UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

UNCTAD

TEACHING MATERIAL ON

TRADE AND GENDER LINKAGES:

THE GENDER IMPACT OF TECHNOLOGICAL UPGRADING IN AGRICULTURE

UNITED NATIONS

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

UNCTAD

TEACHING MATERIAL ON

TRADE AND GENDER LINKAGES:

THE GENDER IMPACT OF TECHNOLOGICAL UPGRADING IN AGRICULTURE

UNITED NATIONS
Geneva, 2020

United Nations Publications
405 East 42nd Street
New York, New York 10017
United States of America

Email: publications@un.org
Website: shop.un.org

United Nations publication issued by the United Nations Conference on Trade and Development.

UNCTAD/DITC/2020/1

ISBN: 978-92-1-112984-7
eISBN: 978-92-1-005119-4
Sales no.: E.20.II.D.22

ACKNOWLEDGMENTS

This module was prepared by an UNCTAD team including Elizabeth Ramey (lead author) and Chiara Piovani. Comments and suggestions were provided by Bob Bell Jr., Katalin Bokor, Laura Cyron, Claudia Contreras, Angel Gonzalez-Sanz, Katerina Joklova, Mariangela Linoci, Dong Wu, and Simonetta Zarrilli at UNCTAD; and by Valentina Franchi, Flavia Grassi, Maria Magdalena Heinrich, Jamie Morrison, Tacko Ndiaye, and Ide Nozomi at the Food and Agriculture Organization of the United Nations. Comments were also provided by Nursel Aydiner Avsar.

The module was coordinated and supervised by Simonetta Zarrilli, Chief of the Trade, Gender and Development Programme at UNCTAD.

David Einhorn was in charge of English editing.

The publication of this module was made possible by the financial support of the Government of Finland, which is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF BOXES

LIST OF FIGURES

LIST OF TABLES

1. Introduction

This study examines the nexus between technology in agriculture and trade from a gender perspective. It is part of the teaching package on trade and gender prepared by the United Nations Conference on Trade and Development (UNCTAD)[1], though it also serves as a stand-alone module.

The study begins with an overview of the relationship between trade and gender that will provide the reader with the basic foundational concepts. It then explores the opportunities for women and the challenges they face in the process of technological innovation and adoption in agriculture. Typically, women face many barriers in access to agricultural technologies, and those technologies that are available often fail to address women's particular needs. This study aims to understand how inequality in the process of innovation and dissemination of technology affects women's access to trade in agriculture, and to evaluate how reducing this form of inequality could strengthen women's opportunities to participate in and benefit from trade-related activities in the sector. Access to appropriate technology and the capacity to use it effectively are important factors to support women in agriculture, both as instruments for women to undertake new productive initiatives and/or to expand existing activities in agrifood value chains.[2]

The next section provides an introduction to the role of gender in the economy, with an emphasis on the multiple dimensions of gender inequalities and the economic relevance – apart from reasons related to human rights and social justice – of pursuing gender equality. Section 3 presents the two-way relationship between gender and trade: gender-based inequalities affect trade outcomes and trade has gender-differentiated effects. Section 4 begins a gender analysis of technology in agriculture and trade with an overview of women's roles in agriculture, and Section 5 then examines the interplay between agricultural technology and trade. Section 6 discusses various kinds of technologies in agriculture, and explores how technology can help support the participation of women in agrifood value chains (from production to storage, processing, packaging, and distribution) and foster ecological sustainability. This section also examines the channels through which agricultural technologies can impact women's participation in agricultural trade. Section 7 examines the barriers constraining women's adoption of technology. The final section concludes and offers policy recommendations.

At the end of this module, students should be able to:

- Understand why gender matters in the economy
- Describe the interplay between gender and trade
- Appreciate the impact of gender inequalities in agriculture on trade outcomes
- Understand the relationship between technology and trade in agriculture, and explain why it matters in the process of economic development
- Know the types of technologies – from basic to advanced digital – used in agrifood value chains (from production to harvest and post-harvest) and in sustainable agriculture
- Appreciate the effects of agricultural technology on women's participation in trade
- Identify the constraints influencing women's adoption and use of agricultural technologies, as well as possible solutions
- List policy recommendations to foster women's access to technology and trade in agriculture.

2. Gender in the economy: Key concepts and relations

The concept of *gender* refers to the social norms and practices that ascribe different rights, opportunities, and responsibilities to men and women based on their sex, and typically assign an inferior status to those born female. Gender, in contrast to sex, is not the result of a "natural" distinction, but rather is a socially constructed category that assigns specific gender-based characteristics and behaviors to men and women in the household, the economy, and the society at large based on the system of norms, customs, and beliefs that prevail in each specific socio-cultural context. Gender-based differences in a society are then compounded by other social stratifiers, such as class, age, race, and ethnicity.

In this analysis, the focus is on the gender biases that may prevent women from accessing the same economic opportunities and roles as men. In this context, the term "gender inequality" refers to barriers that create economic disadvantages for women (e.g. limited or lack of land ownership); in contrast, the term "gender equality" refers to equitable treatment of men and women. According to UN Women, "Equality does not mean that women and men will become the same but that women's and men's rights, responsibilities and opportunities will not depend on whether they are born male or female. Gender equality implies that the interests, needs and priorities of both women and men are taken into consideration, recognizing the diversity of different groups of women and men."[3]

By focusing on the multiple forms of gender biases that impact economic outcomes, this study examines the economy as a "gendered structure." This means that it explicitly identifies and accounts for the various forms of gender inequalities that underlie economic institutions, relations, and transactions. By doing so, we acknowledge that gender inequalities lead to power imbalances between men and women, which have a critical impact on the economy. On the other hand, this also helps identify what changes need to occur to empower women and overcome existing gender inequalities.

Feminist economists have long contended that economic inquiry should not only deal with productive paid work (or "production," which is typically considered the exclusive domain of economics), but should also include unpaid work (also referred to as "reproduction" or "unpaid care work"). Housework, cooking, child care, elderly care, collecting water and fuel, and attending any other physical or emotional need within the household or the community constitute essential supportive activities, which critically contribute to both social welfare and the steady functioning of the paid economic sphere. Based on traditional gender norms, it is women who handle the bulk of responsibilities in these non-market activities. On the basis of traditional economic analysis, however, this work is invisible and has no economic relevance (Razavi, 2007).

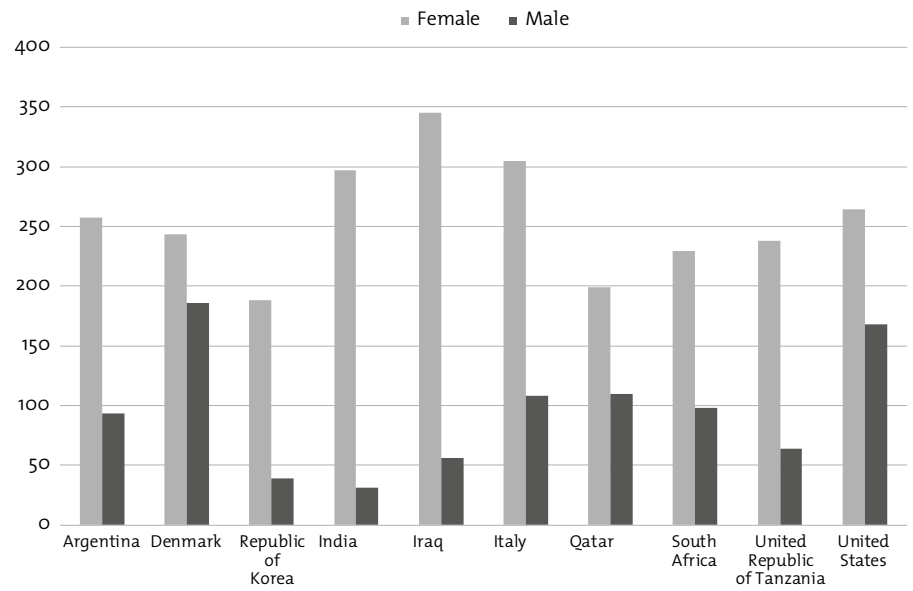
To grasp the magnitude of unpaid work, which tends to be invisible in the official statistics, time-use surveys have become a key source of information. Figure 1 shows the average amount of time men and women spend each day on unpaid care work in selected countries across the world. As defined by ILO (2018a), unpaid care work includes domestic services for own final use within the household, caregiving services within the household, and community services and help to other households. In India, women spend on average close to five hours per day on unpaid work, as compared to men who only spend about half an hour. For Argentina, the corresponding figures are four hours and one and a half hours. In both developing and industrialized countries, women consistently hold the primary responsibility of unpaid work.

As women are expected to hold the lion's share of unpaid care work, they are constrained in their capacity to access the paid labour market at par with men. Figure 2 shows the ratio of female to male labour force participation in different world regions. The highest ratio is observed in sub-Saharan Africa (85 per cent) and the lowest in the Middle East and North Africa (30 per cent). Consistently, on average, a smaller share of women compared to men engages with paid work.[4]

On average, prevailing gender norms all over the world tend to support a gender division of labour that primarily associates women with the sphere of reproduction and men with the sphere of production. Gender biases also affect women's participation in the paid economy, resulting both in "horizontal" and "vertical" gender segregation of the labour market. "Horizontal gender segregation" refers to the observed pattern that sees women concentrated in fewer sectors than men – such as food production in agriculture, textiles and garments in manufacturing, and social services in the tertiary sector. "Vertical gender segregation" (also called the "glass ceiling effect") refers to women's underrepresentation in leadership and decision-making positions. Figure 3 presents data on women's representation in parliaments and in managerial positions. In all world regions, the female shares lie between about 10 and 40 per cent. Male dominance in leadership positions is especially marked in Arab States and South Asia.

Figure 1

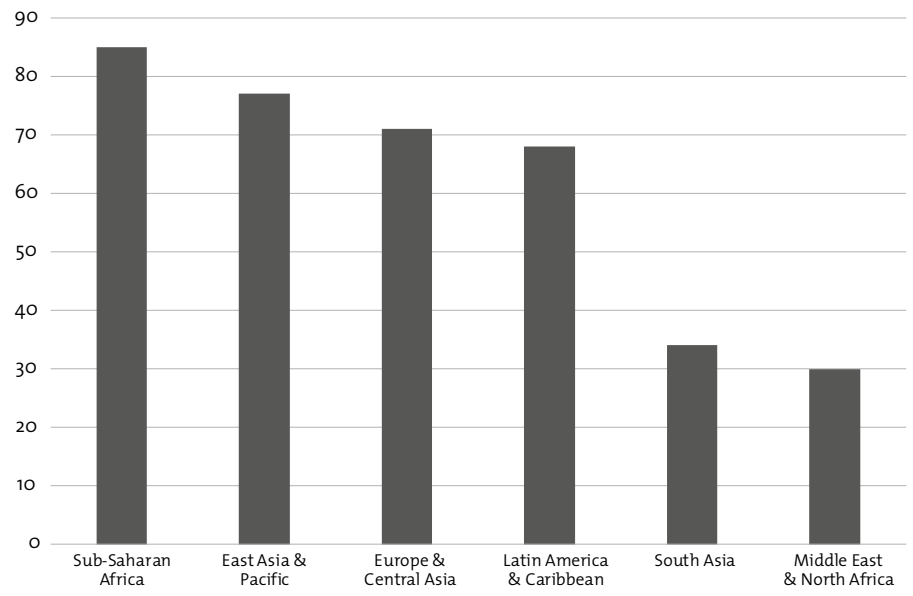
Average time (minutes) per day spent on unpaid work by sex, selected countries



Source: ILO (2018a).
Note: Data based on most recent year available.

Figure 2

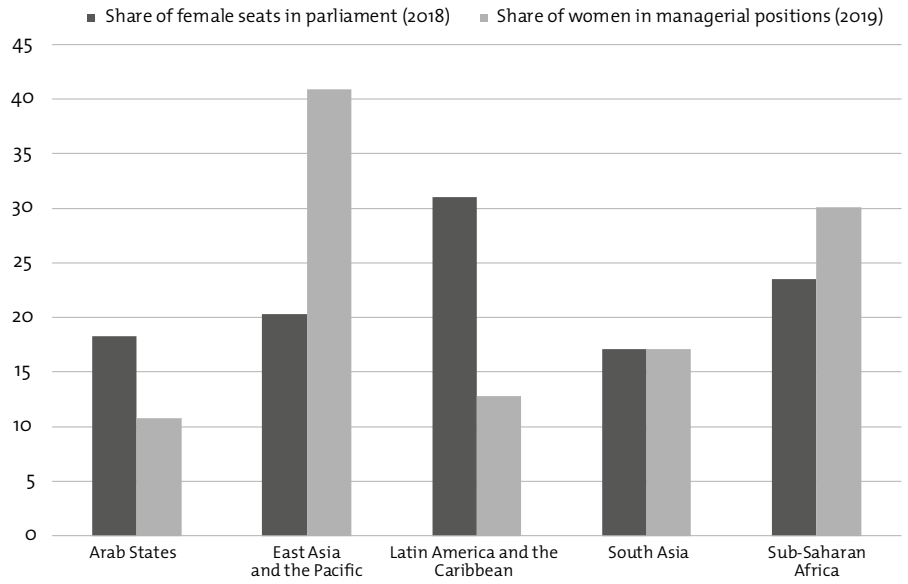
Ratio of female to male labour force participation rate by region, 2019 (per cent)



Source: World Bank, World Development Indicators (2020).

Figure 3

Female representation in leadership positions by region, latest year available (per cent)



Sources: UNDP (2019) and ILOSTAT (2020).

Women are also more likely than men to search for flexible job arrangements to be able to combine paid work with care responsibilities, which may greatly affect their career and income opportunities and, in turn, their capacity to access credit and other productive resources. Much more than men, women thus face the "double burden" of holding both paid and unpaid work. This means that women are more likely than men to search for part-time employment and/or hold more precarious forms of work.

Table 1 provides examples of the gender disparities with respect to part-time employment. Typically, women work far more often in part-time jobs than men. Alternatively, because of the lower pay associated with these types of jobs, women may even decide to not engage with paid work, which makes them dependent on the income of their husband (or other male family members) and therefore vulnerable.

To evaluate the nature of work, the International Labour Organization (ILO) provides international, sex-disaggregated data on employment status. As shown in Figure 4, women constitute a smaller share of employers and a larger share of "contributing family workers" (also known as unpaid family workers) than men.[5] In relation to the latter category, the gender gap is particularly striking in South Asia, where women account for 33.5 per cent of

Table 1

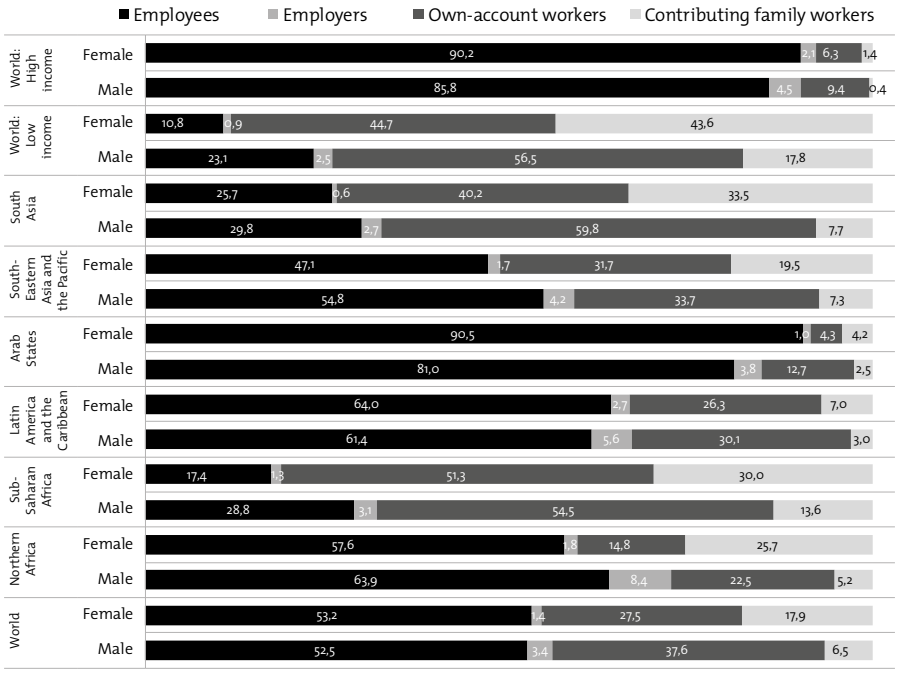
Part-time employment by sex, selected countries, 2018 (per cent)

	Part-time employment, female (per cent of total female employment)	Part-time employment, male (per cent of total male employment)
Argentina	52.0	26.8
Brazil	35.5	21.0
Egypt	21.2	11.8
Euro area	50.5	25.9
Indonesia	42.1	25.8
Namibia	30.9	20.3
South Africa	20.9	11.8
Sweden	53.3	38.8
Turkey	33.4	18.0
United States	28.0	16.5

Source: World Bank, World Development Indicators (2020).

Figure 4

International distribution of total employment by status and sex, 2019 (per cent)



Source: ILOSTAT (2020).

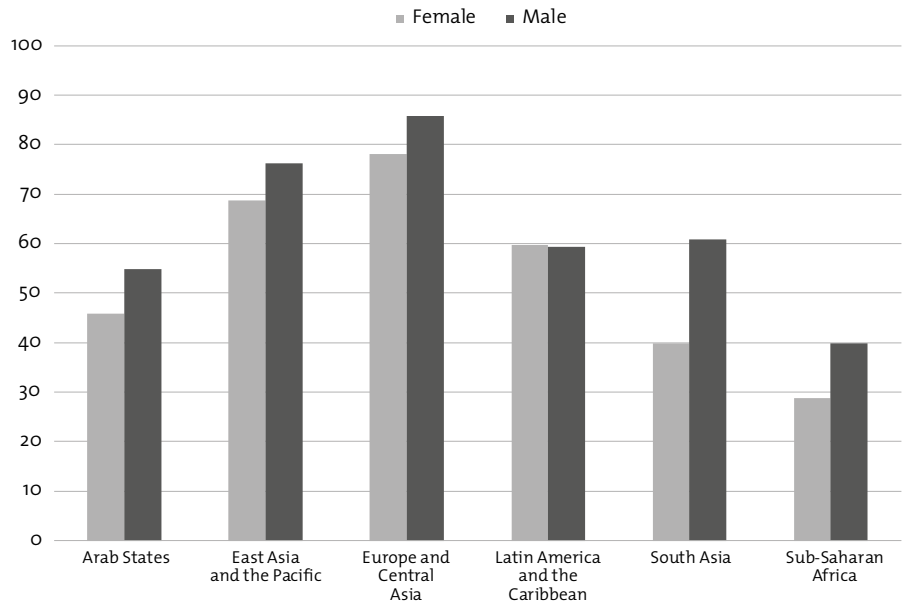
family work compared with about 8 per cent for men. Family work constitutes the most vulnerable form of employment, as it implies no independent access to income.

The traditional social norms associating women's primary role with the sphere of the household, in addition to constituting both horizontal and vertical gender segregation, underlie gender gaps in education and in access to economic assets and resources.[6]

Figure 5 shows the male and female population shares with at least some secondary education in different world regions. With the exception of Latin America and the Caribbean, women typically receive less education than men in all world regions.

Figure 5

Population with at least some secondary education, by sex and region, 2010–2018 (per cent)



Source: UNDP (2019).

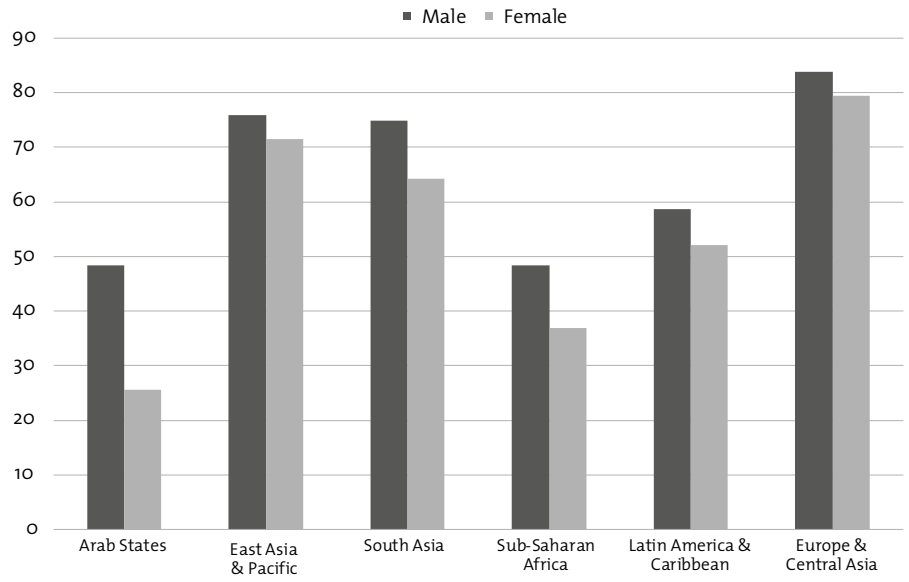
Note: Data refer to the most recent year available during the period specified. The population ages are 25 and older.

Figures 6 and 7 show that women – in comparison to men – engage less with financial institutions and financial transactions, and own a much smaller percentage of agricultural land. In many African and Asian countries, women face barriers to their right to own and inherit land due to statutory and customary law (World Bank, 2020).

The gender gaps in education and economic resources contribute to perpetuating the economic disadvantage of women. Women's lower education and knowledge, in particular in fields in which technological upgrading matters, may limit their competitiveness and ability to access skilled and better-paid employment opportunities. Because of more limited ownership of assets, women have no or less collateral to offer to banks, and so are constrained in their capacity to access credit and other financial services.

Figure 6

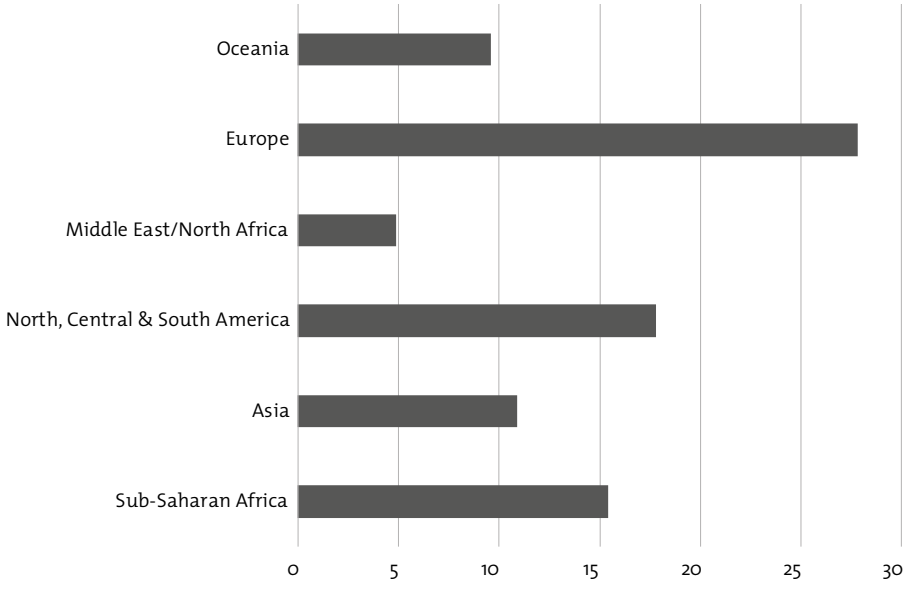
Proportion of adults (15 years and older) with an account at a bank or other financial institution or with a mobile money service provider, by sex and region, 2017



Source: World Bank, World Development Indicators (2020).

Figure 7

Female agricultural holders by region (weighted), 2015 (per cent of total agricultural holders)



Source: Food and Agriculture Organization of the United Nations, Gender and Land Rights Database (2015).

Data show that women's unequal access to economic inputs is a major factor behind the productivity gap between men and women. In the case of agriculture, for example, empirical evidence from different countries shows that women are as productive as their male counterparts, but because of fewer entitlements to land and limited access to inputs, they are less efficient and produce a lower volume of crops (FAO, 2011).

The disadvantage experienced by women in the economy is compounded by the gender gap in earnings. Historically, women's earnings are lower than men's either because of gender segregation (both horizontal and vertical) or because of direct gender discrimination. In some instances, the gap is also explained by women's socialization to accept their secondary role in the economy.

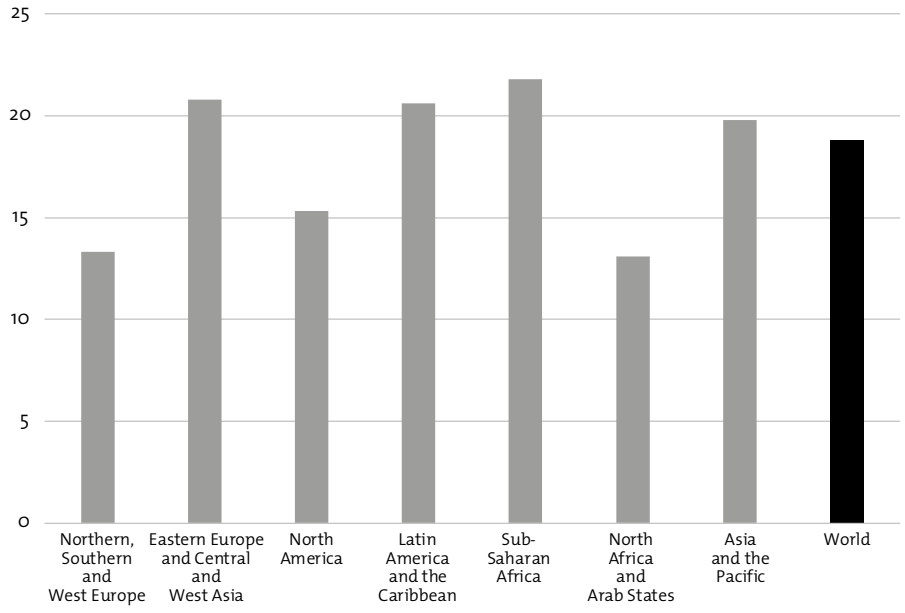
The traditional measure used to evaluate earnings from a gender perspective is called the "raw gender wage gap," which is calculated as the difference between the remuneration of men and women, measured as a ratio of the remuneration of men. A major constraint in the calculation of the gender wage gap across countries is data availability and cross-country comparability. When sex-disaggregated data exist, they are mostly available only for non-agricultural work and often only for the formal manufacturing sector (neglecting the informal sector). Also, often they are available monthly rather than hourly (which precludes taking into account the different number of hours spent in the paid sphere of the economy by men and women), and are affected by the inclusion or exclusion of overtime pay, bonuses, payments in kind, and other allowances.

To address some of these drawbacks, the ILO has developed an alternative measure of gender pay differences referred to as the "factor-weighted gender pay gap."[7] The first step of this methodology consists of disaggregating female and male workers in (relatively) homogeneous subgroups and estimating the gender pay gap in each subgroup.[8] The second step requires calculating the weighted average of all the subgroups' estimated gender pay gaps, with weights corresponding to the size of each subgroup in the total number of workers.[9]

Figure 8 shows regional-disaggregated data on the factor-weighted gender pay gap, as provided by the ILO (2018b). Around the world there are clearly gender disparities in earnings; on average, women are paid about 80 per cent that of men.[10] The largest portion of earning differentials between men and women cannot be explained by differences in either education or labour market characteristics (e.g. age, experience, occupation, or industry). Based on ILO (2018b), there are three drivers behind the unexplained share of remuneration gaps: women tend to have lower wage returns on education than men (for equal occupations as well); average wages tend to be lower in highly

Figure 8

Factor-weighted gender pay gap by region, 2008–2017 (per cent)



Source: ILO (2018b).

Note: Data are the most recent available.

Table 2

Gender Development Index by region, 2018

	Gender Development Index	Human Development Index		Life expectancy at birth (years)		Expected years of schooling (years)		Means years of schooling (years)		Estimated gross national income per capita (in 2011 PPP US$)	
		Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Arab States	**0.856**	0.634	0.74	73.8	70.2	11.7	12.3	6.4	7.8	5,338	25,343
East Asia and the Pacific	**0.962**	0.725	0.754	77.8	72.9	13.5	13.3	7.5	8.3	11,385	17,728
Europe and Central Asia	**0.953**	0.757	0.794	77.5	70.8	14.4	14.7	9.9	10.5	10,588	20,674
Latin America and the Caribbean	**0.978**	0.747	0.764	78.6	72.3	14.9	14.1	8.6	8.5	9,836	18,004
South Asia	**0.828**	0.57	0.688	71.1	68.5	12.0	11.6	5.0	8.0	2,639	10,693
Sub-Saharan Africa	**0.891**	0.507	0.569	62.9	59.4	9.3	10.4	4.8	6.6	2,752	4,133

Source: UNDP (2019).

Note: PPP: purchasing power parity.

feminized occupations and enterprises; and mothers tend to be paid less than non-mothers (also known as the "motherhood pay gap"). This finding points to the importance of national measures that promote equal pay between men and women, increase wages in feminized enterprises and industries, and reduce women's burden of family responsibilities through care policies and/or more equitable distribution of family duties between men and women (ILO, 2018b).

There are various aggregate indices to measure gender inequality. Among them, the Gender Development Index (GDI) is provided annually by the United Nations Development Programme (UNDP) in the *Human Development Report*. It is available both by country and by region, which allows for a regional comparative evaluation of gender disparities around the world.[11]

The GDI measures gender disparities in levels of human development, as measured by health, education, and income as part of the Human Development Index (HDI). The GDI is calculated as the ratio of women's HDI to men's HDI, so it can be interpreted as the percentage by which women achieve men's HDI. The GDI is calculated for 166 countries, which are then grouped in the regions indicated in Table 2. As shown, women's HDI is always below men's HDI; the largest gap is observed in South Asia (with women achieving 82.8 per cent of men's HDI). Important gaps can also be observed in the Arab States (85.6 per cent) and sub-Saharan Africa (90 per cent).

Box 1

Gender equality: International legal instruments and goals

The Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW) was signed by governments in 1979, entered into force in 1981, and has been ratified to date by 187 governments. CEDAW is the first legally binding instrument that prohibits discrimination against women in all domains. It is also the first document that states that women's rights are human rights. The convention is the first document that explicitly recognizes that urban and rural areas face different challenges. Article 14 of CEDAW revolves around rural women, spelling out the rights that should be guaranteed to women to ensure gender equality and, in turn, that development in rural areas should be inclusive.

The Beijing Declaration and Platform for Action (BDPfA) was signed in 1995 by 189 governments. The BDPfA is the first international legal instrument to incorporate a detailed set of strategic actions to ensure gender equality, which is identified as a matter of human rights and social justice, but also development and peace. The BDPfA revolves around 12 areas of concern: poverty, education and training, health, violence against women, armed conflict, the economy, power and decision-making, institutional mechanisms for the advancement of women, human rights, the media, the environment, and the girl-child.

Among the Millennium Development Goals (MDGs) – eight development goals set in 2000 to be achieved by 2015 – MDG3 focuses on gender equality and women's empowerment. Specifically, it aims "to eliminate gender disparity in primary and secondary education by 2005, and in all levels of education by 2015."

Since the expiration of the MDGs, the Sustainable Development Goals (SDGs) have been set to be achieved by 2030. They consist of 17 development goals that aim to end poverty, build sustainable economies, and ensure peace and prosperity for all people by 2030. Gender equality is a stand-alone goal (SDG5), but gender equality and women's empowerment are also integral to the fulfilment of each of the 17 SDGs.

Source: UNCTAD Secretariat.

Box 1 provides a review of the international commitments towards gender equality. Gender equality is a fundamental human right, but it is also central to social and economic development. As stated by UNDP, "Gender equality and women's empowerment are not add-on issues in the development dialogue, but a mainstream dimension of the development discourse locally, nationally and globally" (UNDP, 2016, p.41).

3. Gender and trade: A bi-directional relationship

There is a bi-directional relationship between trade and gender: on the one hand, trade outcomes vary by gender, in turn impinging on women's economic empowerment and well-being;[12] on the other hand, gender inequalities affect trade strategies for competitiveness, export performance, and trade policy effects. Let us examine both sides of this relationship.

Trade affects the distribution of income and resources, including between men and women, through various channels. First, trade may lead to changes in the structure of production, with export sectors expanding and import-competing sectors contracting. This, in turn, affects employment and workers' compensation. In the context of economic volatility and the dominance of multinational corporations in world markets, the quality and security of employment tend to be reduced, and small-scale producers and low-skilled workers often bear the largest burden. Second, trade leads to a change in the relative prices of goods and services, which generate changes in real incomes that affect groups of producers and workers differently. Finally, trade openness may lead to a reduction in tariff revenues, which may have gender-specific effects through the impact on the size and composition of government expenditure (e.g. a reduction in social programmes and infrastructure).[13]

Following conventional trade theory – based on the Heckscher-Ohlin-Stolper-Samuelson theorems – a country's comparative advantage is based on its factor endowments (typically, labour,– including low-skill vs. high-skill labour – or capital), and a country will export those commodities that use its abundant factor intensively. With trade liberalization, the demand in world markets for those commodities is expected to rise, which will raise the compensation to the relatively abundant factor that is used intensively in exports. As developing countries are abundant in unskilled labour (and women constitute the bulk of unskilled labour), based on conventional theory trade liberalization should raise the demand for women's labour (and lower the demand for male labour). In turn, women's wages should rise (and men's wages should fall). Based on this framework, trade liberalization thus helps promote gender equality.

These claims have been challenged both by heterodox economic theory and empirical evidence. Heterodox economic theory contends that in international markets firms compete based on absolute production costs (rather than relative costs, as argued by conventional theory).[14] Women thus may serve as a source of competitive advantage for export-oriented firms to keep labour costs low.[15] For this reason, women's labour demand is likely to rise, but without an increase in women's wages. Rather than promoting gender equality, trade may perpetuate or even exacerbate gender inequalities.

The historical evidence indicates that – following trade liberalization – female workers and producers are less likely to enter the expanding sectors (other than the traditionally female-dominated sectors such as garments) due to traditional gender norms and gender biases that limit women's access to productive resources and training. As a result, in the context of global integration, gender segregation has only marginally declined in developing countries. Female labour force participation has in fact increased, but a large share of women have remained concentrated in low-skilled activities, with little chance to access higher-value-added jobs that remain male-dominated.

In manufacturing and services, export sectors have experienced a phenomenon known as "feminization of labour." The term refers to both an increase in female employment – typically in labour-intensive, low-value-added, low-wage activities – and an extension of insecure working conditions, which have traditionally characterized female jobs, to male jobs (Standing, 1989, 1999).[16] As producers, women – because of lower access to capital, technical skills, and education, in addition to larger unpaid care responsibilities – are more likely to own more informal, smaller, and less profitable businesses than their male counterparts.

In agriculture, trade has had more mixed effects. Women are often perceived as secondary workers who are relatively easier to lay off due to their low bargaining power. Women are often found in subsistence agriculture, which – in open markets – can be displaced by cheap imports. Women as producers face more severe

challenges in accessing international markets than do men (due to greater difficulties in meeting technical requirements, regulations, accessing credit, etc.). Trade liberalization, however, may benefit women farmers by providing larger markets for exports as well as opportunities to be integrated into global supply chains as producers (see Section 4).

Moving to the impact of gender inequalities on trade, two dimensions should be considered: first, how gender inequality is used to promote export competitiveness and, in turn, economic growth; and second, how gender inequality hinders the capacity of women to become exporters and, thus, limits trade performance. Borrowing the terminology from van Staveren et al. (2007) and Elson (2007), female employees constitute a "source of competitive advantage" and "underachievers of competitive advantage" in their own enterprises, respectively.

As women tend to be paid less than men due to discriminatory gender norms and practices, female workers can be a source of price competitiveness for firms facing intense international competition (e.g. for export-oriented firms that have integrated into the low-value segment of global value chains (GVCs), and are under great pressure to fulfil orders). Since labour costs constitute a large share of total costs, the gender wage gap can be exploited to cut costs. Women also constitute a large share of dependent subcontract workers (i.e. "homeworkers"), who are poorly paid and lack social security benefits. This type of employment can also be exploited as a source of competitive advantage. Women workers have represented a key source of competitiveness for some developing countries in labour-intensive exports, but in the long run this it is neither a sustainable nor a desirable strategy. It can impact countries' terms of trade[17] and it is in conflict with the ILO's core labour standards and the United Nations Sustainable Development Goals.

As producers, women – often as small entrepreneurs or self- employed workers – face various types of discrimination due to patriarchal norms, traditions, and customary laws. This leads to gender inequalities in three domains: (1) health, nutrition, and technical and vocational training, in addition to holding the double role as expected caregivers and producers;[18] (2) access to resources and opportunities (e.g. property, credit, technology, etc.); and (3) security, as women often have to cope with gender-based violence. These sources of gender disparities seriously impair women's capacity to be as competitive as men in international markets.

The interplay between trade and gender shows the need to introduce gender provisions in trade agreements (e.g. equal working conditions for men and women). Towards these goals, collaboration among various government departments – with the participation of women's organizations in civil society and/or multilateral development cooperation programmes – can raise the prospects that gender concerns will be taken into account in trade policies. This would help enhance the economic participation of women, especially in the production of goods with higher-value-added content, in turn contributing to reduce vertical and horizontal gender segregation.

4. Women's roles in agriculture and trade

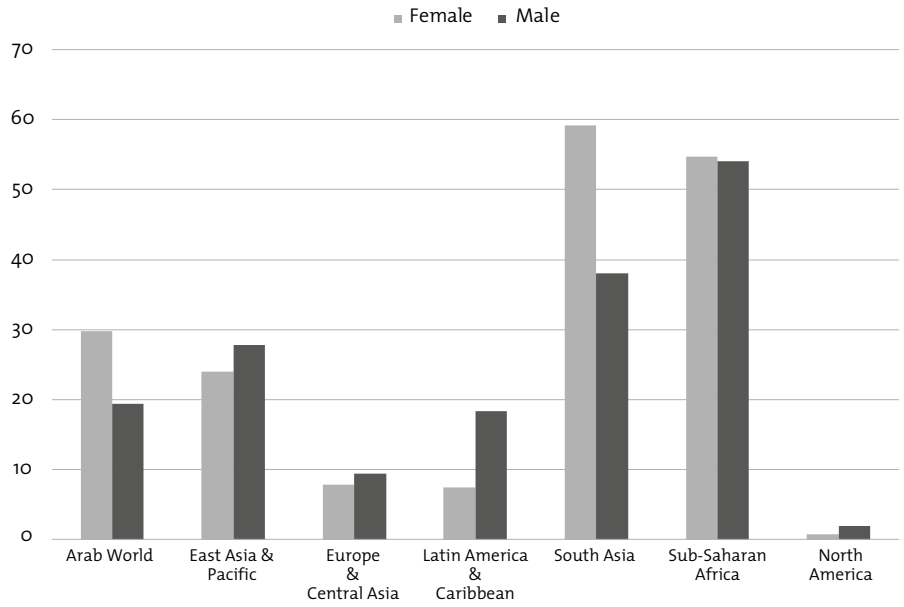
Women are involved in trade in the agricultural sector in multiple ways: as contributing family workers, as farmers on their own account, as entrepreneurs running on- and off-farm businesses, and as wage workers. Rural households in developing countries typically pursue multiple livelihood strategies to diversify their income sources. Thus, women (as well as men) are often simultaneously involved in a wide range of activities and contractual arrangements, and this is observed in virtually all agricultural subsectors. Different economic roles, therefore, often tend to blend together.

Women constitute over 60 per cent of the work force in agriculture in low-income countries and about 30 per cent in middle-income countries (World Bank, World Development Indicators, 2020). Based on data from the early 2000s, women were found to provide over 50 per cent of the world's food, and more than 80 per cent of the food in households and regions that are identified as food insecure (Shiva, 2009).

Figure 9 shows the shares of men and women employed in agriculture in different world regions. Agriculture is clearly a major source of employment for women in both South Asia and sub-Saharan Africa (about 60 and 55 per cent of total female employment, respectively). It also remains important in the Arab world and East Asia and the Pacific (30 and 24 per cent, respectively).

Figure 9

Employment in agriculture by sex and region, 2019 (per cent of female and male employment)



Source: World Bank, World Development Indicators (2020).

Women are highly involved in family farming, which remains by far the most predominant form of agriculture worldwide: almost 90 per cent of all farms globally – more than 570 million – are run by families and rely primarily on family labour (FAO, 2014, 2018c).

Both men and women in family farming in developing countries are involved in multiple income-earning activities as a livelihood strategy. Daily and seasonally, women work on the farm but are also engaged in off-farm income-generating activities, such as processing and sales. In contrast to men, however, women also perform a disproportionate share of unpaid agricultural work (IFC, 2013). Male relatives usually own the land and women do not have access to or control over the resources employed by the family business. Often, women have little decision-making power and do not have control over their earnings, which are often paid out to male relatives. Women's unpaid labour is critical to keep the cost of cash crop exports low, increasing their competitiveness in global markets.

Beyond farming, women constitute about half of the labour force in small-scale fisheries, and an estimated 290 million women and girls rely on livestock to generate income (FAO, 2016b, 2018g). Women also play a leading role in small-scale aquaculture production and processing, where household-based enterprises led by women are becoming increasingly common (FAO, 2016b). In many countries, women are also highly involved in the forestry and agroforestry value chains, although the lack of sex-disaggregated data make it difficult to provide global estimates on the degree of their participation (FAO, 2013).

Although agriculture is key for women's livelihood, men and women tend to hold different economic roles in the sector due to various forms of gender bias. Following the traditional gender division of labour – which assigns to women the lion's share of unpaid care work and to men the leading role as income providers[19] – women tend to be disproportionately involved in those subsistence activities that can be more easily managed alongside household responsibilities, such as cultivating vegetables and taking care of homestead gardens (Grassi et al., 2015). Consequently, women are less involved in commercial agriculture than men and, when they do get involved, they tend to hold lower-skilled, lower-pay positions.[20] Women are thus often used as a source of competitive advantage in agriculture. Women, in fact, are disadvantaged in access to education and training, coupled with the time and mobility constraints deriving from their disproportionate burden of domestic and care work, which prevents them from being as competitive as men.[21] As a result, women are disproportionately employed in part-time, seasonal, and low-paid occupations both in export-oriented industries and in local and regional agri-food value chains (FAO, 2018a). Furthermore, rural wage employment is characterized by a high incidence of seasonal jobs for both men and

women due to the specificities of the sector, but in most countries women are more likely than men to be employed seasonally (FAO, 2011).

Over the past few decades, the expansion of global agricultural trade has opened new opportunities for women to engage in paid work outside the family farm. In particular, the shift from more traditional export crops (such as cocoa, coffee, and sugar) to non-traditional agricultural export crops (such as fruits, vegetables, and flowers), which are more labour-intensive to produce and process, has increased the demand for agricultural workers (World Bank, 2016; UNCTAD, 2016). Women in agricultural-based economies, however, tend to engage with international trade more through wage employment on estate farms or packing houses than directly through the product markets. Women are often preferred for these occupations because they are perceived as secondary workers with lower bargaining power than men, and thus easier to be laid off.

Agro-industrial development represents a strategic source of diversification in agricultural production, and is of critical importance to provide employment and income opportunities for the rural population.[22] Agro-industrial activities are characterized by high levels of female participation, especially in low-income countries (FAO, 2017b). This especially applies to dairy, roots and tubers, and fisheries, where home-based and community-based processing units and activities are quite common. The increased demand for processed food in the expanding urban market in many countries has opened new market opportunities for family-run or women-led small-scale agro-processors. However, that demand is also characterized by increased food quality and safety standards, which women might find more difficult to comply with due to their disadvantaged access to training, services, information, and adequate technologies (FAO, 2018a). In developing countries, women-owned enterprises are mostly small-scale and operate in the informal sector, but are an important source of local employment, especially for other female workers.

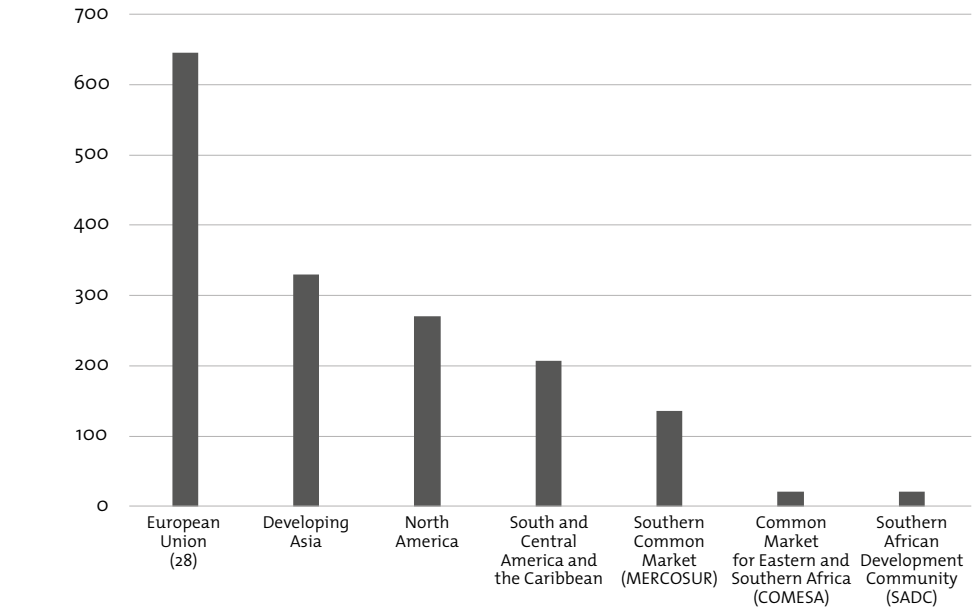
5. Agricultural technology and trade

Worldwide, more than 450 million farmers – 85 per cent of whom operate on two hectares or less – buy or rent inputs, equipment, and machinery from a variety of local service providers and industrial firms, and supply their products to a network of processors, traders, and retailers. Increasingly complex regional and global agrifood value chains link producers to about 7 billion potential consumers worldwide (FAO, 2015).

Two notable trends have been observed during the transformation of world food and agriculture trade in the past two decades (OECD, 2019). First, emerging and developing countries have been increasingly involved in global trade (both imports and exports). Figure 10 shows that Developing Asia has become the world's second largest market (by value) for the export of agricultural

Figure 10

Export markets of agricultural products by value, 2017 (billions of US$)



Source: WTO (2020).

products, and South and Central America and the Caribbean are the fourth largest (preceded by North America). Exports from middle- and low-income countries increased from 9.4 per cent of global agricultural trade value in 2000 to 20.1 per cent in 2015. The growing importance of large emerging economies – especially, China, Brazil, India, and Indonesia – has marked a major change in world agricultural markets. A key aspect of this change has been the rapid growth in South-South trade (FAO, 2018e).

Second, agricultural commodities increasingly travel along GVCs, typically under the direction of one or a few large multinational firms that have come to dominate trading, processing, and retailing of agricultural products.

Both of these trends are linked to the role of technology in agriculture. Agricultural production more than tripled between 1960 and 2015 in the context of the development of Green Revolution technologies (FAO, 2017b).[23] Today, however, there are new pressures on food production due to changes in dietary habits, with less consumption of cereals and more consumption of meats and dairy products, which – under the dominant industrial agriculture paradigm – are very energy-intensive. Urbanization in the context of a growing world population is increasing demand for processed, packaged, and prepared foods. Increasing demand for biofuels has led to the expansion of crop production, (e.g. corn and maize). These transformations, compounded by environmental challenges (e.g. climate change, biodiversity loss, land degradation, and the water crisis) have led to an increased focus on sustainable production to integrate social and environmental goals in the process of economic development (IPBES, 2019; McIntyre et al., 2009; UNCTAD, 2013).

Improvements in agricultural productivity through the adoption and diffusion of agricultural technologies allow for expanding production of goods that can be made commercially available for export (ILO and UNCTAD, 2013). Agricultural exports can play an important role in economy-wide growth and development (ILO and UNCTAD, 2013; DFID, 2015). There are two notable channels through which agriculture has the potential to contribute to economic growth through exports. First, there are expanding opportunities in high-value agricultural exports and agro-processing. The shift toward high-value exports has been most dramatic in Asia and Latin America, whereas in Africa this process has been occurring more slowly (Swinnen, 2015). High-value agricultural exports have important potential for raising rural incomes because their production is often labour-intensive (Swinnen, 2015).

Second, commercialization can improve incomes and livelihoods for producers, which can drive demand for inputs and services from other sectors. This stimulates employment both in related upstream activities – such as seed multiplication, fertilizer production, and supply of other inputs – and downstream activities – such as agro-processing and storage. It also contributes to rural economic diversification through increased production of local nonagricultural goods and services such as housing and transportation. The creation of a range of nonagricultural jobs and incomes, in turn, can have positive spillover effects on the rest of the economy.[24]

Successful technology-driven agricultural development can therefore promote trade, and access to technologies can promote greater access to domestic, regional, and global agricultural markets and value chains (Mellor, 1987; DFID, 2015).

When discussing the potential impact of agricultural technology on trade and development, both positive and negative environmental and economic aspects must be examined. This is particularly relevant given the global urgency to support a sustainable production model. To meet these challenges, food systems will not only have to adapt and become more diversified, but also produce more with less, while preserving planetary boundaries and enhancing the livelihoods of farmers (FAO, 2017b).[25] From an environmental point of view, technology can support more efficient use of natural resources such as water and land. However, it can also accelerate the depletion of non-renewable resources and contribute to the deterioration of the natural environment (e.g. intensive ploughing depletes soil fertility).

As for economic impacts, technology can promote farmers' income by increasing yields and by enhancing value addition in the agricultural sector. Technology, however, can also lead to job losses though automation and mechanization, and through the generation of larger demand for skilled workers over workers performing routine tasks (WTO, 2017).[26] In addition, technology can strengthen the market power of international agrobusinesses and large farms vis-à-vis small-scale farming, in turn reinforcing disparities within countries or between high-income countries and countries with high rates of hunger and poverty.

In this context, trade can help technology in agriculture generate net economic gains by fostering productivity and food production, and by generating new income and employment opportunities. Madagascar provides evidence of these positive effects. Since the 1990s, smallholder farmers, now numbering in the thousands, have supplied high-value fruits and vegetables to Europe under contract farming combined with intensive farm assistance and supervision programs to fulfill complex quality requirements and phyto-sanitary standards of supermarkets (Minten et al., 2009). Technology spillovers have helped increase rice productivity by 70 per cent, improving farmer incomes and food security. The effects have been especially strong for the poorest farmers (FAO, 2015 Swinnen, 2015).

Trade can also help stimulate the adoption of agricultural technology through its effects on both output and input markets. Production for global markets as well as import competition can provide farmers with the incentive to invest in new technologies,[27] and it can help generate the income to do so. In addition, global markets can help farmers access many new technologies such as improved seeds, chemical fertilizers, or machinery. Globalization of production can also facilitate the transfer of knowledge to geographically dispersed participants. In this sense, GVCs can play a crucial role in linking producers and other actors to reliable market outlets, providing access to key inputs, and facilitating technology transfers (FAO, 2015).

6. Technology in agriculture and women's participation in trade

This section provides an overview of technologies that are of particular relevance for women's roles in agriculture and trade,[28] and examines the gendered differentiated effects of agricultural technologies.

6.1 Technology in all nodes of the food chain

Production processes in agriculture can be more or less complex, depending on the scale of operation and on the sector or commodity (i.e. crops, fisheries and aquaculture, forestry, and livestock). It is also often the case that small-to-medium-scale commercial farming entities, where women are more likely to be employed, do not limit themselves to one farming activity alone, but rather integrate crops with forestry, livestock, or aquaculture production. These various activities require different technologies. Technological developments, driven by the private sector and development partners, have focused on this diversity of requirements.

Among key production technologies, there are particular inputs, in the form of improved seeds or animal breeds, designed or adapted to better fit local conditions and needs. Box 2 explains how artificial insemination technologies can foster high quality breeding and productivity.

Technology has allowed for mechanization of agricultural production across all of its subsectors. This applies to a wide range of operations, such as land clearance, crop management and animal health, water usage, and the application of fertilizers and pesticides. When considering technologies for harvesting and post-harvesting, it is important to note that the handling of commodities and products contributes to the definition of their market value, in a context where regional and international buyers are increasingly pushing for higher quality standards and sanitary measures/certifications for food quality and safety.

During harvest, time and labour availability are always of the essence and technology is very important, as farmers need to ensure that the crops or produce they harvest are not damaged and that they have systems in place

Box 2

Artificial insemination technologies that support goat and sheep production in the Caribbean

Faced with challenges in obtaining goats of high-quality breeding stock from overseas due to physical risks for the animals and high expenses, farmers in the Caribbean have shifted to importing frozen semen to improve the genetic stock and diversity of their goat and sheep herds.

In 2015, the Guyana Livestock Development Authority and the Food and Agriculture Organization of the United Nations (FAO) collaborated to strengthen the capacity of livestock technicians from Dominica, Grenada, Suriname, St. Lucia, and Guyana to apply small ruminant breeding technologies, with a focus on artificial insemination in goats. This training followed similar sessions in Antigua, Dominica, The Bahamas, Belize, and St. Kitts and Nevis.

The training sessions put in place a solid technical foundation that will ensure that the countries can successfully implement and manage a goat artificial insemination programme, with the aim of modernizing and strengthening the small ruminant sector.

Source: FAO (2015).

to appropriately manage their goods. Moreover, consumer demand is spread evenly throughout the year while agricultural commodities are seasonal, which calls for appropriate storage to avoid losses and to preserve seeds for the next season. Depending on the commodity, there are different technologies supporting harvest and post-production activities such as processing, storage, and transport. Post-harvest technologies can help link small and medium-scale farmers to regional and international markets. See Annex 1 for examples in the production of cereals, perishable commodities, and essential oils.

Technology does not only support production processes. It has gradually grown to play an ever-increasing role in support of the other nodes of the food chain, linked to the aggregation (drying, storing, shelling, and cooling products), processing (sorting and milling), and distribution (packaging and shipping) of food. Technology also supports appropriate linkages between the nodes through finance, transport, and organizational processes.

6.2 Digital technologies

The concept of agricultural technology today is no longer limited to biological innovations (improved seeds and animal breeds), mechanization (machinery and equipment), and improved inputs (irrigation, fertilizers, and pesticides). Beyond production itself, technology is also embodied in management and organizational processes. This covers storage and market infrastructure – such as warehouses and food collection points – as well as means of transport for agricultural goods and the entire sphere of information and communication technologies. The most innovative technologies consist of mobile applications that connect farmers to key services and information, ranging from veterinary or horticultural experts and advice to weather reports, market information and product buyers, global positions systems (GPS) for mapping soil quality or crop yields, and data management systems such as blockchain, which allows for reliable and traceable digitable records of transactions, in turn strengthening linkages along the entire food chain and expanding sources of financing.

The design and dissemination of digital technologies can help address a number of different challenges, such as the availability of labour, the depletion of natural resources, climate change, biodiversity, and human health. In this regard, the concept of "agriculture 4.0" refers to the use of modern technologies (e.g. artificial intelligence,[29] the Internet of Things,[30] drones, big data analytics[31]) to generate efficient and sustainable production in agriculture. This approach targets precision agriculture, which focuses on increasing production efficiency by utilizing a set of information technologies and automated equipment. Agriculture 4.0, however, is also about connected and knowledge-based production systems that focus on ever-increasing automation, efficiency in the food chain, and improved management processes. Among the key technologies, there are devices and applications that provide access to information and services, such as drones, GPS, geographic information system (GIS), sensors, and mobile phones. Some of these devices can increasingly store, share, and analyze "big data" to support agricultural forecasting and inform smarter decision-making (Braun et al., 2018).

Some technologies, such as mobile applications and e-commerce platforms, are already commonly used and accessible to farmers. Others, such as artificial intelligence and blockchain, which are more sophisticated and complex, are still partly under development. Some technologies are knowledge-intensive and costly to operate and maintain, so their utilization varies depending on the commodity and scale of a farming operation. Potential users of these technologies must be willing and able to invest in the acquisition of the required skills, and organizations must be in place to support the transition to more digitalized operations.

Sophisticated digital agricultural technologies are transforming food production and trade systems, and they offer opportunities for farmers to increase productivity, sustainability, competitiveness, market linkages, and participation in agriculture value chains. Digital agriculture can help women and other smallholders in developing countries overcome or compensate for the barriers they face in improving their competitiveness and accessing export markets (OECD, 2019). It can also complement existing technologies, making women farmers more productive. Box 3 provides one example of how the Internet of Things technology can be applied in agriculture to help women overcome constraints to mobility and improve efficiency.[32]

The increased flow of information enabled by digital technology can also create incentives for smallholders to add value to their products, as information about production practices, quality, or other dimensions that might bring a price premium can be recorded and passed along to consumers. One example is being piloted for coffee exports from Ethiopia and Uganda, where

Box 3

Addressing constraints on women's mobility: Nano Ganesh

Mobile phones can be used to control machinery remotely. Nano Ganesh is a remote control for water pumps developed by an Indian company, Ossian Agro Automation. Its electronic hardware for turning pumps off and on can be activated remotely by mobile phone. This helps women (and men) farmers use water more efficiently. Without remote controls, farmers either have to make special trips to the fields at night to turn pumps on (electricity is often available only during off-peak hours), or they have to leave the pumps on to run on the intermittent electricity supply, wasting water, reducing income, and eroding soil. Women farmers, in particular, find the nighttime trips risky and difficult. This innovation has also generated new activities, which provide additional sources of income for women in the company's rural call centers, electronics assembly, and in marketing and training.

Source: FAO (2018a).

between 19 and 28 per cent of coffee-producing households are headed by women (International Coffee Organization, 2018). Bext360 combines all machine vision and blockchain technologies. The "bextmachine" at coffee collection points evaluates the coffee cherries when farmers deposit them, provides a market price along with advice on how to improve the quality, and then tracks the coffee to the end consumer. This increases farmers' return for investing in high-quality production practices (OECD, 2019).

6.3 Gender-differentiated effects of agricultural technologies

Upgrades in agricultural technology can positively impact a country's trade in agriculture. This process, however, often happens at the expense of small family farms, where women constitute a large share of the workforce, albeit often unpaid and invisible. Mechanization and industrial agriculture – also referred to as the Green Revolution technologies – have often favored better-off farmers who can adopt new technologies to increase production and profits more quickly. This initial advantage tends to widen as increased profits are reinvested in more sophisticated technologies to further increase productivity. Smaller farmers may be displaced onto less fertile land, or abandon or sell their farms, leading to land concentration in the hands of fewer, larger commercial enterprises. Experience has shown that small-scale actors need institutional and financial support and access to appropriate technologies to be able to increase efficiency and increase their competitiveness.

Historically, Green Revolution technologies have exhibited important gender-differentiated effects. The case of high-yielding varieties of rice in Asia illustrates how rural women's work burden often increased (rather than being reduced), and how women from poor households often lost their livelihoods. Adopting the package of high-yielding varieties of seeds, machinery, irrigation technologies, and chemical fertilizers and pesticides increased the need for cash income, which often intensified women's work burden in small-holder farms, either by pushing them into agricultural wage work, or into doing more unpaid work to avoid the use of hired labourers. On the other hand, landless women who relied on wage labour for survival often lost their livelihoods to mechanization of post-harvest activities or suffered from flat or falling wages. Men tended to take over more of the buying and selling of crops, and to own and operate the new equipment, reducing women's control of income produced and relegating them to the more labour-intensive tasks of weeding and transplanting.

In addition, the focus on increased yields ignored the many other uses of rice plants, including as fodder for livestock or for fish ponds, and as straw for mats or thatching, which served important domestic uses and as the basis of income-generating activities. In addition, the use of purchased hybrid seeds over indigenous varieties tended to overlook and undermine women's role in preserving and managing local biodiversity (FAO, n.d.; Sobha, 2007).

As this discussion indicates, technologies may have important benefits in terms of improving yields, increasing incomes, and supporting trade, but these benefits may be distributed unequally. The concerns associated with the Green Revolution continue to be an issue with new technological developments. While increasing numbers of male and female smallholders benefit from participation in modern agricultural supply chains, the gender-differentiated impacts of new technologies must be carefully considered. Future technological change in agriculture must be more inclusive, while meeting the challenges of increasingly globalized and complex agricultural value chains and taking into account the urgent need to reduce agriculture's environmental footprint.

The following subsections examine some ways in which agricultural technology can present new opportunities for women's participation in

trade. In particular, we examine technologies for meeting standards in (1) high-value agricultural production and (2) green technologies and sustainable agriculture practices, which are some of the key areas for the development of agricultural technology moving forward.

6.4 Technology in global value chains: Opening opportunities for women

As mentioned in Section 3, expanding trade in high-value agricultural products such as fresh fruits and vegetables through GVCs represents a promising opportunity for women and other small-scale producers and processors in developing countries, provided they can meet the standards and regulations for safety, quality, and efficiency required by these markets.[33] Standard requirements, which have become more stringent and widespread in recent decades, are among the primary constraints to trade in agriculture (Redden 2017).

There is widespread evidence that the proliferation of gender-blind standards has led to the exclusion of women and other small agents from GVCs because women, as producers, are more likely to lack the financial or technical capacity for compliance. Thus, standards may favor larger, more industrialized, formal enterprises and contribute to the consolidation of actors across nodes of value chains (Redden, 2017; Swinnen, 2015; UNECE, 2019). For example, in some cases food safety and other standards for fresh produce have caused a shift from smallholder to vertically-integrated estate production (UNECE, 2019).[34]

Technology can either help widen or close these gaps. Access to technology, resources, and technical expertise is often a prerequisite for participation in production processes and business operations within GVCs – a prerequisite that women may find it difficult to meet (Bamber and Fernandez-Stark, 2013).

On the other hand, women who do get access to new technologies through GVCs may obtain the means to achieve competitiveness and meet international standards. In this process, women can benefit both as small producers and entrepreneurs, and as workers. Participation in GVCs is a means of accessing technology, extension services, and other resources provided by lead firms to ensure that their suppliers meet the demand for high-quality products. And workers whose employers invest in training or technology transfer may receive a wage premium and greater job security. All of these impacts can create flow-on welfare effects for the wider community.

Many high-value-added crops require labour-intensive production techniques, which cannot be easily mechanized and in which women often specialize. In this regard, for example, women small producers have been successful in breaking into the segments of horticulture value chains that require careful handling or attention to detail, thus capitalizing on traditional gender roles that associate men with tasks requiring physical strength and women with tasks requiring precision and dexterity.

The horticulture industry is of great importance for developing countries because of its economic returns and employment generation, which enable positive interplay between trade and technology as described in Section 3 (Bamber and Fernandez-Stark, 2013). There are cases in which access to simple yet appropriate technology, along with training, has enabled women to successfully upgrade to meet standards and achieve competitiveness in GVCs. One example is in the production of mangoes in Burkina Faso. Mango So is a medium-sized fruit and vegetable processing company established in 2001 that contracts with numerous local producers. Eighty-five per cent of its factory workers are women. The company faced challenges in meeting sanitary and phytosanitary standards and organic certification standards for supplying the European market. A major issue was the use of wooden tables to process mangoes, as the wood is prone to pest and soil contamination. Another key issue was access to efficient technology for drying mangoes. With support from the Enhanced Integrated Framework (EIF)[35] and the World Bank Aid for Trade, Mango So was able to acquire steel tables for processing and new drying tunnels, as well as provide training on production practices, hygiene, safety, and use of the new equipment. The result has been increased training and upgraded employment opportunities for women working for Mango So, along with increased employment for others in the community as exports have expanded along with income-earning opportunities (Redden, 2017; UNECE, 2019).

Another interesting case refers to the use of new technology for processing shea butter, an activity traditionally done by women that has helped them gain access to a particularly promising niche market and high-value GVC. Shea butter has been dubbed "women's gold," not only for its gold colour, but also because it provides livelihoods for millions of women across Africa. While there is growing demand for natural and organic shea butter for food and cosmetic uses in markets in the United States and Europe, and shea is indigenous

to Africa, the shea nut is often exported and processed elsewhere because processors in Africa have been unable to ensure consistent and high quality of their shea butter. New technologies such as kneaders, roasters, hydraulic or screw presses, and nut crushers have helped mechanize some shea processing operations to complement traditional manual methods. This has enabled women to improve the quality of the shea butter they process, and to access lucrative markets, improving profitability and incomes (Europa, 2018). One study of women-owned microenterprises in Northern Ghana found that the adopters of improved shea butter processing technologies had better performance in terms of increased income, savings, employment, investment, and credit levels (Mohammed et al., 2013).

Finally, technology has helped women access high-value GVCs in honey production. Ethiopia is the largest producer of honey in Africa, but the quality and yield from traditional hives is too low to meet the growing global demand for high-quality honey, beeswax, and other bee products. Traditional harvesting and hive technologies are inefficient and unprofitable, and largely male-dominated. Traditional hives are made of hollow logs hanging from trees located away from homes, making it difficult to monitor the quality of honey and requiring climbing trees. In addition, honey is usually harvested at night. This presents numerous challenges for women, for whom household duties or social conventions prevent them from traveling long distances and climbing trees at night. Modern box and frame hive technology can make it easier to harvest honey at the right time, requires very little land, is relatively cheap, and can be located near homes, thus offering the entry point for women to participate in the honey value chains and to produce higher-quality and greater quantities of honey. For instance, through its work with Zembaba, an umbrella organization of beekeeper cooperatives, Oxfam has expanded women's role in honey production and marketing in the Amhara region of Ethiopia. Growing demand for honey has been used to leverage support for greater participation by women, and through new hive technology, women have been able to provide a higher quality product and expand their participation in a lucrative market (King, 2013; KIT, Agri-ProFocus and IIRR. 2012).

Digital technologies can also help women and other smallholders better access upstream inputs and knowledge, facilitating their potential integration into global value chains. Information and communications technology (ICT) can help women address many of the traditional barriers to adopting new technologies in agriculture, such as time and mobility constraints, access to finance, information, training, networks, and markets. Traditional technologies such as rural radios continue to be important, but newer ICT such as smartphones and the Internet are increasingly important prerequisites for the use of digital agricultural technologies. The following are examples of recent digital technologies that can support women's competitiveness and integration in global markets:

- The use of remote sensing, the Internet of Things solutions using wireless sensor network systems (such as the example discussed in Box 3), and applications based on machine learning and machine vision can help smallholders access services in remote areas where experts are unavailable (OECD, 2019).
- A new platform in Africa, developed with the support of the Food and Agriculture Organization (FAO) and the Consortium of International Agricultural Centers (CGIAR) in Africa, aims to provide cheap and affordable access to knowledge on crop diseases, including for crops with which women are more likely to be involved, with easy-to-understand images and other content.
- An artificial intelligence (AI), smartphone-based assistant called Nuru (Swahili for "light") can diagnose multiple diseases in cassava, pest infestations in African maize, and diseases in potatoes and wheat (OECD, 2019). Plant diseases and pests are a significant threat to production, and losses of food crops can be particularly devastating for smallholders and prevent them from being able to expand commercial production or to take the risks of adopting new production practices.
- UN Women's "Buy From Women" enterprise platform launched in Rwanda in 2016 maps farmers' plots and generates a production forecast, which help women smallholders negotiate more precisely with buyers and financial institutions. Farmers can also access information about market prices and weather, training on climate-smart agricultural practices (Munyaradzi et al., 2019; see Annex 2), mobile money, and suppliers, customers, and financers (FAO, 2018b; UN Women, 2016).

Digital agriculture technologies can also help women overcome constraints to accessing higher-value markets for their products. For example, these technologies can help solve problems of coordination between buyers and

large numbers of geographically scattered smallholders in value chains, making it easier for smallholders to learn about and meet the demands for product quantity, quality, and safety, and less risky and costly for the buyers to rely on those smallholders. These technologies can also help women farmers cooperate among themselves and increase their bargaining power. Various platforms have been developed to connect buyers and sellers by providing market information or virtual marketplaces. One example is the Connected Farmer Alliance, a public-private partnership between the United States Agency for International Development (USAID), Vodafone, and TechnoServe that enables agribusiness to use M-Pesa mobile money to make purchases from farmers and to extend loans.

6.5 Organic farming, green technologies, and agroecology: Striving for sustainable agriculture

Organic farming provides a promising area to support the ability of women to increase their participation in high-value agriculture activities and trade, while at the same targeting a reduction in the environmental impact of conventional agriculture. Organic production is typically dominated by small-scale farmers – many of whom are women – and relies on techniques such as crop rotation, composting, and biological pest control (in place of fertilizers and pesticides). The use of genetically modified organisms is also prohibited. Organic farming can thus use locally available inputs and technologies (ILO and UNCTAD, 2013). Demand for organic food has been expanding rapidly worldwide due to growing health and environmental concerns, and the trend is expected to continue (Willer and Lernoud, 2019). As women tend to have limited access to chemicals and other inputs associated with industrial agriculture, and thus are more likely to use traditional production systems, with the right assistance they may consider obtaining organic certification to access high-value niche markets, such as those for certified organic products, thus turning a disadvantage into a strength (World Bank et al., 2009).

Women may also be more capable of adopting innovative sustainable practices and green technologies when they start as outsiders in activities from which they have traditionally been excluded.[36] For example, women members of Manduvira, a fair-trade sugar cooperative in Paraguay, were found to be early adopters of biodynamic farming techniques in sugarcane farming,[37] a cash crop with which women have relatively little experience. One of the reasons found for this was that, having grown up as farmers, men are more "set in their ways" while women are "often more eager to receive guidance" (Clugston, 2014: 4).

Even if gender-based constraints limit women's participation in organic farming, women may still find opportunities as suppliers of inputs to organic production processes. For example, women in Mali are largely excluded from organic cotton production because they lack access to organic fertilizers and credit, and their household responsibilities interfere with the labour demands of weeding and composting. Instead, they produce biopesticides from kobi oil, an input that has become essential for pest management and has created a new income-earning opportunity (KIT, Agri-ProFocus and IIRR. 2012).

There is increasing international recognition that the global environmental crisis and the urgency of food security for a growing population call for a paradigmatic shift in agriculture production towards agro-ecological practices (UNCTAD, 2013). While organic production focuses on input substitution (i.e. a biological insecticide in place of a more toxic synthetic one) that leaves the monoculture structure unchanged, agroecology commits to a more holistic transformation. Agroecology is based on the "application of ecological concepts and principles to the design and management of sustainable agroecosystems" (Gliessman, 2007: 18). The technology that is the foundation of agroecology involves the integration of traditional, local knowledge and practices with modern agroecological science. The goal is to replace conventional production methods (based on monocultures, and energy-intensive industrial inputs) with sustainable agrosystem management (in which external inputs are replaced with local biological interaction synergies[38]) in order to support poly cultures, biodiversity, ecological conservation, and energy efficiency, in turn fostering more resilient farming systems.

Agroecology has the potential to promote food security for a growing population, empower smallholder farms, and help promote climate stabilization by reducing dependence on chemicals and fossil fuels (Altieri, 2009; Migliorini and Wezel, 2017; UNCTAD, 2013, 2017). At the core of agroecology is shared knowledge among local farmers and between farmers and technical experts. There is evidence that this participatory approach has led to a new recognition of the role of women in rural economies and to initiatives that have helped address gender inequality. For

example, in Casemance, Senegal, rural women's organizations have been active in promoting the use of agroecology to support food production, while also advocating for rights and resources (e.g. access to land) and representation in decision-making (New Field Foundation, 2010). Similarly, in Uruguay, the *Calmañana* herb co-operative – an organization established by women in the 1990s – provides technical assistance to help households increase income and food security through the use of agroecological principles. The cooperative puts women's interests at the centre of its mission in the form of income diversification, fulfilment of family nutrition, and support for solidarity and women's leadership (Oliver, 2016).[39]

Supporting agroecology – which, as discussed in UNCTAD (2013), is key for the long-term sustainability of agriculture – can help re-value women's traditional knowledge on seed conservation, biodiversity, and nutrition (Shiva, 2016) while also opening up new possibilities for their economic participation in agriculture and participation in trade.[40] In addition, agroecology is characterized by lower initial costs, simple production techniques, and stable returns. This makes agroecology more affordable and accessible for women than industrial agriculture.

There is evidence that agroecological practices can be a pathway for women's empowerment. For example, the system of rice intensification [41] – an agroecological method for growing rice – can achieve 20 to 50 per cent higher yields than conventional production methods, facilitating greater income generation and food security. About 90 per cent of the world's rice is produced in Asia and women play a major role in rice farming. In Indonesia, women contribute over 70 per cent of labour in upland rice production; in Bangladesh, women constitute over 45 per cent of labour in the sector (Segal and Minh, 2019). Rice production is also heavily dependent on women's unpaid and/or low-valued labour (Nguyen et al., 2019). With conventional practices, in fact, women perform backbreaking tasks like seedling removal, which involves constantly bending over to transplant and weed in hot and humid conditions. The SRI potentially enables women to work under healthier conditions and raise productivity, which can help generate surplus for the market. The principles of the system of rice intensification have been adapted to other crops as well, such as wheat, maize, millet, sorghum, vegetables, and tubers (Tiki, et al., 2015).

7. Factors affecting women's adoption of technologies

Based on the concepts explained in Section 3, due to discriminatory social norms and gender stereotypes women in agriculture in all regions face constraints that impinge on their productive and entrepreneurial potential and affect their ability to participate in and benefit at par with men from trade expansion and value chain development (UNCTAD, 2014). In agriculture, women face limited access to land, financial resources and credit, extension services, training, rural development policymaking, and reliable public transportation and rural infrastructure to market their products. Many of these constraints contribute to explaining women's lower access to and use of technology and related inputs. Men and women do not necessarily have different propensities or abilities to use agricultural technologies, but gender-based constraints – in particular, women's more limited ability to access information and training – explain differences in technology access and use.

Gender differences in the use of inputs and technology vary across regions and circumstances, suggesting that specific local conditions matter. However, evidence consistently suggests that men adopt new agricultural production technologies at higher rates and faster than women (Ragasa 2012).[42] There are gender gaps for a wide range of agricultural inputs and technologies, including machines and tools, fertilizers, crop protection products, animal breeds, improved plant varieties, and irrigation schemes (FAO, 2018a; Peterman et al., 2014; Croppenstedt et al., 2013). These differences apply across the spectrum of technologies from basic to sophisticated digital agriculture technologies and ICT. A considerable gender gap persists, for example, in relation to mobile ownership and use of the Internet. Based on ITU (2019), the Internet gender user gap is 22.8 per cent in developing countries and 42.8 in the least-developed countries.[43]

These sources of inequality are important in relation to trade because women's lack of access to technologies and other resources contributes to their lower productivity and segregation into positions of economic vulnerability in agriculture.[44] Because access to technology facilitates participation in trade and trade provides opportunities to access technology, women in agriculture are often confronted with a low-productivity trap. For example, a number of studies have found that women's yields are lower than men's within the same household. These yield differences almost always disappear,

however, when the level of access or usage of resources – in particular technology-related inputs and services such as fertilizer or extension services – are taken into account (Croppenstedt et al., 2013). This low-productivity trap, in turn, inhibits an efficient functioning of value chains and an expansion of trade, as women input providers miss out on potential markets, and agribusinesses miss out on the potential for high-quality and reliable supplies of produce from women farmers and agro-processors (FAO 2019a).

7.1. Gender bias in agriculture research and development

Due to the traditional sources of gender bias, the important role that women play in agriculture and food systems contrasts with their limited representation among researchers, scientists, professors, graduate students, and managers at agricultural research and development organizations. In sub-Saharan Africa, for example, only one in four agricultural researchers is female, while in Latin America the number is one in three (Beintema and Marcantonio, 2010). While the number of women in research organizations has begun to increase in recent years, women remain underrepresented in higher-level positions and educational degrees, and therefore rarely participate in decision-making about agricultural innovations (Meinzen-Dick, et al., 2010: 76).

Greater gender balance in innovation activities can yield a variety of benefits. First, women may have a unique perspective on the challenges faced by all farmers, and female farmers in particular. Second, a greater diversity of perspectives contributes to a greater diversity of insights and creative problem-solving. Various studies indicate that gender-balanced teams function more effectively. For example, researchers at the University of Castilla La Mancha in Spain found that gender-balanced research teams in a technological context were associated with higher levels of ground-breaking innovation than those that were either all male or all female (Díaz-García et al., 2013).

A lack of women at all levels of research, but particularly in managerial and upper-level research positions, makes it less likely that the particular needs of women in food systems will be addressed appropriately through agriculture research and development. This shortage of women in agricultural research can be self-perpetuating, as a lack of role models for girls and young women sends the message that these fields are not for them. In the case of sub-Saharan African countries, sex-disaggregated data on agricultural researchers at different levels of authority and expertise – ranging from students to managers, which include directors, deans, and department heads – shows that men account for at least 60 per cent of all of these positions. The imbalance is greater at higher-level positions. Men's dominance is especially striking at the managerial level, with a share of over 80 per cent (Beintema and Marcantonio, 2010).[45]

These imbalances tend to compound the implicit gender bias observed in the content of research and development in agriculture, which tend to focus on commercial agricultural products and activities, such as cash crops and large livestock, which are typically managed or controlled by men. In contrast, kitchen gardens, small livestock, and small-scale commercial and staple crops, commonly viewed as female pursuits, receive less research attention. Similarly, women's needs for labour-saving technologies in their processing and production tasks such as weeding, transplanting, and drying are underserved. This is due to the fact that much of women's work in agriculture is underestimated, as it is often provided as an unpaid contribution to family farms or businesses and considered to be just an extension of "household work."

When technological research and development fail to account for women's needs, women are less likely to adopt the resulting innovations, reinforcing the idea that they are unqualified or uninterested in technology. For example, male and female farmers often prefer different crops or crop varieties. Men who grow maize to sell prioritize particular traits, such as high yield, and so are more likely to adopt the more expensive high-yielding varieties, which require more fertilizer and chemicals to grow. Women, on the other hand, are often more likely to prioritize traits related to their household and caregiving responsibilities, and to adopt technologies that are consistent with their roles in production for family use or for sale in local markets. Thus, women may prefer crop varieties that respond to their priorities in terms of nutrition, taste, safety, and ease of processing and cooking. Women's varietal choices are also linked to their roles in processing and selling traditional maize products as well as other factors such as cooking time (due to its impact on firewood and labour needs) (Beuchelt and Badstue, 2013).

One area where women's needs are often overlooked in the design of technologies is women's physical needs. Technologies are often designed with the average man's body and strength in mind, making tools and equipment difficult or even impossible for women to use.

Box 4

Technology is not gender-neutral: Mechanized potato selection and gender roles

Researchers from the Latin American gender team of the International Potato Center (CIP) in Lima, Peru wanted to understand what underlies technology adoption decisions for men and women in high-elevation Andean communities where farming systems are based on potato cultivation. The researchers from CIP, which is part of the Consortium of International Agricultural Centers, found that technology adoption decisions are the result of the complex interaction of multiple factors, including the characteristics of the technology itself and gender roles. In turn, the technologies that are ultimately adopted may carry forward gender biases if the needs of users are not taken into ac count at all stages.

For example, in Jacopampa, Plurinational State of Bolivia, women are responsible for manually sorting and selecting potatoes by size. But although equipment to save time by mechanizing this task was introduced, it was never actually adopted. The women who were the targeted users of the technology, in fact, were not explicitly included in the collection of feedback and demonstration of the new technology. More men than women participated in validation meetings about the new equipment, and they were able to operate the equipment without difficulty. However, the equipment was not suited to the physical requirements of women. As a result, women found the equipment too high to operate, and had difficulty lifting the heavy bags of potatoes to feed into the machine. Once this barrier to adoption was understood, a simpler, gravity-fed, low bearing machine was suc cessfully introduced.

Sources: Babini (2017); and Polar et al. (2017: 42).

Ploughs, for example, are often too heavy or have handles that are too high. In one case, treadle pumps for irrigating fields in Bangladesh were designed for the average weight and strength of a man, but mostly used by women who suffered pain and exhaustion as a result. Fertilizer is typically sold in sealed 50-kg bags that are heavy to lift and require access to transport, credit, and adequate storage, access that women are less likely to have. Smaller bags are both more costly and more likely to be adulterated (Croppenstedt et al., 2013).

In contrast to these examples, Box 4 presents an example of how collecting feedback from women helped to design a new labour-saving machine for potato sorting.

7.2 Extension services and access to information and knowledge

Extension services are a key channel through which producers get information through training and demonstrations by extension agents about new products and practices generated in agricultural research and development institutions. Extension services, however, are characterized by many forms of gender bias.

First, women are underrepresented as extension agents. Only 15 per cent of extension workers worldwide are women (FAO, 2018a). Second, in general, women also have less access to extension services than men. For example, in Mozambique, twice as many men as women in agricultural value chains benefit from extension services (45 versus 23 per cent). In Honduras, women account for just 33 per cent of extension service beneficiaries. The same is true for Asian countries. In Cambodia and Viet Nam, for example, women account for just 10 and 25 per cent of the beneficiaries of extension services, respectively (Bamber and Staritz, 2016).

As women's role in agriculture often goes unrecognized due to prevailing gender stereotypes, women remain largely underserved by advisory and business development services, which fail to target them as legitimate clients. Extension typically targets export-oriented crops, which tend to be male-dominated. Extension agents may also provide information to men only, assuming they are responsible for making most production decisions and will pass along the information to others in the household.

In their design and implementation, extension services often do not acknowledge the gender-specific obstacles experienced by women. Training may be scheduled at times or locations that are not accessible to women due to their childcare and other responsibilities, or their inability to travel. Services may not take into account women's more limited access to radios and mobile phones. Services delivered by male agents or trainers may also be inaccessible to women where social norms prohibit them from interacting with males who are not their relatives. As a result of these obstacles, women often rely on second-hand information from informal networks rather than from expert providers. This helps explain why their uptake of improved practices, technologies, and business skills and, by consequence, their productivity and efficiency, are often lower than that of their male counterparts (FAO, 2018d). In addition, rural women are more likely to have lower levels of education and literacy, and often speak only indigenous languages. This inhibits their capacity to make informed choices about technologies and to adopt and use them effectively. When women are given appropriate information, they can play a key role in adopting improved technologies and practices, as discussed in Box 5 regarding the case of women's empowerment and households' adoption of high-yielding varieties of rice in Southeast Asia.

Box 5

Women's empowerment in agriculture and innovation in Southeast Asia

How can women's empowerment lead to better adoption of agricultural and farming technology? That question motivated a study by Akter et al. (2017) of 12,000 farming households in Southeast Asia that assessed women's empowerment using a measure called the Women's Empowerment in Agriculture Index. The index considers a series of factors to measure empowerment, including data on access to extension services (training, agricultural information, and agricultural technologies).

The division of farming tasks between men and women in the region demonstrates common patterns. Men dominate decision-making over most resources, whereas women's participation in key decisions varies across the region. For example, the study found that the largest degree of women's involvement in decision-making is in the Philippines. Most rice farming decisions there are made jointly by husbands and wives, and women play important roles in community and agricultural groups. Women also participate more actively than men in most agricultural meetings organized by the local extension office, and their husbands listen to the information they convey.

In Myanmar and Indonesia, on the other hand, there is low representation of women in formal groups, which leads to a lack of access to extension services. Women in these two countries are keen to participate in meetings and training, but invitations typically are only extended to men.

Ac cording to the study, empowered women have access to more networks and information, including about available technologies, that enable them to make more informed production decisions for their farms and advocate for measures that would improve household incomes and welfare. This finding shows the importance of addressing gender gaps in agriculture through country-specific gender interventions.

Source: Akter et al. (2017).

These issues are compounded by the top-down organization of research, development, and extension systems. New knowledge typically originates in research institutions, gets incorporated into new products and practices for users, and finally flows into extension systems and is distributed to farmers and other users through training and demonstration. Farmers are typically seen as passive recipients of knowledge and as dependent on external sources of expertise that flow in one direction through a hierarchical structure. Conventional approaches therefore lack feedback mechanisms through which research, development, and extension institutions can collect information about technology users, especially women, and be held accountable for meeting their needs. Extension services should explicitly account for gender roles in agriculture, including through the recruitment of female extension workers (UNCTAD, 2017).

7.3 Innovative approaches to research, development, and extension

Since the mid-1990s, there has been growing recognition that centralized research, development, and extension systems have failed to deliver substantial benefits to women by promoting innovations that benefit farmers who already have greater access to assets and education. Alternative approaches to agricultural innovation and extension seek to address the problems associated with the conventional top-down model of innovation by moving toward more holistic, systems-based, and integrated approaches that address the multiple dimensions of innovation processes and recognize multiple actors and their needs. These approaches are built around the recognition that knowledge is not simply transferred from providers to users, but generated and exchanged in a continuous learning process (World Bank et al., 2009: 258).

The concept of agricultural innovation systems has been developed to conceptualize innovation as an inclusive process that involves not only research and development, but also collective participation, sharing of knowledge among diverse agents, and context-specific conditions (Freeman, 1987; World Bank et al., 2009; World Bank, 2011). In this framework, farmers and other stakeholders have the opportunity to develop agricultural technology along with researchers. Women are explicitly recognized as critical actors in agricultural innovation systems as is the need to incorporate their perspectives and involve them (World Bank et al., 2009).

Participatory approaches have the benefit of identifying and incorporating the needs of farmers and other users as well as building on their existing knowledge in technology development, monitoring, and evaluation. While participatory approaches are not necessarily gender-sensitive, those that explicitly incorporate a gender dimension show promising results. Participatory approaches – as well as innovation platforms[46] – can help recognize and develop women's innovative and technical capacity in order to enable them to better solve their own problems (Carr and Hartl, 2010). Box 6 discusses how a gender-sensitive participatory approach

Box 6

Gender impacts of participatory plant breeding programs

Participatory plant breeding programs involve farmers directly in the process of plant breeding and creating new plant varieties. Researchers are able to draw on farmers' knowledge and experience of local conditions, while farmers can select and adapt crop varieties to their specific environments, agricultural practices, and needs. Many studies find that participatory plant breeding leads to faster adoption and higher yields because it explicitly incorporates and responds to the interests and priorities of diverse users. However, many studies also indicate that the benefits for women are limited unless these programs incorporate an explicit gender dimension and address women's specific constraints, such as lack of mobility and transport, time burden, need for knowledge and training, and gender norms.

Women are often central to local agricultural innovation systems, particularly with respect to plant breeding techniques, generation of new plant varieties, and serving as repositories of knowledge about local varieties and genetic information. In various parts of the world, women are responsible for sorting and selecting seeds for different crops. In a survey of over 150 participatory plant breeding projects, Ashby and Lilja (2004) found that consulting women and involving them in varietal evaluation led to better ac ceptability and faster adoption. Cec carelli and Grando (2007) conclude that participatory plant breeding gives voice to farmers and marginalized women in combining scientific discovery and traditional knowledge. Participatory plant breeding approaches that involve women in the development of NERICA (or New Rice for Africa, a new high-yield rice variety) in West Africa and beans in Rwanda have led to better performing varieties and enhanced benefits for women.

Sources: ACET, ed. (2017); Meinzen-Dick et al. (2010); and Ragasa et al. (2014).

to plant breeding can benefit women. Box 7 discusses the Papa Andina Project, which involves the use of an innovation platform for bringing together a variety of stakeholders, with explicit attention to recognizing and valuing women's traditional roles, knowledge, and importance to successful research and innovation.

Participatory approaches can be considered for agricultural extension services as well. They could include informal or formal peer-to-peer sharing of information by participants rather than delivery in a top-down manner by outside experts. One example is the Farmer Field Schools (FFSs), initiated by the FAO in 1989 in Asia, which have now expanded to more than 90 countries in all regions. Participants in an FFS learn by doing and experimenting with new practices in their own local contexts, guided by a trained facilitator. Evidence shows that the FFS approach is effective in developing the technical skills of farmers, improving productivity and income, and in many cases contributing to gender equality and women's empowerment. The use of the approach in Jordan and Tunisia, for example, helped women gain self-confidence and increased community recognition of their work. It also increased opportunities for women to network among themselves, which led to the formation of formal and informal organizations (FAO, 2016a).

Box 7

Papa Andina: Promoting women's participation in agricultural research and innovation

The Papa Andina project, launched in Peru, Plurinational State of Bolivia, and Ecuador in 1998 and hosted by the International Potato Center combines new institutional arrangements for fostering agricultural innovation, namely a stakeholder platform and a participatory market chain approach. The project aims to help smallholders access modern marketing chains and includes several innovative gender elements. The project is funded by the Swiss Agency for Development and Cooperation, among other donors.

The Papa Andina network brings together researchers, farmers, agricultural service providers, and market chain actors such as chefs, supermarkets, and processors. The network works to create new mutually reinforcing relationships, production techniques, products, and markets. One of the results of the project has been the creation of a high-value niche market for small-scale potato farmers through the branding of traditional potato varieties. T'ikapapa is the commercial brand supporting the sale and export of native potatoes in the region. Other results include new pest management techniques, higher yields, higher prices for native potatoes, increased farmer revenues, more stable markets, and increased farmer self-esteem.

Donor agencies established the need for a gender analysis and the involvement of women farmers in research and development as a key requirement of the project. Resource-poor women farmers are viewed as key stakeholders in the potato value chain. Events and activities highlight women's knowledge, so that their roles are recognized and reinforced. For example, innovation fairs provide opportunities for farmers and communities to highlight the enormous genetic diversity of the potatoes they cultivate – at one fair, a family exhibited more than 600 varieties – as well as women's important role in the preservation and maintenance of that diversity. Papa Andina demonstrates the value of women's involvement in agricultural innovation. Women have reported feeling recognized and rewarded for their efforts, and they have also been able to access new commercial opportunities.

Sources: World Bank et al. (2009); and Devaux et al. (2011).

7.4 Other constraints

This subsection examines the impact of constraints discussed in Sections 1 and 2 on technology adoption by women and presents some solutions. It is important to highlight that gender-based constraints tend to be interlinked and mutually reinforcing. For example, women's lack of ownership of land and other forms of collateral limits their access to financial services, which, in turn, inhibits their ability to purchase many forms of new technologies and inputs such as machinery (IFC, 2016). Based on this observation, this subsection considers the interplay between women's access to inputs and technology and gender barriers to women's autonomy and participation in leadership and decision-making; barriers to access to financial services, productive resources, and ICT; and women's work burden and time poverty. As noted above, discriminatory cultural norms and laws, in addition to gender stereotypes, are the underlying drivers – directly or indirectly – of these constraints and inequalities.

7.4.1 Women's autonomy and participation in leadership and decision-making

As discussed in Section 1, women tend to be underrepresented in positions of authority, as they typically face limitations on their participation in leadership and decision-making. This also applies to decision-making and priority-setting regarding agricultural technology at several levels, including households, communities, and organizations. For example, in many countries women are disadvantaged in their access to local associations and organizations. Membership in producer associations or cooperatives is often given automatically to the male member of the household, despite the fact that the bulk of the work might be done by the woman. Women's participation may also be hampered by time and travel constraints, costs or rules requiring asset ownership, or minimum size of a business as conditions to participate.

Participation in such groups has important benefits, particularly for small-scale producers who have greater access to resources and bargaining power when they can act collectively. Benefits include networking, learning about market opportunities, accessing information, getting help and support, and relieving other gender-based constraints in access to resources, finance, and training. A number of studies find that local producer organizations are important in promoting technology use (Ragasa, 2012). This can be especially important for women, as they are more likely to operate smaller-scale enterprises, and it is easier for small-scale farmers to gain access to new technologies when they can pool their resources through producer organizations or cooperatives.

Cooperatives and producer organizations for women can be effective means of helping women access the benefits of networks and institutional support as well as overcome obstacles to affordability and transfer of information about new technologies. "Women-only" branding can be an innovative marketing way to overcome barriers to women's access to cooperatives and producer organizations. Box 8 discusses two examples of how such branding supports women's collective action through rural producer organizations, which, in turn, can help address a number of gender-related constraints to women's adoption of technology and participation in trade.

Box 8

Women-only branding and rural producer organizations: Café Femenino and Las Hermanas

Women generally lack access to formal, urban, international markets as well as to rural producer organizations. The case of women-only branding by women's coffee producer cooperatives illustrates an innovative way that women can address these barriers and gain access to high-value niche markets for fair trade and socially responsible products.

Marketed as "coffee that empowers," Café Femenino, a woman-owned brand of coffee, was founded in 2004 by Peruvian women farmers, and now includes 10 cooperatives of women coffee farmers in Plurinational State of Bolivia, Brazil, Colombia, Guatemala, Mexico, Nicaragua, Peru, Rwanda, and Sumatra. The brand is sold in the United States, Canada, Australia, United Kingdom, and continental Europe as fair-trade, organic and high-quality coffee. To women farmers who participate in the brand, cooperatives provide legal rights to the land they farm, leadership positions within the cooperatives, financial and decision-making power, and direct payment for their coffee. Fair trade premiums increase the visibility and value of women's work in coffee production, while boosting family incomes. These arrangements have resulted in improved living conditions in coffee-growing areas, including better nutrition, improved sanitation, new wet-processing mills, and new roads.

The fair trade and organic coffee grower's cooperative in Nicaragua, SOPPEXCCA, markets the coffee made by its women producers under a separate label called "Las Hermanas." It has been supplying Peets Coffee, a United States specialty coffee retailer, since 2001. The superior quality of Las Hermanas has been recognized in the annual "Cup of Excellence" coffee competition. The premiums generated by the brand have helped women develop their technical capacity in coffee production; produce, manage, and market their own coffee; and gain titles to land.

Sources: Café Femenino (2018); Chan (2010); KIT et al. (2012); and World Bank et al. (2009).

7.4.2 Access to financial services

Limited access to finance is another major constraint to women's productivity and efficiency in agriculture. Without sufficient access to credit, women are often unable to bear the risks and upfront costs associated with purchasing new equipment and inputs that embody new technologies, or making the innovations and investments necessary to expand their businesses, adopt new production practices, or meet the standards required for international trade. Although the number of female "agripreneurs" is increasing, because women are typically "underachievers of competitive advantage" (as discussed in Section 2), there is only a small group of top-performing, growth-oriented women entrepreneurs. This explains why, rather than targeting commercial opportunities, the vast majority of women's enterprises revolve around subsistence production (UNCTAD 2014; IFC, 2016; FAO, 2018d).

Alternative financial models that work for women have been largely limited to small-scale, context-specific arrangements. Input suppliers and buyers, cooperatives, and microfinance institutions are becoming increasingly important financing channels for smallholders and small and medium-size enterprises. However, the availability of financial products and the volumes of credit and savings provided by these informal or semi-formal institutions might not be sufficient for women entrepreneurs to consolidate or expand their business. These kinds of institutions also tend to be credit-led and fail to provide the broader range of financial services that agri-entrepreneurs need. For these reasons, it is important to strengthen links with formal financial institutions by both building the capacity of these service providers to better target women workers and entrepreneurs in the agriculture sector, and by supporting the introduction of innovative financial products. Some examples of innovative financial arrangements that have had some success include women-only financial products and funds, arrangements that accept a broader range of types of collateral, group lending schemes, investment clubs, ICT-led services, forward financing provided by agribusiness, and bridging partnerships between formal and semi-formal and microfinance institutions (FAO, 2018a).

7.4.3 Access to productive resources

Women's disadvantage in ownership of and access to productive resources (e.g. labour,[47] land, livestock, water, fisheries, and forest) is a key factor in explaining differences in adoption rates as well as productivity between male and female farmers (Doss, 2001; Ragasa, 2012).

Men's greater control of land and labour means that they have not only collateral to access credit to finance the purchase of new technologies and workers to implement them, but also greater access to contract farming and more lucrative roles in modern agricultural value chains – and the access to new technologies that these roles can bring (Croppenstedt et al., 2013). Such access, along with clearly defined and secure ownership and control of productive resources, are key to providing women with the appropriate incentives and abilities to adopt new technologies, and to promote sustainable use of these assets. Box 9 illustrates how a gender-sensitive approach focused on securing access to land and livestock assets, combined with training, promoted women's adoption of new technologies and allowed women to engage in additional income-earning activities in Nepal.

Box 9

Communal leasehold forestry arrangements and labour-saving forestry and livestock practices in Nepal

In 2004, Nepal adopted an innovative institutional arrangement that allowed for increasing tree crops and livestock without degrading the forest. The programme has also provided important improvements to women's livelihoods. Through the Leasehold Forestry and Livestock Programme, communities in the Himalayan foothills were granted 40-year renewable leases over the forest, and new crops and goats were introduced along with sustainable production practices and business and marketing techniques. The programme provided women – who are often landless and spend much time each day collecting water, animal fodder, or wood for fuel – with access to land where they could rear their goats and plant suitable grasses, legumes, and fodder trees. The Food and Agriculture Organization of the United Nations provided technical assistance and capacity-building to a number of projects that promoted communal forestry leaseholding. In particular, women adopted a type of grass that was utilized for making brooms, the sale of which provided an additional source of income. The grass was also used for forage of livestock and the dried stems as sticks to support growing vegetables.

Women using the assigned land (rather than walking long distances searching for ground grasses) reported significant time savings (between 3 and 10 hours per day). This enabled them to engage in other income-earning activities.

The case of Nepal shows how a gender-sensitive strategy focusing on access to land and livestock assets, in addition to training, can enhance women's adoption of technologies.

Sources: FAO (2019a); and Shapiro et al. (2015).

7.4.4 Access to information and communications technology

While much progress has been made in recent decades, a gender gap still persists in access to ICT. This is especially the case for rural women in developing countries who face what is known as a triple divide: digital, rural, and gender (FAO, 2018a). This gap means that fewer women participate not only in the use, but also in the development of digital agricultural technologies. For example, the Overseas Development Institute finds that digital agriculture in East Africa is resulting in new forms of exclusion. In the dynamic "AgTech" industry, women own fewer than 30 per cent of firms in Kenya, Uganda, and Rwanda, and none in the United Republic of Tanzania, South Sudan, and Burundi (Krishnan, 2018).

One way to promote women's greater digital literacy and challenge stereotypes blocking women's use of ICT is to design digital platforms specifically to meet women's needs. One example is the #VALUE4HERConnect digital platform, Africa's first online platform for female agripreneurs. The platform, part of a program led by the Technical Centre for Agricultural and Rural Cooperation (CTA) to empower women in agriculture, was launched in 2019 and has over 400 women members. Through the network, women can access buyers, market information, financing, and capacity-building opportunities, as well as a Women2Women forum for sharing information to help them grow their businesses, access global markets, and increase incomes (Biztech Africa, 2019; CTA, 2019).

7.4.5 Women's work burden and time poverty

As discussed in Section 1, the division of labour based on traditional gender roles, assigns women a major – if not exclusive – responsibility for domestic and care work, and this burden is likely to be particularly time-consuming and onerous in rural areas due to the lack of services and infrastructure.

Helping women access labour-saving technologies is an important, yet often overlooked, way to help them free up time and improve their agricultural productivity. Labour-saving technologies that target production and post-harvest activities can help women save time in planting, cultivating, harvesting, processing, packing, storing, and transporting agricultural products. Box 10 discusses an initiative to promote mechanization in African agriculture. Climate-smart practices such as zero-till or low-till agriculture have the potential to reduce the drudgery for women of such tasks as hand weeding. Other labour-saving practices include integrated systems such as the rice-fish or rice-shrimp aquaponics system. Rice and fish are cultivated together, and fish feed on the weeds while also fertilizing the rice. This can reduce the time that women spend weeding and applying chemicals to the rice (FAO 2019a).

Box 10

"Banish the hand hoe to the museum:" Sustainable agricultural mechanization in Africa

An initiative to promote sustainable agricultural mechanization in Africa under the slogan to "banish the hand hoe to the museum by 2025" is challenging the stereotypical image of an African woman cultivating her farm with a simple hand hoe. In part, this image reflects the reality of low levels of mechanization in Africa. There are 5 tractors for every 1,000 farmers in Africa, compared with almost 1,600 tractors for every 1,000 farmers in the United States. This is compounded by gender-based norms that relegate women to the labour-intensive tasks of weeding along with gender-based constraints on their access to mechanized equipment. For example, in some parts of Africa, it is considered inappropriate for women to work with oxen or to drive tractors (Ragasa, 2012).

Sustainable mechanization is a means to reduce the burden of hard labour, relieve labour shortages, improve productivity of agricultural operations, and enhance profitability and market access. Sustainability refers to the technology's economic, social, environmental, and cultural dimensions.

A public-private partnership between the Alliance for a Green Revolution in Africa and the Leasing Leveraging Livelihoods Consortium, for example, seeks to overcome the two key barriers to mechanization in African agriculture – lack of financing and lack of training – by coupling lease-to-own financing with training on how to use the equipment.

Sources: USAID (2016); and Food and Agriculture Organization, Sustainable agricultural mechanization, available at http://www.fao.org/sustainable-agricultural-mechanization/overview/what-is-sustainable-mechanization/en/ (accessed 1 May 2020).

8. Conclusions and policy recommendations

This module presented key concepts on the interplay between gender, the economy, and trade and applied them to a gender analysis of the interaction between technology in agriculture and trade. On the one hand, women face barriers in access to existing technologies; on the other hand, technological innovation often does not take into account women's needs and economic roles. These forms of gender inequality can prevent women from accessing trade in agriculture or benefitting from trade in the same way as their male counterparts. Since technology facilitates trade, and trade, in turn, provides opportunities to access technology, women in agriculture are often confronted with a low-productivity trap. When countries increase their participation in trade in the agricultural sector – as has been the case for developing countries over the last few decades – women workers tend to be hired as sources of competitive advantage and women entrepreneurs are often underachievers of comparative advantage.

Agriculture – encompassing not only raising crops, fish, and animals, but also activities related to food processing and packaging – is a key sector for women's livelihoods around the world. Over the last few decades, developing countries have become important traders in agriculture (especially in the export of high-value commodities), and agriculture has increasingly become organized around global value chains. However, as women's primary role is still often associated with householding, a large number of women perform unpaid agricultural work or hold irregular, precarious jobs in export-oriented activities and/or in agrifood value chains.

Trade liberalization, by itself, has differentiated effects on women, depending on the incidence of gender inequalities in the society and the economy, and on household dynamics. Gender-sensitive measures are critical to ensure that rural women participate in and benefit from trade (not only international trade, but also regional and subregional trade). Technology in agriculture can be a powerful tool to increase women's economic status, and trade can represent a vehicle for access to and the diffusion of technologies. Labour-saving technologies can raise women's productivity, providing them with the time to engage in income-generating activities and the capabilities to potentially meet international standards and access higher-value markets. As traditional activities become mechanized, however, some women may face (at least temporarily) job losses, while some activities may become more profitable but be acquired by men. In these circumstances, it is important to adopt appropriate policies supporting training and extension services, credit provision, and dissemination of information on new economic opportunities for women, in addition to measures supporting women's ownership and control of technologies.

To address the gender bias in the process of technology diffusion and innovation, gender sensitivity needs to be adopted from the initial stages of research and development (including the hiring of high-level research and managerial positions) to the stages of extension. This is key to ensure that technology can support women's empowerment and help reduce sources of gender discrimination (UNCTAD, 2011).

At the national level, agricultural policy and science, technology, and innovation should adopt a gender-sensitive approach, with special concern afforded to increasing participatory links between agricultural research institutions and female smallholder farmers.

Gender considerations should be taken directly into account in setting policies and research priorities to ensure that the different economic roles and challenges of both men and women are appropriately recognized (e.g. physical differences, differential trait preferences, different crops and practices targeted for research and improvement, and production of field crops versus food processing and its distribution). In this regard, it is important to support capacity-building in data collection and processing in the agricultural sector, involving both agricultural ministries and national statistical offices.

Targeting greater participation of women in agricultural research requires supporting women in higher education in science and improving their access to both formal and informal networks where they are often discriminated against. A key pre-condition is institutional support to challenge cultural stereotypes that tend to perceive science as a male field and caregiving as primarily women's work. In this regard, family-related policies can play a very important role in reducing women's burden of family responsibilities and help raise their productivity and economic opportunities (e.g. child care, parental leave, health care, transport, etc.).

Affordable, government-sponsored training and education are a key prerequisite to make extension more inclusive. Extension services, which are critical for the dissemination of innovation, should consider experimenting with

new delivery methods or employ more female extension agents to guarantee that both men and women receive equal exposure to information and knowledge. For example, training should be scheduled and organized taking into account women's family responsibilities and cultural norms. There is also evidence that female extension agents can be more successful in reaching female farmers, especially in remote rural areas and in more patriarchal societies (Meinzen-Dick et al. 2014; see also A.2.1 in Annex 2).

Digital technologies have been increasingly adopted in extension services and are becoming an important source of information and productivity. However, because women are less involved in ICT, there is a need for more public effort to increase access to and use of ICT by the rural poor. Education and training are essential to help women take advantage of new digital technologies, so addressing gender disparities at all levels of education and training is key.

There is evidence that participatory approaches to the process of technical change and extension can be successful to ensure that innovation and dissemination reflects the needs of the various stakeholders involved. However, an explicit gender dimension is required in order for participatory approaches to help in tackling women's constraints and gender barriers. This will require institutional support to foster the organization of women into groups, which will help with information-sharing, building support networks, and promoting effective change.

Participatory approaches should receive great attention, especially in the context of ongoing ecological challenges and the urgency for technological innovation in agriculture to help generate sustainability. Women, in fact, are typically the custodians of traditional knowledge, which includes biodiversity conservation. Biodiversity – in contrast to the dominant monoculture system – supports soil fertility and crop resilience to pests and diseases without the use of external inputs (Shiva, 1992, 2016). Based on the evidence that a larger number of women than men tend to reject technologies that may have an adverse impact on the environment and local communities, women's involvement in decision-making and the incorporation of gender considerations throughout the process of technological change and adoption can advance gender equality while supporting sustainable farming practices and reducing the carbon footprint of agriculture (UN Women et al. 2016). Government support to organic farming, climate-smart approaches, and agroecological practices is critical to contribute to climate stabilization and preservation of biodiversity, while also providing great economic opportunities for small-scale farmers, especially women (see A.2.2 in Annex 2).

The adoption of agricultural innovation is intrinsically related to access to and control of productive resources. In order for women to benefit from technical change, it is important to evaluate how in each context public investment (especially in infrastructure), financial services, and the legal setting affect men and women, and identify what corrections can be made to reduce the gender gap in the control of economic resources. Customary and statutory legal rights, marriage laws, and inheritance provisions are all legal areas that often prevent women from having control of the land at par with men (Bamber and Staritz, 2016). Gender sensitization training for officials and information campaigns are valuable tools to help raise gender awareness and adopt gender targets. In this regard, it is important to strengthen efforts to collect sex-disaggregated data to help shed light on the various forms of gender inequality and inform gender-sensitive policies.

Technology has the potential to help women increase productivity, become more competitive in trade, and access higher-value activities in the global agrifood chains.[48] In addition, technology can help in developing sustainable farming practices, which are essential to cope with the effects of climate change and to improve the livelihoods of rural women (who are at especially high risk of suffering the impact of the climate crisis) (Huyer, 2016). Addressing the existing gender gaps in access to technology and the process of innovation is an important step towards fulfilling the 2030 Sustainable Development Goals, including those for food security, sustainable agriculture, gender equality, and empowerment of all women and girls.

Exercises and questions for discussion

1. What are some commonly observed dimensions of gender inequality that affect women's participation in the economy?
2. How can gender disparities in earnings be measured?
3. How can trade affect the gender distribution of income and resources? And how can gender inequalities impact trade?
4. What are the different forms of gender bias in the agriculture sector?
5. What opportunities has global agricultural trade opened for women?
6. How has technology contributed to transform world agriculture markets?
7. What are the key economic and environmental challenges that have led to a growing search for sustainable techniques of production?
8. How can agricultural technology positively impact trade? And how can trade support productivity and innovation in agriculture?
9. Why and in what ways do agricultural technologies typically exhibit gender-differentiated effects?
10. How can technology support women's competitiveness and integration in global value chains?
11. In what ways can sustainable production practices support women's empowerment?
12. What are the key explanatory factors behind the gender gaps in the adoption of technologies?
13. How can research and development and extension become gender-sensitive?
14. What are some examples of initiatives aiming to tackle the gender-based constraints that impinge on women's adoption of technology?
15. What measures could national policies consider to help women benefit from technological change?

Annex 1. Overview of technologies in agriculture

This annex presents examples of key agricultural technologies in three broad areas: production, harvest and post-harvest, and digital technologies. Without aiming to be exhaustive, the annex aims to highlight those technologies that are most relevant to women engaged with trade in agriculture

Category	Subcategory	Examples
Production technologies	**Seeds and breeds** designed or adapted to fit local conditions and needs	**New Rice for Africa (NERICA)**, a cross between African and Asian rice species, with short growth duration and resistance to harsh conditions. **Artificial Insemination** to increase genetic diversity for remote livestock populations, helping farmers adapt to changing conditions and demands.
	Animal health technologies	**Vaccines and antibiotics**, which can reduce the burden of diseases.
	Mechanization of a wide range of operations including land clearance, management, water usage, application of fertilizers, and pesticides **Smart energy** such as solar, wind, biomass, and hydroelectric can replace fossil fuels and diesel engines	**Drip irrigation systems**, which are highly adaptable to different topography and efficient, and particularly suited to fruit and vegetable value chain. Drip irrigation favours use by women because there are less physical strength requirements (Bamber and Fernandez-Stark, 2013). **Wind turbines** that run farm machinery, pumps, air-conditioners, and poultry equipment. **Solar-powered surface irrigation water lifting stations**; solar-powered pumps are particularly suitable for women, as they are not as heavy as traditional pumps and can be located near the house (Theis et al., 2018).
	Sustainable practices to increase production while preserving the environment	**Organic agriculture**, which relies on ecosystem management rather than external inputs; and eliminates the use of synthetic inputs such as fertilizers and pesticides, genetically modified seeds and breeds, irradiation, preservatives, additives, and veterinary drugs. **Conservation agriculture**, which focuses on soil preservation through minimum disturbance, permanent cover, and crop rotation. No-till methods can reduce women's work burden when they are primarily responsible for weeding. **Agroecology**, described by the FAO (2018h, 1) as "an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. It seeks to optimize the interactions between plants, animals, humans and the environment while taking into consideration the social aspects that need to be addressed for a sustainable and fair food system." For example, **aquaponics** combines aquaculture and hydroponics so that farmers cultivate complementary plants and aquatic animals in a recirculating environment. According to the FAO (2018h, 2), "Agroecological innovations are based on the co-creation of knowledge, combining science with the traditional, practical and local knowledge of producers. By enhancing their autonomy and adaptive capacity, agroecology empowers producers and communities as key agents of change." **Integrated pest management**, which minimizes the use of pesticides, is a combination of crop management approaches from cultural, biological, mechanical, and chemical perspectives; techniques include intercropping, crop rotation, efficient fertilizer application, mulching, and cover cropping (among others).

Category	Subcategory	Examples
Harvest and post-harvest technologies	**Harvest, processing, and storage technologies** for non-perishable commodities such as cereals	**Tractors** can perform a variety of functions: **combine harvesters** cut, thresh, and pre-clean the grain; **mechanical drying** offers reduced handling losses and better control over air temperature and space (Kumar and Kalita, 2017); **mills** grind grains into flour and can be powered by water, wind, or motors and come in a variety of sizes; **bags** for storing flour prevent moisture and pest contamination and spoilage; **processes of treating and handling food stop or control spoilage and minimize the possibility of foodborne illness; food fortification** can help meet nutritional objectives; and compliance with measure, such as Good Manufacturing Practices and Hazard Analysis and Critical Control Points can strengthen **food security**.
	Cold chain technologies for perishable commodities, such as **fruits and vegetables, fresh milk, meat, and fish**	**Cold chain technologies** vary from simple methods using ice to forced air, hydro-cooling, or vacuum cooling; **cold storage technologies** can range from small walk-in cold rooms to large-scale commercial refrigerated warehouses; for transport, cold can be provided with ice or **trailer-mounted refrigeration systems** (Kitinoja, 2013).
	Technologies for commercialization of specialty and traditional crops and products to ensure high-quality and consistent production	Production of **essential oils, spice, oleoresins, powders, and specialty extracts and blends** relies on indigenous knowledge plus technologies for **processing**, such as **steam distillation** or **extraction with food solvents** such as ethanol (Douglas et al., 2005).
Digital technologies (Agriculture 4.0)	**Digital platforms and mobile phone applications (apps)** allow access to information and key services (for example, e-commerce or e-extension) targeted to the agricultural sector, including weather forecasts, advice on crop management, information on market prices, veterinary and financial services	**AgriMarketplace** mobile phone app connects producers and traders. **e-Nutrifood** provides information on producing, conserving, and eating nutritious foods. **Weather and Crop Calendar** provides farmers with early warning systems to adapt to climate change. **Cure and Feed Livestock** provides information on disease control and feeding strategies (FAO, 2019b).
	Internet of Things (IoT) refers to technologies that connect the Internet to **sensors** and other devices that transmit information; networked sensors in the IoT monitor the health, location, and activities of people and animals, production processes, and the natural environment (OECD, 2019)	**Animal biochip transponders** can monitor blood pressure, temperature, or digestion. **Water management** using IoT sensors to monitor the function of remote water pumps can anticipate maintenance needs and pump malfunctions (Westbase.Io 2018). **Drones** can be used to survey crops, and potentially for pest management and to time planting and harvesting as technology progresses.
	Distributed ledger technologies are decentralized digital systems for recording transactions	**Blockchain technology**, which according to the FAO's AGROVOC Multilingual Thesaurus is "an information technology that acts as a shared ledger for digital storage and tracking of data associated with a product or service, from the raw production stage until it lands in the consumer's hand in real time" (http://agrovoc.uniroma2.it/agrovoc/agrovoc/en/page/c_4c8d2418). Blockchain is a database for recording transactions as well as a platform to execute **smart contracts** that can digitally facilitate, verify, or enforce a contract (OECD, 2019; Tripoli and Schmidhuber, 2018). Blockchain traces the provenance of products along the value chain and contributes to faster and more reliable financial transactions. The first attempts to use blockchain technologies in the seafood industry were initiated in 2017, but it has not been widely adopted to date because of the fear of sharing commercial data with competitors (FAO, 2018f).

Source: Prepared by the UNCTAD secretariat.

Annex 2. Case studies

A.2.1. Florence Kondylis, Valerie Mueller, Glenn Sheriff and Siyao Zhu (2016): "Do female instructors reduce gender bias in diffusion of sustainable land management Techniques? Experimental evidence from Mozambique"

Objective and background

This paper evaluates the role of gender in the dissemination of sustainable land management (SLM) techniques in Mozambique. Specifically, the paper examines whether introducing female messengers improves information dissemination of SLM to female famers.

Data and methodology

The analysis uses a large-scale field experiment in the Zambezi valley of Mozambique. In 2010, the experimental communities were randomly selected to have a female messenger trained in SLM requested to teach the techniques to other women.

Household panel surveys were conducted in the experimental areas 15 and 27 months after the initial training in October 2010. The surveys targeted SLM awareness, knowledge, and adoption; they were administered to at most two individuals per household, the household head, and his/her partner or spouse. The final sample included 2,461 men and 3,423 women in 3,685 households in 2012 and 2,122 men and 2,954 women in 3,440 households in 2013.

Findings

The results show that women's awareness of SLM increased by 9 percentage points in 2012 and that adoption of the technique increased by 5 percentage points in 2013 in communities with female messengers. The traditional provision of training in SLM practices to male messengers only had a significant impact on male farmers.

These results indicate that the provision of extension services through male-dominated networks may perpetuate gender inequalities in agriculture. In contrast, adding a female messenger may increase women's access to information. This outcome is due to two reasons: first, male messengers appear to be incentivized by the presence of female messengers to more effectively connect to both male and female farmers; second, female famers seem to be motivated by the presence of female messengers to increase their demand for information.

A.2.2 Munyaradzi Junia Mutenje, Cathy Rozel Farnworth, Clare Stirling, Christian Thierfelder, Walter Mupangwa, and Isaiah Nyagumbo (2019): "A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology"

Objective and background

This study aims to evaluate whether there are gender-based costs and benefits associated with climate-smart agriculture (CSA) and to assess their relationship with intra-household decision-making practices among small farmer households in Malawi, Mozambique, and Zambia. CSA technologies refer to measures that aim to increase productivity, help farmers adapt to the effects of climate change and manage climate risks, and reduce the carbon footprint of agriculture.

Data and methodology

The empirical analysis follows three stages: (1) an *ex-post* cost-benefit analysis of different CSA options at the household level; (2) stochastic dominance to assess the role of perceived risks in the adoption consideration of CSA technologies; and (3) a dynamic mixed multinomial logit to identify the factors that influence the households' decision to invest in CSA technologies.

The data include 1,440, 696, and 1,448 households in Malawi, Mozambique, and Zambia, respectively, covering 3,622, 2,106 and 5,212 maize-legume plots in these three countries over two years.

Findings

The cost-benefit analysis indicates that CSA technologies that included soil and water conservation improved maize varieties, and that cereal-legume diversification is associated with net positive economic benefits. The analysis of maize yields suggests that risk-averse farmers prefer CSA technologies that minimize production risks. The regression analysis shows that women's bargaining power, exposure to drought shock, and access to CSA technology information increase the likelihood of investing in CSA technologies. The positive role exercised by women's bargaining power indicates that, to foster the adoption of CSA options among smallholder farmers, it is important to promote women's active participation in intra-household decision-making. The empirical evidence thus suggests that the success of CSA depends on both technical CSA interventions and programs that support women's empowerment within the household.

A.2.3. Sophie Theis, Nicole Lefore, Ruth Meinzen-Dick, and Elizabeth Bryan (2018): "What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania"

Objective and background

This study focuses on the intrahousehold distribution of benefits from technology adoption, using small-scale irrigation technologies as a case study. The objective is to go beyond the traditional focus on technology adoption as a goal in and of itself by evaluating the extent to which both men and women within the same household gain from adoption or acquisition of technology.

Data and methodology

This study uses qualitative data collected in 19 communities in Ethiopia, Ghana, and the United Republic of Tanzania in 2016. Specifically, the study is based on 38 gender-separated focus groups (i.e. 19 focus groups of men and 19 focus group of women), with each focus group including between 5 and 16 men or women. The discussion questions centred around gender preferences for water technologies, technology choices, roles and responsibilities of both men and women, household use and management of irrigation technologies, and perceived benefits and incentives related to small-scale irrigation technology adoption.

Findings

The empirical results from the three countries show that the costs and benefits of technology adoption are not equally distributed within the household. As women's primary economic role is associated with domestic duties and agricultural work on family plots, men tend to hold more rights of use, management, fructus, and alienation, as well as stronger claims to these rights. Consistent with previous studies, these findings indicate that targeting women with technology alone is unlikely to ensure full ownership and management of the technology by women because of asymmetric bargaining power within the household. Supporting women's economic empowerment through technology (e.g. distributing motor pumps to women) is by itself insufficient if not accompanied by complementary social and institutional changes that promote more equitable gender roles and relations.

REFERENCES

ACET, ed. (2017). *African Transformation Report 2017 - Agriculture Powering Africa's Economic Transformation*. (African Center for Economic Transformation. Accra, Ghana and Washington, DC). Available at http://acetforafrica.org/acet/wp-content/uploads/publications/2017/10/ATR17-full-report.pdf

AgDevCo (2017). Successful models to empower women in outgrower schemes. Case Study No. 2. Available at https://www.agdevco.com/uploads/reports/SDU_Gender_Case%20Study_AW_digital_Jan%202018.pdf.

Akter S, Rutsaert P, Luis J, Htwe NM, San SS, Raharjo B and Pustika A (2017). Women's empowerment and gender equity in agriculture: A different perspective from Southeast Asia. *Food Policy*. 69:270–279. Available at https://doi.org/10.1016/j.foodpol.2017.05.003.

Ali D, Deininger K and Duponchel M (2016). Investigating the gender gap in agricultural productivity: Evidence from Uganda. *World Development*. 87:152–170.

Altieri MA (2009). Agroecology, small farms, and food sovereignty. *Monthly Review* (July-August):102–113.

Ashby J and Lilja N (2004). Participatory Research: Does It Work? Evidence from Participatory Plant Breeding. Paper presented at the 4th International Crop Congress: New directions for a diverse planet. Brisbane, Queensland, Australia, 26 September to 1 October.

Babini C (2017). Technology is not gender neutral. Consortium of International Agricultural Centers Available at http://www.rtb.cgiar.org/blog/2017/10/15/technology-is-not-gender-neutral/

Bamber P, and Fernandez-Stark K (2013). Global value chains, economic upgrading, and gender in the horticulture industry. In: Staritz C and Reis GR, eds. *Global Value Chains, Economic Upgrading, and Gender*. World Bank. Washington, DC

Bamber P, and Staritz C (2016). *The Gender Dimensions of Global Value Chains*. International Centre for Trade and Sustainable Development. Geneva.

Beintema NM and Marcantonio FD (2010). Female participation in African agricultural research and higher education – new insights: Synthesis of the ASTI-Award benchmarking survey on gender-disaggregated capacity indicators. IFPRI Discussion Paper No. 00957. International Food Policy Research Institute . Available at : https://gatesopenresearch.org/documents/3-357

Beuchelt T and Badstue L (2013). Gender, nutrition- and climate-smart food production: Opportunities and trade-offs. *Food Security*. 5:709–721. Available at https://doi.org/10.1007/s12571-013-0290-8.

Biztech Africa (2019). Africa's first online platform for female agripreneurs launched. 14 June. Available at https://www.biztechafrica.com/article/africas-first-online-platform-female-agripreneurs-/14716/

Braun AT, Colangelo E and Steckel T (2018). Farming in the era of Industrie 4.0. *Procedia CIRP*. 72:979–984.

Café Femenino (2018). Our story. Available at Rhttps://www.cafefemenino.com/story

Carr M and Hartl M (2010). *Lightening the Load: Labour Saving Technologies and Practices for Rural Women*. Practical Action Publishing.

Ceccarelli S and Grando S (2007). Decentralized-participatory plant breeding: An example of demand driven research. *Euphytica*. 155:349–360.

Chan M-K (2010). Improving opportunities for women in smallholder-based supply chains. Bill and Melinda Gates Foundation. Available at https://docs.gatesfoundation.org/documents/gender-value-chain-guide.pdf

Clugston C (2014). The business case for women's participation in agricultural cooperatives: A case study of the Manduvira Sugarcane Cooperative, Paraguay. ACDI/VOCA. Available at http://www.acdivoca.org/wp-content/uploads/2016/05/ACDI-VOCA-Leland-CDP-Paraguay-Business-Case-for-Women-Participation-Agricultural-Cooperatives.pdf.

Croppenstedt A, Goldstein M and Rosas N (2013). Gender and agriculture: Inefficiencies, segregation, and low productivity traps. *The World Bank Research Observer*. 28(1):79–109.

CTA (2019). #VALUE4HERConnect. Technical Centre for Agricultural and Rural Cooperation ACP-EU. Wageningen, The Netherlands. Available at https://value4her.hivebrite.com/

Desmarais AA (2003). The via Campesina: Peasant women at the frontiers of food sovereignty. *Canadian Women Studies*. 23(1):140–145.

Devaux A, Ordinola M and Horton D, eds. (2011). Innovation for development: The Papa Andina experience. International Potato Center (CIP), Lima, Peru.

DFID (2015). DFID's conceptual framework on agriculture. Department for International Development. London.

Díaz-García C, González-Moreno A and Sáez-Martínez F (2013). Gender diversity within R&D teams: Its impact on radicalness of innovation. *Innovation: Management, Policy and Practice*. 15(2):149–160.

Doss CR (2001). Designing agricultural technology for African women farmers: Lessons from 25 years of experience. *World Development*. 29(12):2075–2092. Available at https://doi.org/10.1016/S0305-750X(01)00088-2.

Doss CR (2015). Women and agricultural productivity: What does the evidence tell us? Yale University Economic Growth Center Discussion Paper No. 1051. Available at https://papers.ssrn.com/abstract=2682663

Douglas M, Heyes J and Smallfield B (2005). Herbs, spices and essential oils: Post-harvest operations in developing countries. United Nations Industrial Development Organization and the Food and Agriculture Organization. Vienna. Available at http://www.fao.org/3/a-i5090e.pdf

Duflo E (2012). Women empowerment and economic development. *Journal of Economic Literature*. 50(4): 1051–1079.

Elson D (2007). International Trade and Gender Equality: Women as Achievers of Competitive Advantage and as Sources of Competitive Advantage. Presented at the International Labour Organization International Symposium on Gender at the Heart of Globalization.

Europa M (2018). African tech innovation in the driver's seat of shea butter evolution. *Face 2 Face Africa.com*. 25 January. Available at https://face2faceafrica.com/article/african-tech-innovation-drivers-seat-shea-butter-evolution

FAO (n.d.). Women and the green revolution. In: *Women: The key to food security.* Food and Agriculture Organization of the United Nations. Rome. Available at http://www.fao.org/3/x0171e/x0171e00.htm#TopOfPage

FAO (2006). *Gender and Law: Women's Rights in Agriculture*. Food and Agriculture Organization of the United Nations. Rome.

FAO (2011). *The State of Food and Agriculture 2010-11: Women in Agriculture: Closing the Gender Gap for Development*. (Food and Agriculture Organization of the United Nations). Rome. Available at http://www.fao.org/publications/sofa/2010-11/en/

FAO (2013). *Women in Forestry: Challenges and Opportunities.* (Food and Agriculture Organization of the United Nations. Rome).

FAO (2014). *The State of Food and Agriculture 2014: Innovation in Family Farming.* (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/a-i4040e.pdf

FAO (2015). *The State of Agricultural Commodity Markets 2015*. (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/a-i5090e.pdf.

FAO (2016a). *Developing Gender-sensitive Value Chains: A Guiding Framework.* (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/a-i6462e.pdf.

FAO (2016b). *Promoting Gender Equality and Women's Empowerment in Fisheries and Aquaculture.* (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/a-i6623e.pdf

FAO (2017a). Food systems and value chains: definitions and characteristics. In: *Climate Smart Agriculture Sourcebook,* 2nd edition. Food and Agriculture Organization of the United Nations. Rome. Available at http://www.fao.org/climate-smart-agriculture-sourcebook/production-resources/module-b10-value-chains/chapter-b10-2/en/

FAO (2017b). *The State of Food and Agriculture 2017: Leveraging Food Systems for Inclusive Rural Transformation*. (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/a-i7658e.pdf.

FAO (2018a). Developing gender-sensitive value chains. Guidelines for practitioners. Food and Agriculture Organization of the United Nations. Rome.

FAO (2018b). e-Agriculture: Women, agriculture and ICTs. Food and Agriculture Organization of the United Nations. Rome. 1 September. Available at http://www.fao.org/e-agriculture/news/women-agriculture-and-icts

FAO (2018c). *FAO's Work on Family Farming. Preparing for the Decade of Family Farming (2019–2028) to Achieve the SDGs.* (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/CA1465EN/ca1465en.pdf.

FAO (2018d). *Gender and ICTs: Mainstreaming Gender in the Use of Information and Communication Technologies (ICTs) for Agriculture and Rural Development*. (Food and Agriculture Organization of the United Nations. Rome). Available at https://www.un-ilibrary.org/women-and-gender-issues/gender-and-icts_f02215d2-en

FAO (2018e). *The State of Agricultural Commodity Markets 2018.* (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/I9542EN/i9542en.pdf.

FAO (2018f). *The State of World Fisheries and Aquaculture: Meeting the Sustainable Development Goals.* (Food and Agriculture Organization of the United Nations. Rome).

FAO (2018g). *World Livestock - Transforming the Livestock Sector through the Sustainable Development Goals.* (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/CA1201EN/ca1201en.pdf

FAO (2018h.) *The 10 Elements of Agroecology - Guiding the Transition to Systainable Food and Agricultural Systems*. (Food and Agriculture Organization of the United Nations. Rome). Available at http://www.fao.org/3/I9037EN/i9037en.pdf

FAO (2019a). *Fostering the Uptake of Labour-saving Technologies.* (Food and Agriculture Organization of the United Nations. Rome.) Available at http://www.fao.org/3/CA2731EN/ca2731en.pdf

FAO (2019b). In action - Digital services in Africa. Food and Agriculture Organization of the United Nations. Rome. Available at http://www.fao.org/in-action/africa-digital-services-portfolio/en/

Freeman C (1987). *Technology Policy and Economic Performance: Lessons from Japan*. Pinter. London.

Gliessman SR (2007). *Agroecology: Ecological Processes in Sustainable Agriculture*. Boca Raton, FL. CRC Press.

Grassi F, Landberg J and Huyer (2015). *Running Out of Time: The Reduction of Women's Work Burden in Agricultural Production*. Food and Agriculture Organization of the United Nations. Rome. Available at http://www.fao.org/3/a-i4741e.pdf

Homann-Kee Tui S, Adekunle A, Lundy M, Tucker J, Birachi E, Schut M, Klerkx L, Ballantyne PG, Duncan AJ, Cadilhon JJ and Mundy P (2013). What are innovation platforms? Innovation Platforms Practice Brief 1. International Livestock Research Institute. Nairobi.

Huyer S (2016). Closing the gender gap in agriculture. *Gender, Technology and Development*. 20(2):105–116. Available at https://doi.org/10.1177/0971852416643872

IFC (2013). *Working with Smallholders A Handbook for Firms Building Sustainable Supply Chains*. (International Finance Corporation. Washington, DC). Available at https://www.ifc.org/wps/wcm/connect/8dc5628042112fdbba2fff494779b2ad/Handbook+-+Working+with+Smallholders.pdf?MOD=AJPERES

IFC (2016). *Investing in Women along Agribusiness Value Chains*. (International Finance Corporation. Washington, DC). Available at https://www.ifc.org/wps/wcm/connect/d19235d7-2ba7-4f7b-b0c6-5198fe9e4d30/Women+in+Agri+VC_Report_FINAL.pdf?MOD=AJPERES

ILO (1993). Resolution concerning the International Classification of Status in Employment. 13th International Conference of Labour Statisticians. International Labour Organization. Geneva.

ILO (2018a). *Care Work and Care Jobs - For the Future of Decent Work*. (International Labour Organization. Geneva).

ILO (2018b). *Global Wage Report 2018/2019 - What Lies Behind Gender Pay Gaps*. (International Labour Organization. Geneva).

ILO and UNCTAD (2013). *Shared Harvests: Agriculture, Trade and Employment*. (International Labour Organization and the United Nations Conference on Trade and Development. Geneva).

International Coffee Organization (2018). *Gender Equality in the Coffee Sector*. (ICO. London).

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn.

ITU (2019). *Measuring Digital Development - Facts and Figures* 2019. (International Telecommunication Union. Geneva).

King S (2013). Women's collective action in the honey sector in Ethiopia. Oxfam International. February.

KIT, Agri-ProFocus, and International Institute of Rural Reconstruction (2012). *Challenging Chains to Change: Gender Equity in Agricultural Value Chain Development*. (KIT Publishers, Royal Tropical Institute. Amsterdam).

Kitinoja L (2013). Use of cold chains for reducing food losses in developing countries. PEF White Paper No. 13-03. The Postharvest Education Foundation.

Kondylis F, Mueller V, Sheriff G and Zhu S (2016). Do female instructors reduce gender bias in diffusion of sustainable land management techniques? Experimental evidence from Mozambique. *World Development* 78:436–449.

Krishnan A (2018). How AgTech is changing East African economies. Overseas Development Institute. 11 October. Available at https://www.odi.org/blogs/10693-how-agtech-changing-east-african-economies (accessed 5 May 2019).

Kumar D and Kaalita P (2017). *Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries*. (ADM Institute for the Prevention of Postharvest Loss. University of Illinois at Urbana-Champaign).

Marsden K and Garzia M (1998). Agro-industrial policy reviews - Methodological guidelines. Training Materials for Agricultural Planning No. 42. Food and Agriculture Organization of the United Nations. Rome.

McIntyre BD, Herren HR, Wakhungu J and Watson RT (2009). *Agriculture at a Crossroads: International Assessment of Agricultural Knowledge, Science and Technology for Development Global Report*. Island Press. Washington, DC.

Meinzen-Dick R, Quisumbing AR and Behrman JA (2014). A system that delivers: Integrating gender into agricultural research, development, and extension. In: Quisumbing A, Meinzen-Dick R, Raney T, Croppenstedt A, Behrman J and Peterman A, eds. *Gender in Agriculture*. Springer. Dordrecht

Meinzen-Dick R, Quisumbing A, Behrman J, Biermayr-Jenzano P, Wilde V, Noordeloos M, Ragasa C and Beintema N (2010). Engendering agricultural research. IFPRI Discussion Paper No. 00973. International Food Policy Research Institute. Washington, DC. Available at http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/1655/filename/1656.pdf

Mellor JW (1987). Links between technology, agricultural development, economic growth and trade creation. In: Ryan J, ed. *Building on Success: Agricultural Research, Technology and Policy for Development*. Australian Center for International Agricultural Research. Canberra.

Migliorini P and Wezel A (2017). Converging and diverging principles and practices of organic agriculture regulations and agroecology: A review. *Agronomy for Sustainable Development*. 37(63).

Minten F Randrianarison L and Swinnen J (2009). Global retail chains and poor farmers: Evidence from Madagascar. *World Development*. 37(11):1728–1741.

Mohammed F, Boateng S and Al-hassan S (2013). Effects of adoption of improved shea butter processing technology on women's livelihoods. *American Journal of Humanities and Social Sciences*. 1(4):244–250.

Monjane B (2015). Peasant women power in Mozambique. *Farming Matters*. December.

Moser C (1989). Gender planning in the third world: Meeting practical and strategic gender needs. *World Development*. 17(11): 1799–1825.

Munyaradzi JM, Farnworth CR, Stirling C, Thierfelder C, Mupangwa W and Nyagumbo I (2019). A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics*. 163: 126–137.

New Field Foundation (2010). Rural women's associations and sustainable agriculture in Casamance, Senegal. New Field Foundation. Available at https://tinyurl.com/72q2me5

Nguyen H, Mortensen S and Pravalprukskul P (2019). Pathways for women's empowerment in agriculture in South and Southeast Asia. Stockholm Environment Institute (SEI) Discussion Brief. January.

OECD (2019). *Digital Opportunities for Trade in Agriculture and Food Sectors*. (Organisation for Economic Co-operation and Development. Paris).

Oliver B (2016). The earth gives us so much: Agroecology and rural women's leadership in Uruguay *Culture, Agriculture, Food and the Environment: The Journal of Culture and Agriculture*. Available at https://doi.org/10.1111/cuag.12064

Segal R and Minh LN (2019). *Unfair Harvest - The State of Rice in Asia*. Oxfam. London. Available at https://www.oxfam.org/en/research/unfair-harvest-state-rice-asia

Peterman A, Behrman J, and Quisumbing A (2014). A review of empirical evidence on gender differences in nonland agricultural inputs, technology, and services in developing countries. In: Quisumbing A, Meinzen-Dick R, Raney T, Croppenstedt A, Behrman J and Peterman A, eds. *Gender in Agriculture*. Springer. Dordrecht.

Polar V, Babini C and Velasco C (2017). *Technology Is Not Gender Neutral: Factors that Influence the Potential Adoption of Agricultural Technology by Men and Women*. International Potato Center. La Paz, Bolivia.

Quisumbing AR, Meinzen-Dick RS, Raney TL, Croppenstedt A, Behrman JA, and Peterman A (2014). Synopsis of gender in agriculture: Closing the knowledge gap. IFPRI Issue Brief No. 84. International Food Policy Research Institute. Available at https://ideas.repec.org/p/fpr/issbrf/84.html

Ragasa C (2012). Gender and Institutional Dimensions of Agricultural Technology Adoption. Presented at the International Association of Agricultural Economists Triennial Conference, Foz do Igausu, Brazil. August. Available at http://ageconsearch.umn.edu/bitstream/126747/2/IAAE.2012.gender.pdf

Ragasa C, Sengupta D, Osorio M, Ourabah Haddad N and Mathieson K (2014). *Gender-specific Approaches and Rural Institutions for Improving Access to and Adoption of Technological Innovations*. Food and Agriculture Organization of the United Nations. Rome.

Razavi S (2007). The political and social economy of care in a development context: Conceptual issues, research questions and policy options. UNRISD Programme Paper No. 3. United Nations Research Institute for Social Development. Geneva.

Redden J (2017). *The Role of Aid for Trade in Building the Capacity of Developing Country Firms to Meet Sustainability Standards*. International Centre for Trade and Sustainable Development. Geneva. Available at https://www.greenindustryplatform.org/sites/default/files/downloads/resource/The%20Role%20of%20Aid%20for%20Trade%20in%20Building%20the%20Capacity%20of%20Developing%20Country%20Firms%20to%20Meet%20Sustainability%20Standards.pdf.

Rockström J, Steffen W and Noone K (2009). A safe operating space for humanity. *Nature*. 461:472–475

Shapiro B, Adhikari BR, Baral NR, Hancock B, Kafley G, Koirala P and Reijmerinck J (2015). *Regenerating Forests and Livelihoods in Nepal: A New Lease on Life – Unfolding the Experience of 20 Years of Poverty Alleviation through Leasehold Forestry in the Himalayas*. CABI. Wallingford, UK.

Shiva V (1992). Women's indigenous knowledge and biodiversity conservation. *India International Centre Quarterly*. 19(1/2):205–214.

Shiva V (2009). Women and the gendered politics of food. *Philosophical Topics*. 37(2):17-32.

Shiva V (2016). *Who Really Feeds the World? The Failures of Agrobusiness and the Promise of Agroecology*. North Atlantic Books. Berkley, CA.

Sobha I (2007). Green Revolution: Impact on gender. *Journal of Human Ecology*. 22(2):107–113.

Sommerville C, Cohen M, Pantanella E, Stakus A, and Lovatelli A (2014). Small-scale aquaponics food production Integrated fish and plant farming. FAO Fisheries and Aquaculture Technical Paper 589. Food and Agriculture Organization of the United Nations. Rome.

Standing G (1989). Global feminization through flexible labour. *World Development*. 17(7):1077–1095.

Standing G (1999). Global feminization through flexible labour: A theme revisited. *World Development*. 27(3):583–602.

Stoop W and van Walsum E (2013). SRI - A grassroots revolution. *Faming Matters* (March).

Swinnen J (2015). *Value Chains, Agricultural Markets and Food Security*. Food and Agriculture Organization of the United Nations. Rome. Available at http://www.fao.org/3/a-i5226e.pdf.

Tejiani S and Milberg W (2010). Global defeminization? Industrial upgrading, occupational segmentation and manufacturing employment in middle-income countries. Working Paper No. 2010-1. Schwartz Center for Economic Policy Analysis and Department of Economics, School for Social Research, New School.

Theis S, Lefore N, Meinzen-Dick R and Bryan E (2018). What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. *Agriculture and Human Values*. 35(3):671–684.

Tiki S, Chun LL and Savann O (2015). SRI cultivates the well-being of women. *Farming Matters* (December).

Tripoli, M and Schmidhuber J (2018). *Emerging Opportunities for the Application of Blockchain in the Agri-food Industry*. Food and Agriculture Organization of the United Nations and International Centre for Trade and Sustainable Development. Rome and Geneva.

Twin (2013). *Empowering Women Farmers in Agricultural Value Chains*. Available at http://www.fairtradeamerica.org/~/media/fairtrade%20america/files/reports/empowering-women-farmers-in-agricultural-value-chains-twin%20(2013).pdf

UNCTAD (2011). *Applying a Gender Lens to Science, Cechnology and Innovation.* (United Nations publication. New York and Geneva).

UNCTAD (2013). *Trade and Environment Review 2013: Wake Up Before It Is Too Late.* (United Nations publication. Geneva).

UNCTAD (2014a). *Teaching Material on Trade and Gender. Volume 1: Unfolding the Links*. (United Nations publication. New York and Geneva).

UNCTAD (2014b). *Teaching Material on Trade and Gender. Volume 2: Empirical Analysis of the Trade and Gender Links.* (United Nations publication. New York and Geneva).

UNCTAD (2016). *Trade as a Tool for the Economic Empowerment of Women.* Note by the United Nations Conference on Trade and Development Secretariat. (United Nations publication. Geneva). Available at https://unctad.org/meetings/en/SessionalDocuments/ciem8d2_en.pdf

UNCTAD (2017). *The Role of Science, Technology and Innovation in Ensuring Food Security by 2030*. (United Nations publication. Geneva).

UNCTAD (2019). *Borderline: Women in Informal Cross-border Trade in Malawi, the United Republic of Tanzania and Zambia.* (United Nations publication. Geneva).

UNDP (2016). *Human Development Report 2016 - Human Development for Everyone.* (United Nations Development Programme. New York).

UNDP (2019). *Human Development Report 2019– Beyond Income, Beyond Averages, Beyond Today: Inequalities in Human Development in the 21st Century.* (United Nations Development Programme. New York).

UNECE (2019). *Gender Responsive Standards*. (United Nations Economic Commission for Europe. Geneva).

UN Women (2016). Empowering women farmers of Rwanda through mobile technology. 13 October. Available at http://www.unwomen.org/news/stories/2016/10/empowering-women-farmers-of-rwanda-through-mobile-technology (accessed 5 May 2019).

UN Women, UN Desa, and UNFCCC (2016). Implementation of gender-responsive climate action in the context of sustainable development. Expert Group Meeting Report. Bonn, Germany. 14–16 October.

USAID (2016). New model aims to banish the hoe to the museum. U.S. Agency for International Development. Washington DC. 11 November. Available at http://agra.org/sstp/news/new-model-aims-to-banish-the-hoe-to-the-museum

van Staveren I, Elson D, Grown C and Çağatay N, eds. (2007). *The Feminist Economics of Trade*. Routledge. London and New York.

Webster T (2017). Films from the climate change front line. The New Humanitarian. 24 December. Available at https://www.thenewhumanitarian.org/video/2017/12/24/films-climate-change-front-line (accessed 5 May 2019).

Westbase.io (2018). IoT for farming in developing countries – How can it help? 24 October. Available at https://www.westbase.io/iot-for-farming-in-developing-countries/ (accessed 12 June 2019).

Willer H and Lernoud J (2019). The world of organic agriculture. Statistics and emerging trends 2019. Research Institute of Organic Agriculture (FiBL), Frick and IFOAM - Organics International. Bonn.

World Bank, ed. (2011). *Agricultural Innovation Systems: An Investment Sourcebook*. (World Bank. Washington, DC).

World Bank (2016). *World Feminization of Agriculture in the Context of Rural Transformations: What Is the Evidence?* (World Bank. Washington, DC). Available at http://documents.worldbank.org/curated/en/790991487093210959/pdf/ACS20815-WP-PUBLIC-Feminization-of-AgricultureWorld-BankFAO-FINAL.pdf

World Bank (2019). *World Development Report 2019: The Changing Nature of Work*. (World Bank. Washington, DC).

World Bank (2020). *Women, Business and the Law 2020*. (World Bank. Washington, DC).

World Bank, Food and Agriculture Organization of the United Nations, and International Fund for Agricultural Development, eds. (2009). *Gender in Agriculture Sourcebook*. (World Bank. Washington, DC).

WTO (2017). *World Trade Report. Trade, Technology and Jobs*. (World Trade Organization. Geneva).

ENDNOTES

[1] The teaching manual is comprised of Volume 1 (*Unfolding the Links*) (UNCTAD, 2014a) and Volume 2 (*Empirical Analysis of the Trade and Gender Links*) (UNCTAD, 2014b). The teaching manual has been developed with the intention of enhancing the capacity of policymakers, civil society organizations, and academics to evaluate the gender effects of trade and trade policy and formulate gender-equitable policies. The three modules of Volume 1 have been followed by the development of additional teaching devoted to examine the specific circumstances and institutions of individual world regions, namely the Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Southern Africa Development Community (SADC), and Southern Common Market (MERCOSUR).

[2] An agrifood value chain "incorporates the full range of activities required to bring a product or service from conception to production, delivery to consumers, and final disposal after use" (World Bank et al. 2009: 174). In the modern global economy, food production is often the result of a series of interlinked activities, including harvesting, processing, distribution, consumption and disposal. The range of actors and their interlinked value-adding activities involved in food markets leads to the establishment of "food systems." Food systems are comprised of all food products that originate from crop and livestock production, forestry, fisheries, and aquaculture, as well as the broader economic, societal, and natural environments in which these diverse production systems are embedded (FAO, 2017a).

[3] See UN Women, Gender mainstreaming: concepts and definitions. Available at https://www.un.org/womenwatch/osagi/conceptsandefinitions.htm.

[4] It is important to note that in the poorest countries, as indicated by the case of sub-Saharan Africa, women often have to work – and thus have no choice – given the high incidence of poverty and the lack of social safety nets provided by the state.

[5] As defined by the ILO (1993: 3), a contributing family worker is "a person who holds a self-employment job in a market-oriented establishment operated by a related person living in the same household, and who cannot be regarded as a partner because of the degree of his or her commitment to the operation of the establishment, in terms of the working time or other factors to be determined by national circumstances, is not at a level comparable with that of the head of the establishment."

[6] The Millennium Project Task Force on Education and Gender Equality has developed an operational framework that distinguishes between three domains of gender equality: (a) capabilities (e.g. knowledge and health); (b) access to resources and opportunities (e.g. ownership of economic assets, employment, political representation); and (c) security (i.e. vulnerability to violence and conflict). This module focuses on the first two domains.

[7] "Pay" is measured as wages or earnings received by employees, as opposed to income received through other forms of labour (e.g. self-employment).

[8] Subgroups are identified through the following primary criteria: age, working-time status, and public-sector vs. private-sector employment (ILO, 2018b).

[9] In comparison to the factor-weighted gender pay gap, the raw gender wage gap underestimates the magnitude of gender earning differentials in more than 70 per cent of the countries examined by the ILO (2018b).

[10] This example should help in reading the values shown in Figure 8. In the world, the factor-weighted gender pay gap is 18.8 per cent. This means that women are paid 81.2 per cent of what men are paid. The same criterion should be used to interpret the other data.

[11] Other aggregate indicators available are the Gender Inequality Index provided annually by the United Nations Development Programme in the *Human Development Report*; the Gender Gap Index introduced by the World Economic Forum in 2006; and the Social Institutions and Gender Index launched in 2009 by the Organisation for Economic Co-operation and Development.

[12] It is important to note that the impact on women, in turn, varies based on age, class, ethnicity, and other social stratifiers.

[13] Even if the government manages to replace tariff revenues with alternative tax revenue (through either direct or indirect taxes), this shift may have a gender-differentiated impact.

[14] Absolute costs refer to the level of production costs, which are used as a measure of efficiency. Lower production costs indicate higher efficiency. Relative costs are based on the concept of opportunity cost, which is defined as the value of the next-best alternative to the current use of the available economic resources. Lower opportunity cost indicates higher relative efficiency.

[15] The principle of comparative advantage, which is at the core of standard trade theory, suggests that countries compete based on relative unit costs. In contrast, the concept of competitive advantage states that countries compete based on absolute unit costs (rather than relative costs).

[16] As economies shift to the production of higher-value-added goods at higher capital intensity, feminization of employment may be reversed (i.e. "defeminization" of employment). Women, in fact, are preferred for low-productivity, low-pay jobs (Tejani and Milberg, 2010).

[17] Higher gender wage differentials lead to lower export prices; in turn, per any given level of exports, a country can purchase fewer imports.

[18] These dimensions are referred to as "capabilities."

[19] Care work is particularly time-consuming and onerous in rural areas due to lack of services and infrastructure.

[20] There is evidence that even when a crop is traditionally female-intensive, its commercial exploitation causes men to enter the sector and take over production and/or marketing.

[21] A study for Uganda found that care activities accounted for half of the difference in productivity between male- and female-owned plots, after taking into account factors such as increased access to inputs (Ali et al., 2016).

[22] Agro-industries refer to those industries that use raw materials and/or intermediate products generated in the agricultural sector. According to the International Standard Industrial Classification (ISIC), agro-industry includes the food industry, beverages and tobacco; textiles, wearing apparel and leather-industries; wood and wood products, including furniture; paper and paper products, printing and publishing; and rubber products (Marsden and Garzia, 1998).

[23] Green Revolution technologies refer to industrial agriculture technologies, which include higher-yielding seed varieties, more effective pesticides and fertilizers, and new irrigation systems. Initially developed by Norman Borlaug, an American scientist in Mexico in the 1940s, Green Revolution technologies spread worldwide in the 1940s and 1950s.

[24] This potential effect needs to be balanced with the historical evidence. Because of trade liberalization and food policies that subsidize industrial agriculture to make food products cheap, agricultural production has become much more energy- and capital-intensive. It has proved increasingly difficult for small farmers in developing countries to remain competitive and many of them have been forced to move to urban areas.

[25] Planetary boundaries refer to the environmental limits within which humanity can pursue development in a sustainable manner (Rockström et al., 2009).

[26] According to the World Bank (2019), however, the extent of job losses due to automation is unclear, whereas there is evidence that technology leads to a net increase in labour demand.

[27] New technologies do not necessarily refer to innovative techniques of production from a global perspective; they can also refer to modernization of production through the adoption of available technologies.

[28] See Annex 1 for an explanation and examples of each technology.

[29] Artificial intelligence refers to the use of computer systems or computer-controlled robots to perform tasks that traditionally require human intelligence.

[30] Internet of Things technology refers to interconnection via the Internet of computing devices and digital machines capable of collecting and sharing digital information.

[31] Big data analytics consists of the process of extracting information from "big data," which are defined by the large and diverse types of data collected through a wide variety of sources (e.g. social networks, customer databases, mobile applications, business transactions, etc.)

[32] See Annex 1 for a discussion of the Internet of Things.

[33] Standards may cover a range of aspects related to production, including worker health and safety, environmental sustainability, product quality, or efficiency of the production process. One important category of mandatory standards for agricultural products is sanitary and phytosanitary standards, which cover human, animal, and plant life or health, and may specify how products should be handled or that they should not contain harmful substances (UNECE, 2019). Other examples of standards include fair trade, whether a product is organic, gender equality, or other social responsibility standards. The increase in standards has been exponential in recent years – with over 20,000 types, according to the International Organization for Standardization (ISO) – and is attributed to growing consumer awareness and the concern by lead firms in GVCs to ensure high quality and corporate reputation (Redden, 2017).

[34] It is important to note that the impacts of these shifts may differ depending on the nature of economic participation. For example, although women as smallholder producers may lose out from such a change, women as workers in estate production may benefit in terms of better working conditions, pay, and stability of employment (UNECE, 2019).

[35] The EIF is a multilateral organization that provides technical and financial support to the least-developed countries to enhance their participation in the international trade system.

[36] The advantage of "outsider" status has been seen in other cases as well. For example, since the 1990s the growth of more lucrative employment opportunities in services and software in India that require English-speaking skills has provided job opportunities for women who had been excluded from traditional caste networks for finding jobs. As a result, among the lower castes, girls are now more likely to be educated in English than boys, because they are "free" from the social expectations that keep the boys locked into traditional, but less lucrative, career paths (Duflo, 2012).

[37] Biodynamic farming is an approach to sustainable and organic farming that requires the application of very specific biodynamic preparations and allows access to lucrative niche markets (Clugston, 2014).

[38] Agroecology exploits complementarities between different elements of nature (among crops, plants, soils, and animals). As examples, traditional poly culture bean, corn, and squash cropping can help enhance the yield of all of them; the squash controls weeds, and beans fix nitrogen (Gliessman, 2007). Aquaponics allows for combining aquaculture (raising aquatic animals in tanks) with hydroponics (cultivating plants in water) in a symbiotic environment (Somerville et al., 2003). Following the principles of agroecology, ecologically balanced agriculture can avoid the use of fertilizers and pesticides, support productivity, and build on local, diverse agrosystems (Shiva, 2013).

[39] La Via Campesina, an international farmers' movement started in the early 1990s to advocate for small-scale and sustainable farming, has placed gender issues (e.g. equality and human rights, economic justice, and social development) at the center of its agenda (Desmarais, 2003)

[40] For example, the Mozambican Farmer's Union, UNAC, has promoted agroecology to support as the conservation of native seeds and local systems of food production. Women play a key role in many of UNAC's activities (Monjane, 2015).

[41] The system of rice intensification (SRI) originated in Madagascar in 1980 and since then has spread worldwide. As explained by Stoop and van Walsum (2013: 8), "SRI is not a fixed package of practices but involves a set of interdependent agronomic principles. It is a system, and scientists are now looking at the fundamental plant physiological processes that can explain the SRI phenomenon. The practice of spacing single plants more widely enables plants to create more and stronger tillers and roots and become much more efficient in their uptake of water and nutrients and in utilizing solar radiation. The result is a crop that is more resilient to droughts, pests and diseases. Moreover, the combination of aerobic soil conditions and the use of organic fertilizer creates a favourable environment for interactions between roots and the soil's micro-organisms – a factor that has been seriously neglected by modern farming methods and research."

[42] The definition of agriculture generally employed in these studies is limited to production and harvest activities. Also, due to significant data constraints, most studies simply compare only male- and female-headed households, which leaves out female farmers in male-headed households (Ragasa 2012). For an extensive discussion of measurement and data-related issues, see Doss (2015). A related issue is that the vast majority of existing studies focus on sub-Saharan Africa, where men and women are typically responsible for separate plots and agricultural activities are more gender-differentiated, and hence sex-disaggregated data are easier to gather. A recent survey of the state of gender research

in agriculture found that 59 per cent of studies were conducted in sub-Saharan Africa, followed by 22 per cent in South Asia, 10 per cent in Latin America, and 6 per cent in Southeast Asia (Quisumbing et al., 2014).

[43] The Internet user gender gap is measured as the difference between the Internet user penetration rates for males and females relative to the Internet user penetration rate for males, calculated as a percentage (ITU, 2019).

[44] In the language of Module 3, women in agriculture may be "sources of competitive advantage" as paid or unpaid family workers contributing to the commercial activities of others or "underachievers of competitive advantage" as owners of their own businesses or as self-employed producers. In terms of women as sources of competitive advantage, producers use existing inequalities to cut costs and increase exports by hiring female workers for lower-wage, lower-skilled, casual, and flexible work. In terms of underachievers of competitive advantage, which is the most relevant case to the discussion here, gender inequality can be a barrier to the growth and competitiveness of women-owned businesses (UNCTAD, 2014a).

[45] The evidence refers to nine sub-Saharan countries: Botswana, Ghana, Kenya, Malawi, Mozambique, Nigeria, Senegal, South Africa, Uganda, and Zambia (Beintema and Marcantonio, 2010).

[46] According to Homann-Kee et al. (2013: 1), "An innovation platform is a space for learning and change. It is a group of individuals (who often represent organizations) with different backgrounds and interests: farmers, traders, food processors, researchers, government officials etc. The members come together to diagnose problems, identify opportunities and find ways to achieve their goals. They may design and implement activities as a platform, or coordinate activities by individual members."

[47] Women who manage agricultural activities are found to face more challenges than men in hiring workers (Doss, 2001).

[48] See A.2.3 in Annex 2 for a study on intra-household distribution of benefits from technology adoption.

ISBN 978-92-1-112984-7

Layout and Printing at United Nations, Geneva – 2007134 **(E)** – September 2020 – 571 – **UNCTAD/DITC/2020/1**