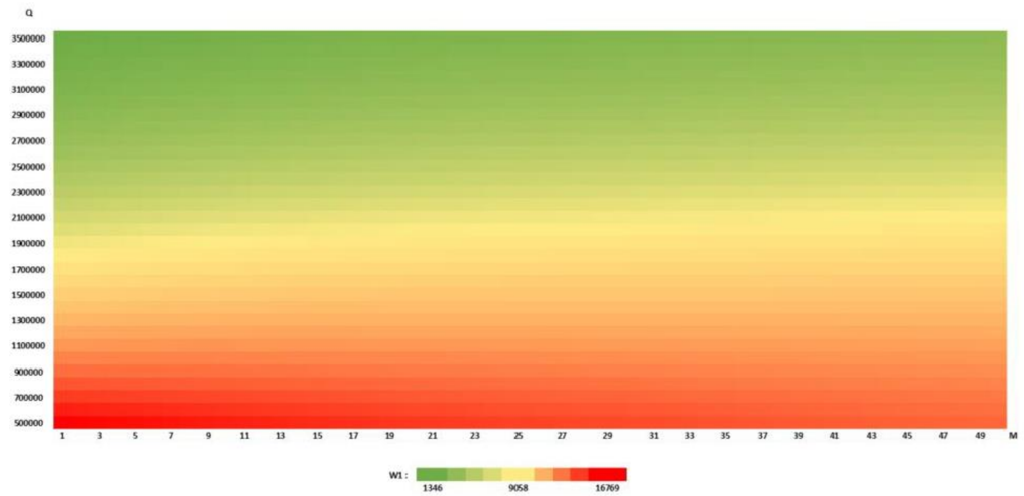
The middle graph reports the share of market-oriented producers effectively selling their produce on the market under different production levels. Accordingly, the higher is the domestic production, the lower is the market participation of farmers, induced by the corresponding lower producer price shown in the upper graph. Conversely higher participation is obtained when overall production is lower and producer prices are therefore higher.

Note however that this effect is non-linear as smaller production levels yield an increased exclusion of producers from the market. This effect is driven by the presence of fixed cost in commercialization at farmer-level. If production is too low and even if prices are high, some producers (the least efficient or smaller ones) will no longer find it worthwhile to sell their product on the market. This fixed cost can alternatively be interpreted as fixed needs for home-consumption such that, when production is low, fewer farmers have marketable surplus at their disposal.

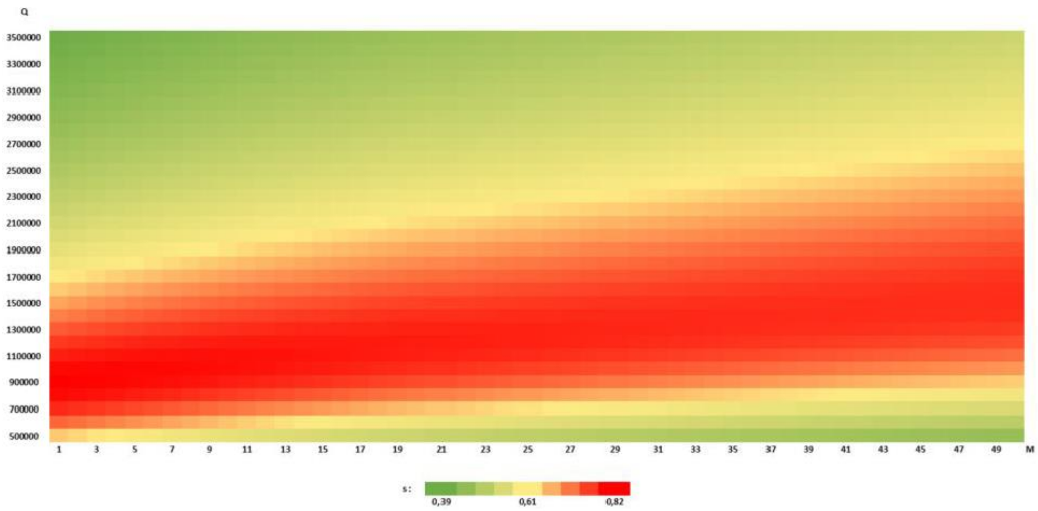
This point deserves further discussion as it challenges standard assumptions regarding the effect of domestic climatic shocks on local producers' well-being under different levels of market concentration. First, for a given level of market concentration, it may be incorrect to assume that a negative production shock systematically reduces the participation of local producers to the market. Consider for instance an agrifood value chain characterized by 25 larger intermediaries. In this graph – based on a moderate international price of ETB 5 500 per tonnes – market participation decreases for higher levels of production. Starting from a local production of 1.5 million tonnes, and increasing it by 50 percent to 2.25 million tonnes, one sees a decreased participation, moving from the red to the green zone. This is explained by the fact that increased local production reduces local producer prices such that, the increase in quantity does not compensate the loss in per-unit value. For the less efficient producers, this translates in an inability to cover the fixed commercialization costs and thus reduces their market participation. The same is true on the lower part of the figure. Starting from a production of 1.5 million tonnes and this time decreasing it by 50 percent to 0.75 million tonnes, one moves again from a high (red) market participation to a lower (green) one.

Figure 5. Ethiopian wheat agrifood value chains' response to local production variations under varying concentration of midstream intermediaries

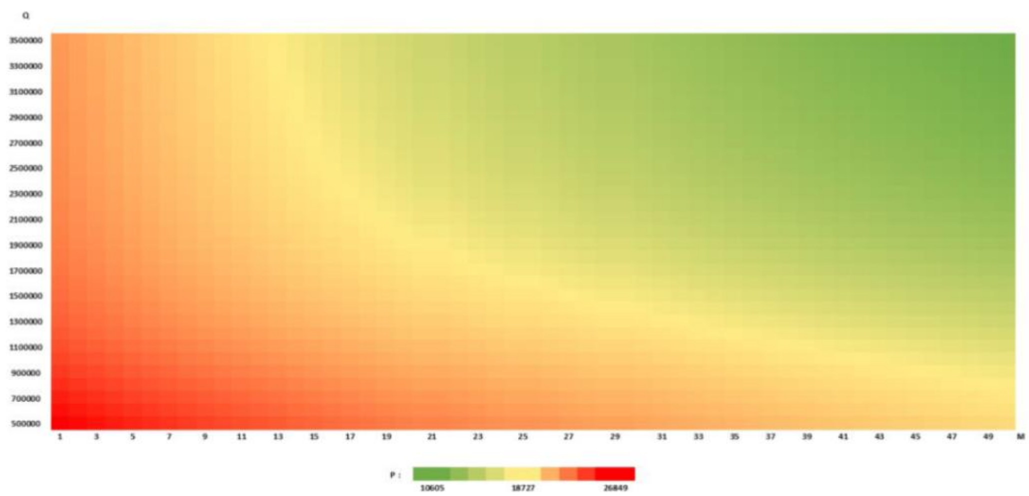
a. Producer price



b. Producer participation in market



c. Consumer price



Source: Authors' own elaboration.

The bottom graph yields a somewhat different perspective for food security. Accordingly, variations along the horizontal axis (concentration of intermediaries) tend to dominate that of the vertical one (production level). For an intermediary level of production (1.5 million tonnes), consumer prices are twice as large if the number of large intermediaries is small as compared to a situation where they are more numerous. These level differences hold if one varies the production level. There is no clear indication that different levels of midstream concentration yield more or less variability of consumer price in response to local production shocks.

Overall, analyzing the resilience of the Ethiopian wheat agrifood value chain to production shocks yields a nuanced response with respect to the concentration of midstream intermediaries. On the one hand, more competitive markets are associated with lower consumer prices. However, on the other hand, domestic producers' well-being can, in not too severe adverse situations, benefit from the reduction in local production irrespective of midstream concentration. For more severe shocks, however, producers' well-being is higher under highly concentrated midstream segments of the agrifood value chain.

6.2.3 Ethiopian wheat agrifood value chains resilience to changes in access to external markets

In Figure 6, we report a last set of simulation outputs, this time focusing on access to external markets. Market integration can significantly contribute to the resilience of agrifood value chain, in that it allows deficit areas to source product from those areas with excess supply. One simplified way to assess domestic reaction to higher/lower levels of market integration can be drawn from Figure 4, by simply varying the level of external prices and assessing how local prices vary as a response – and in doing this, understand how midstream concentration affects this relation. As a complement, one may wish to assess how quantity constraints on access to external markets affect the local agrifood value chain.

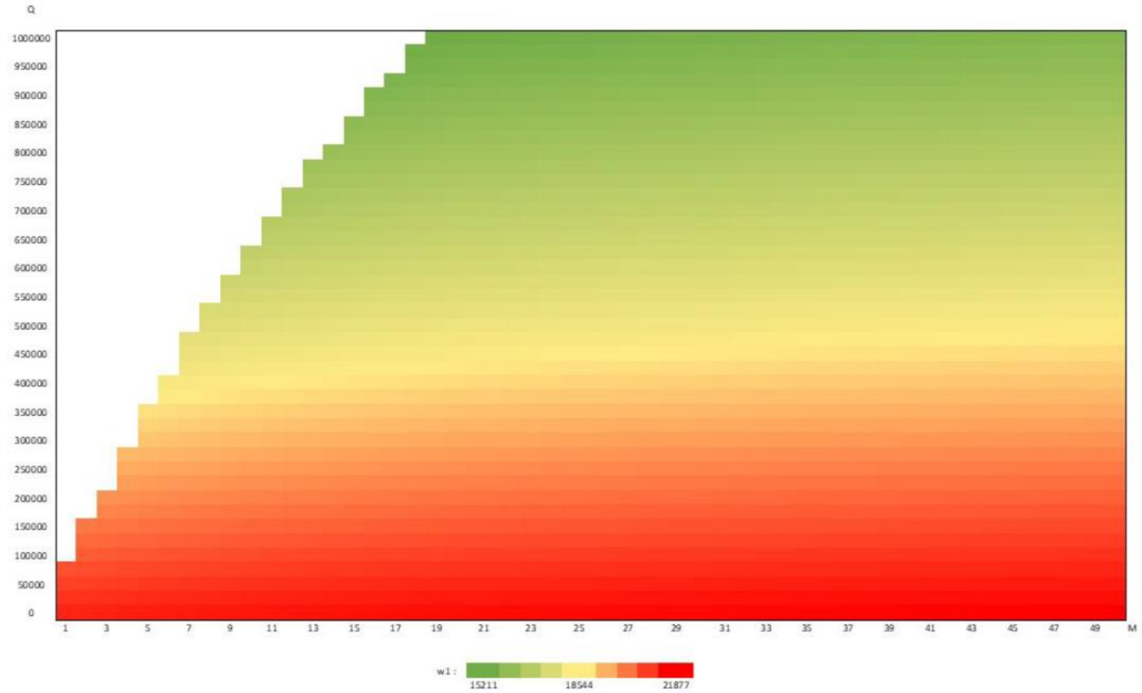
Limited access to external markets is sometimes the result of deliberate policies seeking to protect local producers from external competition. These policies may also result from monetary constraints. In many low-income countries, foreign exchange reserves are low, constraining the sourcing of products from international markets labelled in US dollars, for instance. Last, access to external sources of products may also result from isolation generated by political conflicts. For example, in Ethiopia, the entire regional state of Tigray was almost entirely isolated for two years. An analysis of the Tigray wheat agrifood value chain during this period would thus correspond to a situation where no imports are possible.

The two graphs in Figure 6 present the evolution of producer and consumer prices under varying levels of physical access to the international market (the share of producers participating in markets is not reported here as it generates qualitatively similar results). The northwest parts of the graphs are left empty as they correspond to situations where the import quota is not binding: intermediaries would not want to import more than the enforced quota. In both figures, prices are at their highest for low levels of import quotas (bottom part of the graph), and decrease as the level of allowed imports increase. Thus, and in line with standard theory, import quotas, when binding, positively affect producers' income while negatively affecting consumers' purchasing power.

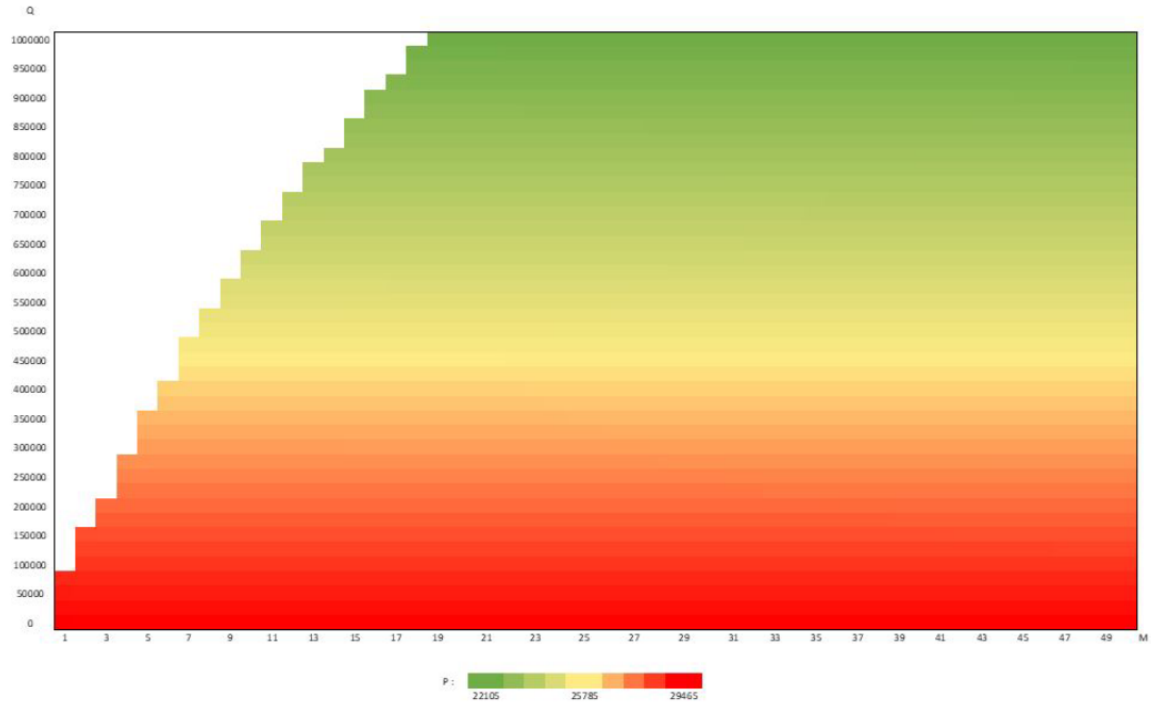
In both figures, one finds only little variations along the horizontal dimension: quotas affect the Ethiopian wheat agrifood value chain fairly similarly, whether the number of large intermediaries is small or large. Further simulations may, however, complement these analyses.

Figure 6. Ethiopian wheat agrifood value chains' response to changes in access to external markets under varying concentration of midstream intermediaries

a. Producer price



b. Consumer price



Source: Authors' own elaboration.

Limited access to external markets is sometimes the result of deliberate policies, seeking to protect local producers from external competition. These policies may also result from monetary constraints: in many low-income countries, foreign exchange reserves are low, constraining the sourcing of product from international markets labelled in USD for instance. Last, access to external sources of product may also result from isolation generated by political conflicts. In Ethiopia, the entire regional state of Tigray was almost entirely isolated for two years. An analysis of the Tigray wheat agrifood value chain during this period would thus correspond to a situation where no imports are possible.

The two graphs in Figure 6 present the evolution of producer and consumer prices under varying level of physical access to the international market (the share of producers participating to markets is not reported here as it generates qualitatively similar results). The north-west parts of the graphs are left empty as they correspond to situations where the import quota is not binding: intermediaries would not want to import more than the enforced quota. In both figures prices are at their highest for low levels of import quotas (bottom part of the graph), and decrease as the level of allowed imports increase. Thus, and in line with standard theory, import quotas, when they are binding, positively affect producers' income while they negatively affect consumers' purchasing power.

On both figures, one finds only little variations along the horizontal dimension: quotas affect the Ethiopian wheat agrifood value chain in a fairly similar way, whether the number of large intermediaries is small or large. Further simulations may however complement these analyses.

6.2.4 Relevance for policies

From Figures 4, 5 and 6, one obtains a broad picture on the role played by midstream segment concentration on the resilience of the Ethiopian wheat agrifood value chain in 2013. At the time, the most concentrated segment of the agrifood value chain was that of flour factories, within which only a handful of large actors operated along with hundreds of micro-units. This in-itself translated in low producer and consumer price response to international variations, although at a costs of lower producer income and lower consumer purchasing power. This limited number of large intermediaries did not however protect the agrifood value chain from climatic shocks affecting local production. If anything, producers' income were less exposed to production shocks under the concentrated midstream segment situation that characterized the agrifood value chain at the time. Last, one sees that a sharp reduction in access to external markets would have affected the agrifood value chain in similar ways, irrespective of the concentration level in the midstream segment of the agrifood value chain.

Together these results may contribute to inform *ex ante* policies. In an overly simplified way, one may for instance face two policy choices:

i. One that seeks to strengthen large intermediaries, as their leading position jeopardizes the functioning of the agrifood value chain if they were to stop their operations – in a way similar to the set of policies supporting actors that are "too big to fail" in other economic sectors.

ii. One that seeks to promote the entry or emergence of other large intermediaries as a means to render the midstream segment more competitive. Over the recent years

Ethiopia, the number of large-scale flour factories has for instance increased more than tenfold.

Further analyses may however be needed to better inform these and other policy options. The proposed simulator can for instance be used to assess how an import quota affects the agrifood value chain at time of a climatic shock and given the midstream concentration of the agrifood value chain. One may also wish to investigate how policies affecting consumer prices translate to producer prices given midstream concentration. These are only two of several examples that one may seek to investigate, using the simple simulation tool proposed here.

7 Discussion

As part of a broad reflection on the resilience of agrifood value chains in low-income and fragile countries, this paper investigates the role of market structure in the translation of external stressors and shocks to a set of key local food-security outcomes. Its aim is to propose a new avenue for research and analyses than can enter the existing analytical toolbox and contribute to inform policy decisions seeking to enhance the resilience of agrifood value chain.

Specifically, it proposes a simplified analytical framework, whose theoretical foundations associate perfect and imperfect competition along a supply chain and shows how concentration of midstream segments of the agrifood value chain yields differential reactions to climatic shocks, variations in (external) international prices or access to (external) international supply. This analysis is motivated by the general observation that while midstream segments of agrifood value chain can feature a large number of intermediaries and guarantee some level of economic activity, it is often the case that the situation is dominated by a limited number of larger (and possibly) more efficient ones. The proposed analytical framework shows how the size and number of these larger actors can affect the transmission of external shocks to the equilibrium prices and quantity responses at different levels of the agrifood value chain, from producers upstream to consumers downstream. The framework also accounts for midstream actors' capacities to source product from both local producers as well as from external sources (such as international markets if the considered agrifood value chain is defined at the national level). Accordingly, large intermediaries can optimize the amount of product that they source on the external market (on which they have no price influence), and on the local one (which they are more capable of influencing through their operations).

The analytical framework can yield a large set of predictions, many of which are not easily described analytically. For policy purpose, one may be interested in the combined or separate effects of various shocks, under various levels of market structure. As a first step, this White Paper develops a numerical solver and simulation tool, from which one can visualize a large number of simulation outcomes. Using an exceptionally large and precise set of information on the Ethiopian wheat agrifood value chain in 2013, the paper illustrates the kind of predictions and related visual representation that can be obtained from such tool.

Yet, precise information on midstream segments of agrifood value chain is seldom available, and the proposed analytical framework of limited use unless it can be informed by locally-relevant value for their key parameters. This paper further investigates this issue and proposes a dedicated data-collection tool, which can accommodate various sources of information. Importantly, parametrizing the analytical framework does not require large and often complex data collection efforts: all necessary information can be sourced from field officers and local experts, possibly triangulated with survey-based measures or official sources when they are available. Here also, the automated data collection tool is Microsoft Excel-based facilitating its use in most contexts.

The analytical framework and related simulation and data collection tools presented here are only illustrative of a direction for further research and analyses. As such, it is largely incomplete and further extensions would be necessary to generate a fuller set of policy-relevant information and simulations. A possible list of extension includes the following.

At farmer-level, the current framework only accounts for their decisions to participate or not to the market. It essentially assumes that this decision is driven by farmers' possibility of making post-production profit from selling their produce, given a fixed cost in commercialization and the market price that they face. These assumptions could be reviewed in the context of a model integrating input purchases (made ahead of production) in order to better discuss supply capacity in raw materials that would not depend solely on weather conditions.

At midstream segments, another extension of the analytical framework could account for a greater number of levels of transformation and distribution in the vertical dimension of the agrifood value chain. These different levels may indeed have a non-passive role in the transmission of prices (one could for instance consider "double marginalization" effects that would have harmful consequences on food security) but also have a role in "bypassing" the spot market through privileged contractual relations between upstream and downstream markets. The simple model proposed here lends itself fairly well to this kind of generalization, at cost of only minor complexification.

At consumer-level, further work should account for consumer reaction to changes in prices, accounting for the local availability of food substitutes. In turn, a broader framework would account for the effect of supply shocks in the AFVCs catering these substitute products, onto the agrifood value chain under consideration. The analysis could also account for issues of quality differentiation. Food-safety issues such as presence of Aflatoxins, or other non-directly observable quality attributes (such as protein content, moisture levels, or flour extraction rates) all affect choices and relationships between actors in agrifood value chain. All these aspects, which in our opinion cannot be credibly studied by a purely generic approach, could nevertheless be integrated into the proposed analytical framework (and into the numerical simulator) for more sector-specific studies.

In terms of usefulness for policy guidance, this approach can also be expanded in several dimensions. First, the set of predicted outcomes may be expanded to better reflect important dimensions of food-security related to the functioning of agrifood value chain. One such important outcome may for instance be related to labour market outcomes, accounting for the labour implication of shocks affecting midstream segments of agrifood value chain. Second, the analytical framework can be expanded to more clearly reflect policy options and simulated outcomes. As discussed in this paper, some policies can easily be incorporated through changes in values of the corresponding parameter. Others would however need further developments. In particular, the current analytical framework does not account for the type of price regulation that can be obtained from policies at various levels of agrifood value chain (ex. price floor/ceiling at producers/consumers levels), or the use of public food reserves.

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Annex 1. Detailed analytical framework

This annex describes in detail the analytical framework presented in the main text. We start by describing the agents present in this simplified agrifood value chain: local producers, intermediaries and consumers. Then solve the model accounting for the simultaneous existence of two types of intermediaries: larger and more efficient ones who can source from both local and external markets; smaller and less efficient ones who can only source product on the local market. In a last part, we allow for policy interventions which restrict efficient intermediaries' access to the external market.

Building blocks

Local producers

Consider that there are N farmers, indexed as $i = 1, ..., N$, each producing a quantity of product $q \geq 0$ potentially available for sale on local market. Let $Q = Nq$ measure the aggregate potential supply on the local market. N is large such that farmers are price takers in their output sales, although farmers are heterogeneous in their efficiency along a parameter $e \in [0,1]$. In order to sell her product, farmer i must account for a fixed costs $G(e)$ given by:

$$G(e) = G - \alpha e, \ (0 \leq \alpha \leq 1) \tag{1}$$

Thus, a farmer with efficiency level $e \in [0,1]$ will engage in the commercialization of output q if and only if:

$$\omega_1 . q \geq G - \alpha e \Leftrightarrow e > \hat{e} = \frac{G - \omega_1 q}{\alpha} \tag{2}$$

Accordingly, if $\hat{e} \leq 0$ (ω_1 is large), all farmers will participate in the market. If $\hat{e} = 1$ (ω_1 is low), none of the local production will be sold on the market. The intermediary case of partial market participation ($\hat{e} \in]0,1[$) is obtained at the following condition C:

$$G - \alpha > \omega_1 q < G \qquad \text{(Condition C)}$$

Assuming that condition C is always satisfied, let s measure market participation rate of farmers, with:

$$s = \frac{1}{\alpha}[\omega_1 q - (G - \alpha)] \tag{3}$$

Under these conditions, overall market supply of local production is given by:

$$S = Q(1 - \hat{e}) = \frac{Nq}{\alpha}[\omega_1 q - (G - \alpha)] \tag{4}$$

Intermediaries

Consider that there are two groups of intermediaries purchasing products from farmers on the local product market and transforming it into final consumer product at rate $\lambda \geq 0$ (a quantity x of raw product yields a quantity λx of final product).

Group 1: Efficient intermediaries. There are M efficient intermediaries in the value chain, indexed as $j = 1, ..., M$, who can source product from both local(domestic) and external(international) markets. On the external market, price is set at ω_1 and Intermediaries incur a specific quadratic cost when sourcing product from it:

$$c_0\left(x_0^j\right) = c_0 \cdot \left[x_0^j\right]^2 \quad (5)$$

where x_0^j is the quantity purchased on the external market by intermediary j. Similarly, when sourcing a quantity x_0 of product from the local market at price ω_1, intermediary j incurs costs $c_1\left(x_1^j\right)$:

$$c_1\left(x_1^j\right) = c_1 \cdot \left[x_1^j\right]^2, j = 1, \ldots, M \quad (6)$$

Calibration note: Cost parameters c_0 and c_1 are sourcing costs (as opposed to commercialization costs). Their actual value must be adapted to the agrifood value chain that is being studied; they may be identical or different.

Group 2: Inefficient intermediaries. There are T "small intermediaries", in that the size of their operation does not permit them to have any effect on prices in the local market. There are typically more intermediaries in this group than in the previous one ($T > M$), oftentimes by a large margin ($T \gg M$).

Intermediaries in this group do not have access to the external market, and thus source all their raw product from the local one. Accounting for some level of economies of scale in the sourcing operations, we assume that these intermediaries face higher per-unit costs in the corresponding operations:

$$c_2\left(x_1^j\right) = c_2 \cdot \left[x_1^j\right]^2, j = M + 1, \ldots, M + T, (T \gg M) \quad (7)$$

Consumers

We consider a population of K consumers, heterogeneous with respect to their disposable income R for the purchase of the food item generated by the AFVC of interest. We assume that R is uniformly distributed over the interval $\left[\underline{R}, \bar{R}\right]$, and the utility a consumer derives from the purchase of one unit of final product is given by the corresponding surplus $U = R - p$, where p is the unit price. A consumer thus purchases the product if the corresponding utility is positive ($p \leq R$). Aggregate demand Y on the final market is then defined as:

$$Y = \begin{cases} K if p \leq \underline{R} \\ K \cdot \dfrac{(\bar{R} - p)}{(\bar{R} - \underline{R})} if \underline{R} \leq p \leq \bar{R} \\ 0 if p \geq \bar{R} \end{cases} \quad (8)$$

In the intermediary case where demand is positive though not all consumers decide to purchase products from the market, one obtains an inverse demand function which is defined in its linear form as:

$$p(Y) = a - b \cdot Y (a \geq 0, b \geq 0) \quad (9)$$

with $a = \bar{R}$ and $b = \frac{\bar{R} - \underline{R}}{K}$.

Calibration note: Estimations of parameters a and b can be facilitated by obtaining values of the maximal disposable income for the product under study ($\bar{R}$), along with measures the price-elasticity of consumption ζ for a given level Y_0 of consumption ($b = \frac{a}{Y_0(1+\zeta)}$).

Solving the model

Profits of intermediaries

We note $\Pi_1^{j_0}\left(x_0^{j_0}, x_1^{j_0}\right)$ the profit of an efficient (larger) intermediary ($j_0 = 1, \dots, M$) who sources a quantity $x_0^{j_0}$ on the external market at price ω_0, and a quantity $x_1^{j_0}$ on the local one at price ω_1, and transforms the obtained quantity ($x_0^{j_0} + x_1^{j_0}$) into final product ($\lambda\left(x_0^{j_0} + x_1^{j_0}\right)$). Profit is thus given as:

$$\Pi_1^j\left(x_0^{j_0}, x_1^{j_0}\right) = \lambda\left(x_0^{j_0} + x_1^{j_0}\right)\left[a - \lambda b \sum_{j=1}^{M} x_0^j - \lambda b \sum_{j=1}^{M+T} x_1^j\right] - \omega_0 x_0^{j_0} - c_0\left[x_0^{j_0}\right]^2 - \omega_1 x_1^{j_0} - c_1\left[x_1^{j_0}\right]^2 \quad (10)$$

The same way, we note $\Pi_2^{j_0}\left(x_1^{j_0}\right)$ the profit of an inefficient intermediary ($j_0 = M+1, \dots, T$) who sources a quantity $x_1^{j_0}$ on the local market at price ω_1, and transforms the obtained quantity into final product ($\lambda\left(x_1^{j_0}\right)$).

$$\Pi_2^{j_0}\left(x_1^{j_0}\right) = \lambda\left(x_1^{j_0}\right)\left[a - \lambda b \sum_{j=1}^{M} x_0^j - \lambda b \sum_{j=1}^{M+T} x_1^j\right] - \omega_1 x_1^{j_0} - c_1\left[x_1^{j_0}\right]^2 \quad (11)$$

We thus define the strategies adopted by the intermediaries by the quantities purchased from both external and local markets for the (larger) efficient ones, and on the local market only for the (smaller) inefficient ones. This strategic choice is informed by their anticipations on both prices and sourcing costs on these markets, along with the final price on consumer market.

Nash equilibrium between intermediaries

The existence of a unique Nash Equilibrium is guaranteed by the concavity of the profit functions described in Equations (10) and (11). To simplify the analysis, we only consider situations where optimal quantities are always positive (which is also more realistic). These situations therefore correspond to the first order condition of profit maximization:

$$\frac{\partial \Pi_1^{j_0}}{\partial x_0^{j_0}} = \frac{\partial \Pi_1^{j_0}}{\partial x_1^{j_0}} = \frac{\partial \Pi_2^{j_0}}{\partial x_1^{j_0}} = 0 \quad (12)$$

One then verifies that:

$$\begin{cases} \dfrac{\partial \Pi_1^{j_0}}{\partial x_0^{j_0}} = \lambda a - \omega_0 - \lambda^2 b \left[\sum_{j=1}^{M} x_0^j + \sum_{j=1}^{M+T} x_1^j + \left(x_0^{j_0} + x_1^{j_0} \right) \right] - 2c_0 x_0^{j_0} \\ for\ j_0 = 1, \dots, M \\ \dfrac{\partial \Pi_1^{j_0}}{\partial x_1^{j_0}} = \lambda a - \omega_1 - \lambda^2 b \left[\sum_{j=1}^{M} x_0^j + \sum_{j=1}^{M+T} x_1^j + \left(x_0^{j_0} + x_1^{j_0} \right) \right] - 2c_1 x_1^{j_0} \\ for\ j_0 = 1, \dots, M \\ \dfrac{\partial \Pi_2^{j_0}}{\partial x_1^{j_0}} = \lambda a - \omega_1 - \lambda^2 b \left[\sum_{j=1}^{M} x_0^j + \sum_{j=1}^{M+T} x_1^j + x_1^{j_0} \right] - 2c_2 x_1^{j_0} \\ for\ j_0 = M+1, \dots, M+T \end{cases} \quad (13)$$

The equation system [partial_derivatives] must then account for the supply-demand equilibrium on the local producer market:

$$\sum_{j=1}^{M+T} x_1^j = \frac{Nq}{\alpha} [\omega_1 q - (G - \alpha)] \quad (14)$$

which enables the calculation of producer price on the local market:

$$\omega_1 = \frac{\alpha}{Nq^2} \sum_{j=1}^{M+T} x_1^j + \frac{G - \alpha}{q} \quad (15)$$

Given the symmetry of the model (all efficient intermediaries are identical, and likewise for the non-efficient ones), it is possible to only consider the three equilibrium levels of the strategic variables:

$$\begin{cases} x_0^j = U, j = 1, \dots, M \\ x_1^j = V, j = 1, \dots, M \\ x_1^j = W, j = M+1, \dots, M+T \end{cases} \quad (16)$$

As such, variables U, V and W respectively represent the equilibrium level of product sourced from the external market for an efficient producer, the equilibrium level of local sourcing for an efficient producer, and the equilibrium level of local sourcing for an inefficient producer.

Solution

Using equations 12, 13, 14 and 15, one obtains the following four equations system with four unknowns U, V, W and ω_1:

$$
\begin{cases}
a_4 U + a_3 V + a_2 W = \lambda a - \omega_0 \\
a_3 U + a_5 V + a_2 W + \omega_1 = \lambda a \\
a_1 U + a_1 V + a_6 W + \omega_1 = \lambda a \\
a_1 U + a_2 V + a_7 \omega_1 = \dfrac{-\lambda^2 bNq(G-\alpha)}{\alpha}
\end{cases}
\tag{17}
$$

Using the parameters:

$$
\begin{array}{llll}
a_1 & = \lambda^2 bM & a_5 & = \lambda^2 b(M+1) + 2c_1 \\
a_2 & = \lambda^2 bT & a_6 & = \lambda^2 b(T+1) + 2c_2 \\
a_3 & = \lambda^2 b(M+1) & a_7 & = \dfrac{\lambda^2 bNq^2}{\alpha} \\
a_4 & = \lambda^2 b(M+1) + 2c_0 & &
\end{array}
\tag{18}
$$

Numerical solution to the system (17) needs to check that Condition C is verified and that the obtained parameters U, V, W and ω_1 are all positive. Accordingly, one may assess the extent of the studied AFVC's capacity to contribute to food-security. Three food-security related indicators may be tracked in particular:

- ω_1: local producer price, which can be compared to the external (international) one ω_0.
- s: participation of producers to the market, with $s = \frac{1}{\alpha}[\omega_1 q - (G - \alpha)] \in [0,1]$. The closer to 1 is s, the lower is the exclusion of local producers from the market.
- p: consumer price, with $p = a - \lambda b(M.U + M.V + T.W)$ which directly depends on consumers' participation to the market.

Levels of ω_1, s and p directly relate to food security in that they determine producers' income as well as consumers access to the considered food item. They may in turn be analysed in the way they respond to various sources of shocks and stressors affecting production (e.g. adverse climatic event), prices (e.g. surge in external prices), or the capacity to source product from the external market (e.g. conflict isolating a country or a sub-national region within).

Model with constraints on the external market

The non-cooperative equilibrium described above may lead to equilibrium outcomes ω_1, s and p that are considered unsatisfactory from a social welfare perspective. In such situation, a national government may leverage its trade policy to control imports. Such situation may also arise when a government is constrained in its import capacities due to limited foreign exchange reserves.[27]

Suppose for instance that the overall amount of product that is sourced from the external market cannot exceed an exogenous level I, uniformly shared across efficient intermediaries. Each intermediary j, ($j = 1, \ldots, M$) can at most source $\bar{x_0} = \frac{I}{M}$ from the external market.

[27] This may also be true for sub-national AFVC where a government regulates the flow of product across regions. Where a conflict arises and a given region becomes isolated, the region's capacity to source product from the external market may likewise be severely constrained.

In the case where the Nash Equilibrium described above yields a per-intermediary import level $U < \bar{x_0}$, the obtained equilibrium remains valid. In the opposite case, one may proceed by fixing the import level at its maximum ($U = \bar{x_0}$) and calculate the resulting constrained equilibrium with respect to the amount sourced by efficient intermediaries on the local market, x_1^j.[28]

Adapting the system of equations [profits], this time fixing $x_0^j = \bar{x_0}, (j = 1, \dots, M)$, yields:

$$\begin{cases} \dfrac{\partial \Pi_1^{j_0}}{\partial x_1^{j_0}} = \lambda a - \omega_1 - \lambda^2 b \left[M.\bar{x_0} + \sum_{j=1}^{M+T} x_1^j + \left(\bar{x_0} + x_1^{j_0} \right) \right] - 2c_1 x_1^{j_0} \\ for\ j_0 = 1, \dots, M \\ \dfrac{\partial \Pi_2^{j_0}}{\partial x_1^{j_0}} = \lambda a - \omega_1 - \lambda^2 b \left[M.\bar{x_0} + \sum_{j=1}^{M+T} x_1^j + x_1^{j_0} \right] - 2c_2 x_1^{j_0} \\ for\ j_0 = M+1, \dots, M+T \end{cases} \quad (19)$$

Combined with equation (15), one obtains the new system whose solution yields: the new equilibrium quantities $x_1^{j_0} \equiv V', (j_0 = 1, \dots, M)$ and $x_1^{j_0} \equiv W', (j_0 = M+1, \dots, T)$, with $x_0^{j_0} = \bar{x_0} = \frac{I}{M}, (j_0 = 1, \dots, M)$; and the new equilibrium local producer price ω'_1:

$$\begin{cases} a_5 V' + a_2 W' + \omega'_1 = \lambda[a - \lambda b \bar{x_0}(M+1)] \\ a_1 V' + a_6 W' + \omega'_1 = \lambda[a - bM\bar{x_0}] \\ a_1 V' + a_2 W' - a_7 \omega'_1 = \dfrac{-\lambda^2 bNq(G-\alpha)}{\alpha} \end{cases} \quad (20)$$

Parameters values $a_1 - a_7$ are obtained from parameter list (18). Condition C must again be verified along with the positive values for $\bar{x_0}, V', W'$ and ω'_1.

As a final note, this conceptual framework allows for the study of other policy interventions. For instance, a policy intervention seeking to increase consumers' income (or more directly, subsidize consumers' purchase of the product under study) can be introduced through a substantial decrease in parameter b of the model.

[28] We assume here that the resulting equilibrium is indeed binding at the level of the import constraint. While reasonable in real life terms, it supposes that there are no corresponding domains of validity.

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