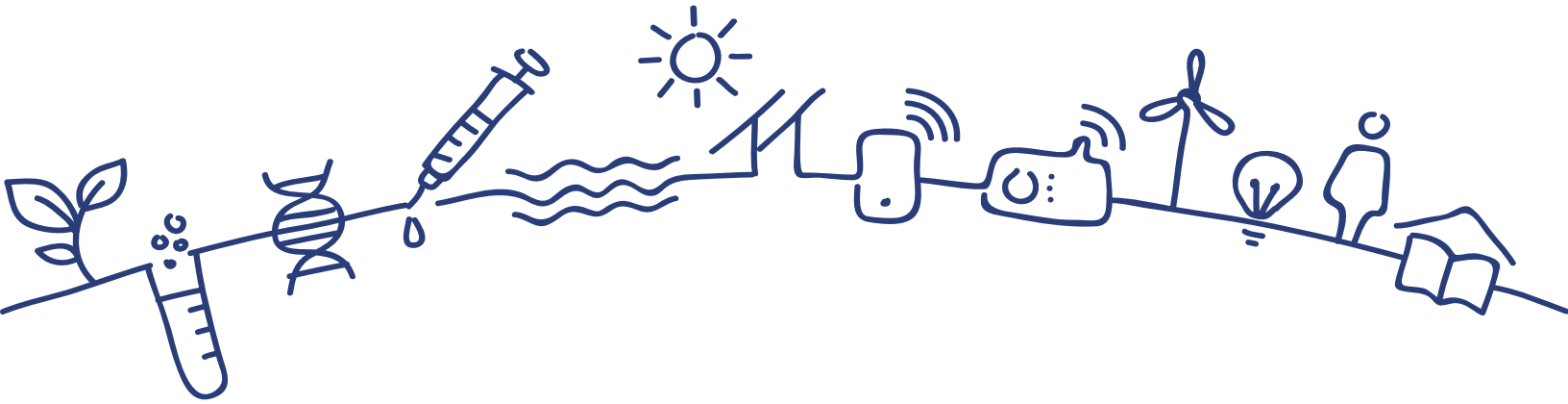
50 BREAKTHROUGHS

Critical scientific and technological advances needed for sustainable global development



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NOTES ON METHODOLOGY AND LAYOUT

Traditionally studies focused on future-facing topics have relied on surveys of experts, using approaches like the Delphi Method[1], a structured iterative process of interviews and reviews. Early in our study, we discovered two challenges with such a process. First, the absence of a broad, credible evidence base about what works has led to entrenched opinions. Second, such an approach would likely have led to a laundry list of 50 *technologies* or *devices*, rather than to a robust problem analysis which logically leads to the *breakthroughs* required—agnostic to specific technologies.

Hence, this study employs a six-part approach to reach its conclusions:

1. Describe and analyze the 5-10 most important contextual facts about the specific problem.
2. Identify the key challenges, which have kept effective solutions from becoming a reality.
3. Identify, based on input from recognized topic-specific experts, the most promising interventions to overcome those hurdles.
4. Determine the dependence of each of these interventions on: policy reforms, infrastructure development, education and human capital development, behavior change, access to user finance, an innovative business model, and finally, a new breakthrough technology.
5. We focus on interventions with a significant dependence on a breakthrough technology, and identify the important parameters the technology needs to fulfill. Based on the underlying technical challenges, we then estimate the time-to-market by when these breakthroughs may become deployable products.
6. Finally, we identify the most important hurdles to sustainable, large-scale deployment, based on many of the factors listed above (e.g., policy reforms, etc.), and score the difficulty of deployment on a 5-point scale: simple, feasible, complex, challenging, and extremely challenging. The purpose of this final analysis is to encourage technologists and funders to understand these challenges before making major investments in their work.

Each chapter is divided into three parts: Core Facts and Analysis, Key Challenges, and Scientific and Technological Breakthroughs. The 5-point scale and the complexity we ascribe to each of the factors and constraints relevant to the deployment of a particular technology are illustrated in **Table A**. The lowest score (feasible) is reserved for cases when the particular constraint is not relevant to deployment; the constraint is given the highest score (extremely challenging) if it can be a serious bottleneck to deployment. The aggregate score reflects the overall degree of difficulty, considering the collective weight of the individual constraints. The methodology is clearly subjective. **Exhibit A** is a sample of how we have illustrated the difficulty of deployment for each breakthrough across the study. This particular sample highlights a CHALLENGING breakthrough.

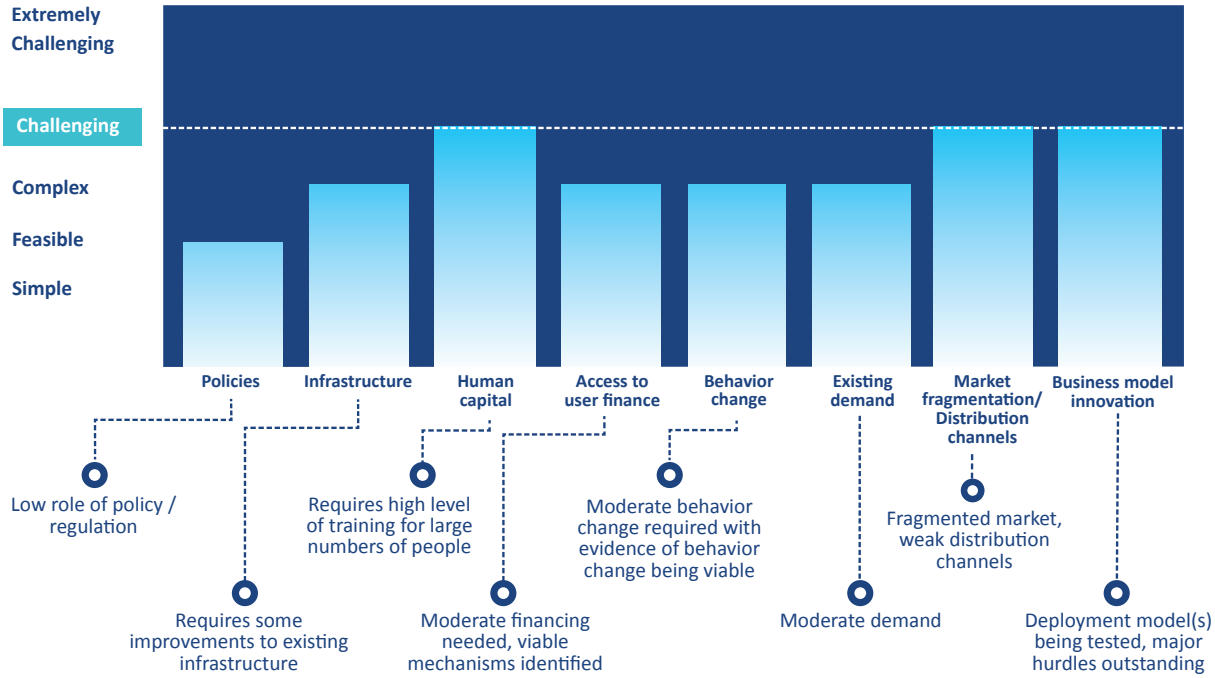
[1] A structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts who anonymously reply to questionnaires and subsequently receive feedback in the form of a statistical representation of the 'group response', after which the process repeats itself. The Delphi method is based on the assumption that group judgments are more valid than individual judgments. It was originally developed by the RAND Corporation in the 1950's to forecast the impact of technology on warfare.

Table A

	Simple	Feasible	Complex	Challenging	Extremely Challenging
Policies	Minimal role of policy/regulation	Low role of policy/regulation	Regulated market with supportive policies	Highly regulated market with policy changes required	Highly regulated and controversial changes required
Infrastructure	Minimal need for infrastructure	Dependent on existing infrastructure	Requires some improvements to existing infrastructure	Requires moderate improvements to infrastructure	Requires major improvements to infrastructure
Human capital	Minimal need for human capital development	Low-moderate need for human capital development	Moderate need to train a limited number of people	Requires high level of training for large numbers of people	Requires national scale training programs
Access to user finance	Financing not required	Limited financing required	Moderate financing needed, viable mechanisms available	Significant financing required, limited mechanisms available	Significant financing required, no identified mechanism
Behavior change	No behavior change required	Minimal behavior change required	Moderate behavior change required with evidence of behavior change being viable	Major behavior change required, potentially on daily basis	Significant behavior change needed on daily basis, changes contrary to cultural norms
Existing demand	Strong existing demand	Existing demand	Moderate demand	Low demand, needs to be built	Extremely low demand or not a perceived need
Market fragmentation/ Distribution channels	Highly concentrated market or well defined channels	Fairly concentrated market and/or well defined channels	Moderate fragmentation of customers, under-developed channels	Fragmented market, weak distribution channels	Highly fragmented, challenging to reach customers
Business model innovation	Clear deployment models existing at scale	Deployment model in process of scaling	Deployment model(s) being tested	Deployment model(s) being tested, major hurdles outstanding	No identified deployment model, major hurdles identified

Exhibit A

Breakthrough – Difficulty of deployment



GENDER EQUITY

It is fair to say that gender equity—defined as a state wherein societies treat women and men alike, by custom, by law, and in practice—does not exist. Not in wealthy countries, and definitely not in low income countries. The root causes are many: deep-seeded religious and cultural beliefs, the persistence of societal stereotypes and 'boys will be boys' attitudes, the dearth of female perspective in legislation even in the 21st century, and a host of other male-dominated influences. Even in interventions aimed at poverty alleviation, the solutions—technological or otherwise—are more often than not designed by men, without enough understanding of the real needs of users, the majority of whom end up being women.

This inequity manifests itself in a number of ways. Women do most of the world's work, but earn only a fraction of the compensation that men do. They frequently face violence and abuse at home, at the workplace, and by men in other positions of power; too often, they have no recourse. They

are vulnerable to a number of health risks that men are not, but do not have access to the necessary healthcare. The majority of women do not have a voice in how they spend the money they earn, and cannot invest in technologies and tools that can alleviate their condition.

Clearly, none of these problems can be addressed without fundamental changes in societal values and attitudes, complemented by strictly enforced legal protections. While technology itself will not be a definitive or permanent solution, we believe that it can play a supplemental yet vital role. We have identified 6 technology breakthroughs that can play a direct part in enhancing gender equity. Some of these have been identified as breakthroughs in other sections of this study as well.

- An easy to operate, affordable, integrated, and solar-powered suite of medical devices specifically for maternal, child and primary care in low resource settings
- Microbicides to provide a method of protection against HIV/AIDS and Human Papillomavirus (HPV), for those who are otherwise vulnerable to infection through sexual contact with their partner
- A new kind of a home—made with strong lightweight material—especially for the urban poor, with a private toilet, solar-powered lighting and ventilation
- A simple point-of-use, low cost DNA-based rape kit capable of delivering rapid results
- Affordable, lightweight, fuel efficient, solar-powered irrigation pumps
- An affordable mechanized tilling and weeding tool

Throughout human history, most societies in the world have been dominated by men. Religious institutions, from every major faith around the world, have been the exclusive preserve of male leadership and perspective. Men have been able to dictate laws and traditions to their own benefit, often ignoring the perspectives of women, and sometimes manifestly suppressing their rights. While recent decades have seen significant improvements in both law and practice, even the most educated and economically advanced societies today are male-centric; lower income countries, more so.

Not surprisingly then, from an early age, girls and women around the world experience inequities in virtually every aspect of life: access to education; conforming to what constitutes acceptable dress and speech; opportunities for employment; appropriate working conditions and fair wages; land and other economic rights; the right to decide when to marry; the right to choose their partner; the right to contraception; the right to choose if, when, and how many children to have; the share of the responsibility for managing their household work and caring for children; protection from health hazards; security from harassment, abuse and violence; and access to adequate healthcare.

CORE FACTS AND ANALYSIS

Women and girls, accounting for 70% of the 1 billion people living on less than $1 per day, bear the brunt of extreme poverty (Women Moving Millions, 2014). The following discussion analyzes specific hurdles they face along the key aspects of development: basic human rights, education, economic, social and political rights, health, and day-to-day life. These challenges exist throughout the world and across economic classes. Our analysis focuses on developing countries and low income populations, when appropriate. Please note that this section draws heavily from one particular source: the World Bank's 2012 Gender Equity and Development Report.

HUMAN RIGHTS

1 There are more than 90 million 'missing women', primarily in Asia

Sex-selective abortions are common in countries where there is a strong preference among parents for boys, and girls are perceived as an economic burden. In many countries such as India, this is due to social ills like the practice of dowry, as well as a general belief that only boys grow up to support parents in their old age. Other countries have variations of such beliefs. This pressure is further exacerbated by reduced fertility rates, with families now wanting fewer children—and at least one son. China's 'one-child

policy' is an extreme example of external pressure that appears to have compelled parents into sex-selective abortion. Increased access to technologies such as antenatal ultrasound has increased the ability of would-be parents to determine the sex of a fetus, and selectively terminate pregnancies (Kulkarni, 2007) (Hvistendahl, 2011). As a result, the ratio of male-to-female births in a number of Asian countries, particularly China, India, Pakistan, Bangladesh, Afghanistan, Taiwan and South Korea, is well above the expected ratio. The established norm is 105-107 baby boys born for every 100 baby girls. However, in India, the ratio is 113, with some regions going over 155; in China, the number is 119-121, with some regions going as high as 135 (World Economic Forum, 2012) (Hudson & Boer, 2005). This, combined with other health factors, appears to have contributed to a large number of 'missing women', estimated at 90.3 million as of 2005 (Hudson & Boer, 2005), with China and India accounting for the majority (**Exhibit 1**). This phenomenon is discussed in greater detail later in this section.

Actual vs. expected sex ratios, and 'missing women'

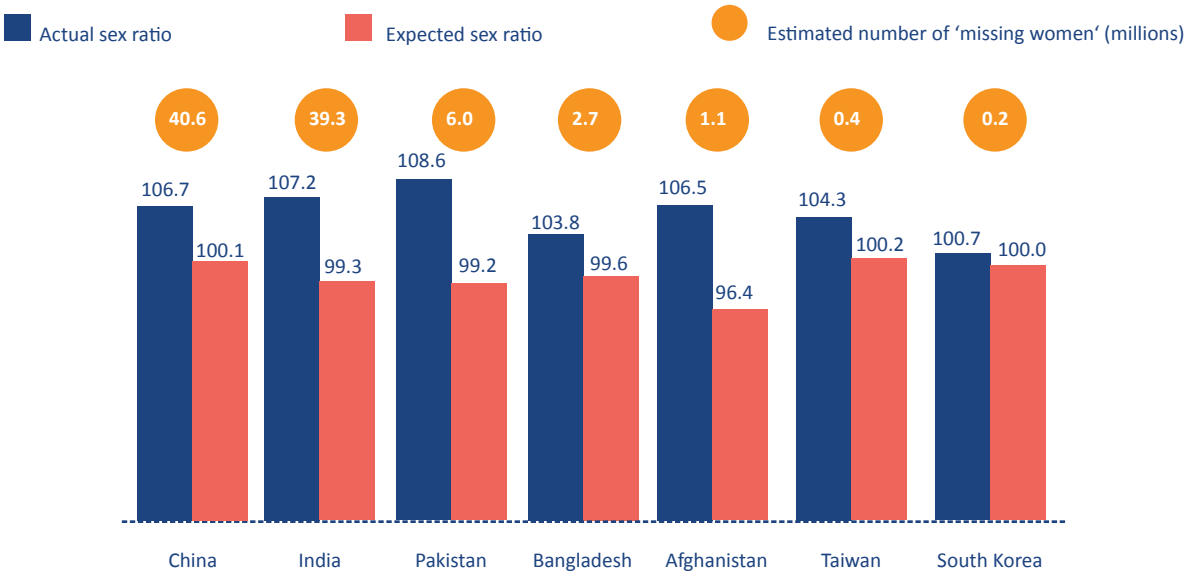


Exhibit 1: Sex-selective abortion, combined with other factors, has led to a higher-than-expected male-female sex ratio in a number of Asian countries. There are as many as 90 million 'missing women' in these countries.

2 Violence against women and girls is common in many parts of the world

Violence and abuse against women and girls is all too common an occurrence, and takes place in many forms—physical, sexual and psychological. While men also face violence, the violence and abuse faced by women is *gendered*, in that it is usually perpetrated by men and often in the context of a one-sided power dynamic.

Domestic violence

According a UN survey, over 30% of women around the world are subjected to physical violence by their partner at least once in their lifetime, many of them in the last 12 months (**Exhibit 2**). Women also face

high rates of sexual violence, with more than 20% of women in surveyed countries reporting assault, not including nonviolent incidents of sexual harassment, at least once in their lifetime (**Exhibit 3**) (UN-ECOSOC, 2010). Equally troubling is that in many countries, violence against women is perceived as acceptable or justifiable, even by the women themselves. Nearly 30% of women in the surveyed countries agreed that wife beating is justified for arguing with the husband, 25% believed it is justified for refusing to have sex, and 21% believe it is justified if the wife accidentally ends up burning the food while cooking. In Guinea, as many as 60% of surveyed women found it permissible to be beaten for refusing sex and in Ethiopia, 81% of women agreed with at least one of these reasons for wife beating (World Bank, 2012).

Proportion of women experiencing physical violence by their partner at least once in their lifetime, and in the last 12 months

1995–2006; Percent

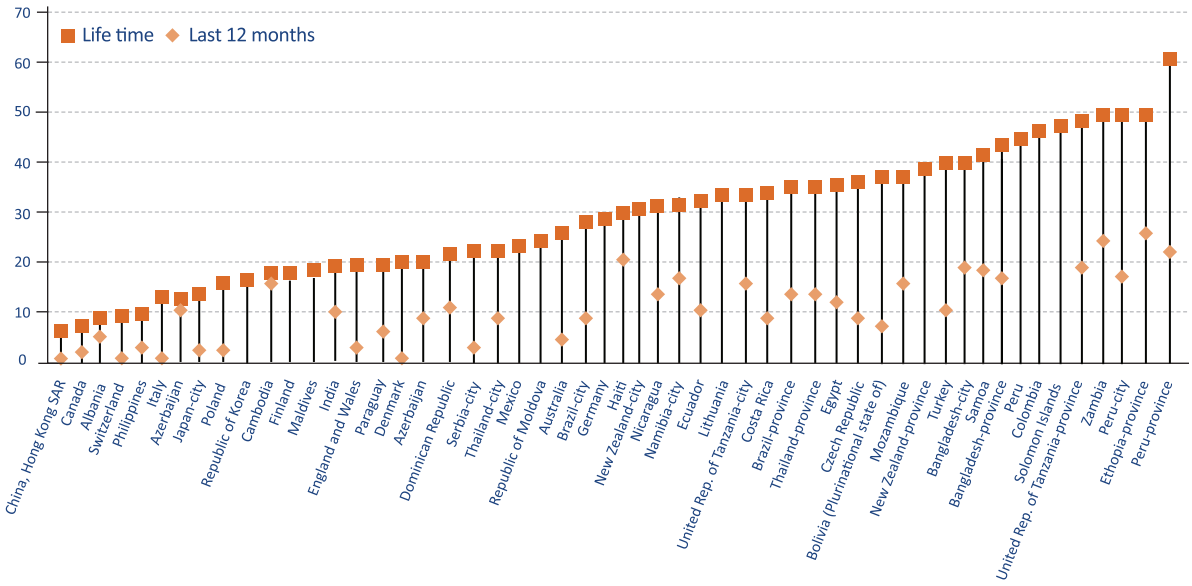


Exhibit 2: More than 30% of women in the surveyed countries reported experiencing physical violence by their partner at least once in their lifetime. Nearly 30% of the surveyed women agreed that wife beating is justified for arguing with the husband and 25% believed it is justified for refusing to have sex. Note that statistics for the last 12 months are not available for all the countries (UN-ECOSOC, 2010).

Proportion of women experiencing sexual violence at least once in their lifetime, and in the last 12 months

2002 - 2006; Percent

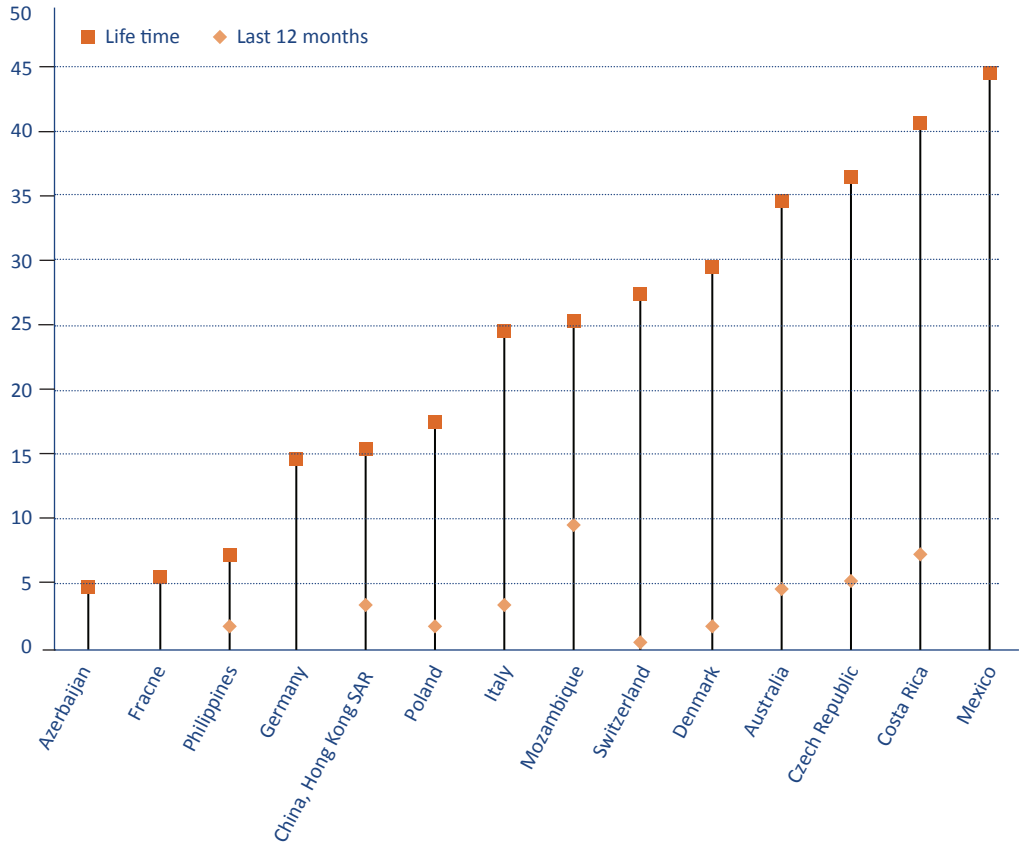


Exhibit 3: In a majority of surveyed countries, more than 20% women reported facing sexual violence at least once in their lifetime. Note that statistics for the last 12 months are not available for all the countries (UN-ECOSOC, 2010).

Human trafficking

Human trafficking, for sexual exploitation and forced labor, is the fastest growing form of organized crime in the world, and the 3rd largest form of criminal enterprise globally (FBI, 2014). There are more than 20 million trafficking victims, of which more than 12 million are women, trafficked for sexual exploitation (UN-ECOSOC, 2010).

Genital mutilation and other culturally sanctioned violent practices

In a number of countries, girls face specific forms of culturally sanctioned violence. While some practices like breast flattening typically take place to keep young girls from showing any outward signs of puberty and 'keep them safe from rape', others like 'sexual cleansing' (by paying an older man to have intercourse with girls as young as 9) occur to prepare girls to enter adulthood (The Guardian, 2012) (The Guardian, 2014).

Another major form of violence against girls and young women is female genital mutilation (FGM), which refers to a range of procedures involving removal or partial cutting of external female genitalia for non-medical reasons. A traditional ritual in many cultures, FGM rates are extremely high (over 80%) in

Guinea, Egypt, Eritrea and Mali (UN-ECOSOC, 2010). In the face of advocacy and awareness campaigns, however, the rates have been dropping somewhat in recent years (**Exhibit 4**).

Percent of women, aged 15-49, subjected to female genital mutilation

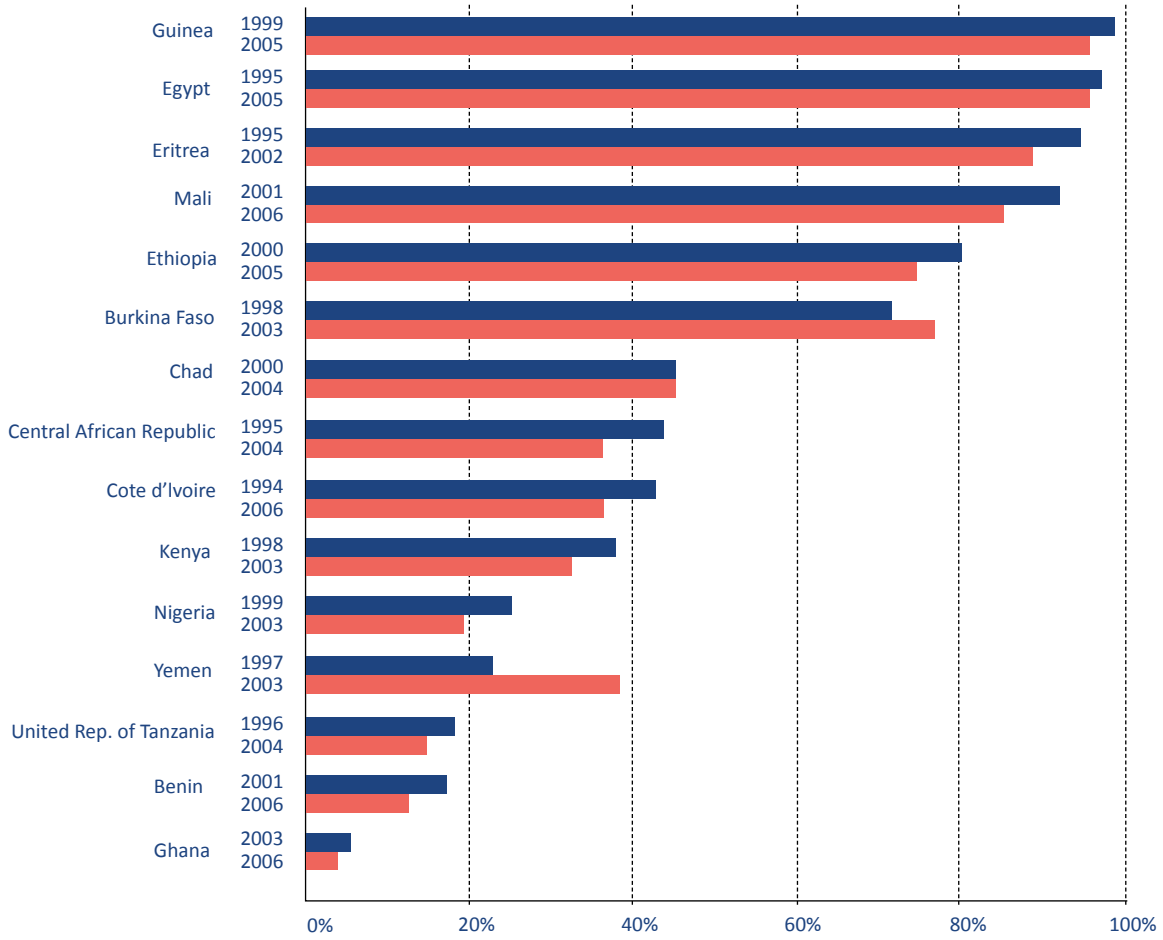


Exhibit 4: Female genital mutilation is a major problem in a number of countries, even though recent campaigns have resulted in small improvements (UN-ECOSOC, 2010).

Honor killings

Each year, an estimated 5,000 women and girls are violently killed by members of their own family or community, in so-called honor killings (UNFPA, 2000). Concentrated in South Asia and the Middle East, such violence is perpetrated on women who are considered to have defied traditional norms and embarrassed their family, usually through acts of intimacy before marriage, by marrying someone outside of the community, or for committing adultery.

Rape as a weapon of war

Many conflicts, especially those with an ethnic or religious rift, involve widespread sexual violence against women and girls, perpetrated by combatants or civilians. According to a UN Security Council resolution, "Women and girls are particularly targeted by the use of sexual violence, including as a tactic of war to humiliate, dominate, instill fear in, disperse and/or forcibly relocate civilian members of a community or ethnic group." (UN Security Council, 2008). Recent examples of large-scale sexual atrocities include the conflicts in the former Yugoslavia, Rwanda, the Democratic Republic of Congo, and Liberia. Seemingly, the motivations range from a desire to humiliate the enemy by impregnating 'their' women, to use HIV as a weapon, or to just brutally exercise power over civilians with neither protection nor recourse (Aginam & Rupiya, 2012).

EDUCATION

3 Despite recent progress in enrollments at the primary school level, gender disparities persist in higher education

A quality education is critical for every girl's ability to access economic opportunities later in life. Moreover, educated women also take better care of, and invest more in their children, who are then more likely to become well educated themselves. Women are also much more involved in teaching children than men are (World Bank, 2012). In Pakistan, for example, children whose mothers have even a single year of education spend an extra hour studying every day, and do better at school (World Bank, 2012). In addition, children of educated women are more likely to be immunized and have good nutrition, lowering the rate of child mortality.

As shown in the section on Education, recent years have seen considerable increases in enrollment rates in sub-Saharan Africa and South Asia. As **Exhibit 5** shows, there have been increases in the relative number of girls and women enrolled across various levels of education. However, gender parity is far from being a reality at the higher levels of education. Only 37% and 43% of tertiary enrollees in sub-Saharan Africa and South Asia, respectively, are women. While the male-female ratio is more on par in primary school, traditional beliefs and opinions about gender roles leads parents to discourage their daughters from pursuing an education as they grow older. As **Exhibit 6** and **Exhibit 7** show, these disparities are pronounced in lower income regions of the world, especially in poorer population segments. In some parts of the world, discouragement of girls' education can even turn violent, as recent events in Nigeria and Pakistan have shown (The Guardian, 2014).

While gender disparity, especially in early education today, may seem to be driven more by economic factors than outright gender discrimination (World Bank, 2012), inequality exists and manifests itself in many ways:

- Women today account for two-thirds of the 774 million illiterate adults in the world, a proportion that has remained unchanged since 1990. There are 130 million illiterate women in Africa, and another 341 million in Asia (UN-ECOSOC, 2010).
- In Africa, 41% of women have never attended school, compared with 24% of men. Only 21% of women in Africa have obtained secondary or tertiary education, compared with 30% of men; in Asia, only 25% of women are completing secondary or tertiary school, compared with 41% of men (World Bank, 2012).
- In low and middle income countries, fewer women than men have access to the Internet. The gap is 35% in South Asia, the Middle East and North Africa, and 45% in sub-Saharan Africa (Intel, 2013).

Percent of enrolled students who are female, in South Asia and sub-Saharan Africa

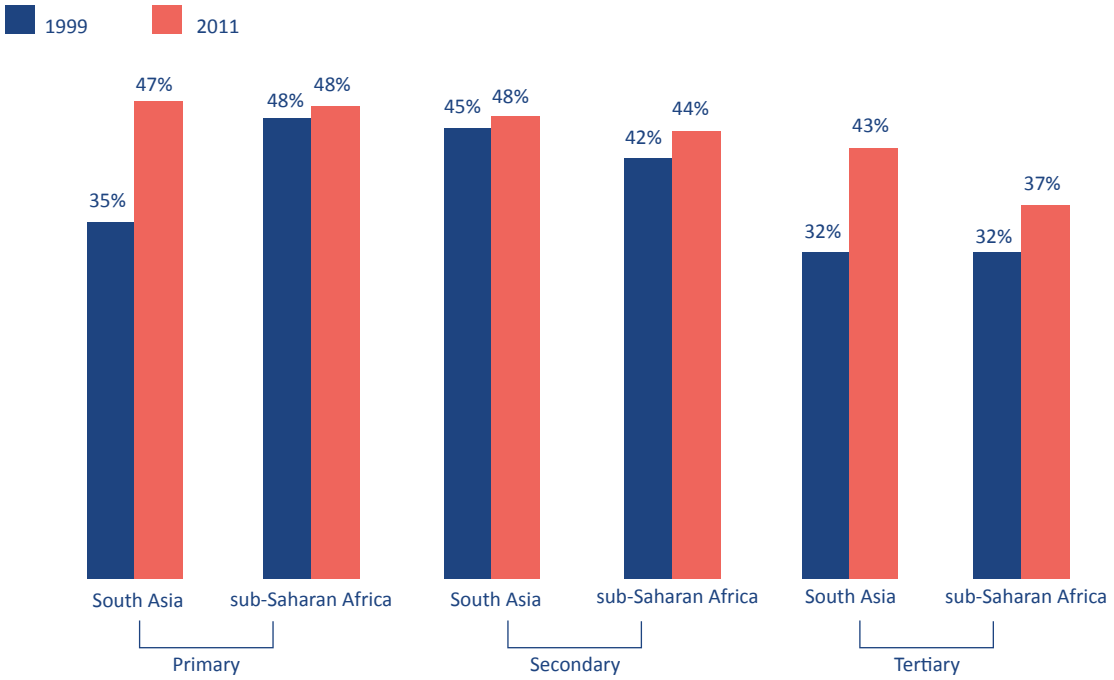


Exhibit 5: Although between 1999 and 2011, female enrollment for all levels of education increased more rapidly than for males, women still comprise a small proportion of total enrollees, especially in sub-Saharan Africa.

Percent of enrolled students who are female, 2011

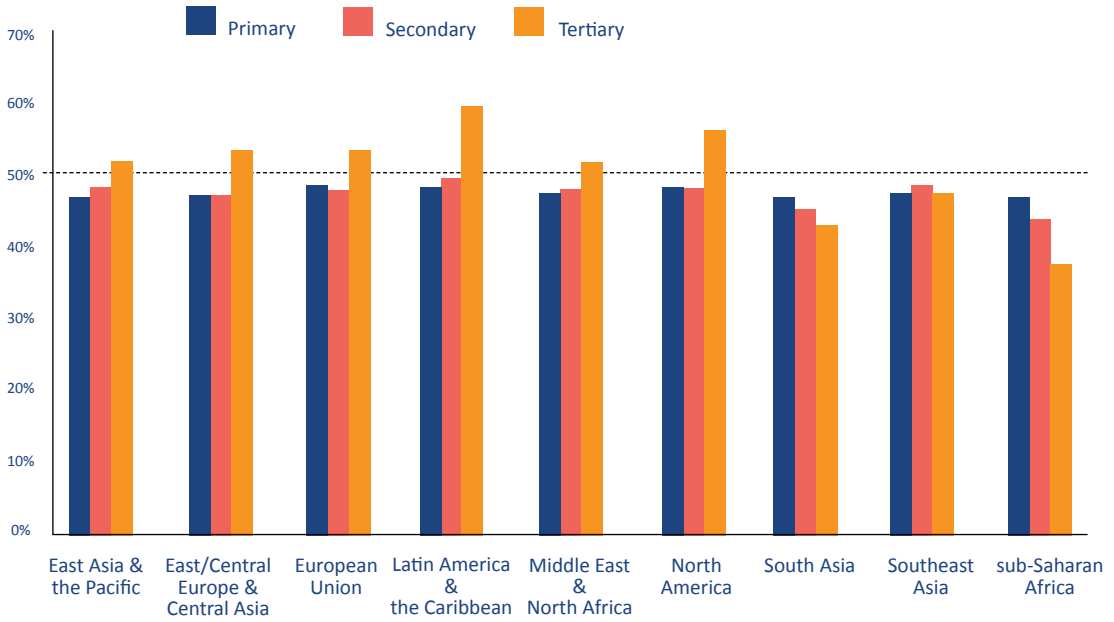


Exhibit 6: South Asia and sub-Saharan Africa trail the rest of the world when it comes to tertiary education for women.

Gender disparity across income levels

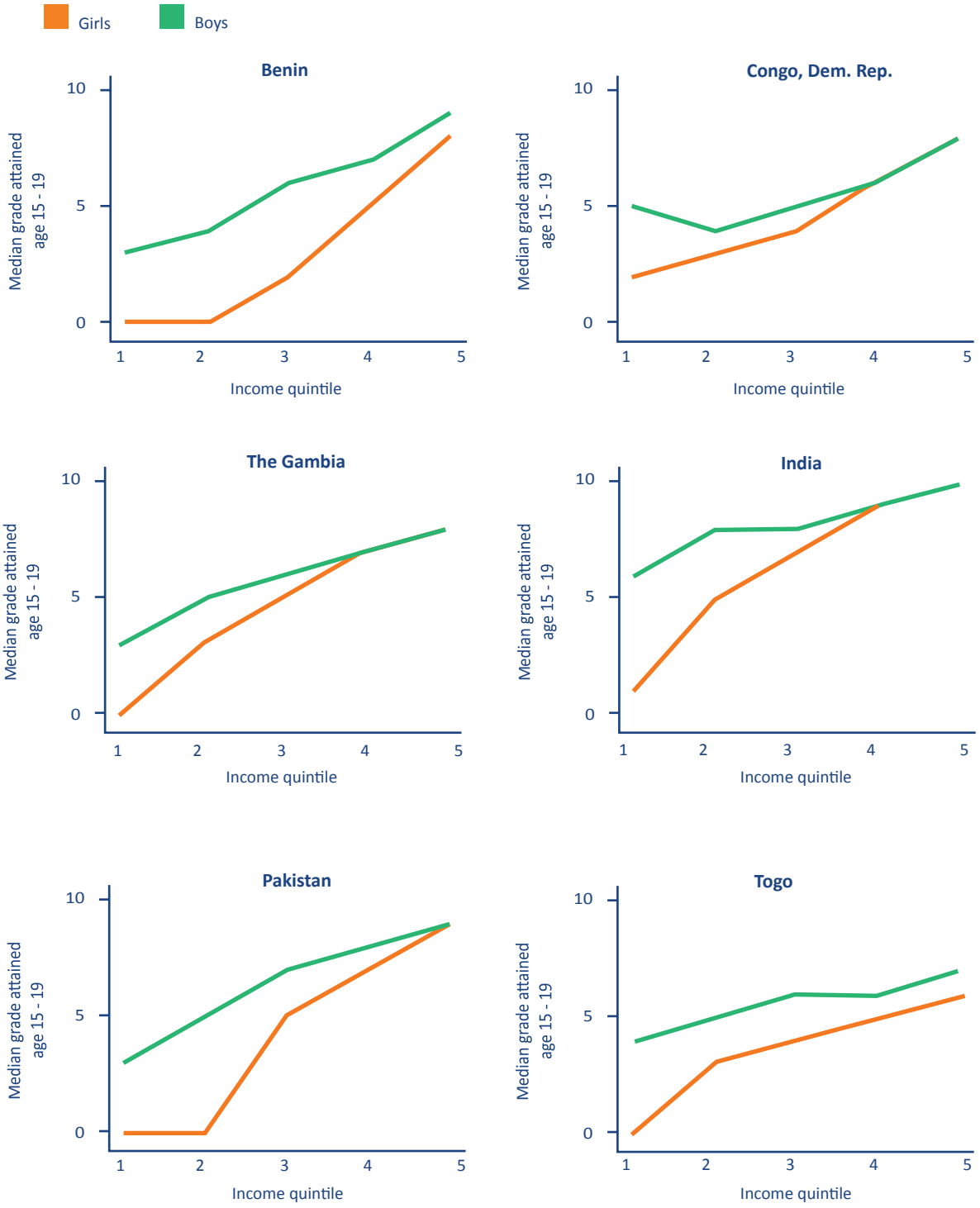


Exhibit 7: In a number of countries in South Asian and sub-Saharan Africa, gender disparities are more conspicuous in lower income population segments (World Bank, 2012). The wealthiest (5th) quintiles have close to equal school enrollment in the 15-19 year age group, while the poorest (1st) quintiles consistently have the highest disparity.

ECONOMIC OPPORTUNITY

4

Women are responsible for more work than men, often in the form of unpaid household work or manual labor, especially in the agriculture sector

Women work two-thirds of the world's working hours, yet earn only 10% of the world's income. This is largely because women continue to bear primary responsibility for the home, spending twice as much time as men on unpaid work such as caring for children and dependent family members, preparing meals, and doing housework like cleaning, washing, gathering firewood, and fetching water. More than 50% of rural households and 25% of urban households in sub-Saharan Africa lack easy access to drinking water—and it is women's work to collect the water, a task that can involve walking many miles and take up the better part of a day. The time women spend on such domestic and otherwise unpaid activities keeps them from schooling and earning (UN-ECOSOC, 2010) (Women Moving Millions, 2014) (World Bank, 2012). **Table 1** shows the share of time women and men spend on various categories of activities. As **Exhibit 8** shows, agriculture represents the single largest form of economic activity for women in South Asia and sub-Saharan Africa (Food and Agriculture Organization, 2011) (International Labour Organization, 2014). They work as producers, laborers, processers, and traders in domestic markets. Although men do much of the heavy manual labor such as ploughing fields and driving draught animals, women do most of the weeding, fertilizing and harvesting, and contribute to a significant share of the workload in food production (**Exhibit 9**). In aggregate, women are responsible for 50% of food production worldwide (FAO, 1995) (UN, 2007).

Type of work men and women engage in

Region		Women				Men			
		Wage & salaried workers	Employers	Own-account workers	Contributing family workers	Wage & salaried workers	Employers	Own-account workers	Contributing family workers
Africa	Northern Africa	46%	2%	19%	33%	58%	8%	22%	12%
	Southern Africa	76%	3%	17%	4%	82%	7%	9%	2%
	Eastern and Western Africa	20%	1%	47%	32%	24%	1%	57%	18%
Asia	Eastern Asia	86%	2%	7%	5%	79%	7%	13%	1%
	South-Eastern Asia	52%	2%	23%	23%	52%	4%	34%	10%
	Southern Asia	30%	1%	22%	47%	44%	3%	41%	12%
	Western Asia	80%	1%	6%	13%	79%	5%	14%	2%
	Central Asia	45%	1%	39%	15%	50%	3%	40%	7%
LAC	Caribbean	80%	2%	16%	2%	68%	3%	28%	1%
	Central America	65%	3%	25%	7%	64%	6%	24%	6%
	South America	63%	3%	28%	6%	62%	6%	29%	3%
Europe	Eastern Europe	84%	2%	10%	4%	78%	4%	17%	1%
	Northern Europe	93%	2%	4%	1%	84%	5%	10%	1%
	Southern Europe	81%	3%	10%	6%	75%	6%	17%	2%
	Western Europe	88%	3%	6%	3%	84%	7%	8%	1%
Other	Other developed regions	89%	2%	7%	2%	83%	5%	11%	1%

Table 1: Women spend a disproportionate share of their time taking care of their households (compared with men), rather than on income-generating activities. The countries with the greatest disparities are in Africa and South / Southeast Asia.

Distribution of women's economic activities

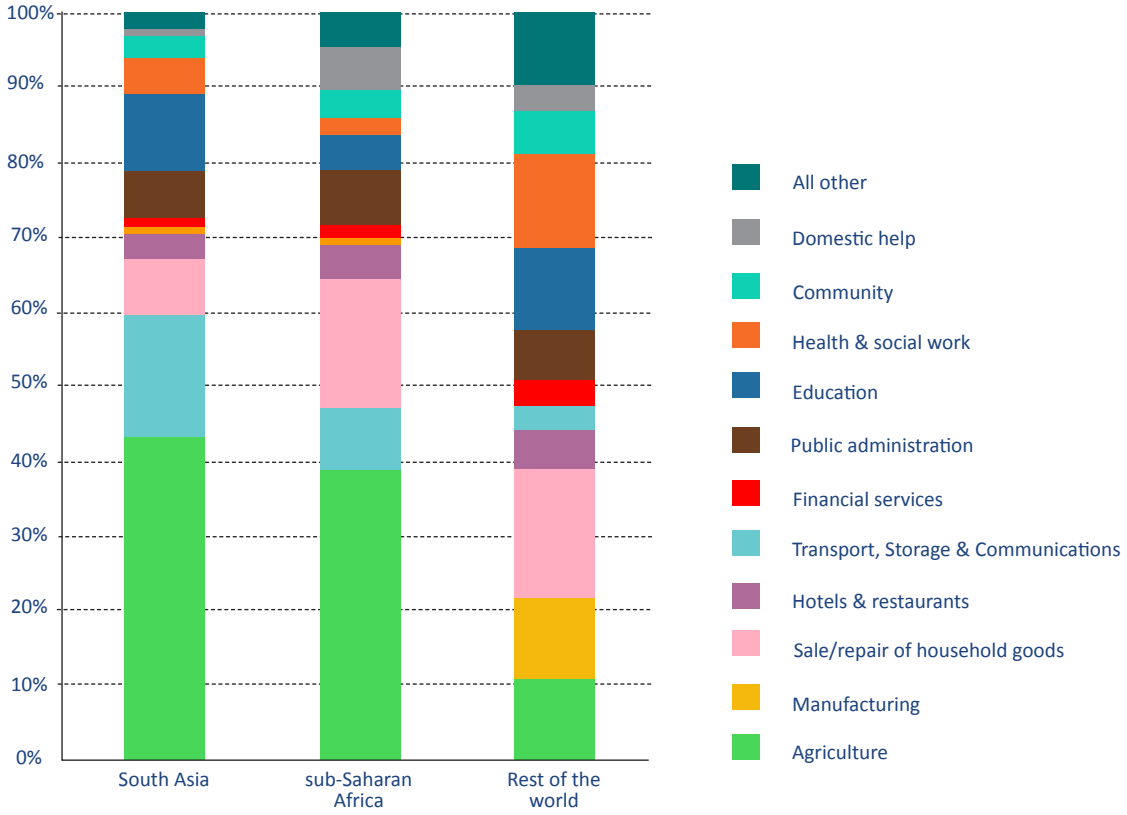


Exhibit 8: Women contribute to a substantial portion of agricultural labor in both South Asia and sub-Saharan Africa, far more than the rest of the world.

Share of agricultural work performed by women across 13 low and middle income countries

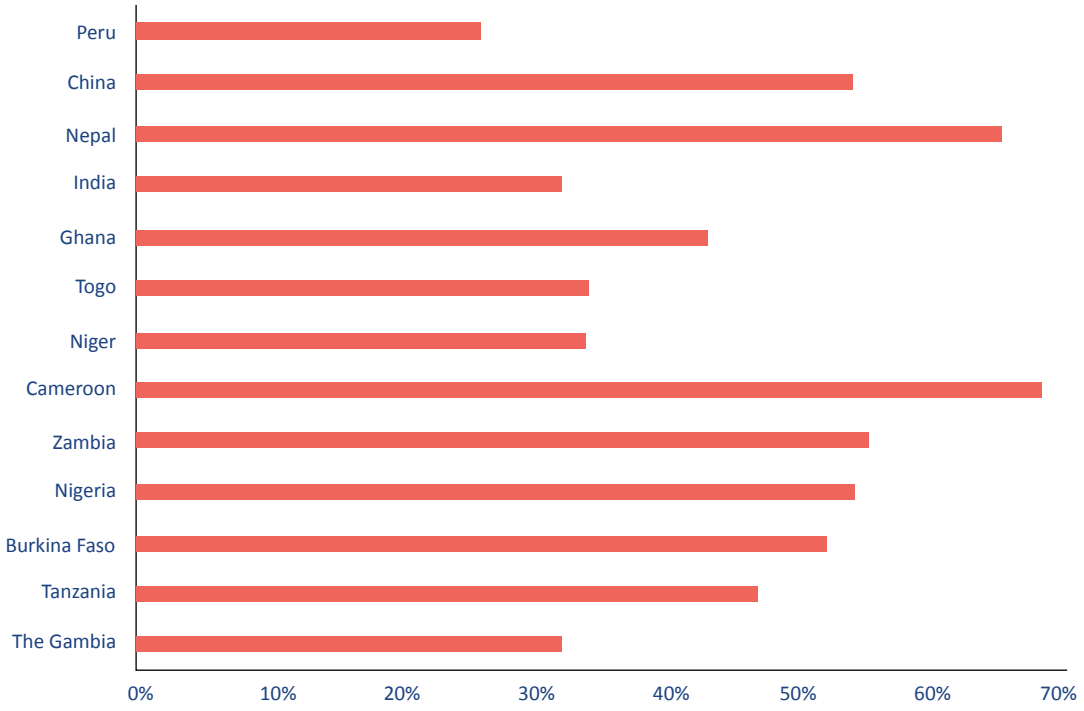


Exhibit 9: Women contribute to a substantial portion of total agricultural labor, ranging from 32% in India, to almost 70% in Cameroon.

5 Women do not enjoy income parity, lack control over income earned, and are deliberately excluded when it comes to owning or inheriting property

Even when women are paid for their work, a persistent remuneration gap exists. Women's wages represent only 70-90% of men's wages in the majority of countries (United Nations, 2010), and in some countries, women earn only 30-50% of what men earn. In Bangladesh, women earn only 12 cents ($0.12) for every dollar earned by men (World Bank, 2012). To make matters worse, women have limited control over how the income they earn is spent. This is particularly true in lower income countries, and even more so in lower income segments of the populations in those countries (**Exhibit 10**).

Women are also disadvantaged with respect to land and property rights, whether through inheritance or marriage. In many countries in Africa and Asia, only men are allowed to own land, by both law and tradition. Additionally, in many countries, women do not have the legal right to a share in paternal or matrimonial property. The consequence of this systemic bias is obvious: women in Kenya represent only 5% of registered landowners, and in Brazil and Paraguay, they own only 11% and 2% of registered land, respectively. Moreover, women's land holdings are far smaller than those of their male counterparts: in Ghana, for example, the average land holding for a man is three times the size of that for a woman (World Bank, 2012). Without land or another non-movable asset as collateral, women have very limited access to credit. Without credit, they cannot purchase seeds, fertilizer, irrigation equipment or other mechanisms for increasing farm productivity. Globally, women receive only 10% of small farmer credit, and only 5% of agricultural extension services (World Economic Forum, 2012).

Percent of women not involved in decision-making about their own income

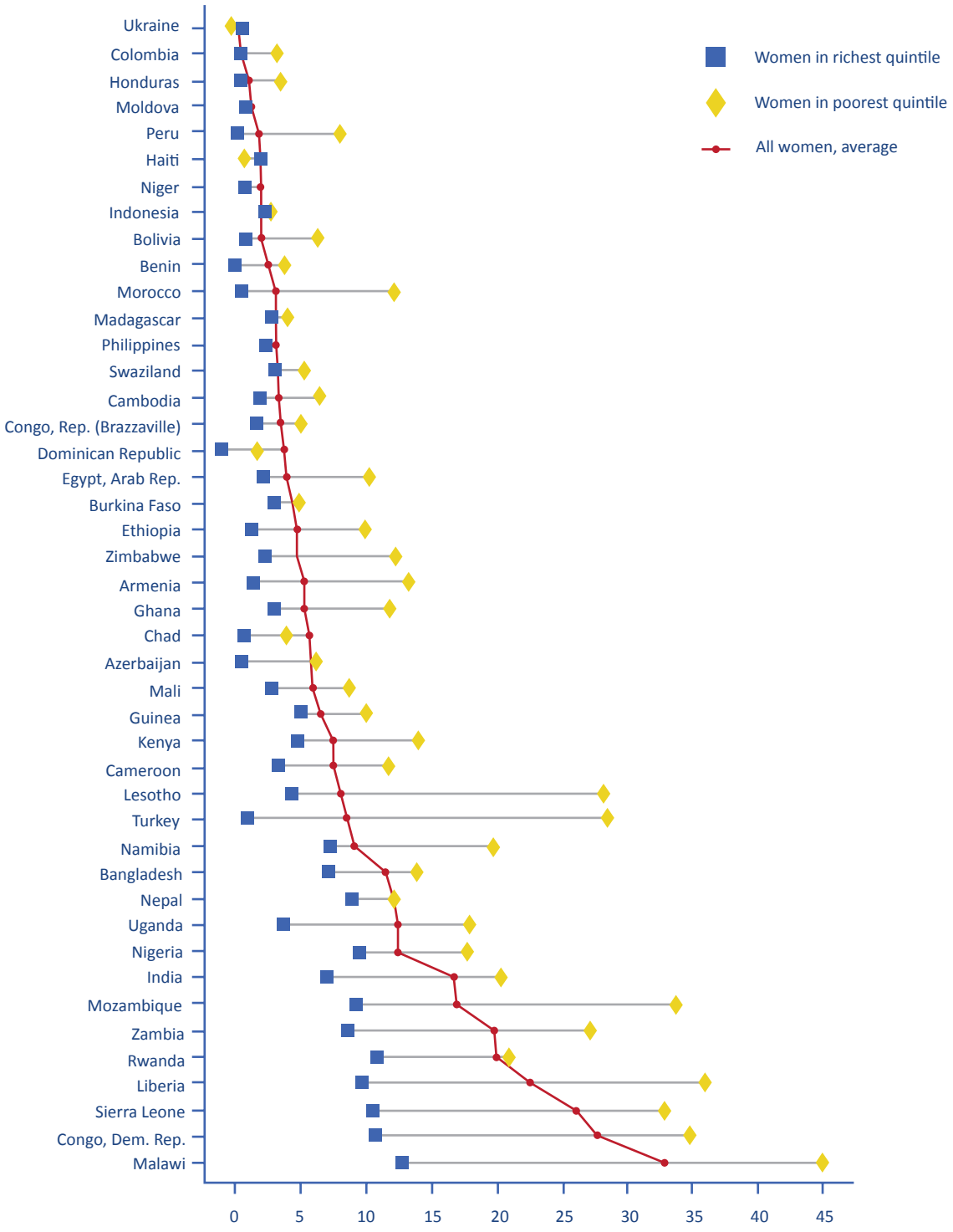


Exhibit 10: Women in lower income segments of the population have limited to almost no say in how they spend their own income.

HEALTH

6 While women have a higher life expectancy, there are 3.9 million 'excess female deaths' each year due to factors like selective abortion, maternal mortality, HIV/AIDS, and indoor air pollution

In every region of the world, and in nearly every country (the only exceptions being Botswana, Mali and Swaziland), women outlive men. As **Exhibit 11** shows, average female life expectancy globally is 4.2 years higher—72.5 years for women, compared with 68.3 for men. The difference, however, dwindles in South Asia (57.9 for women vs. 55.4 years men) and sub-Saharan Africa (69.8 years for women vs. 67.0 years for men) (World Bank, 2014). While the specific reasons are not clear, studies point to the higher incidence of heart disease among men, driven by a combination of genetic factors, as well as behaviors like smoking that are more prevalent among men (Waldron & Johnston, 1976) (Waldron, 1983).

Life expectancy in 2010, males vs. females

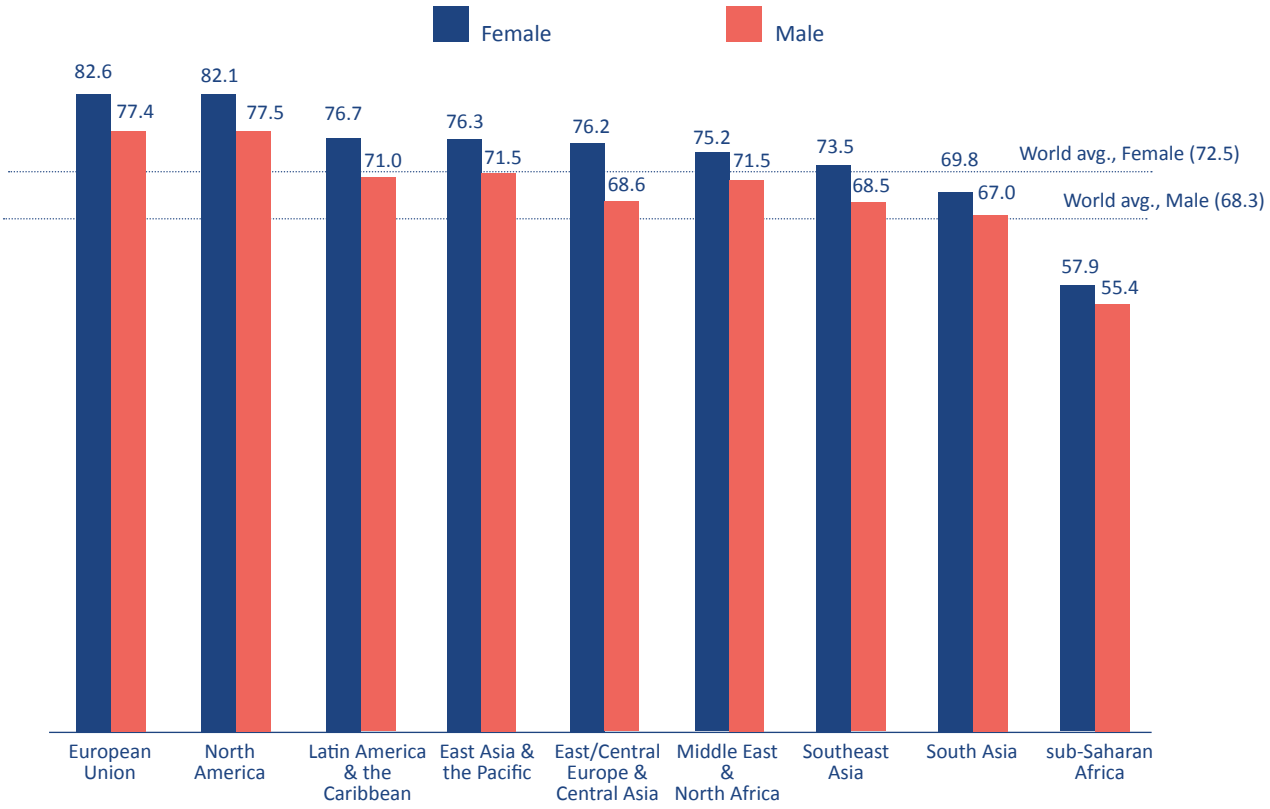


Exhibit 11: Life expectancy of females is higher than that of males, in every region of the world.

These advantages notwithstanding, it is estimated that each year there are 3.9 million cases of 'excess mortality' among girls and women (World Bank, 2012). These deaths (**Table 2**) are concentrated in East Asia (primarily China), sub-Saharan Africa, and South Asia (primarily India). Of these 3.9 million deaths,

1.43 million occur at or before birth due to selective abortion; another 617,000 occur in girls under 5; 158,000 between the ages of 5 and 14 years; 1.35 million in the 15-49 year age range; and 334,000 deaths occur between the ages of 50 and 59 years.

Excess female deaths in the world, by age and region (thousands)

Region	Birth	Under 5	5-14	15-49	50-59	Total
sub-Saharan Africa	53	203	77	751	99	1,182
South Asia	258	323	65	389	126	1,161
East Asia	1,096	78	14	169	76	1,433
Middle East & North Africa	6	7	1	24	15	52
Europe & Central Asia	14	1	0	4	3	23
Latin America	0	5	1	10	17	33
Total	**1,427**	**617**	**158**	**1,347**	**334**	**3,882**

Table 2: 'Excess mortality' among women and girls is concentrated in South Asia, East Asia and sub-Saharan Africa.

The following discussion highlights the main factors leading to female deaths in post-birth age groups

Child mortality

The reasons for the 617,000 excess deaths of girls under 5 are not clear. While some studies have implicated delays in seeking healthcare for girls (Tarozzi & Mahajan, 2007) (World Bank, 2005), a World Bank study on gender equity (World Bank, 2012) did not find conclusive evidence to show why girls in low income populations are worse affected than boys. **Exhibit 12** shows data from the World Bank study (World Bank, 2012) suggesting that there are no meaningful differences between healthcare provided to boys and girls—in countries with higher rates of mortality among girls—when it comes to vaccination, being taken to a health facility for respiratory illness, or stunting.[1] That study concludes that excess female mortality in childhood, "is a result not so much of discrimination as of poor institutions that force households to choose among many bad options, particularly regarding water and sanitation" (World Bank, 2012).

[1] The immunization rates in this example are for polio and measles, neither of which is one of the major drivers of childhood mortality; however, it is likely that children who are vaccinated for these diseases are also vaccinated for other diseases. Respiratory conditions like pneumonia are among the leading causes of mortality among children under 5. Stunting is one of the leading symptoms of malnutrition among children.

Key health statistics for boys vs. girls, across a large number of low income countries

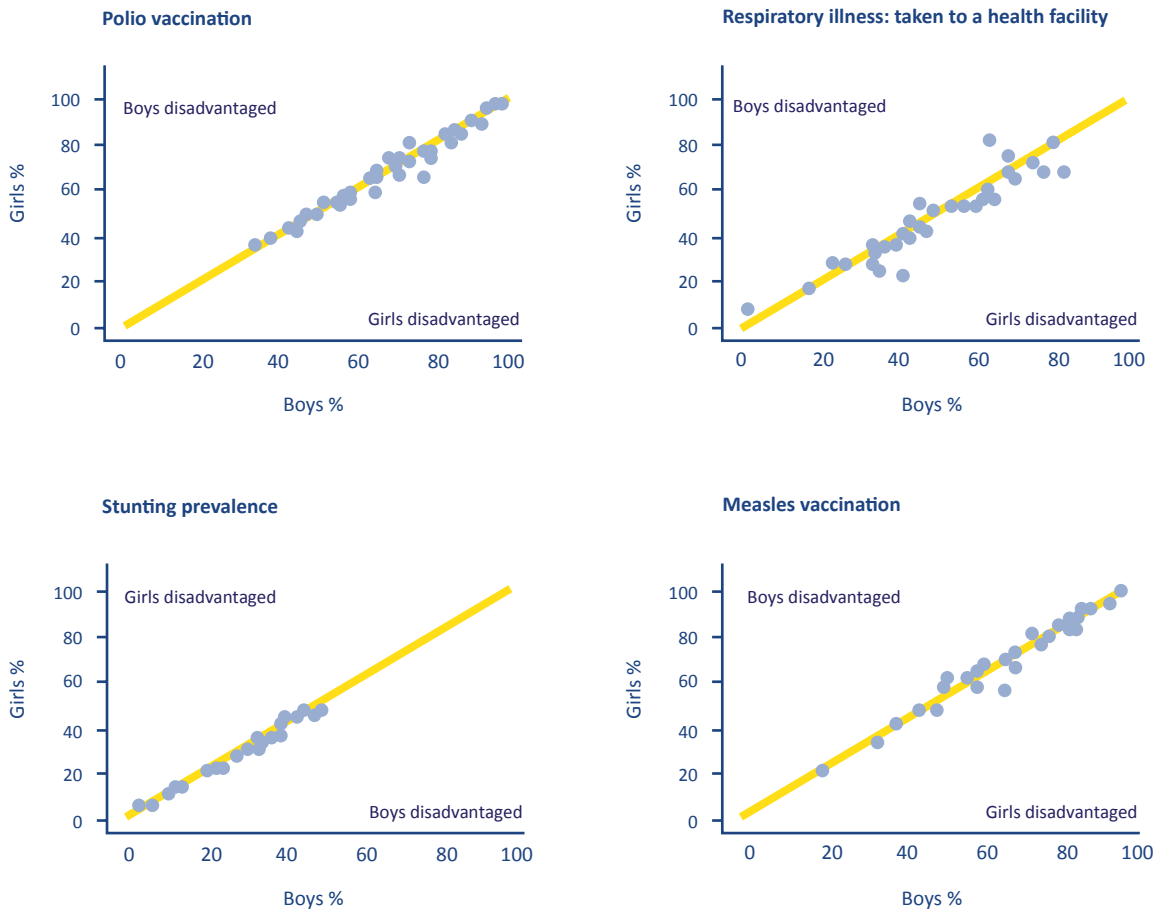


Exhibit 12: There appears to be little gender disparity among children, with respect to vaccination rates, nutrition outcomes, or use of health services (World Bank, 2012). This makes it difficult to explain the causes behind the 617,000 'excess deaths' of girls under 5.

Maternal mortality

As the chapter on maternal mortality in the Global Health section of our study discusses, about 300,000 women die each year during childbirth (WHO, 2014). It is one of the leading causes of death among women of childbearing age in South Asia and sub-Saharan Africa. Among the main drivers of maternal mortality is the fact that a large number of births take place at home and are administered by untrained traditional birth attendants. There is a systemic absence of maternal healthcare in low income countries—without enough adequately equipped clinics, trained clinicians, or means of escalation in the event of complications. In fact, across the largest countries in South Asia and sub-Saharan Africa, only 37% pregnant women receive the WHO recommended 4+ antenatal care visits, which are crucial for determining the health of both mother and the unborn child. While the majority of maternal deaths are due to weak healthcare systems, 10-15% of maternal deaths are caused by unsafe abortions, in countries where abortion is restricted or is inaccessible.

HIV/AIDS

Women are more susceptible to HIV/AIDS due to both sociological and biological factors. The latter include the surface area of the cervix and vagina (compared to the surface area of parts of the male penis); the

increased likelihood of tears along the surface of the vagina, particularly in younger women who tend to have immature genital tracts (compared with parts of the penis); the higher fluid volume of semen entering the woman's body (compared with the volume of vaginal secretion entering the man's body); the higher viral concentration in semen (compared with that in vaginal secretion); and the warm, moist environment inside the vagina, which is ideal for the HIV virus to thrive. Sociological factors include notions about masculinity due to which men tend to have a higher number of—and younger—female sexual partners (than the other way around); the unwillingness of men to use condoms or get circumcised; and the practice of douching (washing the vagina with soap), which destroys natural protective bacteria (UNAIDS, 2011) (World Bank, 2012) (Canada AIDS Society, 2014). As a result, prevalence of HIV among women in sub-Saharan Africa is almost twice that among men (2.5% vs. 1.3%, respectively) (**Exhibit 13**), women account for 60% of HIV infections, with the gender gap in prevalence largest for younger adults. After age 34, HIV prevalence rates are similar for men and women. Prenatal care, care during childbirth, and children's vaccination rates have suffered most in regions and areas where HIV rates are the highest.

Prevalence of HIV in 2012, ages 15-24 years

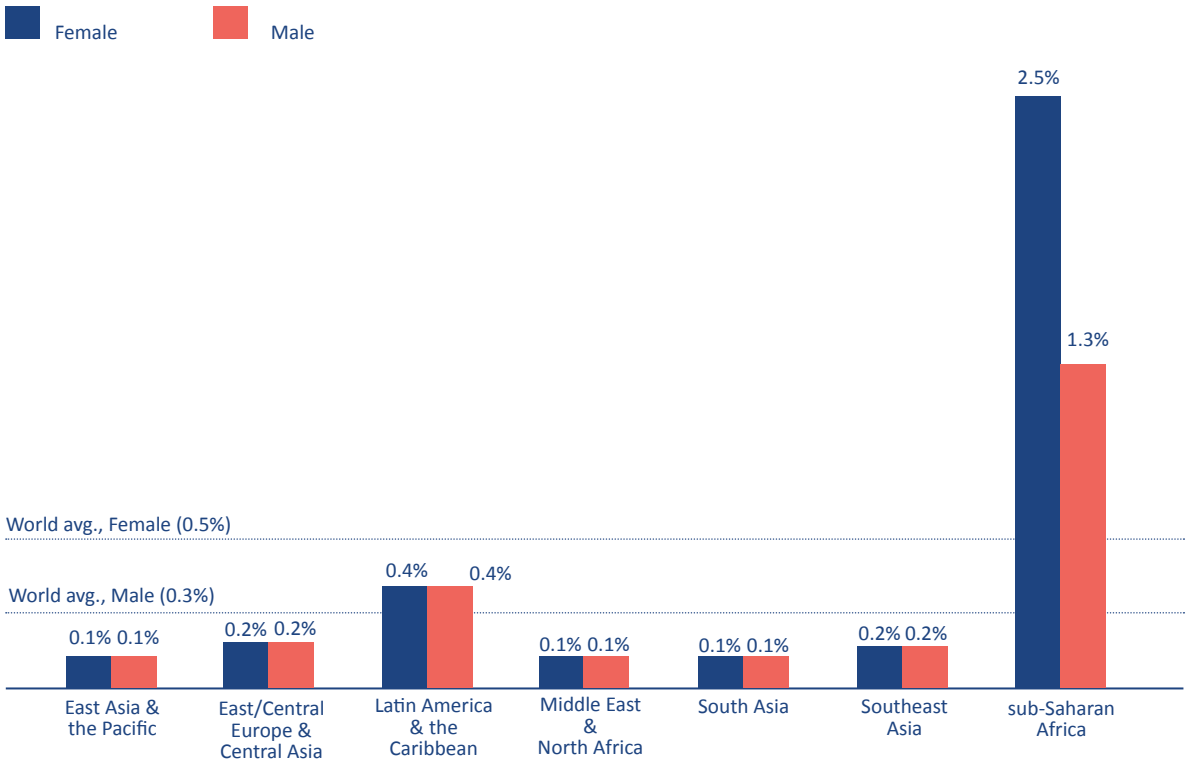


Exhibit 13: In sub-Saharan Africa, the prevalence of HIV among women is almost twice that among men. In other parts of the world, prevalence among men and women is roughly the same.

Cervical cancer

Every year, over 270,000 women die from cervical cancer, which is caused by the Human Papillomavirus (HPV). The infection is acquired through sexual contact, and is the single most common form of viral infection of the reproductive tract. It is most common in the early years of sexual activity, and does not necessarily require penetrative intercourse for transmission. Most cases of HPV infection heal by themselves in a few months and do not lead to life-threatening disease. However, the lesions caused by infection can lead to

cervical cancer in women over the course of 15-20 years, based on a number of risk factors: weak immune system; first intercourse with an infected partner; multiple sexual partners; and tobacco use. HPV vaccines for both men and women—recommended prior to first sexual encounter—are available for the strains most commonly linked to cervical cancer. However, these vaccines are either not broadly available in developing countries, or are unaffordable. Once the cancer sets in, the only methods for treatment are those similar to other forms of cancer—surgery, radiation therapy, and chemotherapy (WHO, 2014).

Household (indoor) air pollution

Around the world, women do most of the household cooking. In developing countries, low income women cook using traditional stoves using fuels like wood or biomass, which emit high levels of smoke. This pollution causes respiratory infections, heart disease and lung cancer, leading to 4.3 million deaths each year. Of these, 3.1 million deaths occur in South and Southeast Asia, 600,000 in sub-Saharan Africa, and 200,000 in the Middle East and North Africa. While women face greater exposure to indoor air pollution, men account for a higher share of the mortality from respiratory and lung diseases due to higher underlying disease rates: 46% of the deaths (1.99 million) are those of men, and 41% (1.77 million) are women; 13% (534,000) are children (WHO, 2014). Over the past few years, a number of fuel efficient and clean cookstoves have been developed, but virtually none have achieved sustainable scale. One of the main reasons is that these stoves are competing against an alternative which is free, and the long-standing traditional choice (i.e., the traditional three-stone or mud hearth). In addition, while there is clearly a health imperative in reducing household air pollution through cleaner stoves, it is not clear that there is demand for them. Presumably, this is because those most exposed high indoor air pollution do not see any short-term value in cleaner stoves, especially considering their economic means. In a number of urban markets, liquefied petroleum gas (LPG) stoves appear to be gaining traction (GACC, 2013).

Sanitation and menstrual hygiene

There are several other issues which disproportionately affect low income women, but often do not receive adequate recognition in the conversation about global health. Due to the lack of sanitation and safe toilets, millions of women have to urinate and defecate in the open. This is not only a question of basic dignity and hygiene, but also makes women and girls vulnerable to sexual abuse and violence when they use public facilities, or venture out late at night to relieve themselves (BBC, 2014).

Another major issue is the lack of affordable sanitary pads. Without these, women and adolescent girls have to either stay home, or use uncomfortable cloth rags that lead to poor menstrual hygiene, and may cause reproductive tract infections. Lack of access to suitable sanitary care products causes many girls to interrupt their schooling (sometimes even dropout of school), and older women to interrupt their work and livelihood (BBC, 2014). A recent study found that over 70% of menstruating women in India could not afford usable products (Times of India, 2011). Other evidence suggests that the problem is similarly severe in many other low income countries in Africa (One Foundation, 2014).

7 Women and girls in low income populations have limited voice in critical decisions regarding marriage and family planning

The lack of agency in the context of family life begins at an early age, and is particularly prevalent among lower income families. Many girls from low income families are forced to marry at an early age; and in marriage, many are not able to exercise choice in the use of contraception, or in having children. As **Exhibit 14** (World Bank, 2012) shows, women in lower income populations tend to be married at a significantly younger age than their wealthier counterparts. In these populations, one of the main reasons for low contraceptive use is the refusal by men to use male condoms (despite significant improvements in access) and the lack of availability of female condoms. Such factors lead to significantly higher fertility rates among women in lower income groups. As **Exhibit 15** shows, women in the poorest quintiles of many countries have twice as many (or more) children as women in the wealthiest quintile. The poorer the country, the greater the gap between the fertility rates of the rich and poor appears to be. Encouragingly, only 18% of women today live in countries where average fertility is above 3 births per woman. This trend is important because lower fertility rates—and the ability of women to have a say in how many children they have, how early they begin having them, how long they wait between pregnancies, and when to stop having children—has proven critical to their own health and wellbeing, as well as that of their children and families (World Bank, 2012). It is also encouraging that long-acting reversible contraceptives (LARCs) like intrauterine devices (IUDs) are becoming increasingly available and affordable in developing countries.

USAID

Percent of girls who are married under the age of 18, in different income quintiles

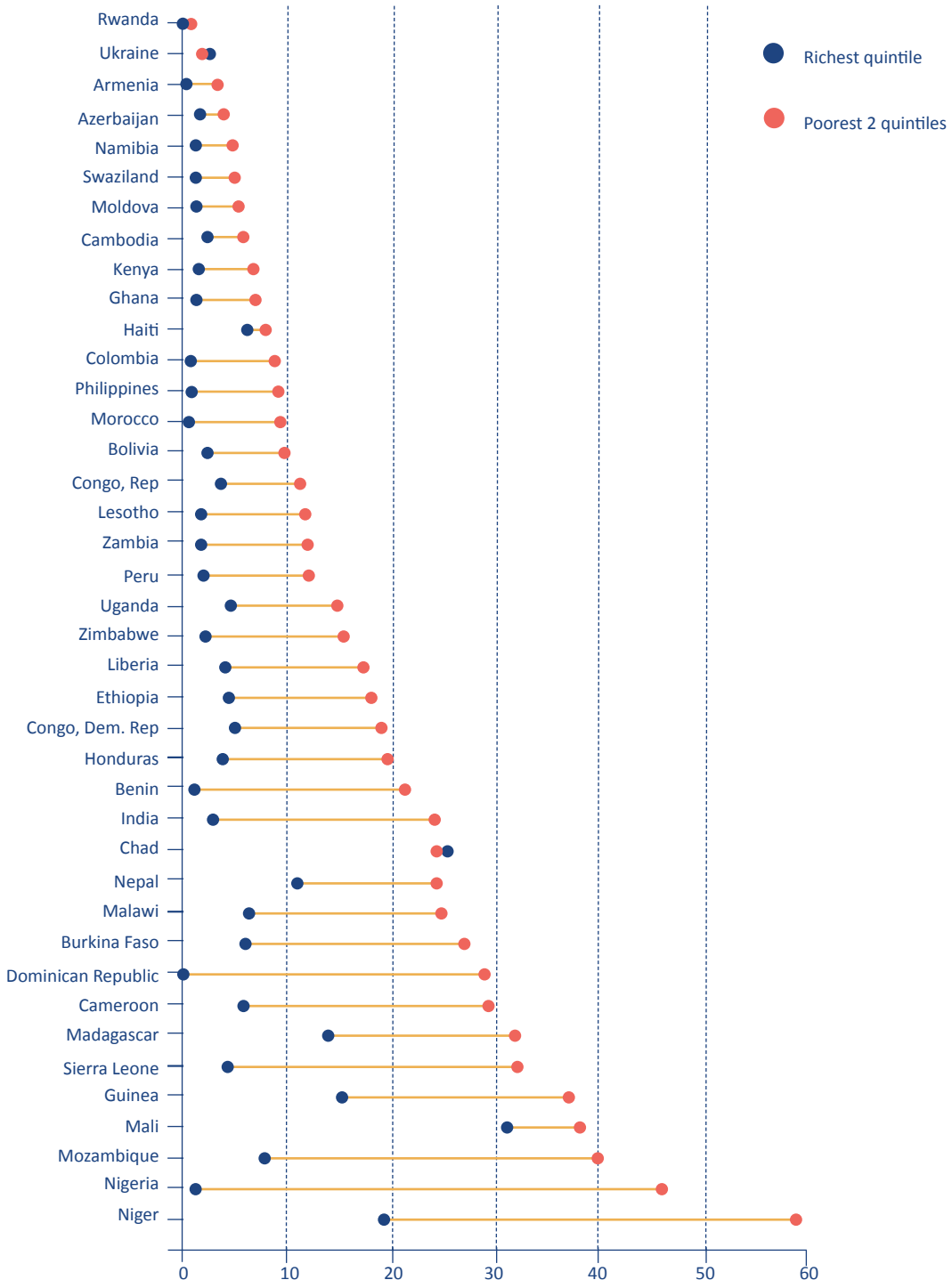


Exhibit 14: Underage marriage is a common phenomenon among low income families in many countries (World Bank, 2012).

Fertility rates across different income quintiles

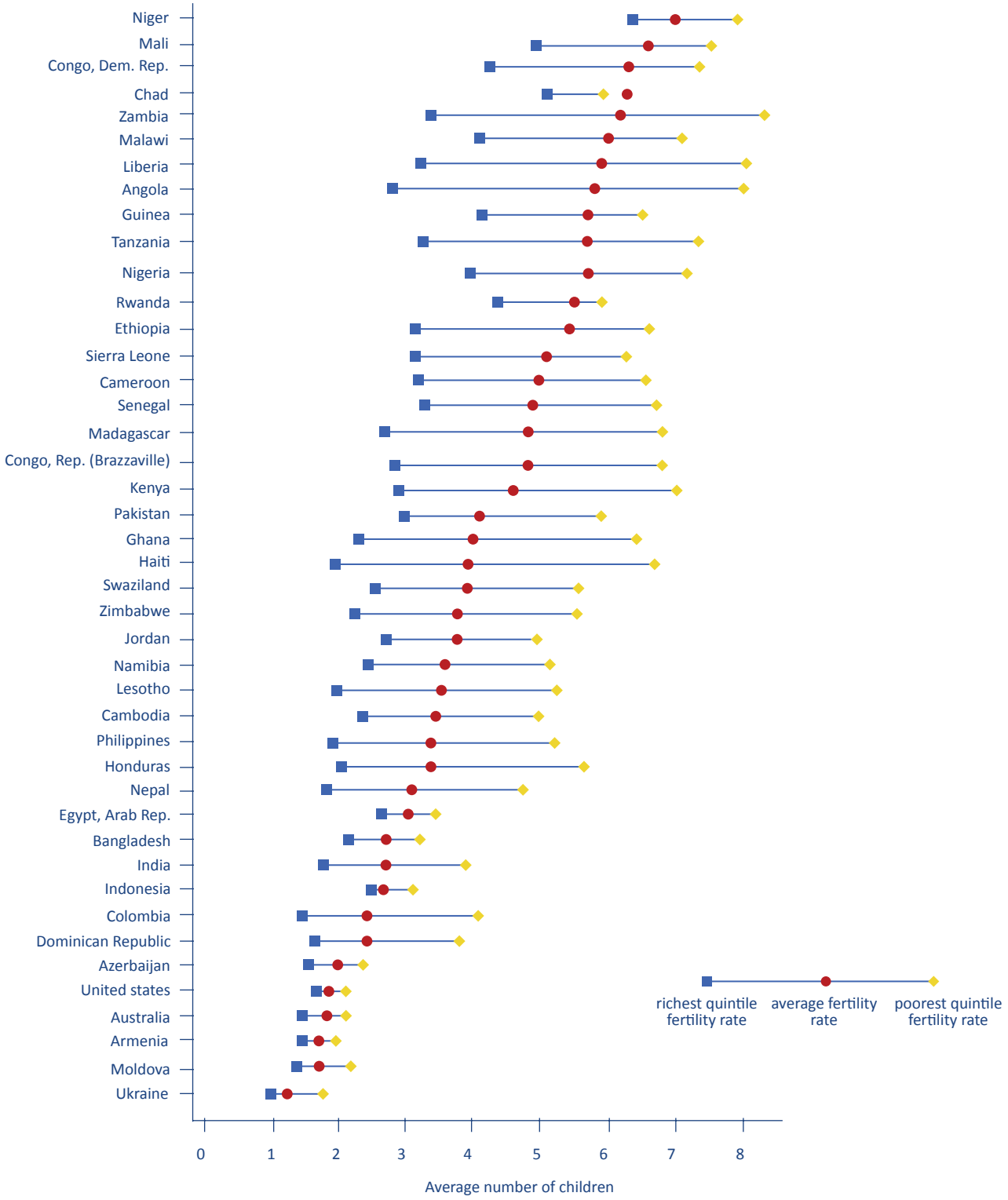


Exhibit 15: Fertility rates vary dramatically by income quintile; by a factor of two between the wealthiest and poorest income quintiles in many countries (World Bank, 2012).

KEY CHALLENGES

There are many reasons why gender equity does not exist in the world today. Some reasons are obvious, while others are complex and nuanced. Some reasons are seemingly addressable, while others are deep-rooted, and threaten to be an ongoing struggle. Some reasons affect women across income groups, while others are particular to low income populations. The following is a summary—admittedly oversimplified—of the reasons why gender disparities exist among low income populations.

1 Laws to ensure gender equity and protection of women, already weak or poorly enforced in many countries, are even more badly enforced for low income women

Laws are typically written by male-dominated legislatures and do not reflect the context and challenges faced by women; sometimes, they are outright discriminatory. For example, even in countries like the US, until very recent legislation like the Lilly Ledbetter Fair Pay Act of 2009 (United States Senate, 2009), equal pay for equal work had not been fully guaranteed by law. On the other hand, acts like Kenya's 2014 polygamy law (The Guardian, 2014), are actively creating barriers against equity. Even when fair laws are on the books, there is strong evidence to suggest that they are not enforced, especially for low income women (World Bank, 2012) (Mehta, 2013). In most regions of the world, fewer than one-fourth of national parliamentarians are women (**Exhibit 16**).

Percent of national parliamentary seats held by women

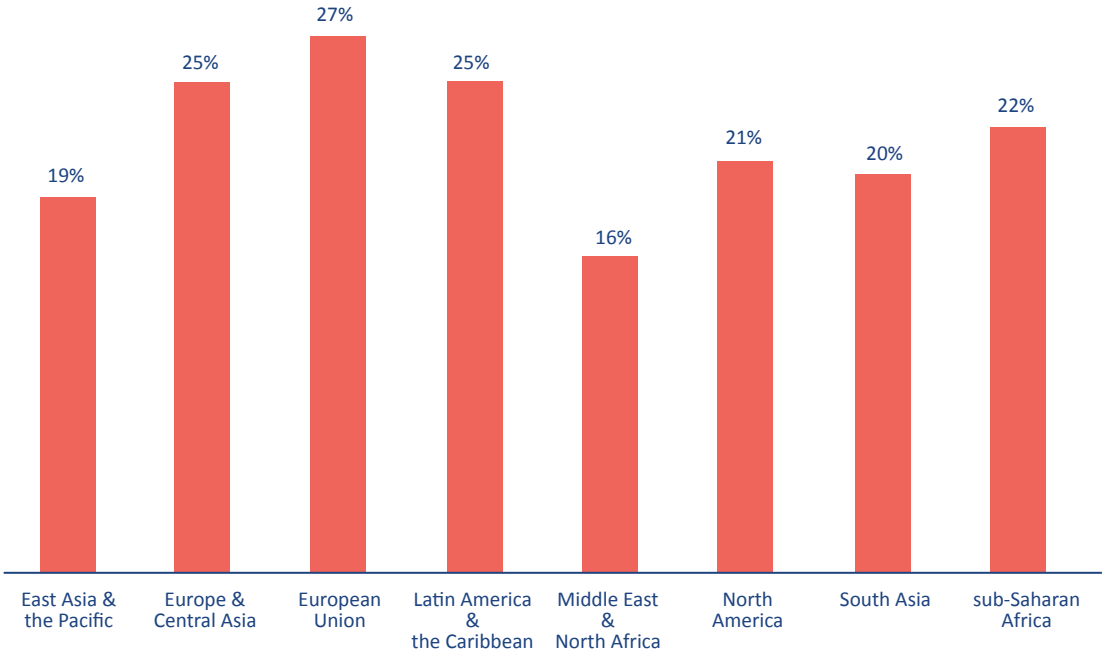


Exhibit 16: Throughout the world, women comprise a very small portion of national parliaments (World Bank, 2012).

2 Customary practices, often discriminatory, coexist with formal constitutional laws

A number of countries have plural legal systems, in which traditional laws and practices coexist with more modern constitutions and legal frameworks. To be clear, not all traditional laws are necessarily discriminatory towards women, nor do modern constitutional laws necessarily guarantee more protections. Still, it is reasonable to assume that newer laws, based on international standards and legislative debates, and under higher levels of scrutiny from the media, tend to be more inclusive than traditional practices. As **Exhibit 17** shows, almost all countries in sub-Saharan Africa recognize traditional laws, and a substantial number of them are either silent on discriminatory practices or explicitly exempt women from non-discrimination.

Plural legal systems are also an issue in other parts of the world. In Pakistan and other Islamic countries, for example there is heavy pressure from religious leaders to impose Sharia Law (which can impose many restrictions on girls and women, including denial of education). Similarly, the legal systems in countries like India and Israel have also created separate laws for religious groups. Often, such laws based on interpretation of religious scripture—rather than modern constitutional principles—tend to discriminate against women (Amien, 2006) (ACLU, 2014). Across the board, wealthier urban populations and women tend to have access to better legal protections from these traditional laws and practices.

Plural legal systems in sub-Saharan Africa

Constitution recognizes customary law but prohibits discrimination

Constitution recognizes customary law but explicitly exempts it from non-discrimination

Constitution is silent about customary law

Exhibit 17: Customary laws are part of the formal legal system in most countries in sub-Saharan Africa. This leads to discriminatory practices and laws in much of the region (World Bank, 2012).

3 There are a range of barriers preventing women from seeking available services, leading to a lack of transparency into the condition and specific needs of individual women

Even when women are subjected to physical abuse or other forms of violence, they very often do not seek remedial services available to them. There are a number of reasons: stigma associated with filing claims; a lack of awareness about their rights or the services available; a lack of trust in the system to deliver effective results; the inconvenience of the process involved, given their household and other responsibilities; lack of support from the family or community; and the threat—implicit or explicit—of additional violence. **Exhibit 18** (World Bank, 2012) shows results from surveys, conducted in a number of countries, which found that only a small portion of the women subjected to domestic violence sought recourse.

Percent of abused women who seek available remedial services

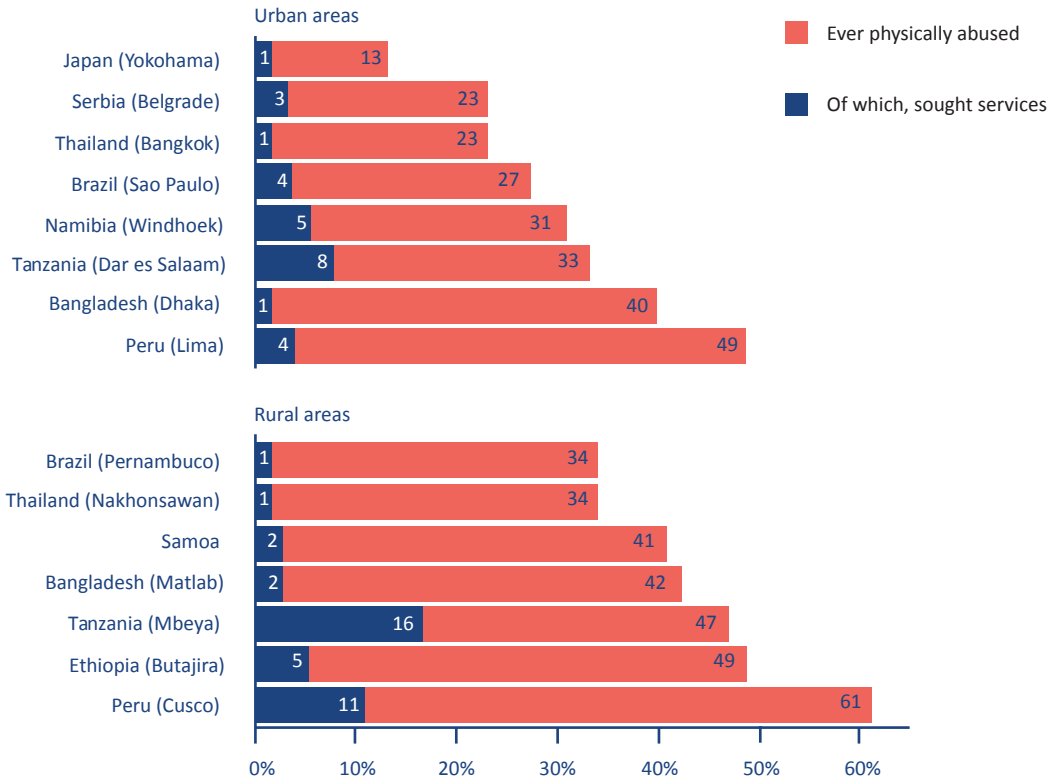


Exhibit 18: In domestic violence cases, the vast majority of women do not seek available remedial services (World Bank, 2012). This reluctance is driven by cultural practices, social stigma (or, inversely, support), and interpersonal family dynamics.

4 Technologies aimed at combating poverty are typically not developed with women in mind, even in the face of evidence that women constitute the majority of users

There is a growing body of work that is doing a more accurate accounting of the quantum of work women do, whether or not they are compensated for it, and their contribution to broader economic and social development. Women constitute the majority of farmers, health workers, and educators in many countries, but technologies are often not designed with women users in mind; too often, they are designed by men, with input from men. For example, manual treadle pumps used for irrigation in much of Africa have been reported to be too strenuous and inconvenient for women to use, and women have to employ young men to operate the pumps for them (Kay & Brabben, 2000). Women's physical strength, size, mobility, traditional clothing constraints, whether or not they carry children with them during their workday, as well as cultural constraints, are all critical factors that are not taken into account often enough in technology and product design. Another important consideration not taken into account is the distance traveled—while carrying various types of loads—by women on a routine basis. By some estimates, over the course of a year, the average rural African woman "transporting water, fuel, or produce will carry more than 80 tons for more than a 1 km distance, while men carry about 10 tons for a 1 km distance." (Ashby, et al., 2008). Suitable solar-powered solutions that can be adapted to the needs of women in rural or semi-rural areas, like the solar rickshaw in India (India Today, 2012), already exist on the market and are slowly converging toward the right price point. With the right financial and regulatory support, such a product will go a long way in improving the quality of day-to-day life for rural women.

5 There are significant systemic gaps in basic healthcare, which disproportionately impacts women

While health outcomes have improved dramatically in recent decades, the development of adequate healthcare infrastructure has been left largely unaddressed in many countries. This is especially true for rural or remote areas. There are far too few functional clinics, far too few adequately trained clinicians to operate them, and far too little funding to build and support the infrastructure. Today, significant gaps in basic healthcare exist in much of rural Africa and South Asia. The physical traits unique to women increases their vulnerability to specific health conditions, and the absence of essential health services disproportionately impacts them. Specifically, the lack of adequate maternal care increases the risk of complications and mortality during childbirth; and the nature of women's reproductive organs increases their vulnerability to sexually transmitted infections like HIV and HPV. As a result, each year, 300,000 women die during childbirth and another 270,000 die from cervical cancer. Also, the prevalence of HIV in sub-Saharan Africa among women is almost twice that among men.

Exposure to a number of health hazards is exacerbated by the poor quality of homes. In particular, inadequate ventilation combined with high levels of indoor air pollution from using traditional cookstoves is a major driver for respiratory diseases. The absence of private toilets exposes women to significantly greater levels of inconvenience and increases the risk of abuse and violence when women are forced relieve themselves in the open or use unsafe public facilities.

The lack of affordable sanitary care products during menstruation increases the risk of reproductive tract infections. While in recent years there has been an increasing effort towards making very low cost sanitary pads available for women, as of 2014, no single product has reached much scale. We believe affordable products will become available within the next 2-3 years but will face the challenge of distribution and adoption, much like other products aimed at the low income retail market.

SCIENTIFIC AND TECHNOLOGICAL BREAKTHROUGHS

Technology will not overcome deep-seeded and archaic societal attitudes that predominantly dictate women's roles and entitlements, and underlie almost every challenge women face. However, when it comes to some disadvantages faced specifically by low income women in developing countries, the following 7 breakthrough technologies can have targeted impact. Note that the issue of gender equity cannot be considered in isolation from other issues discussed in our study. Therefore, the following technological breakthroughs are grouped according the specific aspects of life and development that will be impacted, such as health, agricultural development, digital inclusion and human rights, and have been discussed in other topic-specific sections as well.

HEALTH

The main issues impacting the health of low income women are: a systemic lack of basic healthcare for low income communities, a primary driver for maternal mortality; higher physical vulnerability, as well as the practices of male sexual partners that increase the risk of HIV/AIDS or cervical cancer; cultural norms and the limited voice women have in family planning, which leads to higher-than-desired fertility rates among women from poorer populations; and greater exposure to household air pollution and the consequent risk of respiratory diseases, because of poor ventilation and the use of traditional cookstoves and fuels. There are 3 technological breakthroughs than can address some of these health-related problems.

Breakthrough 1

An easy to operate, affordable, integrated, and solar-powered suite of medical devices specifically for maternal, child and primary care in low resource settings

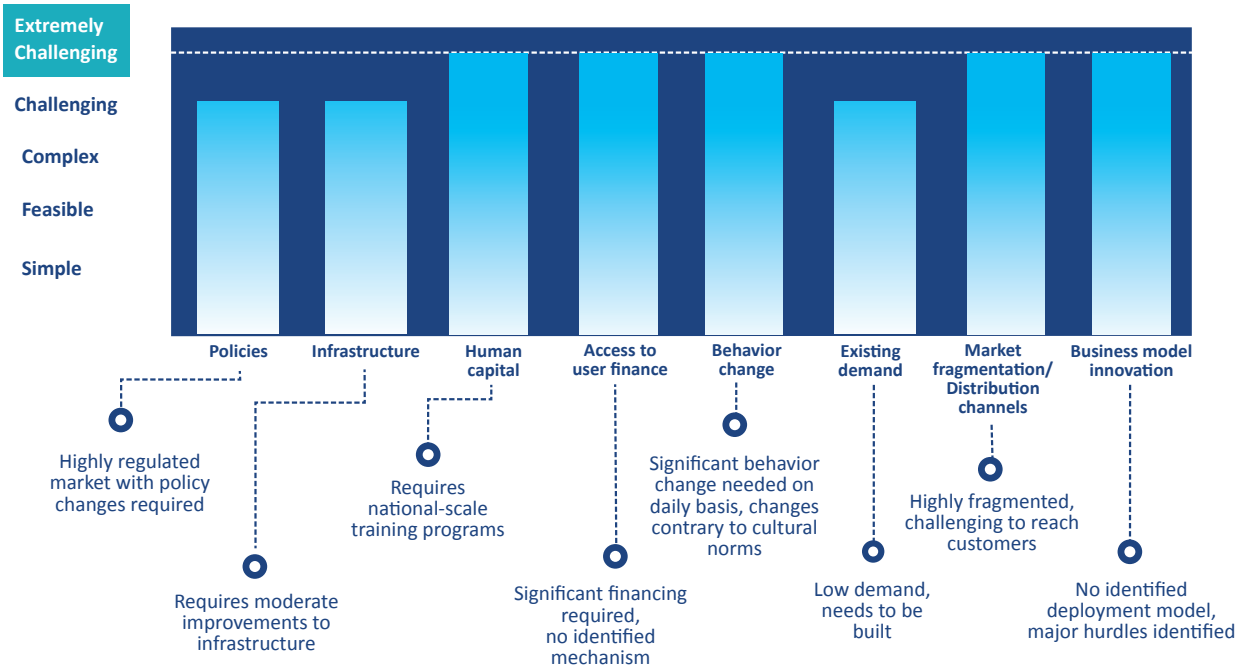
Among the many structural challenges in healthcare delivery in developing countries, is the virtual absence of adequately equipped clinics. The majority of clinics, especially in rural areas serving low income populations, lack even the basic amenities, let alone the equipment necessary to provide essential services. To build a clinic with the equipment necessary to provide basic maternal, neonatal and primary healthcare would likely cost in excess of $100,000. This is based on preliminary research on costs of essential medical devices already available on the market including solar panels, lighting, water purifier, ultrasound, IV, suturing, continuous positive air pressure machine, basic infant incubator, sterilizer, medical refrigerator, smart phone, tablet or other computer and imaging device, diagnostics for commonly occurring conditions, and cost of constructing a basic building. In the absence of adequate public funding, this is clearly too expensive for low income populations; by a factor of 10, based on our high-level assessment. In addition, the logistics of procuring the various components and assembling them into a functioning clinic require considerable effort. As such, we believe this type of a suite or a 'clinic-in-a-box' can be a significant breakthrough if it:

- Combines the aforementioned devices in an easy-to-install 'kit'.
- Costs approximately $10,000 - $15,000, based on our high level assessment of financial feasibility, given published data on how much low income rural families in sub-Saharan Africa and South Asia spend on healthcare.

- Integrates power management, computation/imaging, data, and communication, so that the various devices are easy to install, use, and replace as necessary.

While some of the listed devices are available at the appropriate price point, many are still priced for industrialized markets. Given the number of groups working towards developing individual devices, we believe enough of them will become available (at the right price point), within the next 3-5 years. Within the same time window, it will be possible to develop a platform to integrate the various devices. However, even once such an integrated suite is developed, it will face a large number of deployment challenges. There is not enough public funding to procure a sufficient number of such clinics, the private market is underdeveloped and fragmented, and the regulatory requirements are unclear. Moreover, significant behavior change, encouraged by some form of insurance or financing to allow affordable access, is required for most low income rural communities to seek regular and formal care. Hence, deployment will be EXTREMELY CHALLENGING.

Breakthrough 1 – Difficulty of deployment



Breakthrough 2

Microbicides to provide a method of protection against HIV/AIDS and Human Papillomavirus (HPV), for those who are otherwise vulnerable to infection through sexual contact with their partner

Women, especially those living in societies and situations plagued by gender and income inequality, are often limited in their ability to ensure that their sexual partners use condoms. This risk is exacerbated in places with high rates of sexual violence, and a high prevalence of polygamy. Specific high-risk populations, like sex workers and transgender people, also find themselves restricted in their ability to use protection during sexual contact.

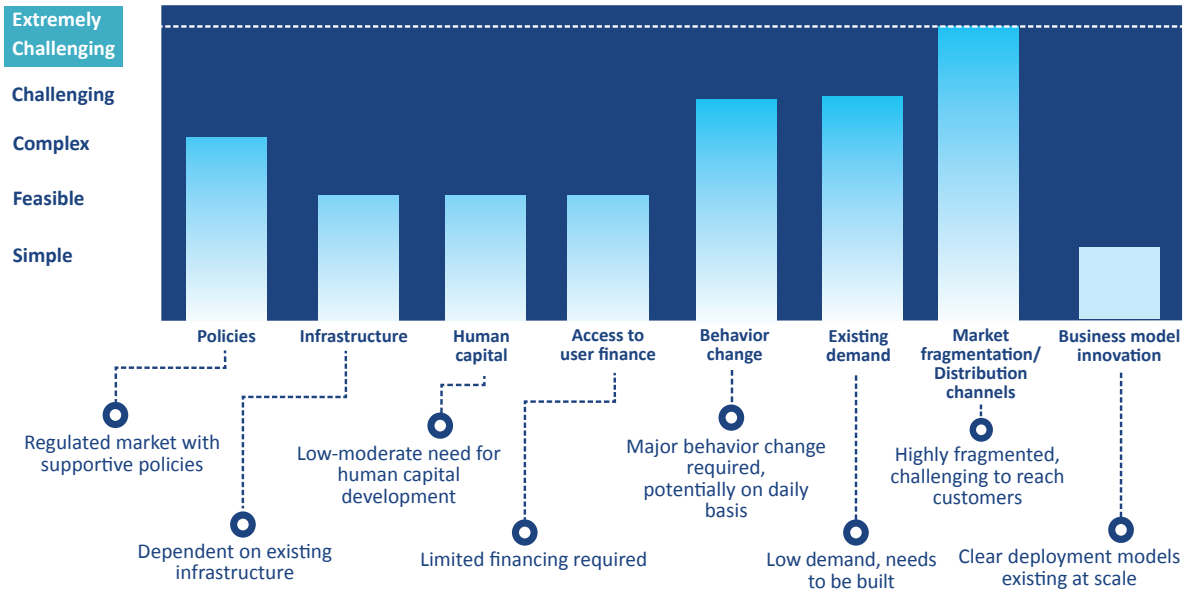
Microbicides are currently under development as vaginal or rectal products designed to protect healthy men and women from HIV/AIDS infection. These products are being tested in multiple forms—vaginal and rectal gels that can be used at the time of sexual contact, and vaginal film, tablets or rings that can slowly release the microbicide drug to provide preventative coverage for up to a month. Unlike vaccines, an effective microbicide must be made into a commodity that individuals will want to and can safely use, on a regular basis. Ideally, microbicides would be discreet (socially acceptable), easy to use, long-lasting, and easy to distribute.

There are several different microbicide candidates currently being studied. In May 2013, 11 phase I trials, 1 phase I/II trial, and 4 phase III trials were underway (AVAC, 2013). Even if a phase III microbicide candidate is found to successfully prevent HIV infection, it will take a few years before it becomes available for use. Any successful product will have to first undergo review and licensing by regulatory agencies. It will also take time to work out the best formulation and dosage, find a suitable delivery method, and identify appropriate distribution channels before the product can be made available to the public. Microbicide gels to prevent HPV, as well as combination microbicides to prevent HIV, HPV and other sexually transmitted infections are also in various stages of development and testing.

Difficulty of deploying microbicides, once available, will depend on human factors, including how easy and convenient they are to use (microbicides require regular reapplication), and whether they are made available to consumers over the counter or by prescription only. To ensure microbicides are widely available to people in low and middle income countries, the price will have to be affordable, and this may mean that profit margins have to be kept low.

Based on the above assessment, the projected time to market readiness is 5-7 years, and the difficulty for deployment is EXTREMELY CHALLENGING.

Breakthrough 2 – Difficulty of deployment



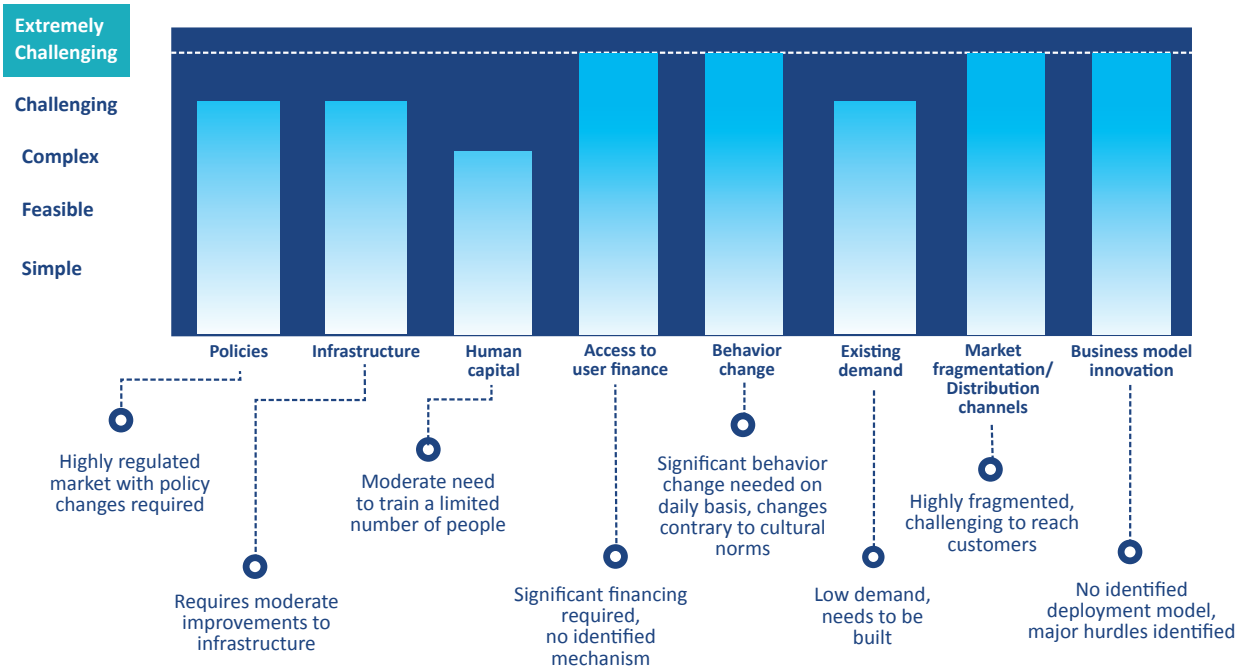
A new kind of a home—made with strong lightweight material—especially for the urban poor, with a private toilet, solar-powered lighting and ventilation

The majority of the poor live in homes made with found material. In urban shantytowns, these homes are densely packed single-story shacks, which are usually off-grid (or have illegal access to grid power), allow very little light or fresh air, have no running water, and no toilet. This heavily contributes to a range of severe health conditions: illnesses from indoor air pollution, the spreading of infectious diseases like pneumonia and TB, as well as diarrheal diseases because the absence of private toilets or clean and convenient public toilets leads to open defecation. Without addressing the problem of decent living conditions, it is unlikely that remedial medical care will lead to significant gains in health in the long run. Currently, the only option for constructing robust homes is brick and cement, which is far too expensive for the poor. Additionally, the absence of clear land rights—and the threat of eviction—makes such permanent homes a risky investment. A new kind of home, with the characteristics listed below, can contribute to a significant improvement in quality of life:

- Very low cost, so that it is affordable for the poor (recognizing that it will often compete with free, found material).
- Robust, so that it withstands harsh weather, and can potentially support a duplex structure.
- Equipped with basic appliances, e.g., solar-powered LED lighting, and a fan or ventilator.
- Equipped with a private in-home toilet, which can be used even without a connection to running water or drainage systems (in principal the waste can be extracted from outside the home, for disposal).
- Aesthetically pleasing and culturally appropriate.
- Lightweight, so that it can be relocated if necessary.

Such construction material currently does not exist, and it is not clear if there are any efforts underway to develop such material at the right price point. It is also not clear what such material would be made of. As such, we believe such a technology is at least 10 years from becoming a reality. Even when it does become available, there are significant dependencies on behavior change, user finance, and policy changes (e.g., for land tenure). The difficulty of deployment in this case will be EXTREMELY CHALLENGING.

Breakthrough 3 – Difficulty of deployment



HUMAN RIGHTS

Women often bear the brunt of human rights violations, especially through sexual violence or physical abuse. While this is especially true in the context of conflict, it is far too common in day-to-day life, across geographies and economic classes. In developing countries, particularly, a major challenge in holding perpetrators of sexual violence accountable is the lack of mechanisms to test, preserve and then use biological evidence in the court of law. One breakthrough can make a difference in collecting biological evidence.

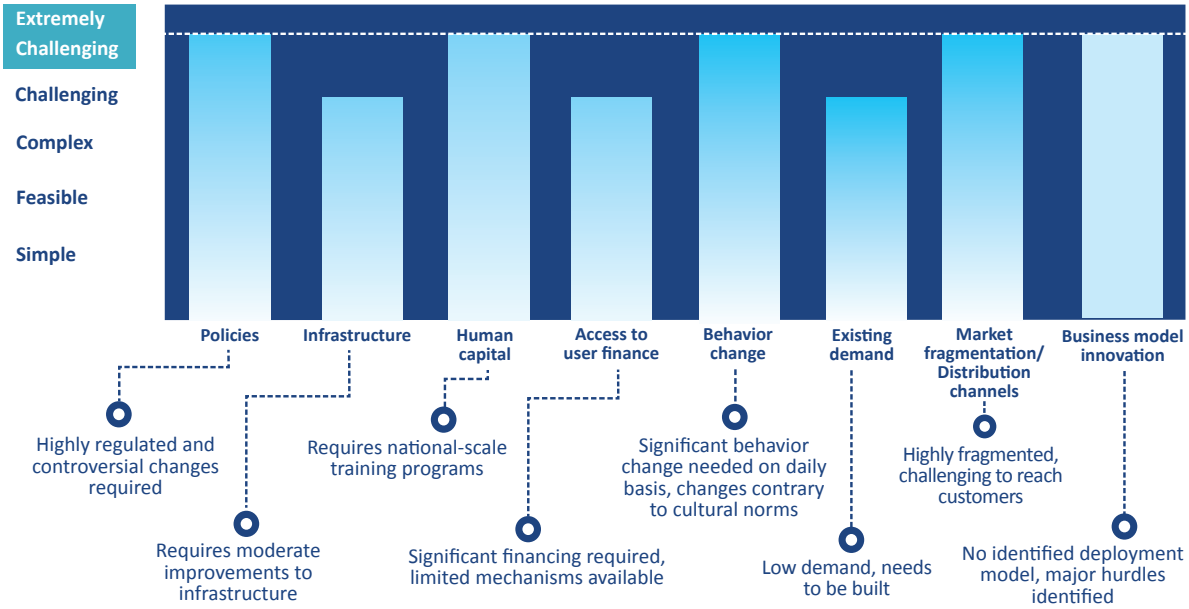
Breakthrough 4

A simple point-of-use, low cost DNA-based rape kit capable of delivering rapid results

Sexual violence occurs for a whole host of reasons, including gender discrimination, societal and interpersonal power dynamics, and impunity that comes from the lack of accountability. A major challenge is that even if a woman overcomes the stigma associated with being a victim of sexual violence and lodges a formal complaint, there is limited evidence to make a robust legal case. Rape kits—to preserve semen and other degradable biological tissue, and conduct DNA analysis on the samples to match against potential perpetrators—are becoming increasingly common in higher income countries. However, these require skilled technicians and a sophisticated, expensive laboratory to analyze the samples. To be useful in low resource or conflict settings, a rape kit would have to be very low cost (under $10 per test, with the processing equipment not more than a few hundred dollars), usable off-grid, and not require much clinical training to use. In addition, the analysis should be rapid, with the ability to digitize and transmit relevant data for secure (presumably cloud-based) storage. Similar low cost DNA-based technologies being prescribed—and developed—for medical diagnostics, seem to be 3-5 years from becoming available on the market. In principle, a DNA-based rape kit should not take more than 5 years beyond that.

However, once such a technology is developed, it will face significant challenges in deployment, along virtually every dimension. Enough facilities (e.g., health clinics) will need to have the device at hand, those administering the test will need some level of training, and financing will be necessary to cover the costs involved. Without financing it will also be very difficult to ensure a steady supply and maintenance of the kits and the processing equipment. Moreover, policy changes will be necessary to determine how the judicial systems of different countries can best use such evidence in their legal proceedings. But most importantly, the behaviors of victims and the community will still have to evolve considerably. Rape kits can be administered only if a victim seeks help immediately after the incident, while the biological evidence is still intact. In other words, deploying such a technology will be EXTREMELY CHALLENGING.

Breakthrough 4 - Difficulty of deployment



ECONOMIC OPPORTUNITY

Women produce 50% of the world's food. While men may be responsible for the heavy manual labor on farms, women are responsible for the rest of the work, both on and off the farm, like tilling, weeding, and threshing. This work is usually very physically demanding and time consuming. Affordable machines to automate these activities can reduce the workload for women. An important factor to consider is that these machines need not necessarily be affordable to individual farmers, but can potentially be used as a shared commodity, if the community dynamic is supportive. The section on Food Security and Agricultural Development describes, in more detail, the specific issues related to agriculture, but in the context of women, 2 technology breakthroughs are particularly important.

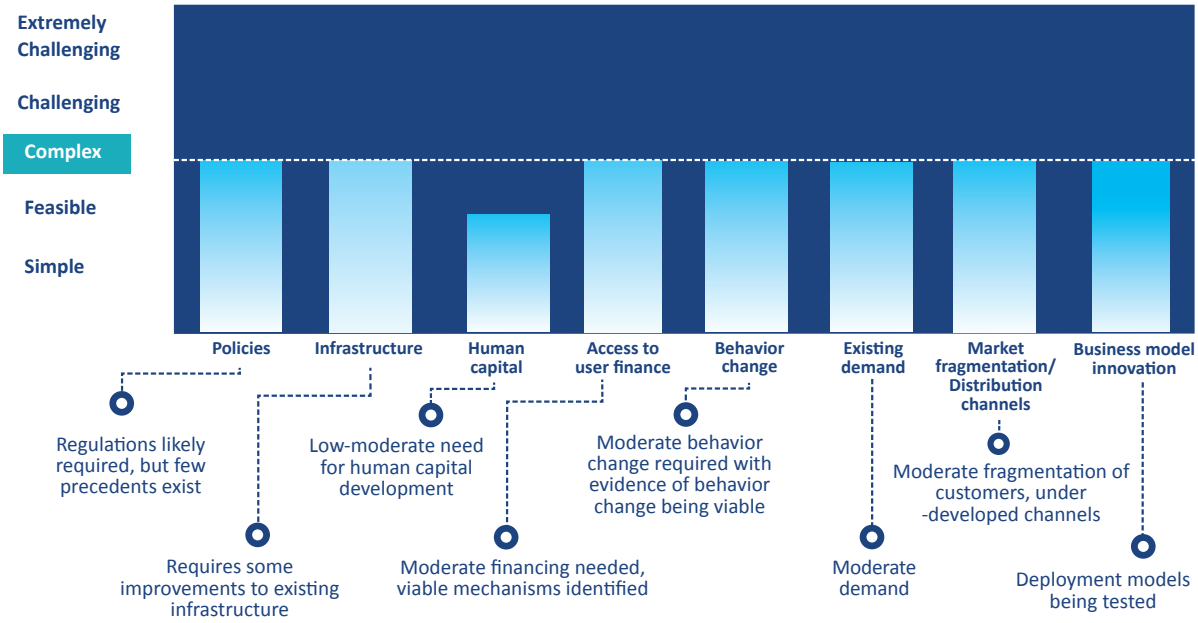
Breakthrough 5

Affordable, lightweight, and fuel efficient solar-powered irrigation pumps

Irrigation is critical for increasing farm yield. The manual (e.g., treadle) pumps currently available are labor intensive and often not suited for the needs of women farmers. Motorized pumps currently on the market require diesel, the cumulative costs of which are high (even though incremental costs might be low). In remote areas, the paucity of distribution mechanisms for diesel is an additional constraint. Affordable solar-powered pumps can be an ideal solution to this problem. A number of organizations are developing solar pumps, and a small number of them are already being used in India. But, the biggest hurdle appears to be throughput—the more the volume of water pumped, the larger and more expensive the solar panel. Considering the effort being dedicated to this problem and the pace with which this market is developing, it is likely that affordable and efficient pumps will become available within the next 2-3 years.

However, even if solar pumps become available, a number of deployment hurdles will need to be tackled; the majority of smallholder farmers in South Asia and sub-Saharan Africa are still extremely poor, live in remote areas, and are used to rain-fed farming. Considerable effort will be necessary for creating demand, providing finance, and training. A critical lesson from the decades of agricultural development in South Asia, is that water can easily be overused, and groundwater easily depleted. It will be important to consider regulating water use in tandem with deploying such pumps, so that irrigation water is used sustainably. Needless to mention, enforcing any such regulations will be very challenging. Hence, we believe that deployment will be COMPLEX.

Breakthrough 5 – Difficulty of deployment



Breakthrough 6

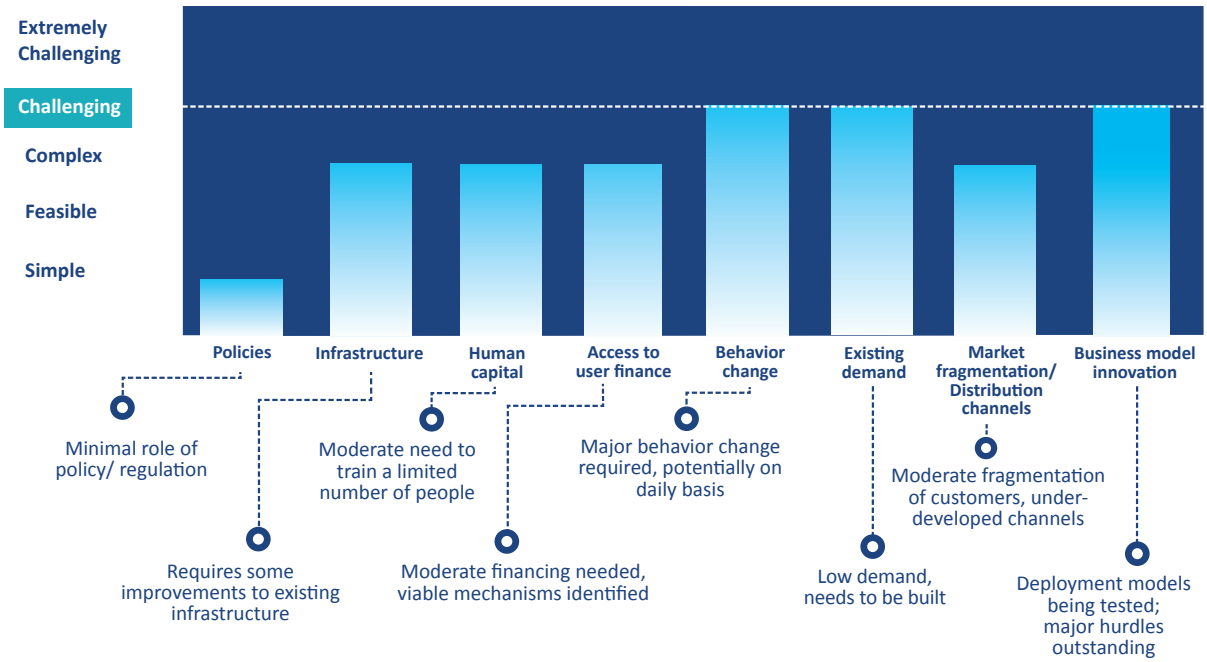
An affordable mechanized tilling or weeding tool

The Striga family of weeds is the single largest cause of on-farm losses for smallholder farmers. Currently, the only way farmers in Africa deal with the weeds, is to spend countless hours pulling them by hand. Indeed, the quintessential image of the act of weeding, is an African woman hunched over, pulling out weeds. Not only is this physically exhausting, but by the time the weeds are visible on the surface, the damage has already been done to the roots of the crops that the farmers sowed for the coming season. Mechanized tillers used by farmers in industrialized countries are far too expensive for the African context, and typically need diesel. A low cost tiller that is either fully or partially mechanized and not dependent on diesel can help African farmers remove weeds before planting.

The obvious technical challenge is to generate enough force to dig through dry—often hard—soil, with as little fuel input as possible. This problem is the same as those involving mechanization across a range of work genres—creating a higher mechanical advantage using limited input force. Machines supplemented by human energy (e.g., pedal-power machines using a bicycle like movement) have been used to run some devices, but the amount of power generated by such machines (typically 0.5 horsepower or less) tends to be significantly less than what is required for mechanized tilling (the smallest mechanized tillers tend to be 3-5 horsepower). The solution likely lies in some combination of human or animal-supplemented power, solar power, and a highly efficient engine. In principle, such a machine should not be complicated to build, but will require considerable field testing to understand operating parameters in various types of soil. There is reason to believe that such an implement can be on the market within the next 3-5 years.

However, even once such an implement becomes available, many farmers may not see the value in investing in mechanized tilling, since they are accustomed to pulling out the weeds after they become visible. Beyond that, such an implement will face the usual challenges of a highly fragmented market, sparse distribution networks, and limited financing options for smallholder farmers. Therefore, we believe that the difficulty of deployment will be CHALLENGING.

Breakthrough 6 – Difficulty of deployment



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