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Rwanda's Agrifood System

Structure and drivers of transformation

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CONTENTS

ABSTRACT

This paper assesses the structure of Rwanda's current and evolving agrifood system and its contribution to national development. The paper reiterates the point that Rwanda's agrifood system stretches well beyond primary agriculture and creates jobs and income opportunities throughout the economy. While off-farm components of Rwanda's agrifood system have generally grown more rapidly than primary agriculture in recent years, growth varies across value chains of the agrifood system in the studied period. The growth diagnostic in this paper reveals that it is domestic markets that have driven the recent growth in Rwanda's AFS other than exports.

The paper's forward-looking analysis assesses potentially differential impacts of value-chain development efforts on broad development outcomes. The analysis measures the synergies and trade-offs of value-chain development in the context of an inclusive agricultural transformation. Such analysis is conducted using the Rwanda Computable General Equilibrium (CGE) model – an adaption of IFPRI's Rural Investment and Policy Analysis (RIAPA) model to the Rwandan context.

The modeling results indicate that value chains differ considerably in their effectiveness in achieving development goals and there are significant trade-offs among different development goals from promoting a specific value chain. The value chains that make a larger contribution to growth or job creation are not necessarily effective in reducing poverty or improving dietary quality – for example, value chains for coffee and tea – while value chains that play an important role in improving dietary quality may contribute less to job creation – such as vegetables or fruits. While there is no single value chain that can achieve all development goals effectively, it is possible to select a diversified set of value chains that complement each other in achieving different development goals. This latter strategy is a more realistic approach to growth and development.

INTRODUCTION

Rwanda has made remarkable economic progress during the past two decades, highlighted by rapid economic growth and poverty reduction. During this period, the country has emerged as a leader among sub-Saharan African countries in promoting innovation, gender equality, and an enabling business environment for development. The government remains strongly committed to a set of ambitious development goals, as set forth in the 2017–2024 National Strategy for Transformation (NST 1) and the corresponding sector-level strategic plans. Gross domestic product (GDP) experienced an average growth rate of 7.8 percent per year between 2000 and 2019, and the country recovered relatively quickly from the recession caused by the COVID-19 pandemic in 2020 (NISR 2022). The country has also experienced a rapid decline in the poverty rate, from 58.9 percent in 2000/01 to 38.2 percent in 2016/17 (NISR 2018a).[1]

Agriculture played an important role in Rwanda's recent economic growth. The sector grew alongside the rest of the economy despite the challenges of scarcity in available agricultural land, small farm sizes, poor infrastructure, limited access to production inputs and technologies, and repeated climate shocks (Dusingizimana et al. 2022; Adolph et al. 2021; Malabo Montpellier Panel 2021; World Bank and GoR 2020). Agriculture also contributed to growth in off-farm components of the agrifood system and helped cushion the economic damages from COVID-19 in 2020 (Pauw et al. 2021a; Aragie et al. 2021). Thus, it is important to understand how Rwanda's agrifood system was transforming and how it contributed to national growth and structural change during the past rapid development period.

Agrifood systems are expected to evolve as countries develop and, eventually, they come to comprise far more than just traditional primary agriculture (Diao et al. 2010; Timmer 1988). Subsistence farming typically dominates agriculture during the earliest stages of development, but as agricultural productivity rises, farmers start to supply surplus production to markets, creating job opportunities for workers in the off-farm economy (Haggblade et al. 2007). Rising rural incomes generate market demand for more diverse products, leading to more processing, packaging, transporting, trading, and other relevant nonfarm activities. In the early stages, agriculture is an engine of rural, and even national, economic growth. Eventually, urbanization, nonfarm economy, and nonagricultural incomes come to play more dominant roles in development, with urban and rural nonfarm consumers creating most of the demand for agricultural outputs via value chains connecting the countryside to cities and towns (Dorosh and Thurlow 2013). This is a general trend of agricultural transformation, while the specific pattern of the trend varies across countries because of the diverse structure and growth trajectory of a particular country's agrifood system.

This paper describes the current and changing structure of Rwanda's agrifood system and evaluates the potential contribution of different value chains to driving faster and more inclusive agricultural transformation. Section 2 introduces a conceptual framework of agrifood system, and its application to the Rwanda data. Section 3 compares Rwanda's agrifood system to those of other countries at different stages of development. Section 4 disaggregates Rwanda's agrifood system across value chains taking into consideration their different market structures. Section 5 examines how Rwanda's agrifood system has contributed to the broad economic transformation, and Section 6 evaluates the perfor-

[1] Note that the poverty headcount ratio for Rwanda assessed at a the $2.15/day poverty line in constant (2017 PPP) terms indicates a 20 percentage points decrease in the poverty rate, from 75 percent in 2000 to 52 percent in 2016 (World Bank 2022).

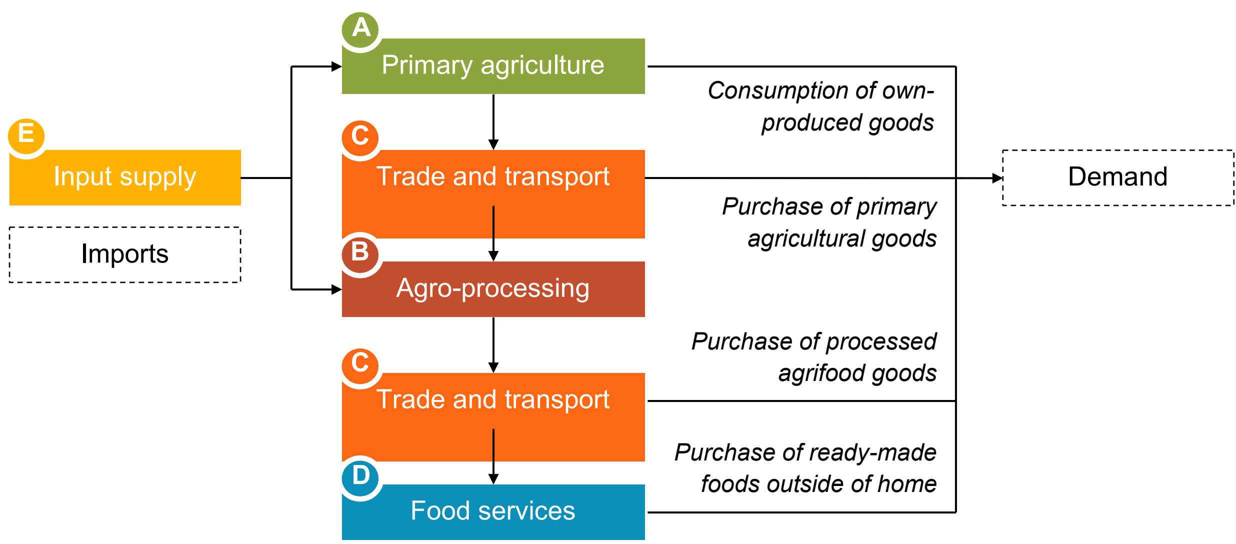
mance and structural change within the agrifood system in the recent years. Section 7 then uses a forward-looking economywide model to assess the diverse contributions of value chain development to broad development outcomes. We conclude by summarizing our findings and outlining an agenda for further research in Section 8.

RWANDA'S AGRIFOOD SYSTEM

A conceptual framework

There are many ways to conceptualize an agrifood system (AFS). For many, it is a complex network of actors, connected by their differing roles in supplying, consuming, and governing agrifood products and jobs (see, e.g., Willett et al. 2019; FAO 2018; Dwivedi et al. 2017). Our objective is to define an agrifood system that is measurable with actual country data and statistics in order to assess the performance and evolution of the system. A simple conceptual framework is presented in Figure 1, in which an agrifood system is characterized by five distinguishable components (A to E in Figure 1). This framework can be applied to our analysis using available economywide time series data and household survey data that allow us to estimate the total size of the AFS and of its various components on both the supply and demand sides of the economy.

Figure 1. Components of an agrifood system



Source: Thurlow et al. (Forthcoming).

Primary agriculture (A) is the first component of an AFS and includes the supply, demand and trade of all agricultural products that are often grouped as crops, livestock, fishing, and forestry. *Agro-processing* (B) is part of the broader manufacturing sector and includes only those manufacturing subsectors associated with processed foods and other agriculture-related nonfood products such as yarn and timber.[2]

[2] Yarn and timber are the immediate downstream subsectors for cotton farming and the forestry sector.

Input supply (E) is the portion of intermediate inputs used directly in agricultural and agro-processing production (e.g., fertilizers and financial services). Inputs that are produced by farmers and processors themselves are excluded in the measure to avoid double-counting, since they are captured in the above components. Only the portion of inputs generated by local producers are included, and the portion is calculated as a share of agriculture and processing's input demand in total economywide demand for that input. For example, if farmers and processors use a third of petroleum produced domestically in the economy, then a third of the domestic petroleum sector is considered part of the AFS. If all petroleum is imported, then this input does not contribute to input component of the AFS (component E).

Trade and transport services (C) consider only the portion of such services associated with transporting, wholesaling, and retailing of agrifood products between farms, firms, and final points of sale (i.e., either domestic markets or the country's border for exported and imported goods). Trade and transport sectors that are included in national accounts data do not separate their services for agrifood and the rest of economy, and so this is estimated using product-level data on transaction cost margins. Transaction costs are the main source of demand for trade and transport services, and so a portion of trade or transport sectors can be attributed to the AFS based on the total share of trade margins on agrifood products relative to the total margins on all marketed products.

Finally, *food services* (D) are associated with services provided in both food production and consumption, plus a portion of the hotels and accommodation sector. Producers of food services (i.e., meals prepared outside the home but excluding those prepared in-home) run standalone operations (e.g., restaurants or stalls), whereas hotels often operate restaurants in addition to providing accommodations and other services. The portion of hotels and accommodation sector that is assigned to the AFS is based on the share of agrifood inputs in the sector's overall intermediate inputs.[3]

In summary, an agrifood system is essentially the sum of all relevant on- and off-farm economic activities and products across all agricultural value chains within a country. Measures of the five components of a country's agrifood system are based on a series of social accounting matrices (SAMs) constructed by IFPRI. The SAMs require the following datasets to construct, and they are available for most countries. Time series of the latest national accounts data are from a country's national statistical agency; for Rwanda, it is the National Institute of Statistics of Rwanda (NISR 2022). Time series data on agricultural production are from Food and Agriculture Organization of the United Nations (FAO 2022a); and time series of export and import data is from United Nations Comtrade database (UN Comtrade 2022).

Estimating employment within an agrifood system relies on various data sources including a country's available population census and household budget and labor force surveys. For Rwanda, these datasets include the 2012 Population and Housing Census (NISR 2012), the Labour Force Survey (NISR, various years), and the Fifth Integrated Household Living Conditions Survey (EICV5) (NISR 2018b).[4] Various international databases (e.g., De Vries et al. 2021; ILO 2020) are also used for estimating employment.

[3] Cross-country analysis using IFPRI's Agrifood System Database indicates that this is a conservative approach that slightly underestimates the part of hotels and accommodation GDP that is associated with the agrifood system.

[4] At the time this paper was written, data collection for the 2022 Population and Housing Census had just been completed. As such, the census results and underlying data were not yet publicly available.

Household survey data is also used for further disaggregation of household consumption across commodities. The recent supply and use tables (SUT) are used to map the interlinkages across sectors for their input and output relationship, and the Rwanda SUT is compiled by NISR and obtained through a joint project between IFPRI and the Ministry of Finance and Economic Planning (MINECOFIN).[5] A SUT dataset is based on a set of national economic surveys including agricultural and industrial surveys. Applying all these datasets, a SAM structures the national economy consistently across different types of economic activities and various sectors/commodities.

Two Rwanda's SAMs for 2009 and 2019 are constructed for the analysis. Both SAMs have same number of economic sectors (90 sectors in total) with the same structure in data compiling such that they can be used to measure the change in the structure of agrifood system and diverse growth across different value chains between 2009 and 2019.

The current structure of Rwanda's agrifood system

The size and structure of Rwanda's agrifood system across its five components is shown in Table 1, which focuses on the supply side of the AFS. Specifically, the table focuses on GDP and employment of the AFS. We define total GDP of the agrifood system as AgGDP+ and total employment of agrifood system as AgEMP+.[6]

Table 1. Rwanda's agrifood system, 2019

	GDP		Employment	
	Value ($ billions)	Share of total (%)	Workers (millions)	Share of total (%)
Total economy	9.5	100	6.3	100
Agrifood system	3.40	35.93	4.29	67.68
Primary agriculture (A)	2.44	25.74	3.95	62.27
Off-farm agrifood system	0.96	10.19	0.34	5.40
Agro-processing (B)	0.53	5.57	0.17	2.63
Trade and transport (C)	0.21	2.19	0.14	2.24
Hotels and food services (D)	0.18	1.91	0.03	0.43
Input supply (E)	0.05	0.53	0.01	0.11
Non-agrifood system	6.1	64.1	2.1	32.3

[5] IFPRI, MINECOFIN, and NISR constructed an updated SAM under the project titled "SAM-CGE Modeling Capacity Building for Evidence-based Policy Analysis and Strategy in Rwanda," which ran from 2017 to 2021 with financial support from the Deutsche Gesellschaft für Internationale Zusammenarbeit Gmb (GIZ). Additional support to the SAM construction and updating was received the European Union, the United States Agency for International Development (USAID), the Bill and Melinda Gates Foundation (BMGF), and the CGIAR Research Program on Policies, Institutions, and Markets (PIM), which is supported by the CGIAR Fund contributors (https://www.cgiar.org/funders/). See IFPRI et al. (2021) for details.

[6] Formal definitions of AgGDP+ and AgEMP+ are provided in Thurlow et al. (forthcoming).

Source: Author's analysis using IFPRI's 2019 Rwanda SAM.
Notes: A to E correspond with the five agrifood system components from Figure 1.

Total AgGDP+ was equal to $3.40 billion in 2019, of which, $2.44 billion was generated from primary agriculture. That is, for every dollar of GDP generated on-farm, an additional 0.39 dollars of GDP was generated off-farm within the AFS. The value of AgGDP+ was about 36 percent of total GDP, of which more than two-third was from primary agriculture and less than one-third from off-farm AFS activities. About 55 percent of the off-farm AFS GDP was from agro-processing, while the remaining 45 percent was split among the three service-related components of the AFS.

The employment of the agrifood system (AgEMP+) accounted for 67.7 percent of total employment, and most of that employment was in primary agriculture, which used 62.3 percent of national total employment. For off-farm AFS employment, jobs were roughly split equally between agro-processing and trade and transport services. With a larger share of off-farm GDP generated from agro-processing (55 percent) that employs half of total off-farm employment, labor productivity (measured by GDP per worker) in agro-processing is higher than labor productivity in service related off-farm activities within the AFS.

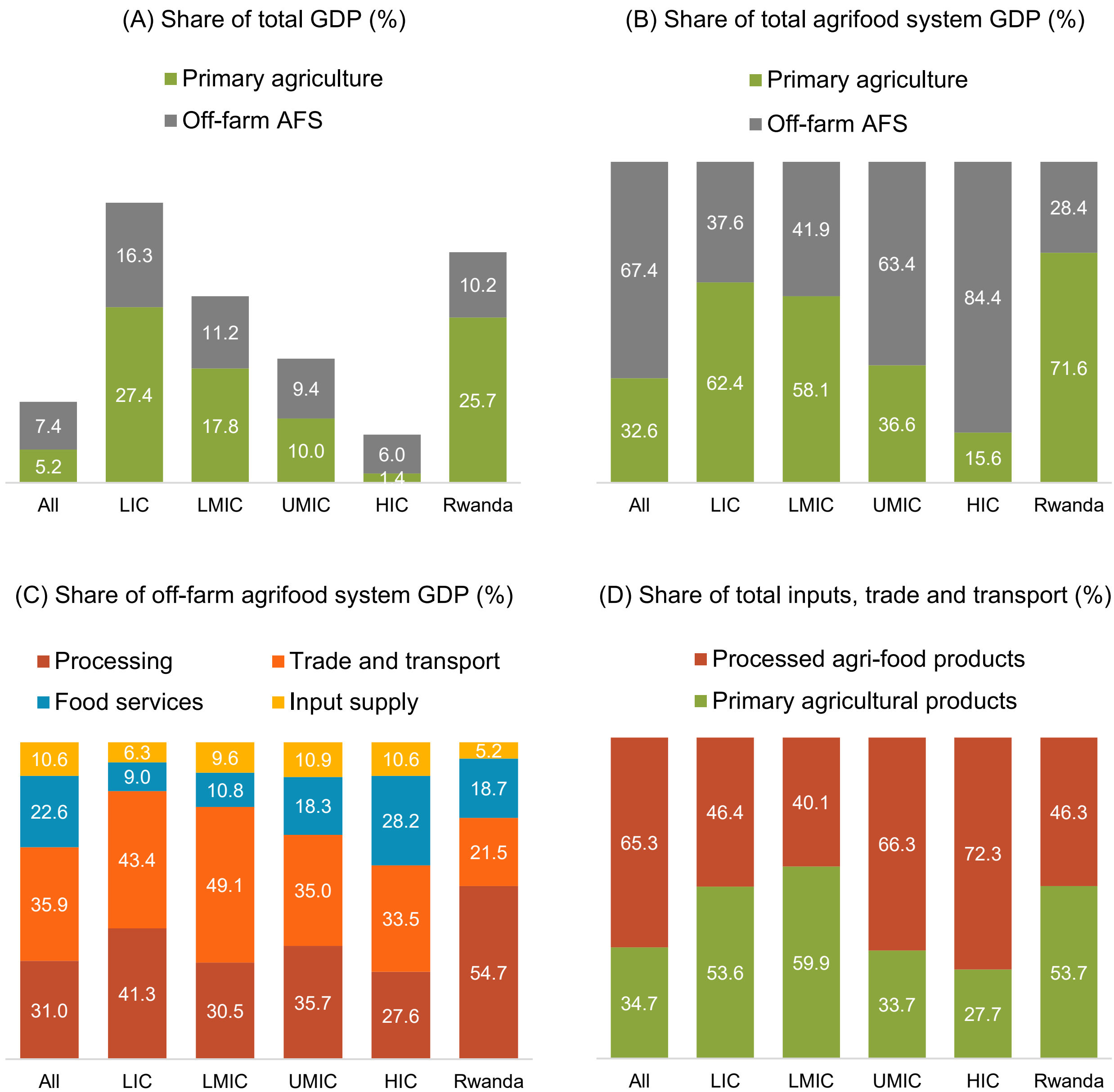
COMPARISONS WITH OTHER COUNTRIES

IFPRI's Agrifood System Database is used to compare Rwanda's agrifood system to those of other countries at different stages of development. IFPRI's Agrifood System Database contains relatively aggregate SAMs for 206 countries. This allows us to assess AgGDP+ and AgEMP+ for these countries, which together cover 96 percent of global GDP and 94 percent of the global population (see Thurlow et al. forthcoming). Figure 2 shows weighted estimates of different income groups following the World Bank's definition, with Rwanda included in the figure for comparison (see final column in each panel). The figure shows the importance and composition of agrifood systems at different stages of development, as proxied by gross national income (GNI) per capita.

Panel A shows that primary agriculture is more important for developing countries, while the share of agriculture in the economy becomes smaller with development. On average, primary agriculture is about 27 percent of total GDP for the less-developed country group – the low-income countries (LIC), while it is only 1 percent for the most-developed country group – the high-income countries (HIC). However, the agrifood system's contribution to the economy remains relatively large, even in the most-developed countries. For example, in Hong Kong (not shown in the figure) agricultural GDP is virtually zero, while the total agrifood system still accounts for 8 percent of total GDP – mainly from the off-farm components of its AgGDP+.

The size of Rwanda's AFS and its breakdown across farm and off-farm components are close to those for the LIC group, which is the group that Rwanda currently belongs to (Figure 2, Panel A). Indeed, while Rwanda has experienced rapid growth in the recent decades, it began from a low base and is still a low-income country today. This makes Rwanda's AFS comparable with the LIC group but also somewhat near the LMIC group.

Figure 2. Decomposing agrifood systems across country income groups, 2019



Source: IFPRI's Agrifood System Database (Thurlow et al. Forthcoming) and 2019 Rwanda social accounting matrix.
Note: LIC are low-income countries, LMIC are lower-middle income, UMIC are upper-middle income, and HIC are high income.

Panel B in Figure 2 shows the contributions of the farm and off-farm components to total AgGDP+, holding total AgGDP+ as 100 (i.e., a different representation of the information in Panel A). At around $4,000 per capita, which is close to the threshold for attaining upper middle-income country (UMIC) status, the value-added generated off the farm exceeds what is generated on the farm. At $40,000 per capita, which is roughly the median income for high-income countries (HIC), primary agriculture is less than 20 percent of total AgGDP+, i.e., more than four dollars of GDP is generated off the farm for each dollar on the farm. Comparing with the LIC average, Rwanda generates more GDP on-farm than the low-income countries' average, mainly because Rwanda's per capita income is still below the average of LIC group.

Panel C of Figure 2 focuses on off-farm AgGDP+ by decomposing it into its four major components. Trade and transport services typically generate less value-added than food services (e.g., restaurants) for higher income countries. For the most-developed country group (HIC), almost 20 percent of off-farm GDP comes from food services, while for the least-developed country group (LIC), the share is less than 10 percent. In this regard, the structure of off-farm AgGDP+ in Rwanda is quite different from the LIC average. The country has a much larger component of food services – double the LIC average. Rwanda's agro-processing also accounts for a large share of off-farm GDP, which reflects the processing requirements of the tradable crop and livestock sectors that will be discussed in the next section. On the other hand, Rwanda has a relatively small trade and transport services sector in its agrifood system, which possibly reflects policy restrictions in informal agricultural trade in urban areas.

Panel D of the figure decomposes the input supply and trade and transport components of the AFS according to primary and processing agriculture. This distinction is useful because, during the early stages of agricultural transformation, we expect there is more value addition off-farm associated with primary products than with processed products. This is supported by the figure, which shows how more off-farm value addition is generated on primary products in lower-income countries, with the opposite being true for high-income countries. Rwanda has an almost identical structure as the LIC group for the value-added of input supply and trade and transport services associated with primary versus processing agriculture.

In summary, the structure of Rwanda's AFS shares many of the characteristics of developing countries at a similar stage of development. However, not all low-income developing countries have grown as rapidly as Rwanda has over the last several decades. This warrants a closer look at Rwanda's agricultural and structural transformation, which will be discussed in Section 5.

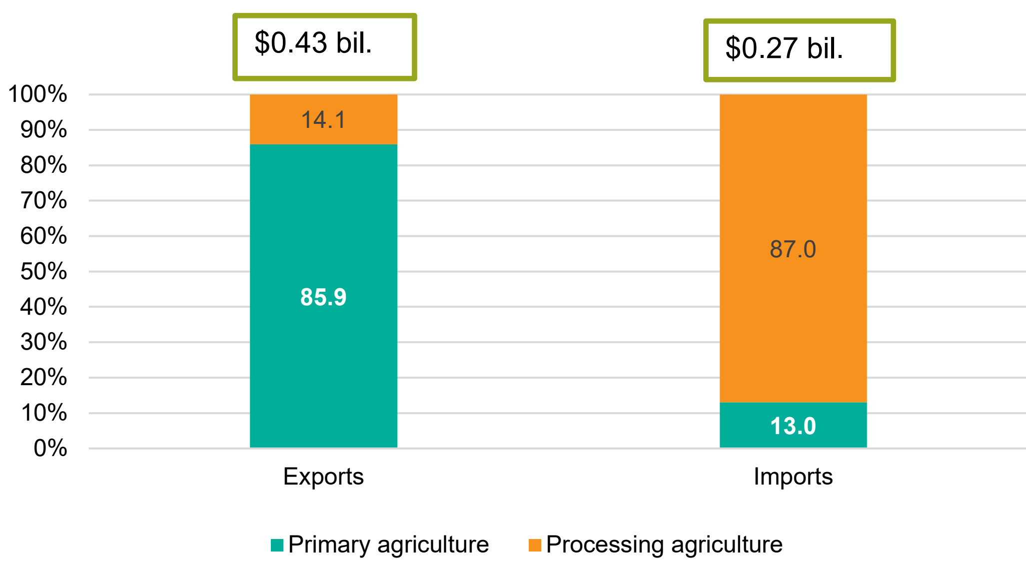
DISAGGREGATING RWANDA'S AGRIFOOD SYSTEM ACROSS VALUE CHAINS

The 2009 and 2019 SAMs cover 36 primary agricultural sectors/commodities and 19 agro-processing sectors/commodities. Decomposing Rwanda's agrifood system across major product groups is important for understanding the performance and changing structure of agrifood system over time. This section focuses on Rwanda's current AFS structure across value chains using the 2019 SAM, while Section 5 analyzes the performance of the AFS and structural changes that have occurred in the last decade using the SAMs for 2009 and 2019.

The structure of a country's AFS is determined not only by the supply-side factors: demand patterns also play an important role in shaping the structure. If a large portion of agricultural products are consumed directly by farmers at home without being exchanged in markets to other value chain actors, then primary agriculture dominates the AFS. On the other hand, if urbanization and increases in non-farm opportunities in rural areas occur, then more agricultural products will likely be traded, with a significant share of them consumed through processing, which increases the size of the off-farm components of the AFS.

International trade is also an important factor in shaping the structure of AFS. When more agricultural products are produced for export, they often require certain levels of processing and rely on export-related logistic services, thereby increasing the demand for off-farm components of the AFS. On the import side, a country often imports food with a certain level of processing, e.g., edible oils, milled rice, flour from some cereal grains, groundnuts, and soybeans, or refined sugar. For this reason, Figure 3 displays the primary and processing components of the AFS for exports and imports in 2019 with their total values. With $0.43 billion in exports and $0.27 billion in imports, Rwanda is a net exporter of primary and processing agriculture combined. However, once we separate this figure between primary agriculture and processing agriculture, Rwanda is a *net exporter* of primary agriculture and a *net importer* of processing agriculture. Though not shown in Figure 3, this distinction can be gauged by comparing the shares of primary and processing agriculture in exports and imports. On the export side, Figure 3 shows that processing agriculture is only 14 percent of agricultural exports, while on the import side, 87 percent of imports are processed agricultural products. This indicates a very different structure of the AFS on the demand side when compared to the supply side measured in AgGDP+.

Figure 3. Shares of primary and processing agricultural trade in 2019 (primary plus processing agricultural exports or imports = 100)

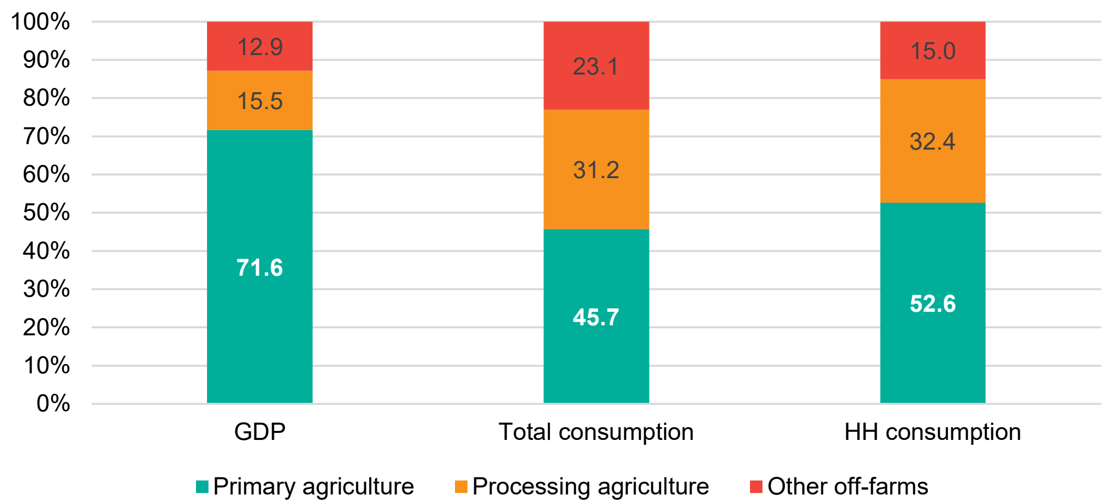


Source: Authors, based on data from the 2019 Rwanda SAM.
Note: $0.43 bil and $0.27 bil. are, respectively, the export and import values of primary and processing agricultural products combined in 2019.

Figure 4 further addresses this departure in the AFS structure between the supply and demand sides by illustrating the comparison between AFS GDP and values of agrifood products in terms of total and household consumption. The figure shows 72 percent of AgGDP+ is from primary agriculture, while on the demand side, primary agriculture accounts for 46 percent and 53 percent of total and household consumption, respectively. More than 30 percent of total and household consumption are in the form of processing agricultural goods, while only 16 percent of AgGDP+ is processing agriculture. The fact that processing agriculture *consumption* is more than double of processing agricultural

GDP is consistent with the export and import structures shown earlier in Figure 3. This is also helpful for identifying a possible driving role of demand in the evolution of Rwanda's AFS, which will be discussed in the next section.

Figure 4. Shares of GDP and consumption of AFS in 2019 (total AFS = 100%)



Source: Authors, based on data from the 2019 Rwanda SAM.
Note: Total consumption includes both final and intermediate consumption, and HH consumption is households' total final consumption.

In our analysis, we group 36 primary agricultural sectors/commodities into 16 groups and map agro-processing sectors and other AFS components into the 16 groups according to their close relationship with each of the 36 primary agricultural sectors. We refer to these 16 groups as "AFS value chains" that combine agricultural sectors/commodities and their related off-farm components but name them according to their primary agricultural products. Some agricultural products, such as maize, rice, groundnuts, soybeans, Irish potatoes, are defined as individual AFS value chains because they are the sectors identified by the Government of Rwanda to be drivers of agricultural transformation in successive Strategic Plans for Agriculture Transformation (PSTAs) (MINAGRI 2018). Other sectors, such as cassava and sweet potatoes, are grouped as a single AFS value chain group. See Appendix for a detailed mapping of the relationship between the 36 primary agricultural sectors and the 16 AFS value chain groups. The 16 value chains are further identified by their trade status including export-oriented, import-substitutable, and less tradable, as explained below. Table 2 groups these 16 value chains under the three trade statuses and presents their shares in GDP for total AFS, primary agriculture, and the aggregate off-farm components.

Table 2. Decomposing agrifood GDP and trade ratios by value chains, 2019

	Agrifood system	Primary agriculture	Off-farm AFS	Exports/output	Imports/consumption
Total				**8.8**	**6.2**
Exportable	**28.3**	**31.6**	**20.1**	**31.1**	**1.9**
Beans	4.4	5.6	1.3	22.8	0.8
Irish potatoes	4.0	5.3	0.7	16.9	
Vegetables	3.0	3.7	0.9	28.2	2.0
Fruits	11.9	11.4	13.1	10.6	2.7
Export crops	5.1	5.6	4.1	88.3	
Importable	**16.9**	**11.5**	**30.7**	**1.3**	**15.4**
Maize	2.3	2.6	1.6	1.0	11.1
Rice	2.9	2.2	4.9		10.9
Other cereals	2.2	1.9	2.9	2.1	9.8
Groundnuts	2.7	1.9	4.8	0.4	22.4
Soybeans	0.3	0.4	0.1		23.6
Other crops	5.2	0.9	16.1	2.2	17.4
Fish	1.2	1.5	0.4		27.4
Less tradable	**50.2**	**57.0**	**33.2**	**1.0**	**1.7**
Other root crops	17.6	20.9	9.1	0.5	0.6
Cattle and milk	9.5	8.2	13.0	1.1	3.1
Other livestock	2.2	3.0	0.3		0.5
Forestry	20.9	24.9	10.7	0.3	3.8

Source: Authors, based on data from the 2019 Rwanda SAM.
Notes: Other root crops denotes other root and tubers, including cassava, sweet potatoes, and other types of roots and tubers, as well as cooking bananas and bananas for beer, while sweet (or dessert) bananas are classified under fruits (see Annex). Exports, imports, output, and consumption used in calculation of trade ratios consider primary agriculture and agro-processing two components of the agrifood systems. Export-oriented (exportable in short) value chains are those with export/output ratios higher than their import/consumption ratios and higher than export/output ratio for total agriculture. Import-substitutable (importable in short) value chains are those with import/consumption ratios higher than their export/output ratios and higher than import/consumption ratio for total agriculture. Less tradable value chains are those with both export/output and import/consumption ratios lower than that for total agriculture.

The last two columns of Table 2 present ratios of export to output and import to total consumption of primary and processing agriculture combined (excluding other off-farm components in the calculation). These ratios are used to identify the trade status of a value chain. A value chain that is export-oriented (referred to as “exportable” hereafter) has a large portion of agricultural products produced for foreign markets, while a value chain identified as import-substitutable (“importable” hereafter) is on the opposite side with a relatively large portion of primary or processing agricultural products imported for meeting domestic demand. Less tradable value chains are in between exportable and importable, with lower dependence on international trade and production more for domestic market. We use the ratio of export to output for total primary and processing agriculture (8.8 percent) and ratio of import to consumption for total primary and processing agriculture (6.2 percent) as cut-offs to assign the tradable status for each of 16 individual value chains. Specifically, exportable value chains are those with export-to-output ratios higher than their import-to-consumption ratios and also higher than the export-to-output ratio for total agriculture; importable value chains are those with import-to-consumption ratios higher than their export-to-output ratios as well as higher than the import-to-consumption ratio for total agriculture. Less tradable value chains are those with both export-to-output and import-to-consumption ratios below the ratios for total agriculture.

In Rwanda, five value chains are identified as exportable value chains: beans; Irish potatoes; vegetables; fruits; and export crops as a group including coffee, tea, pyrethrum, and cut flowers. Seven value chains are identified as importable value chains: maize; rice; other cereals that include sorghum and wheat; groundnuts; soybeans; other crops including sugar; and fish. Four value chains are identified as less tradable: cattle and milk; other root crops, which includes roots and tubers such as cassava and sweet potatoes; other livestock that includes poultry; and forestry.

While the number of value chains identified as less tradable is less than the other categories, most are very large value chains. Together these four value chains account for 50 percent of AgGDP+ and 57 percent of GDP for total primary agriculture. However, these same four value chains account for only 33 percent of GDP for the total off-farm component, indicating that less tradable value chains – especially other root crops and forestry – have rather small off-farm components. Thus, despite the growing importance of purchased and processed foods that are often met by imports, less tradable value chains still generate most of their value-added on the farm. On the other hand, many importable value chains have larger off-farm components. This is consistent with the structure of Rwanda's agrifood system on its demand side, as the lion's shares of both imports and consumption are in processed products.

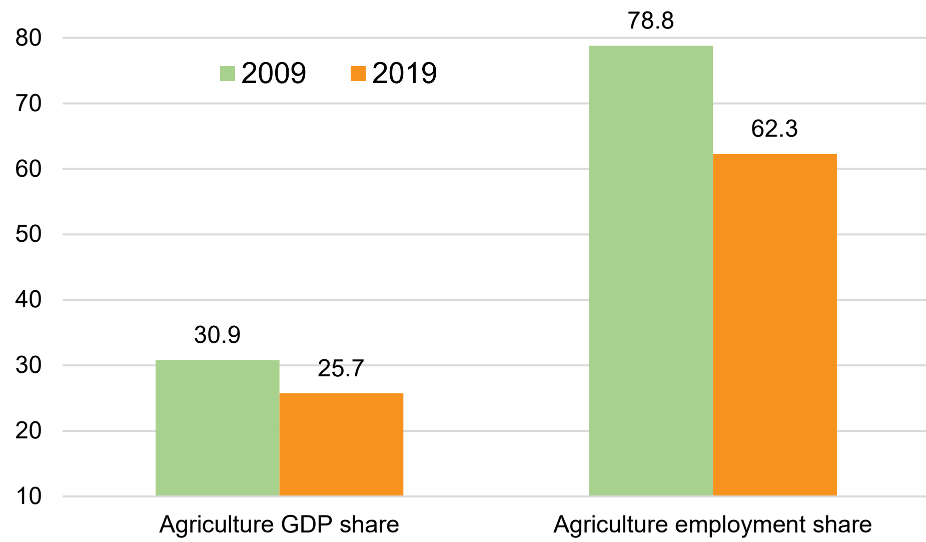
In summary, decomposing AFS across value chains shows significant variation in market shares and structure, and highlights the fact that many of the largest value chains are often less tradable. This allows us to anticipate the different sources of agricultural growth and the different roles of markets in such growth. But before we study growth pattern within Rwanda's AFS in Section 6, we examine the role of agriculture and the agrifood system as a whole in Rwanda's broader economic transformation.

AGRICULTURE IN RECENT ECONOMIC GROWTH AND TRANSFORMATION

This section considers the performance of agriculture as a whole and within Rwanda's broad economic structural transformation. Rapid economic growth is often accompanied by economic structural change. The contribution of agriculture to this structural change process can be assessed from two broad aspects: changes in agriculture's own productivity growth, and the movement of labor from lower-productivity agriculture to higher-productivity nonagricultural sectors. Such labor movement is called structural change-led growth that raises labor productivity economywide (McMillan et al. 2014).

Rwanda's own experience with structural change mirrors that experienced in many other developing countries. As shown in Figure 5, Rwanda's shares of agriculture GDP and employment both declined between 2009 and 2019 with rapid economic growth. Moreover, the share of agricultural employment fell faster than the decline in the share of agricultural GDP, indicating a growth in agricultural labor productivity over time.

Figure 5. Agriculture GDP and employment shares in Rwanda, 2009 and 2019 (percent)

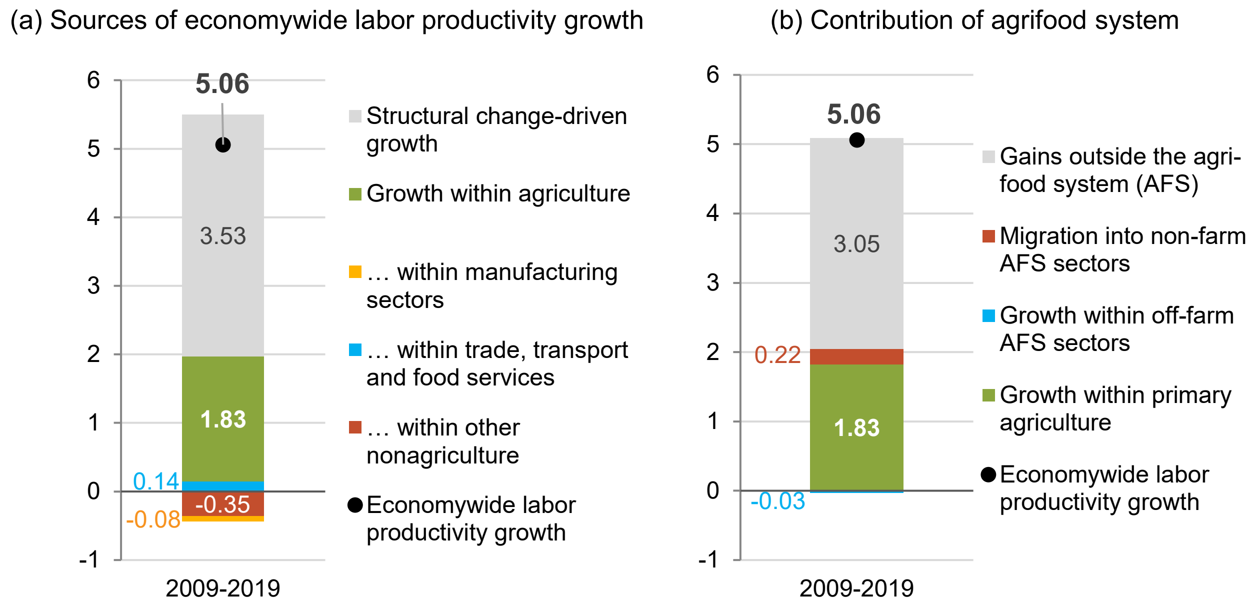


Source: Authors, based on data from the 2009 and 2019 Rwanda SAMs and employment databases.

To shed further light on this aspect of structural change, Figure 6 decomposes the growth of economywide labor productivity observed in Rwanda between 2009 and 2019, following an approach developed by McMillan et al. (2014). As shown in Panel A, economywide labor productivity grew rapidly at 5.06 percent annually during this period. Most of this growth was driven by structural change, i.e., labor moving out of agriculture where labor productivity is generally low, to nonagricultural sectors where labor productivity tends to be much higher than in agriculture. In total, structural change contributed to 3.53 percentage points of annual labor productivity growth in the period 2009–2019. In other words, more than 70 percent of productivity growth can be explained by structural change during the period.

Figure 6 also shows that within-sector labor productivity gains occurred mainly within agriculture, which contributed 1.83 percentage points of the 5.06 percent annual productivity growth, the second largest contributor after structural change-led growth. On the other hand, within-sector productivity growth was negative for nonagricultural sectors as a whole, a pattern observed in many African countries with rapid economic growth and structural change in the recent decades (Diao et al. 2020).

Figure 6. Decomposition of labor productivity growth rate (percentage points, annual average in 2009-2019)



Source: Authors, based on data from the 2009 and 2019 Rwanda SAMs and employment databases.

Panel B of Figure 6 estimates the direct contribution of the whole AFS to economywide labor productivity growth. The within-sector contribution from agriculture is the same in both panels, which is 1.83 percentage points. The migration of workers into the off-farm components of AFS is part of the structural change-led growth shown in Panel A of the figure, while it adds another 0.22 percentage points (out of a total 3.53 percentage points) to the direct contribution of AFS to economywide productivity growth. Thus, the AFS directly accounted for 40 percent of total labor productivity growth in the economy, while AFS made its indirect contribution for the remaining 60 percent of growth originating from moving labor out of primary agriculture and structural change beyond the AFS.

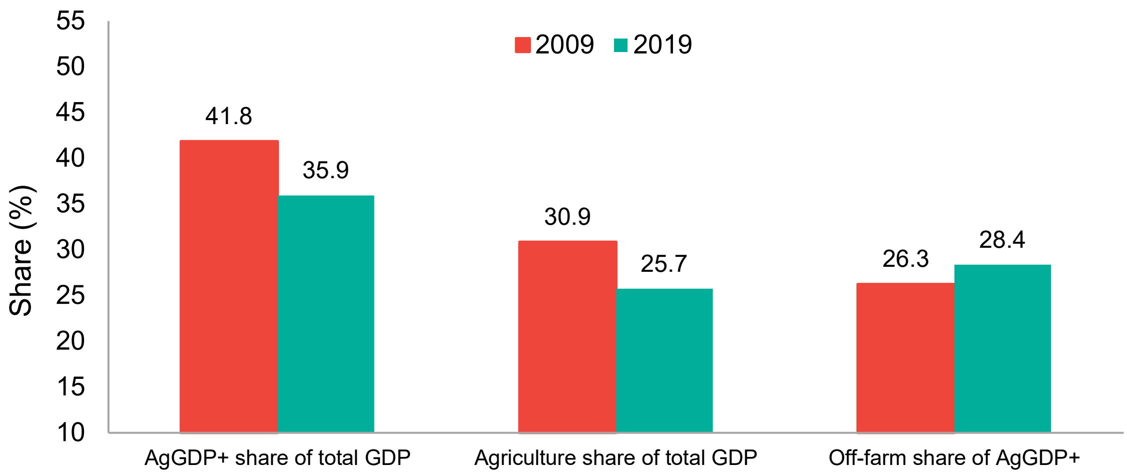
In summary, the rapid economic growth in Rwanda has been accompanied by a similarly rapid process of structural change. Typically, most labor productivity growth comes from structural change that reorients employment towards more productive activities, and this trend is observed in Rwanda. Within this economywide process of growth and structural change, Rwanda's agricultural transformation is proceeding steadily, with GDP growth occurring faster than employment growth within primary agriculture, and creating more employment in the off-farm AFS.

With these trends in mind, it is important to further identify more specific sources of AFS growth – specific value chains – that might accelerate the growth on and beyond the farm. These sources of AFS growth are, in turn, important for accelerating agrifood system and broad economic transformation. Section 6 turns to these issues with an assessment of Rwanda's agrifood system performance and structural change in the last decade.

AGRIFOOD GROWTH AND MARKET STRUCTURE

As illustrated using cross-country data in Section 3, countries that move towards higher levels of development tend to have faster growth in the off-farm components in their agrifood systems. The changing structure of Rwanda's AFS is consistent with the country undergoing this type of agricultural transformation process. Figure 7 first shows how the structure of Rwanda's AFS has changed during the last decade. Primary agriculture's share of the economy has declined from 30.9 percent in 2009 to 25.7 percent in 2019, when measured in constant prices. The broader AFS's share of total GDP has also fallen, but at a slower rate than agriculture. As a result, the contribution of the off-farm components of AFS has risen from 26.3 to 28.4 percent.

Figure 7. Changing structure and contribution of agrifood GDP in Rwanda (2009 and 2019)



Source: Authors, based on data from the 2009 and 2019 Rwanda SAMs.

However, growth performance varied across value chains in Rwanda's AFS. Table 3 identifies the 16 value chains (with their international tradable status in 2019 as defined in Table 2), by whether they have experienced fast or slow growth during the last decade. This is done by comparing their growth rates with the overall growth rate of total AFS during the period in question.

The ranking of the 16 value chains is the same as in Table 2, and they are grouped by three tradable statuses: exportable, importable, and less tradable. The first column of Table 3 shows which value chains experienced growth rates of their AFS GDP faster than the growth rate for the total AgGDP+. Such value chains are labeled "fast growth" in the column, while the remaining value chains without this label have growth rates below the growth rate for total AFS GDP.

In total, there are six value chains with fast growth rates, of which two (rice, and other cereals including wheat) are importable; three (cattle and milk, other livestock including poultry, and forestry) are less tradable; and only one (vegetables) is exportable. That is, most fast-growing value chains are domestic market-oriented, either as less tradable or with the possibility of import substitution. The value chain group for Rwanda's most important export-oriented crops – coffee and tea, together with pyrethrum and cut flowers – have an annual growth rate slightly lower than total AgGDP+, while the value chains of beans and Irish potatoes that target regional markets performed rather disappointingly in growth.

Table 3 also shows that the AFS's off-farm components have a growth rate higher than primary agriculture GDP for all products together, as well as across most value chains regardless of their market structure. Except for the rice value chain, many fast-growth value chains have extremely high growth rates in their off-farm components. These include other cereals (mainly wheat), vegetables, cattle and milk, and other livestock (mainly poultry). The finding that the growth rate is higher for off-farm than on-farm components of the AFS – particularly among fast-growth value chains – indicates that Rwanda's agricultural sector is becoming increasingly market-oriented and moving more and more away from traditional subsistence. This shift has led to increased demand for processing, transport, and trade that creates more off-farm value addition along each value chain as well as more nonfarm jobs. If we compare growth of processing GDP to total off-farm GDP, we notice that processing agriculture has a rather lower growth rate compared to the total off-farm growth rate for the AFS as a whole, while the growth rate of the processing component is slightly higher than the total off-farm growth rate for a few fast-growth value chains.

Table 3. Agrifood system GDP and employment growth decomposition for 2009-2019 (percent)

Value chain type/ *growth rate*	Product	Agrifood system	Agriculture	Off-farm AFS	Processing
	All products	5.4	5.1	6.2	4.7
Exportable					
	Beans	3.8	3.5	7.7	
	Irish potatoes	1.9	1.7	5.9	
fast growth	Vegetables	6.9	6.5	12.5	
	Fruits	3.6	2.8	5.6	4.7
	Export crops	5.0	5.0	5.0	-0.8
Importable					
	Maize	3.4	2.6	7.5	7.3
fast growth	Rice	6.2	8.1	4.4	3.1
fast growth	Other cereals	10.3	9.3	12.3	11.5
	Groundnuts	3.9	5.0	2.8	1.4
	Soybeans	3.9	3.7	8.5	
	Other crops	2.9	1.7	3.0	2.2
	Fish	3.5	3.0	10.0	0.6
Less tradable					
	Other root crops	5.3	5.2	6.1	4.7
fast growth	Cattle and milk	6.8	6.8	6.9	6.0
fast growth	Other livestock	9.6	9.6	11.3	
fast growth	Forestry	6.9	6.6	8.4	8.0

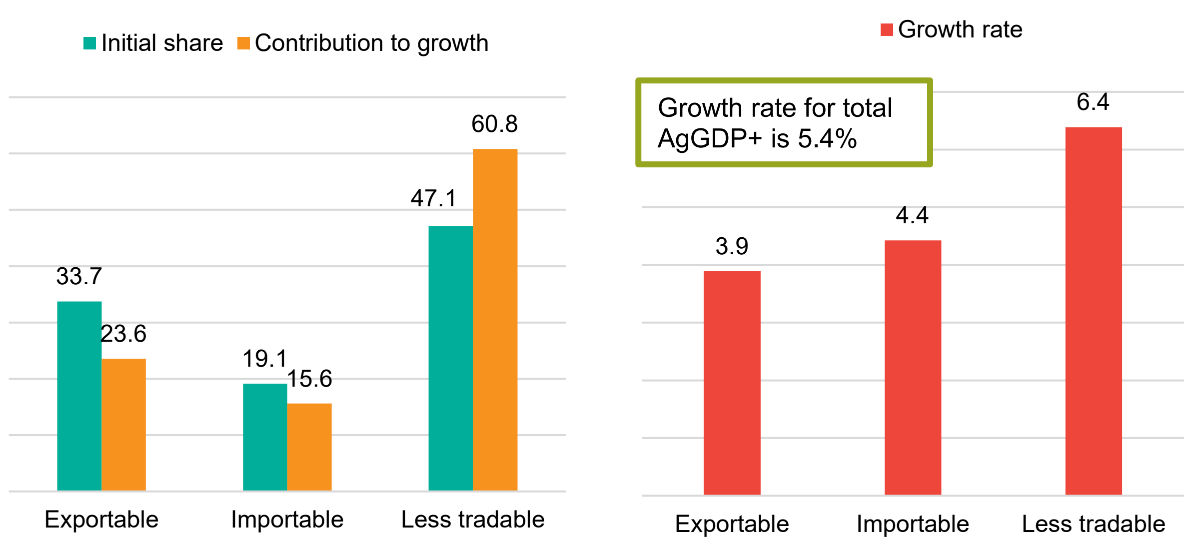
Source: Authors, based on data from the 2009 and 2019 Rwanda SAMs.
Note: Fast growth is referenced to growth rate above 5.4 percent of the annual growth rate for the total agrifood system in 2009-2019.

Figure 8 shows the three types of value chains in terms of (1) their initial shares in AFS GDP, (2) their contribution to increased total AFS GDP; and (3) their annual growth rates. Less tradable value chains are the largest group in the AFS with highest growth rate: 6.4 percent per year, accounting for 47.1 percent of total AFS GDP in 2009 and contributing to 60.8 percent of growth in AFS during 2009–2019. Importable value chains have an annual growth rate of 4.4 percent – that is, lower than the total AFS GDP growth rate of 5.4 percent – and it contributed 15.6 percent to total AFS growth, while its initial size was 19.1 percent of total AFS in 2009. Exportable value chains as a group have relatively poor growth performance with an annual growth rate of 3.9 percent, contributing 23.6 percent to total AFS growth, much lower than its initial size in the AFS (close to 34 percent).

In summary, our growth diagnostic across value chains shows that domestic markets, not exports, seem to be the main driving force of growth in Rwanda's AFS. Thus, understanding the role of domestic demand in AFS transformation is important for designing policies, investments, and programs to promote value chain growth more efficiently. Growth in domestic demand for agrifood comes from household income growth. With urbanization and increasing rural nonfarm opportunities, patterns of nonfarm incomes and the pace of their growth are changing the country's consumption and dietary patterns. This is a fundamental part of the transformation process. These changes have also created growth opportunities for many domestic market-oriented or import-substitutable agricultural value chains, allowing several of them to play a leading role in the growth in Rwanda's AFS during the last decade.

These growth patterns are expected to continue in the coming decades as household incomes continue to grow. This growth trend provides us with a background for the design of forward-looking growth scenarios across value chains to assess differential impacts of various value chains on broad development outcomes. We turn to this assessment in Section 7.

Figure 8. Initial shares of AgGDP+, contribution to increased AgGDP+, and annual growth rates across the aggregate three types of value chains (percent)



Source: Authors, based on data from the 2009 and 2019 Rwanda SAMs.
Notes: Initial share refers to the share in 2009 and total growth of AgGDP+ in 2009-2019 is 100 in the left panel of the figure; growth rate in the right panel is annual average of 2009-2019.

FUTURE DRIVERS OF INCLUSIVE AGRICULTURAL TRANSFORMATION

This section uses the Rwanda CGE model – an adaption of IFPRI's RIAPA model to the Rwandan context – to compare the potential contributions of different value chains to inclusive agricultural transformation of economic growth. This notion of inclusive agricultural transformation is proxied by growth in incomes (GDP) and employment, as well as reductions in poverty and hunger, and the improvement of diet quality. The underlying RIAPA model is briefly described below; see Diao and Thurlow (2012) for a more in-depth description for dynamic CGE models in general.

The RIAPA model

RIAPA comprises a series of interlinked datasets and models that are used to assess growth impacts and inform policy and investment prioritization at a country level. At the core of RIAPA is an economywide CGE model that simulates the functioning of a market economy, including markets for products and factors (i.e., land, labor, and capital). RIAPA measures how growth impacts are mediated through prices and resource reallocations, and ensures that resource and macroeconomic constraints are respected.

Consistent with the SAMs used in the diagnostic analysis described in the previous sections, RIAPA divides Rwanda's economy into 90 sectors. Producers in each sector maximize profits and supply output to national markets or for exports, while products consumed in domestic markets can be imported depending on relative prices, with export and import prices affected by exchange rate movements. Technology of production is sector-specific, that is, unique combinations of factors and intermediate inputs are used in each sector. Rice, for example, is produced using a combination of land, labor, fertilizer, and purchased seeds, while rice milling uses paddy rice as an intermediate input in combination with labor and capital to produce milled rice for final consumption.

Rural and urban labor markets in the model are defined by workers' education levels, and both rural and urban workers can work in agricultural and nonagricultural activities. Agricultural capital is separated into crop, livestock, and nonagricultural categories, and nonagricultural capital is employed in agro-processing and other off-farm components within and outside the agrifood system. Land and most types of labor are in fixed supply, while supply of less-educated rural and urban workers is endogenous by taking into consideration their current underemployment situation. The supply of capital is also endogenous across sectors.

In the model, government collects taxes on enterprises, households, and sales of commodities, and uses these revenues to finance public services including the provision of social protection to the poor through various cash transfer programs, and public investment. Private savings and foreign capital inflows are the two other sources to finance investment, which determines the change in total capital over time. The new capital through investment is allocated to different sectors according to the returns to capital across sectors, making RIAPA a dynamic model with current capital availability determined by previous investment.

RIAPA tracks changes in household incomes and expenditures, including changes in food and nonfood consumption patterns. The 15 household groups in RIAPA are defined by rural and urban consumption quintiles, with rural households further separated into farm and nonfarm groups. RIAPA tracks poverty, food security, and dietary quality impacts using a survey-based microsimulation model linked to the economywide CGE model. The household survey data is drawn from the EICV5 (NISR 2018). All surveyed individual households are mapped to the CGE model's 15 household groups. Estimated consumption changes in the CGE model are applied proportionally to survey households, and post-simulation consumption values are recalculated and compared to poverty and hunger lines to determine households' poverty and hunger status, and to the cost of a healthy reference diet to estimate dietary deprivation.

Comparing growth outcomes of different value chains

RIAPA is used to simulate the system-wide and economywide effects of different AFS value chains through their agricultural productivity growth. In the simulations, total factor productivity growth in the simulated groups of agricultural subsectors is accelerated beyond baseline growth rates, such that total agricultural GDP is a half percent higher by 2025 than is expected with business-as-usual growth in the baseline. However, agricultural subsectors differ significantly in size, and so to achieve the same 0.5 percent increase in *total* agriculture GDP, it is necessary for small size value chains (e.g., soybeans) to expand much more rapidly than large ones (e.g., other root crops). While the targeted increase in total agriculture GDP is always 0.5 percent more by 2025 across all value chain growth scenarios, induced changes in downstream processing activities and demand for input uses and for agricultural trade and transport services vary across value chain growth scenarios. These differences in the relationship between on- and off-farm components of the AFS determine differential growth linkages effects across value chains.

We use changes in five groups of outcome indicators to assess the potential impacts of growth led by different value chains on broad development outcomes in Table 4. The first group of outcome indicators are the poverty impact assessment, which is shown in the first two columns of the table, i.e., changes in the poverty rate and poverty gap. The measure of changes in poverty to growth is the percentage point change in the poverty headcount rate or poverty gap rate resulting from one-percent of increase in the value-added of primary agriculture coming out of the targeted value chains. Consistent with the previous section, there are 14 value chains simulated individually (other crops and forestry value chains were excluded from the simulations).

The third and fourth columns of the table are the food security impact assessment, which is measured by changes in the hunger headcount rate and diet quality index. Similar as poverty to growth elasticity, the hunger measure in the third column is the percentage point change in the hunger headcount rate following from one-percent of increase in value-added of primary agriculture coming out of the targeted value chains. A person is deemed undernourished when they consume fewer calories than what is required for a healthy life (FAO 2022b).

The RIAPA hunger module is a survey-based microsimulation module, which sets the minimum calorie requirement threshold according to the international standard set by FAO at 1,670 kilocalories per adult equivalent per day for individual survey households. For each survey household, the module first imputes household-level calorie availability from each food group (i.e., the same food commodities that are represented in the RIAPA model) based on expenditure and the cost per calorie of a representative food item within that food commodity. Although availability is assessed at household level in the survey, it is adjusted for the age and gender composition of the household. Summing calories across all food commodities yields a total calorie availability per survey household, expressed in adult equivalent terms. Each survey household is mapped to a representative household in the SAM. RIAPA simulations result in changes in food consumption quantities by representative households in the economywide model. There is a direct relationship between food consumption quantities and the calories obtained. The new levels of consumption for individual food groups are therefore calculated for the survey households under each simulation. The baseline and simulated calorie consumption amounts of each survey household are compared against the minimum calorie threshold to estimate the shares of undernourished people, also known as the prevalence of undernutrition.

The other way to analyze food security is to assess diet quality impact, which is presented in the fourth column of the table, where the Reference Diet Deprivation (ReDD) index is used for such assessment. ReDD is an index that defines the extent of the consumption shortfall within and across multiple food groups (described in detail in Pauw et al. 2021). More specifically, it estimates the incidence, breadth, and depth of food consumption gaps across six food groups by comparing observed consumption against consumption levels recommended by the EAT-Lancet healthy reference diet (Willet et al. 2019). In column 4 of the table, the numbers represent the percentage change in the Reference Diet Deprivation (ReDD) index with one percent of increase in agriculture GDP coming out of the targeted value chains. A decrease in ReDD is good as it indicates a narrowing of the multidimensional food consumption gap and thus signifies an improvement in diet quality.

Columns 5–8 of the table capture the impacts on growth and total GDP, AFS GDP (AgGDP+), agricultural GDP (AgGDP), and off-farm AFS GDP (FSGDP_N). They are all measures of growth multipliers, i.e., values in these columns are in billion $US with one billion dollars of increase in value-added of a value chain. The remaining columns of the table (Columns 9–12) are for employment outcomes and the values in the tables are changes in total employment, AFS employment (AgEMP+), agricultural employment (AgEMP) and off-farm AFS employment (FSEMP_N) in million persons with one billion dollars of increase in value-added of a value chain. We discuss these results in detail below.

Results

We begin our exploration of RIAPA results by focusing on the poverty-related outcomes before turning to hunger, dietary diversity, GDP growth, and employment outcomes (Table 4). The poverty-related results first indicate that the national poverty rate falls with growth led by all value chains considered in the model. This is denoted by the negative indicator values in Column 1 of Table 4. We take the first row of the table – the results for the maize value chain – to illustrate the results. The indicator value in this row is -1.38, which means that the national poverty rate falls by 1.38 percentage points with 1 percent of increase in agriculture GDP coming from growth in maize productivity.

Each indicator number is also ranked in the table. The rank for maize in Column 1 of Table 4 is 3, indicating that maize's poverty to growth elasticity of -1.38 makes it the third most effective value chain in reducing poverty, while the "other cereals" value chain with an elasticity of -1.90 ranks at the top, and rice value chain with elasticity of -1.39 comes in second. On the other hand, fruits and the export crops value chains rank at the bottom (numbers 13 and 14, respectively) in the effect on poverty reduction from their growth, but their growth is still pro-poor because the poverty rate falls by 0.31 and 0.27 percentage points respectively, from 1 percent of increase in agriculture GDP coming out of their productivity growth.

Table 4. Estimated poverty, hunger, diet deprivation, economic growth, and employment impact of growth led by different value chains

Value chain	Poverty rate	Poverty gap	Hunger	ReDD index	GDP	AgGDP+	AgGDP	FSGDP_N	Total EMP	AgEMP+	AgEMP	FSEMP_N
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Maize	-1.38 (3)	-0.90 (2)	-2.70 (3)	-1.27 (7)	2.18 (5)	2.40 (4)	2.14 (3)	0.26 (6)	0.21 (6)	0.23 (4)	0.11 (6)	0.13 (6)
Rice	-1.39 (2)	-0.72 (5)	-2.74 (2)	-0.57 (11)	3.35 (2)	3.02 (3)	2.02 (4)	1.00 (1)	0.21 (7)	-0.36 (14)	-0.97 (14)	0.61 (1)
Other cereals	-1.90 (1)	-1.15 (1)	-2.98 (1)	-1.81 (4)	3.43 (1)	3.58 (1)	3.20 (1)	0.38 (4)	0.25 (5)	0.12 (7)	-0.07 (10)	0.19 (4)
Beans	-1.17 (7)	-0.73 (3)	-1.99 (4)	-2.29 (3)	1.03 (10)	1.17 (7)	1.10 (6)	0.08 (10)	0.15 (9)	0.21 (5)	0.18 (5)	0.03 (10)
Groundnuts	-1.20 (5)	-0.53 (7)	-1.55 (5)	-4.84 (1)	2.57 (4)	2.17 (5)	1.61 (5)	0.56 (2)	0.61 (2)	0.02 (12)	-0.32 (13)	0.35 (2)
Soybeans	-1.19 (6)	-0.66 (6)	-1.20 (6)	-1.67 (5)	2.66 (3)	3.07 (2)	2.70 (2)	0.37 (5)	0.79 (1)	0.81 (2)	0.63 (2)	0.18 (5)
Irish potatoes	-0.40 (10)	-0.24 (9)	-0.44 (9)	-0.01 (12)	0.88 (12)	1.01 (12)	1.01 (9)	0.01 (14)	0.11 (11)	0.20 (6)	0.20 (4)	0.00 (14)
Other roots	-0.49 (8)	-0.26 (8)	-0.53 (8)	0.02 (14)	1.15 (7)	1.14 (9)	1.05 (7)	0.09 (9)	0.02 (14)	-0.03 (13)	-0.07 (11)	0.04 (8)
Vegetables	-1.29 (4)	-0.73 (4)	-0.58 (7)	-3.00 (2)	0.78 (13)	0.99 (13)	0.94 (13)	0.05 (12)	0.16 (8)	0.25 (3)	0.23 (3)	0.02 (13)
Fruits	-0.31 (13)	-0.14 (13)	-0.05 (12)	-1.65 (6)	1.05 (9)	1.15 (8)	1.00 (10)	0.15 (7)	0.11 (10)	0.09 (9)	0.04 (8)	0.05 (7)
Export crops	-0.27 (14)	-0.12 (14)	-0.19 (10)	0.01 (13)	0.39 (14)	1.02 (11)	0.91 (14)	0.11 (8)	0.50 (3)	0.83 (1)	0.81 (1)	0.02 (12)
Cattle & milk	-0.42 (9)	-0.22 (10)	-0.18 (11)	-1.20 (9)	1.71 (6)	1.52 (6)	1.05 (8)	0.47 (3)	0.44 (4)	0.10 (8)	-0.15 (12)	0.25 (3)
Other livestock	-0.37 (11)	-0.17 (12)	-0.03 (14)	-1.21 (8)	0.93 (11)	0.99 (14)	0.94 (12)	0.04 (13)	0.09 (13)	0.08 (10)	0.06 (7)	0.03 (11)
Fish	-0.34 (12)	-0.18 (11)	-0.03 (13)	-1.07 (10)	1.09 (8)	1.06 (10)	1.00 (11)	0.06 (11)	0.10 (12)	0.05 (11)	0.02 (9)	0.03 (9)

Source: Authors, based on results from Rwanda CGE model.
Notes: Poverty rate is the share of population with consumption levels below the $1.90 poverty line. Poverty gap is the cumulative distance between poor people's consumption levels and the poverty line. Hunger is the share of population with daily food consumption levels below the required minimum calories defined by FAO. The Reference Diet Deprivation (ReDD) index measures the gap between household consumption of six major food groups and the estimated cost of a healthy diet, and is reported above as the percentage change in ReDD index. AgGDP+ is agrifood system GDP including primary agricultural GDP (AgGDP) and off-farm AFS GDP (FSGDP_N). AgEMP+ is agrifood system employment including employment in primary agriculture (AgEMP) and off-farm AFS employment (FSEMP_N). Changes in all outcome indicators are expressed per unit of agricultural GDP growth driven by productivity growth in a targeted value chain. Two poverty growth elasticities and hunger growth elasticity measure percentage-point changes in the poverty headcount rate, poverty gap, and hunger headcount rate with one percent growth in agricultural GDP. The diet deprivation growth elasticity (DGE) measures the percentage change in the Reference Diet Deprivation (ReDD) index a percent agricultural growth. Values of outcome indicators for various GDP in billion $US and employment in million persons are measured in one $US billion of increase in value-added of a value-chain.

Poverty headcount rates focus simply on the share of people that live below the poverty line, whereas poverty gaps measure how far poor people are, on average, from that poverty line. Poverty gaps therefore better reflect the depth of poverty. Measures of the poverty gap effect of growth are shown in the second column of Table 4. With all indicator values being negative, it shows that growth in agricultural value chains not only helps some poor households move out of poverty (as shown by the reduced poverty rates in Column 1), but also benefits extremely poor households that continue to be poor as the poverty gap is improved (Column 2).

Note that value chain development that lifts those people just below the poverty line out of poverty and hence impacts the poverty headcount rate may not necessarily be similarly effective in improving the lives of the poorest of the poor and therefore reducing the depth of poverty. As such, while the ranks between Columns 1 and Columns 2 are close, there are several exceptions worth noting. For example, the beans value chain ranks seventh in reducing the poverty headcount rate (Column 1) but ranks third in reducing the poverty gap (Column 2). In this case, these figures imply that higher productivity in bean production equally benefits all poor households across the lower portion of the income distribution *more than* its effect on households close to the poverty line.

Next, we examine results for impacts on hunger and dietary quality, which are shown in the third and fourth columns of Table 4. Again, hunger status is improved with growth led by all value chains. Moreover, because hunger is measured by calorie intake, food crops that are high in calories are often more effective in reducing hunger. The fourth column of Table 4 reports the estimated diet-deprivation impact of growth. As explained earlier, a decrease in the ReDD index indicates a narrowing of the gap between households' dietary quality outcomes and the reference healthy diet.

The signs are mostly negative in Column 4 of Table 4, indicating that most value chains are effective at improving diet quality, although the value chains of other root crops and export crops stand out as exceptions. Other root crops include cassava and sweet potatoes, as well as plantains, and they are already a dominant food group in Rwanda. As such, expanding production of these crops reduces dietary diversity and shifts consumption away from other food groups in the reference diet. Similarly, promoting export crops may contribute to household welfare through income-side effects, but it cannot lower prices for foods and hence is unlikely to have significant diet quality impacts. These results are represented by positive values of change in the ReDD index in the fourth column of Table 4 for other root crops and close to zero for export crops. Among the studied 14 value chains, groundnuts and vegetables are the two most effective value chains at improving diet quality in Rwanda, as indicated by the large negative change in their associated ReDD index values.

Next, we examine the GDP impacts resulting from productivity growth in production of primary commodities in the different value chains. Columns 5–8 in Table 4 report the results. Here, it is worth noting that although each scenario is designed to simulate productivity growth in the production of a specific value chain's primary commodity, this does not imply that all additional GDP occurs only within the primary agricultural component of the simulated value chain. Moreover, increasing productivity growth in a specific agricultural subsector alone can benefit or hurt other agricultural sectors depending on the changes in the relative prices across agricultural products as well as changes in the returns to land and capital and wage rates.

In the fifth column of the table, the GDP effects are measured by growth multipliers, i.e., what the gains of total GDP (measured in billions of US dollars) are expected as when agricultural growth occurs in a value chain (measured by its increased value-added of one billion dollars on-farm). Figures in this column show that GDP growth multipliers are greater than one for most value chains, indicating that increases in GDP are more than the additional value-added of one billion dollars on-farm within a value chain. Taking the first row for maize as an example, its GDP growth multiplier is valued at 2.18 (Column 5), which means that with one million dollar increase in value-added of maize production resulting from productivity growth, total GDP increases by 2.18 million dollars. A total of 1.18 million of that GDP is outside maize production's own value-added increase, i.e., these are the gains coming from the maize value-chain's off-farm components and from other value chains. In this regard, other cereals have the largest GDP growth multiplier effect (3.43) followed by rice (3.35).

The sixth column of Table 4 highlights the AFS GDP (AgGDP+) growth multipliers. AgGDP+ is part of GDP. Comparing the values between GDP and AgGDP+ multipliers in a same row (for the same value chain), we note that for some value chains, the multiplier value for AgGDP+ is larger than for GDP, e.g., maize, other cereals, or soybeans. For other value chains, it is opposite, e.g., rice, groundnuts, and cattle and milk value chains. When the value of the AgGDP+ multiplier is larger than the GDP multiplier, it means that part of growth in the AFS is at the cost of crowding out nonagricultural sectors outside the AFS. Obviously, it is unlikely that promoting some agricultural value chains alone will have strong impacts both within and outside the AFS: additional growth outside the AFS also needs policies, investments, and programs that target nonagricultural sectors beyond the AFS.

It is worth pointing out that the soybean value chain takes second place in AFS GDP growth impact with one billion dollars of additional soybean value-added generating 3.07 billion dollars of gains in total AFS GDP, of which 2.70 billion are within agriculture and 0.37 billion are off-farm within the AFS. Soybeans are mainly used as an input to the livestock feed sector in the model, and an additional 1.7 billion dollars of agricultural GDP gains (excluding the one billion for soybean value-added itself) come both from the livestock sectors that benefit from lowered feed cost from soybeans, and from other crops benefiting from land released from soybean production due to its higher productivity.

Column 7 of Table 4 shows the agricultural GDP growth multiplier. While value-added of all targeted value chains is part of agriculture GDP (AgGDP) in Column 7, this column shows that the change in the value of AgGDP is less than one for three value chains: vegetables, export crops, and other livestock. When the value in Column 7 is less than one, it indicates a *crowding-out effect* of promoting a specific value chain. Taking the vegetables value chain as an example, additional one billion dollars of vegetables value-added through the sector's productivity growth result in only 0.94 billion dollars of agriculture GDP, indicating that some non-targeted agricultural sectors are hurt when vegetables compete with these sectors for land. The total amount lost from such agricultural value added is about 60,000 dollars.

On the other hand, many value chains promote growth within agriculture *beyond* their own sectors. The other cereals value chain is a typical example. Column 7 indicates that an additional one billion dollars of value-added in other cereals resulting from productivity growth leads to 3.20 billion dollars more agriculture GDP, of which 2.20 billion comes from other agricultural sectors. To understand why, note that the vegetables are exportable while other cereals are import substitutable. Higher productivity in vegetables makes this value chain more competitive in trade, while increasing exports causes more land to move into vegetable production, reducing the production of other crops. On the other hand, other cereals are import substitutable, and higher productivity allows them to compete with imports without necessarily increasing the use of land. Also, the income elasticity of demand for other cereals that includes sorghum is relatively low compared to the high-value agricultural products such as vegetables. Land can be released from other cereal production at higher productivity levels when the income elasticity of demand is low, benefiting other crops to expand production and leading to a larger multiplier effect from other cereals-led growth.

Although these effects are interesting, we are more interested in the possible off-farm growth gains within the AFS when productivity growth occurs in a targeted value chain. Column 8 of Table 4 captures such growth linkages from on-farm to off-farm in the AFS. Column 8 shows positive numbers for all value chains. This result indicates that agricultural growth in any value chain can benefit either the value chain's *own* off-farm component or the off-farm components of *other* value chains, although in certain situations such growth may hurt other value chains' on-farm component as we discussed in the previous paragraph. The growth gains of off-farm AFS are generally larger for the value chains requiring a certain degree of processing for consumption. Paddy rice, for example, needs to go through milling to become milled rice for consumption, and productivity growth in paddy rice generates the largest amount of off-farm AFS GDP in Column 8 of the table, i.e., one billion dollars of rice value-added created on-farm from higher rice productivity leads to one billion dollars of off-farm AFS GDP. On the other hand, Irish potatoes, which generally do not need to be processed for consumption (as they are currently used in Rwanda today), have the smallest linkage effect: one billion dollars of Irish potato value-added on-farm generates only 10,000 dollars of off-farm AFS GDP.

Next, we move to the impact on employment as shown in Columns 9–12 of Table 4. We begin with employment within agriculture (Column 11) to understand these results. The impact on agricultural employment is mixed, with farm employment falling for five value chains and rising among the other nine. With the export crops and soybean value chains as exceptions, increased on-farm employment from productivity growth in a value chain is very modest when there is such an increase. Given that the growth diagnostic discussed in the previous section shows that it is a common trend for labor to move out of agriculture into nonagricultural activities in the economic transformation process, we are more interested in off-farm employment impacts from value chain growth.

These impacts are reported in Column 12, which shows that off-farm employment in the AFS increases with growth led by each value chain. Moreover, for those value chains for which growth causes agricultural employment to fall, off-farm employment in the AFS often increases more. These results support the historical trends of labor moving from agriculture to non-agriculture, and also point out an important fact that jobs are often created off-farm instead of on-farm when agricultural productivity increases in the current agricultural transformation process.

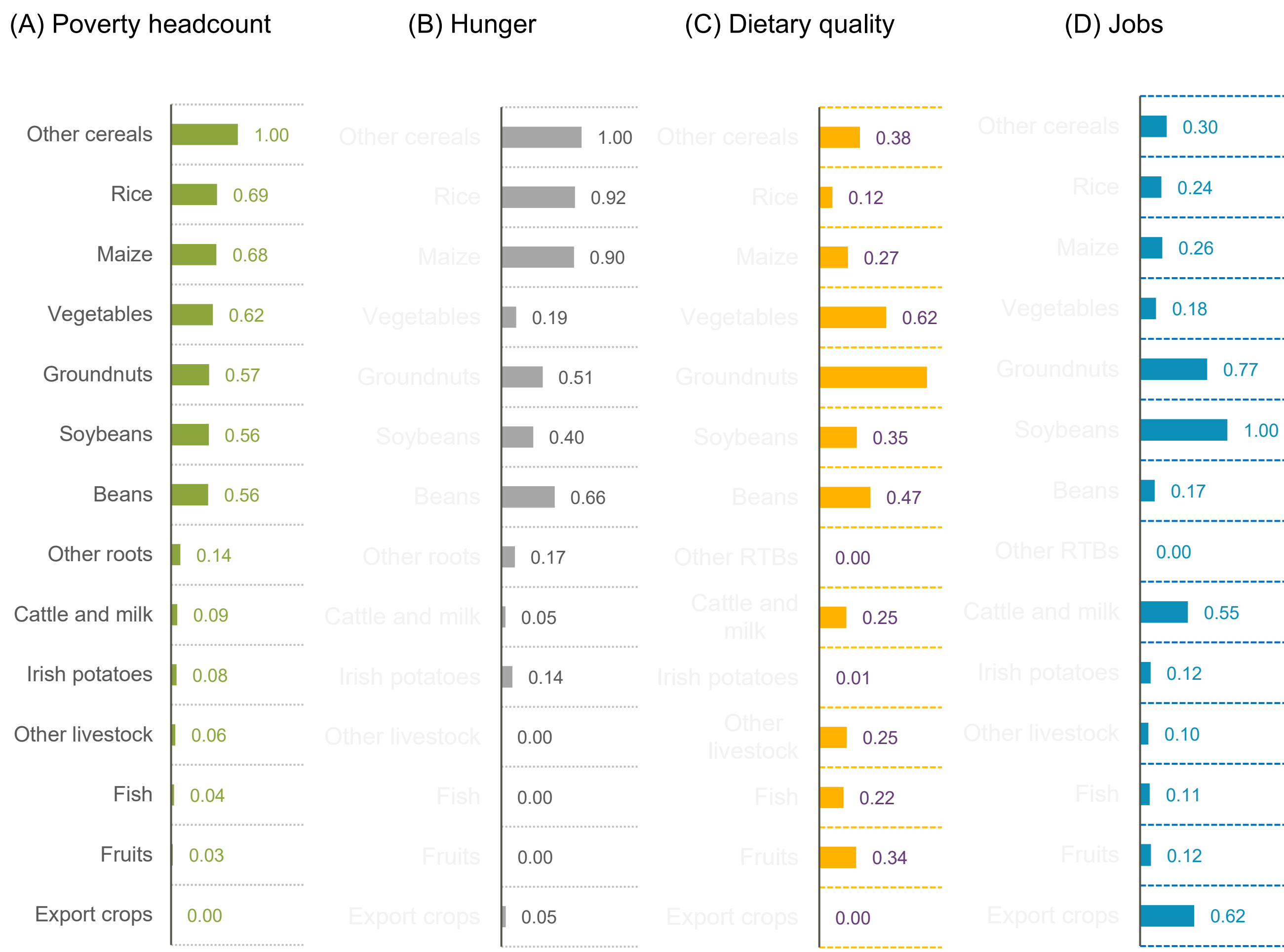
Taking these results together, Table 4 shows that the impacts of productivity growth across Rwanda's value chains differ for each outcome, and a given value chain's rank for one outcome indicator may differ substantially for another outcome indicator. Moreover, it is difficult to identify a single value chain with the highest rank among all outcome indicators. Thus, prioritizing value chains is difficult if we only use the results presented in Table 4. For this reason, we narrow our analysis down to four indicators in the next subsection.

Prioritizing value chains

Figure 9 compares the relative effectiveness of growth in each value chain in achieving four development outcomes: poverty, hunger, diet quality, and jobs. We do not include GDP growth for ease of interpreting the results shown in the figure. We chose changes in the poverty headcount rate for the poverty outcome and changes in total employment for jobs.

Since we are comparing outcomes with different units of measurement, such as poverty rate in percentage terms and employment in million persons, it is necessary to normalize the individual outcome scores to a uniform unit. Moreover, the values of the uniform unit for each outcome indicator are scaled so that the most effective value chain for a particular outcome indicator is given a score of one and the least effective is given a score of zero. Normalization to uniform scores does not alter the relative effectiveness of value chains within each outcome category, but it does make comparisons easier across outcome indicators. Recall that other cereals and export crops were, respectively, the most and least effective value chains in reducing national poverty in Table 4. They remain so after their poverty reduction effects are normalized, i.e., the score for other cereals value chain is one and zero for export crops value chain.

Figure 9. Comparing value chains by normalized scores for selected outcome indicators



Source: Authors, based on results from Rwanda CGE model.

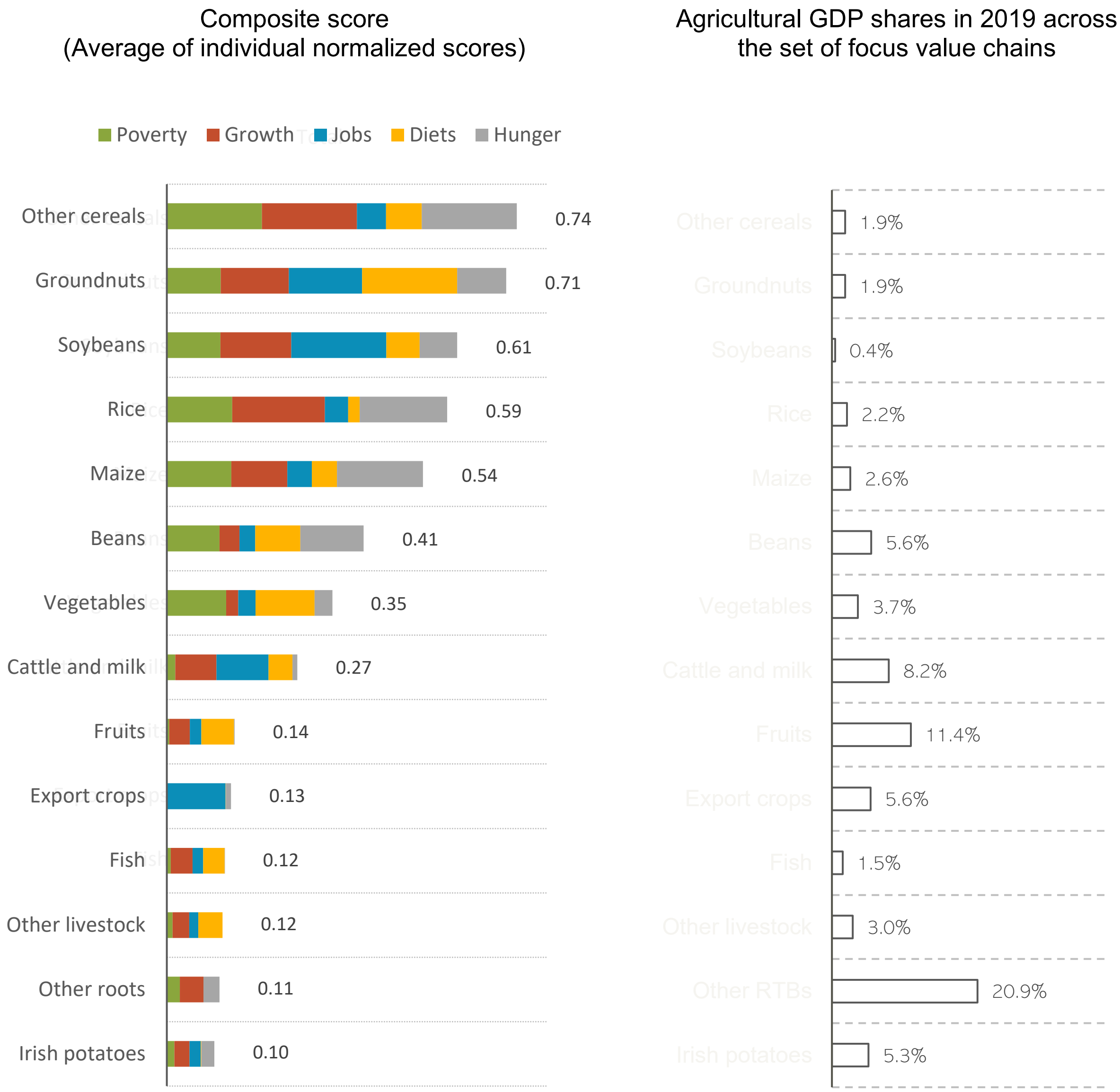
Note: Scores for each outcome category are normalized such that the value chain whose growth is most effective at improving that outcome has a score of one, while the least effective value chain has a score of zero. Jobs represent change in total employment including employment outside AFS.

The value chains in the four panels of Figure 9 are ranked based on the poverty score in Panel A, such that other cereals appear at the top of this panel. In fact, other cereals also rank at the top of Panel B. While the other cereals value chain is the most effective at reducing poverty and improving hunger, it is not the most effective at achieving the other two outcomes. Conversely, the soybean value chain is most effective at increasing total employment, and the groundnut value chain is most effective at improving diet quality, but both are less effective at reducing poverty and improving hunger. Intuitively, the result for the soybean value chain reflects the fact that soybeans are an input to livestock feed production and are not directly consumed by households, while groundnuts are consumed directly by households, helping to improve the current diet gaps in protein and edible oil consumption.

This variation across outcomes indicates the trade-offs in value chain development for achieving different development outcomes and reiterates our finding that there is no single value chain that is the most effective at achieving every development outcome. Promoting several value chains jointly to diversify agricultural growth is likely the optimal strategy for achieving inclusive agricultural transformation in Rwanda.

Identifying which value chains are the most effective also depends primarily on the importance (weights) attached by policymakers, politicians, or Rwandan citizens to each outcome. We consider one option in Figure 10 to show composite scores estimated by assuming that each of the five outcome indicators are *equally* important. In other words, the composite score in the left panel is a simple average of the four normalized scores in Figure 10 plus a normalized score for total GDP that is not included in Figure 10. The value chains are reranked based on the composite score, and the colors in the figure indicate the contribution of each outcome to each value chain's final score. The other cereals value chain, for example, is the highest ranked value chain for three of the five outcomes (poverty, hunger, and GDP) and emerges as the top-ranked value chain overall, despite having less impact on improving dietary quality or creating jobs. Groundnuts, soybeans, and rice also all have relatively high value in the composite scores.

Figure 10. Composite score and ranking based on equally weighted outcomes



Source: Authors, based on results from Rwanda CGE model.
Note: Composite score is a simple average of the normalized scores for the five focus outcome indicators (see Figure 9 for four of the five indicators). Growth is in total GDP and jobs are for total employment.

The analysis suggests that, if outcomes are equally important, many crops and livestock products that are currently identified and prioritized by PSTA 4 are supported by the model results. For example, soybeans, rice, maize, and beans are all prioritized in PSTA 4, and they all rank highly in this figure.

However, Irish potato, which is a cash crop that receives considerable attention in PSTA 4, ranks at the bottom because it is mainly consumed directly and offers little opportunity for value-addition off-farm, and also makes little contribution to improving dietary quality. There may be investments that could change this pattern, for instance, increased use of post-harvest storage infrastructure, or processing into chips and other uses, or the widespread introduction of nutrient-dense biofortified potato. But currently, there is little use of post-harvest infrastructure, insufficient investment in value-added processing, and no immediate expectation of biofortified potato being released in Rwanda. As such, considerable growth in these areas would have to be realized to improve the Irish potato value chain's effectiveness in improving outcomes.

Export crops of tea and coffee also rank low because the main exports of such products do not go through a processing stage in Rwanda, thereby lowering its contribution to off-farm AFS in value addition and jobs. Like Irish potato, export crops make little contribution to improving dietary quality, with the added challenge that these export crops also make little contribution to reducing poverty and hunger.

Other root crops also rank low and have limited contribution to diet quality improvement and employment. Unfortunately, other root crops make up the largest share of the existing agricultural sector (Panel B), which may highlight the need for more rapid diversification away from such crops.

But despite these challenges found in certain value chains, agricultural growth in Rwanda is generally pro-poor, has features that are improving hunger and diet, and is contributing to broad economic growth and job creation. What requires more attention is the fact that sources, drivers, and patterns of agricultural growth matter for the pace and inclusiveness of agricultural transformation. This underscores the need for a data-driven, evidence-based policy and a diverse investment portfolio of value chains to drive future agrifood growth in Rwanda.

CONCLUSION

Rwanda's economy grew rapidly during the past two decades. This growth contributed to significant social and economic gains, including reductions in poverty and hunger. In this report, we used SAMs and an economywide CGE model from Rwanda to understand the structure of Rwanda's current and evolving agrifood system and its contribution to the country's structural transformation and development objectives. Specific attention is paid to crop and livestock value chains that are central to the country's agrifood system, and to the interlinkages between primary agriculture, non-farm components of the agrifood system, and the wider economy. These linkages allow us to simulate the impact of productivity growth on economic growth, poverty, hunger, dietary quality, and employment outcomes.

During the next decades, it is expected that these economywide linkages will grow in importance as labor moves into more productive non-farm activities, as investment increases in agro-processing and other sectors of the economy, and as public spending is prioritized to further accelerate Rwanda's generally pro-poor, pro-growth economic and agricultural transformation process.

The overarching findings of this paper suggest that the transformation process will not occur on its own. The Government of Rwanda and its development partners will continue to make difficult but necessary decisions about priorities in supporting and promoting different agricultural value chains – exportables, importables, and nontradeables – taking into consideration the important contribution that domestic demand makes to achieving multiple outcomes. Decision-makers will also have to think more about the composition of a balanced portfolio of value chain investments that helps to realize Rwanda's ambitious development goals. They will also have to give greater attention to which development outcomes they want to prioritize, recognizing that no single value chain can achieve all outcomes effectively, and that different actors within the agrifood system's policy landscape may strongly prefer one outcome over others.

The diagnostic of the past performance of Rwanda's agrifood system across value chains provides an informative background for the design of forward-looking value chain development scenarios and in understanding more about what is needed for Rwanda's agrifood system to enhance its contribution to the country's development. The Rwanda CGE model and its underlying RIAPA model is a useful analytical tool for this kind of analysis. By identifying alternative sources of agricultural growth that impact multiple development outcomes, the model quantitatively measures the synergies and trade-offs in the inclusiveness of agricultural transformation.

Our findings indicate that value chains differ considerably in their effectiveness in achieving development goals and there are significant trade-offs among different development goals from promoting a specific value chain. The value chains that have a larger contribution to GDP or jobs are not necessarily effective in reducing poverty or improving dietary quality such as coffee and tea, while value chains that play an important role in improving dietary quality may make less contribution to job creation such as vegetables or fruits. Choosing a single value chain to achieve all development objectives seems to be unrealistic for any country to pursue, and a more pragmatic or realistic strategy requires choosing a portfolio of value chains that complement each other across different development goals.

More research on understanding the value chain constraints and innovations is important to expanding both public and private investment in value chain development. This includes more research on market dynamics, including emerging patterns of consumer demand, market competitiveness and industry structure, opportunities posed by technology and innovation, and trends in trade and finance. Nevertheless, our analysis of the measurable characterization, historical patterns, and drivers of agrifood system growth in Rwanda lays the foundation for further analyzing agrifood systems and policies, investments, and programs to facilitate an inclusive structural and agricultural transformation for the country.

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Annex

Table A1: Agricultural products in 2019 SAM and their mapping to value chain groups

Product group	Individual products in the SAM and shares of group's agriculture GDP
Maize	Maize 100%
Rice	Rice 100%
Other cereals	Sorghum & millet 93.5% | Wheat & barley 3.5% | Other cereals 3.1%
Beans	Pulses 100%
Groundnuts	Groundnuts 100%
Soybeans	Other oilseeds 100%
Irish potatoes	Irish potatoes 100%
Other root crops	Cassava 49.7% | Sweet potatoes 23.4% | Other roots 12.4% | Cooking bananas 14.5%
Vegetables	Leafy green vegetables 27.9% | Other vegetables 72.1%
Fruits	Nuts 2.4% | Sweet bananas 59.8% | Other fruits 37.8%
Export crops	Leaf tea 37.4% | Coffee 61.1% | Cut flowers 1.5%
Other crops	Sugarcane 82% | Tobacco 6.3% | Other crops 11.7%
Cattle and milk	Cattle meat 45.6% | Raw milk 54.4%
Other livestock	Poultry meat 27.8% | Eggs 18.8% | Small ruminants 35.8% | Other livestock 17.6%
Fish	Aquaculture 15.5% | Capture fisheries 84.5%
Forestry	Forestry 100%

Source: Authors, based on data from the 2019 Rwanda SAM.

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