Thinking big for smallholder agriculture: realizing agricultural potentials in changing times

A Discussion Paper

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Highlights

- Strategic foresight supports broad assessment agricultural investment opportunities.
- Productivity improvement must complement investments targeting smallholder benefit.
- There is no single model for agricultural investment, local context matters.
- Agriculture can be a motor of economic growth and shared prosperity.

Abstract

Recent advances in approaches to quantitative strategic foresight have enabled new insights into understanding potential futures of the agriculture sector. Quantitative foresight approaches facilitate understanding of different plausible scenarios, especially as related to both endogenous and exogenous factors (e.g., global markets and climate change). These approaches tend to be macroeconomic in nature and resolve trends relative to coarse-grained drivers. In order translate these outputs into strategies that realistically benefit producers across scale, finer resolution and context specific understanding is needed. This paper offers perspective on how foresight analysis can be combined with more pointed assessment of the specific policies, institutions and market requirements needed create more inclusive agricultural investment strategies.

Key Words: foresight; smallholder agriculture; agricultural productivity; shared prosperity, inclusive development

1 Introduction

Over the last several decades scholarly perspectives on agriculture have shifted. Early perspectives looked at the sector merely as a food resource and supplier of surplus labor, then evolved to a view the sector as a necessary developmental stepping stone towards industrialization, and more recently as an explicit driver of growth, especially during early stages of industrialization (Byerlee et al., 2009). More recently, the sector's deep integration with both biophysical and social processes have resulted in more systems oriented perspectives; the expectation is now that agriculture must not only address global food security but must also be environmentally sustainable and contribute to solving development challenges (Hammond and Dube, 2012; Thompson and Scoones, 2009). Simultaneously, the context for examining agricultural systems has changed with globalization and a highly dynamic trade environment (Busch and Bain, 2004), resulting in what has been characterized as a "fundamental reorganization of food systems from farm to plate" in increasingly standard-intensive value chains (McCullough et al., 2008).

The challenges posed by these changing agri-food structures, along with perennial challenges such as infrastructure and capacity deficits, are further compounded by stressors and shifting contexts, such as climate change and structural transformation (Lipper et al., 2014; Schmidhuber and Tubiello, 2007). Smallholder communities in developing countries are particularly vulnerable given typically lower levels of resilience and a lack of safety nets. Considering that smallholders and "family farmers" manage over 50% of agricultural land and an estimated 98% of all farms globally (Graeub et al., 2016), the success or failure of adaptive strategies in the coming decades holds far reaching consequences for global food security and agricultural sustainability. Responding to the combined set of challenges and aggravating stressors requires systematic research and decision-making regarding investment possibilities both in and outside of the agricultural sector (Rickards and Howden, 2012).

In this paper, we explore the issue of investment decisions for agricultural research in light of resource constraints and the need to maximize impacts. We begin with a brief review of challenges and stressors faced by smallholders and move toward looking at opportunities to improve the system and enhance benefit sharing. We then use different forward-looking agricultural investment scenarios simulated using the IMPACT model (Rosegrant et al., 2017) to examine related agricultural system performance. To contextualize the results, we assess the potential impact of different investment scenarios in agriculture with case studies to demonstrate how complimentary policies, institutional and market interventions are critical in ensuring that investments in agriculture research ultimately do have the potential to help the poorer, smallholder producer.

2 Challenges and stressors facing smallholders

The challenges faced by smallholders are complex and often highly localized or context specific (Fao, 2016; Jayne et al., 2010). Morton (2007) distinguishes between challenges arising out of the subsistence farming system itself, challenges specific to smallholders and subsistence agriculture, and identifies climate change as a stressor particularly relevant to smallholder farmers. Subsistence farming systems are typically characterized by their small size and marginal environments (Lal, 2006; Pretty, 1997). Land tenure is often informal and thus insecure, and access to risk insurance products (e.g. droughts and crop disease) is weak at best. The farm system is highly complex and family labor time is often also devoted to off-farm and nonfarm employment to make ends meet (Jayne et al., 2010; Rigg, 2009; van Vliet et al., 2015).

Morton (2007) and others further list land fragmentation and environmental degradation due to population pressures, weak physical infrastructures (roads, electricity, water and storage facilities), low educational capacity, small domestic markets, state fragility and the negative consequences of health problems (e.g. HIV/AIDS and malaria). These issues, together with high barriers to entry into to global markets, protectionist policies, as well as price shocks and volatility, are challenges outside of the control of the individual producer. Morton (2007) and others (Hazell et al., 2010; Jayne et al., 2010;

World Bank, 2008) further list land fragmentation and environmental degradation due to population pressures, weak physical infrastructures (roads, electricity, water and storage facilities), low educational capacity, small domestic markets, state fragility and the negative consequences of health problems (e.g. HIV/AIDS and malaria). These issues, together with high barriers to entry into to global markets, protectionist policies, as well as price shocks and volatility, are challenges outside of the control of the individual producer.

2.1 Climate stressors

Climate change is a significant threat to farmers, and will become increasingly so, particularly for smallholders, given the challenges they already face. Direct impacts occur in the form of higher temperatures and increased concentrations of greenhouse gases, which can affect crop yields (Challinor et al., 2014; Schmidhuber and Tubiello, 2007) and increase the need for water for irrigation that is already in short supply.

Indirect impacts of climate change occur as a response to changes in biophysical phenomena. One such example is changing pest and disease frontiers and corresponding outbreaks that, in some cases, may claim more than 50% of expected harvest (Oerke, 2006). Climate change is also expected to affect the complex interactions between pathogens and the host plants, facilitating the diffusion of new pathogens and the expansion of invasive insect pests (Kroschel et al., 2013). This increases the incidence risk and resulting yield losses. Although there is ample scientific knowledge on the impact of specific climate or environmental variables on the incidence and severity of pests and diseases, research relating these issues to food security and smallholder livelihoods still relatively nascent (Chakraborty and Newton, 2011).

Also associated with climate change is heightened variability, both spatially and temporally, in significant weather events, which translate into price shocks, compounding the existing challenge of price volatility for smallholders. Shocks that affect modern agrifood systems with a strong influence on global food prices can further exacerbate vulnerability and food insecurity in systems with high food import dependency (Chung et al., 2014; Gbegbelegbe et al., 2014; LLoyd's, 2015; Malik and Awadallah, 2013). For example, extreme weather in 2012, which affected maize production in the USA led to global maize prices rising by 25% within a few months and remaining high for several months thereafter; this constrained the ability of poorer countries with high maize import dependency to meet their food consumption requirements (Chung et al., 2014).

Farmers can adapt endogenously to some of these stressors through changes in management though not all farmers have equal adaptive capacity. For example, in the case of conservation agriculture, farmers who adopt a combined set of practices are more likely to realize benefits, but that, "without effective institutional and legal reforms to provide secured land tenure to farmers and increase access to credit, the rate of adoption of CA practices will remain slow," (Tambo and Mockshell, 2018). While the technical and institutional requirements associated with adaptation are generally well-understood, in the case of climate smart agriculture, there remain major gaps in understanding the barriers to adoption and means for overcoming these barriers, especially in relation to vulnerable and marginalized populations (Lipper et al., 2014).

2.2 Socioeconomic stressors and potential in agriculture

Independent of climate change, structural transformation – spurred on by urbanization and a reallocation of factors of production from lower to higher productivity sectors (out of agriculture) – presents smallholders with additional pressure. These processes have gathered considerable momentum in much of the developing world, more or less as foretold in the development trajectory narrative set forth by Lewis (1954). Changes in income levels and standards of living are driving consumption patterns towards more highly processed, high energy, low nutrient foods (Figure 1) (Kearney, 2010); diets are, as a result, simultaneously becoming more homogenous (Khoury et al., 2014) and drawing from a greater number of "foreign" crops (Khoury et al., 2016).

These changing patterns on the consumer side in turn drive further supply-side transformation in the agrifood production system, presenting smallholders with new opportunities to engage in processing and value-addition forward linkages (Lee et al., 2012). And these expanding forward linkage opportunities in turn drive increased demand for improved inputs and other backward linkages (Swinnen and Maertens, 2007). While the rural-urban outmigration of mostly young labor has resulted in farm labor shortages for some countries (Tschirley et al., 2015), much of it remains within the new and expanding value chain linkages (McMillan and Harttgen, 2014).

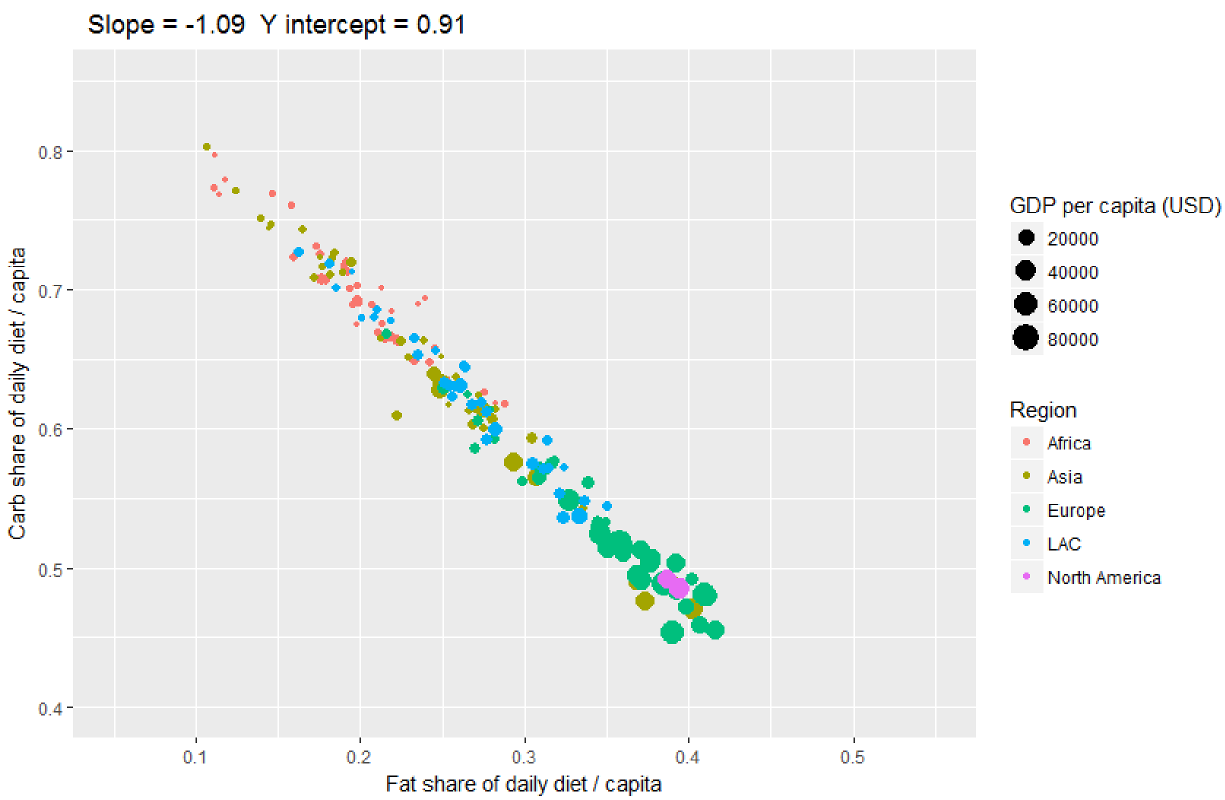


Figure 1: The carbohydrate-fat consumption trade-off with growth. Source: FAO 2010 Data.

In the literature, the economic growth underpinning these structural transformations is often characterized as a "miracle" that is unambiguously beneficial for all segments of the population (McMillan and Harttgen, 2014; Prasad, 2009; Young, 2012). However, in many developing countries the benefits of rising incomes among the upper percentiles have not “trickled down,” but rather gone hand in hand with rising inequality. Moreover, recent analyses suggest that inequality may often be growth neutral (Berg et al., 2012); and that periods of growth are more enduring and favorable for poorer farmers when they are accompanied by a rise in lower income shares (Dabla-norris and Kochhar, 2015; Ostry et al., 2014). In this sense, pro-poor and pro-growth mandates may not be the mutually exclusive, contradictory philosophies they are often made out to be, but rather, as Berg and Ostry put it, “two sides of the same coin” (2011).

Empirical findings such as these bolster a growing consensus that views many of the socio-economic stressors facing smallholders not as inherent in the “nature” of smallholder agriculture, but rather inherent in decades of development strategies that systematically overlook—and often undermine—agriculture’s natural potential as a broad-based, labor intensive engine of participatory growth in LDCs (Byerlee et al., 2009, 2005; Lipton, 2006; von Braun, 2009). As this rebooted vision of agriculture gains traction relative to the “urban bias” and “agro-pessimism” that has repeatedly positioned agriculture as the “handmaiden of industrialization” (Byerlee et al., 2009), attention must turn to the more pragmatic topics surrounding implementation. How, then, can we focus investment in agriculture that builds upon its native strengths and identify opportunities to better take advantage of the unrealized potential and “dead capital” (De Soto, 2001) in agriculture systems? Quantitative foresight is one approach useful for explore the potential future impact of different investment and development scenarios.

3 Leveraging foresight for the smallholder

Though numerous economic, biophysical, and climatic challenges are inevitable (Lipper et al., 2014; Schmidhuber and Tubiello, 2007), there remain substantial opportunities to improve the efficiency of the agricultural system as a tool for improving prosperity of smallholder producers. Opportunities exist to improve food production and use through genetic gain, improved biological control, minimization of waste, and more sustainable and equitable distribution of both the food resource (Godfray et al., 2010; Parfitt et al., 2010); this would be further enhanced by better integration of women and youth through corresponding processes promoting greater inclusion in value chains (Lu and Dudensing, 2015). In order for agricultural to serve as an engine of pro-poor growth and not simply mine the smallholder as a resource for growth elsewhere in the economy, we must learn to identify and operationalize the assets potentially overlooked when rural transformation is viewed through an urban-focused lens.

Strategic foresight approaches allow for the examination of different investment, research and policy scenarios to better understand the potential impacts associated with different decisions and strategies. Focus on increases in productivity in the face of climate change is one potential strategy, with higher yields serving as one aspect in improving the supply dimension of the global agri-food system. This production-innovation and growth narrative may, however, actually limit smallholder prosperity and agricultural sustainability in many cases (Thompson and Scoones, 2009). Foresight approaches allow testing of different scenarios to see, for example, if privileging improvements in yield is as promising as believed, and to test potential complementary investments or other specific innovations.

3.1 Looking at the big picture

Macro-level foresight tools such as computable general equilibrium models can be useful in identifying economic signals in broad geographic areas and economic sectors (Peters et al., 2011). As discussed in the sections above, for the agriculture sector, these changes will likely require careful adaptive measures at multiple policy levels to take advantage of new markets and economic structures. In the agriculture sector, we borrow from the same set of equilibrium-related concepts to understand how productivity, supply and demand interact at different scales and ultimately drive the market for different agricultural commodities. Partial-equilibrium models of the agricultural sector and general equilibrium models of the broader economy offer insights into the production and trade dynamics that result from different scenarios within the agricultural system (Tongeren et al., 2001). These models, likewise, allow for the exploration of the potential impacts of climate change and technological change on the broader agricultural sector through the incorporation of climate-, technology-, and policy-based shocks to productivity (Rosegrant et al., 2014).

Keeping in mind that productivity enhancement alone may only be one aspect of agricultural development, we can use foresight tools to identify how different types of investment affect different geographic areas and commodity groups. Here we leverage the results from a recent scenario analysis exercise (Rosegrant et al., 2017) that used the IMPACT model (Robinson et al., 2015) to understand the potential impacts of different agriculture investment scenarios compared to a pre-established counterfactual. The counterfactual or "reference scenario" used in this exercise offers insights into the way in which climate change, a major stressor of challenges facing smallholders, could affect production and trade of the different commodities under a "business as usual" scenario in which investments in agricultural research held at a minimum.[1]

The result of the reference scenario illustrates how, even under conditions of climate change, agricultural productivity is expected to increase in the world's major regions (Table 1). Increases in productivity are accompanied by substantial increases in food availability and corresponding decreases in the percentage of the population at risk of hunger. The results also show how some regions with currently relatively low rates of productivity like Middle East and North Africa, South Asia and Sub-Saharan Africa are predicted to close the gap with the rest of the world despite expected negative impacts of climate change on productivity. North America, which is already at a production frontier and thought to be hit less hard by climate change, will have a relatively small increase in agricultural productivity over 40 years.

Table 1: Changes 2010-2050 under the reference scenario.

Region	**Agricultural productivity (mt)**	**Food availability (kcal/person/ day)**	**Population at risk of hunger (percent of total)**
East Asia Pacific (EAP)	37.3%	20.2%	-7.6%
Europe (EUR)	31.3%	3.1%	-0.2%
Former Soviet Union (FSU)	30.8%	9.7%	-1.5%
Latin America and the Caribbean (LAC)	38.9%	11.6%	-2.9%
Middle East and North Africa (MEN)	70.4%	4.1%	-1.0%

[1] The reference scenario was based on the Shared Socioeconomic Pathway 2 (SSP2) and Representative Concentration Pathway 8.5 (RCP8.5), realized with the HadGEM2-ES General Circulation Model. For more information, we refer the reader to the USAID Scenario Analysis Report (Rosegrant et al., 2017).

North America (NAM)	19.5%	1.4%	0.0%
South Asia (SAS)	60.2%	72.0%	-12.3%
Sub-Saharan Africa (SSA)	48.0%	18.3%	-13.6%

Source: IFPRI data and *(Rosegrant et al., 2017)*

The aggregate results tend to conceal, however, the sub-regional heterogeneity in terms of climate change impact on trade, specific crops affected, and other variables subject to perturbation at a sub-regional scale. Furthermore, the results in Table 1 do not reflect price volatility, other short-term variability, additional sources of investment in specific agricultural research, or any other focused interventions or policy. Finally, with the exception of sugar and oil crops, the reference scenario does not consider potentially sophisticated value addition processes not reflected at a regional scale. For these reasons, we attempt to leverage these results in order to parse a set of agricultural futures that consider more than change in productivity.

3.2 Thinking beyond productivity, supply, and prices

Changing supply and demand profiles illustrate that, given increasing populations, the demand for agricultural commodities is going to continue to increase and change according to increases wealth and corresponding increasing demand for animal protein and other high energy foods (carbohydrates and fats). At the same time, however, the partial equilibrium representation of the agricultural sector in IMPACT is relatively "pragmatic" (Tongeren et al., 2001) and, as such, simplifies the markets and value chains for a variety of commodities. In order to understand what opportunities may exist that enable smallholders through favorable bioeconomic conditions, we should thus assess how different investment strategies can maximize synergies with agricultural productivity increases and probably supply, demand and price movements.

The previously mentioned study also modeled the effects of several different investment strategies. In this work, we examine a subset of these strategies, which are summarized in Table 2. The subset was selected because of its immediate relevance to smallholders given the many challenges they face. Agricultural research has been and is thought to continue to be an important contributor to a prosperous agricultural system. A regional focus was introduced given comparatively low productivity level and expected high population increases in South Asia and Sub-Saharan Africa. Potential opportunities of participate in value chains are reflected in improved market efficiency.

Building on the smallholder-oriented focus of this paper, we select a number of key commodities that are critical smallholder crops, representing both commodities that are tradable in regional and international markets as well as commodities that, due to their perishability, are more locally traded or serve for on-farm consumption. These are grouped as roots & tubers (R&T), pulses (PUL), fruits and vegetables (V&T), and cereals (CER).

Table 2: Evaluated investment scenarios.

Scenario	**Description**	**Basis**
HIGH+NARS	High levels investment in the CGIAR with investment in the national agriculture research services.	The previous sections illustrate the need for greater institutional capacity to improve smallholder capacity. This scenario addresses the needed agricultural research and increased national capacity.

REGION	Targeted investment in South Asia and Sub-Saharan Africa, with medium investment in Latin America and East Asia.	Though smallholder needs are high throughout the world, there are relatively greater disparities in income equity in SSA and South Asia. The targeted investment addresses this equity issue.
RMM	Improved marketing efficiency through improved transport and lower marketing margins.	This scenario addresses the importance of the value chain infrastructure as a key tool in helping smallholders diversify production and lower costs.
COMP	The comprehensive scenario combining high yield and research scenarios, improved water use and irrigation systems, and improved marketing margins.	A "best case" scenario that will serve to illustrate when specific commodities are highly insensitive to different investment strategies.

In reviewing the results from the comprehensive investment scenario in comparison to the reference scenario (Figure 2), a number of observations are in order. First, we see that for some regions, there are modest to very high increases in food supply across all commodity groups (SSA, SAS, and EAP). Sub-Saharan Africa clearly benefits from the comprehensive investment scenario. In comparison, Latin America and the Caribbean would see high levels of benefits in cereals, pulses and roots and tuber, potential modest benefits in fruits and vegetables, and expected lower supplies in specific cereals. The comprehensive investment scenario does seem to have a strong impact on cereals, pulses and roots and tubers, which is logical given the prevalence of these commodity groups around the world. It should be noted that fruits and vegetables are not CGIAR crops and are therefore not expected to respond much relative to investments analyzed here; changes therein will therefore simply be a function of price interaction with the other crops, itself a telling metric.

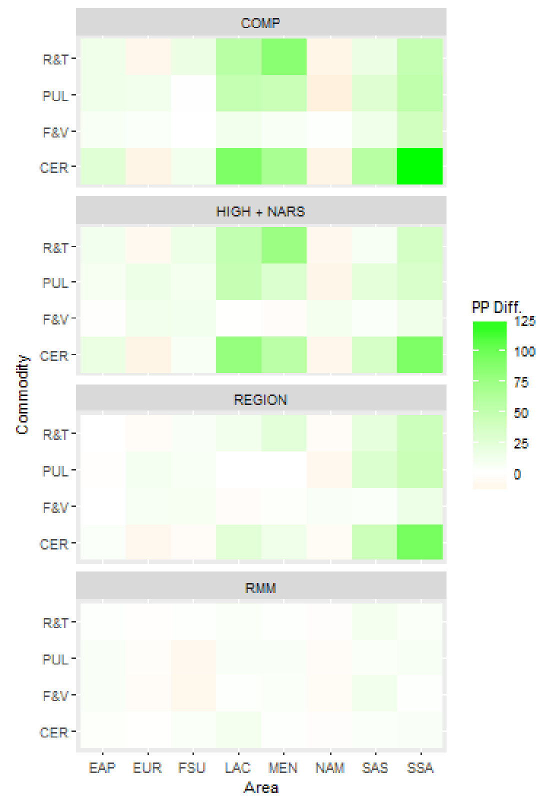


Figure 2: Percentage point difference in the 2015-2050 % change in food supply, comprehensive investment scenario vs. the reference scenario.

Producer prices rise in all of the scenarios considered in Table 1, but rise less so under investment. (Figure 3). For example here, note that price changes are evident for commodities and scenarios that see production changes, but are generally spread across regions because of market interactions. In the key commodity groups of cereals, pulses and roots and tubers, investment scenario producer prices are lower than the reference scenario by 20 to 50 percent points. Whether or not smallholders are net beneficiaries of the relatively lower prices depends on whether they are net producers or net consumers of their product. Net consumers benefit, while net producers are faced with lower incentives to farm.

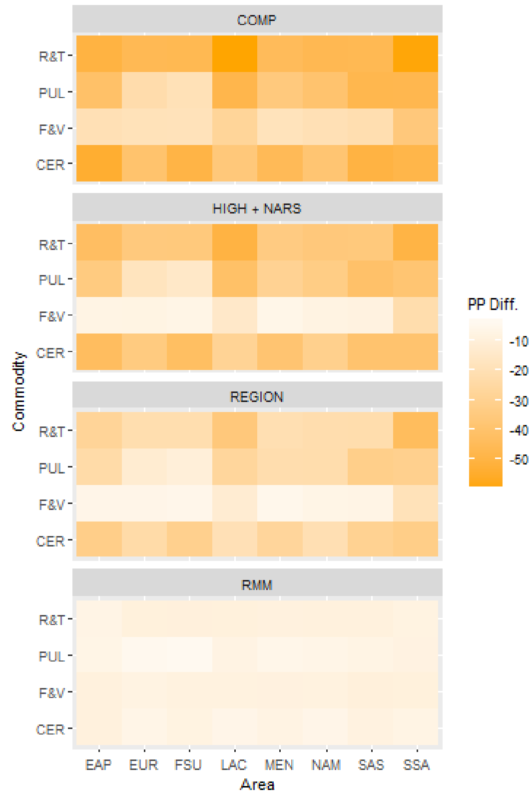


Figure 3: Percentage point difference in the 2015-2050 % change in producer prices, comprehensive investment scenario vs. the reference scenario.

In reviewing the results presented in Figure 2 Figure 3, we see that for some crop and area combinations, the crop response to research is relatively inelastic. That is, the trends are relatively consistent under climate change with and without major investment. As would be expected, lower crop response to research has a correspondingly lower difference in crop prices.

One challenge with global partial equilibrium models is that they group together diverse value-added production systems. These systems exist alongside each other and smallholders are often engaged in more than one value chain with the same agricultural commodity. Value addition may involve the smallholder but often accrues to medium to large-scale enterprises. At the same time, increasing incomes allow the emergence of specialty niche markets to which smallholders can cater directly if sufficiently engaged in the relevant value chains. The scenario analysis study only indirectly addresses the mechanisms to better position smallholders amidst the future expected increases in production and decreases in price. The RMM scenario uses price wedges and, consequently, the scenario is only partly indicative of what could be accomplished through more strategic “complementary investments”. How, then, must we align complementary investments with the productivity-oriented investments that are otherwise typically prioritized in agricultural research?

4 Playing matchmaker: pairing foresight results with contextualized investments for smallholders

The premise of this paper is the idea that agriculture development hinges on more than just increasing productivity. A more holistic view is that investment should improve smallholder ability to maximize profitability. In other words, "potentially profitable smallholder farmers" require context-specific policy environments that not only address investment related to productivity, but also investments in key complementary areas (Fan et al., 2013). Investment scenarios such as RMM and perhaps the "+NARS" only notionally address the idea of complementary investment. While a structural modeling approach can, for example, "contribute to better targeting and prioritization of plant breeding" (Islam et al., 2016), without explicit consideration of the local contexts, it is difficult to know who will benefit from a particular investment and how those benefits will be realized by the individual smallholders.

Arguably, the three main factors that mitigate or reinforce the effectiveness of investment in agricultural research include the presence of relevant, pro-poor policy, the existence of appropriate social and civil institutions, and the establishment of functioning, fair and accessible markets. As Siegel (2005) highlights, however, even in the best case scenarios these factors are often largely exogenous to the smallholder and still require a clear assets and livelihood-based adaptation strategy at the household level. With this in mind, we use policies, institutions, and markets as a framework through which to evaluate how productivity focused investments in agricultural must be paired with complementary investment to ensure maximum smallholder prosperity. We address the idea that return on investment can be maximized if we focus on finding key opportunities that address particular situations arising from the intersection of the challenges described in the previous sections. These opportunities may be crop, context, system, or geographically specific and are presented through case studies from various countries and spanning different commodities.

4.1 Policies and Institutions

In many regards, the scenarios examined in Section 3.2 reflect a specific set of policy interventions. At a minimum, the "+NARS" aspect to the high yield policy reflects a national policy that promotes agricultural research to improve development and dissemination of productivity enhancing technologies. Similarly, RMM reflects national economic policy related to the improvement of infrastructure, a government investment resulting in a new or improved public good. At the regional scale, we can look to examples such as Belo Horizonte in Brazil as one example illustrating the potential of effective policy. In Belo Horizonte, an "alternative food system" was implemented that, at its core, provided government backing to subsidized food sales, food and nutrition assistance, and regulation in food supply chains (Rocha and Lessa, 2009). In this example, the regulatory framework actually empowered both producers and consumers and served to limit exposure to international markets, which would have led to higher volatility.

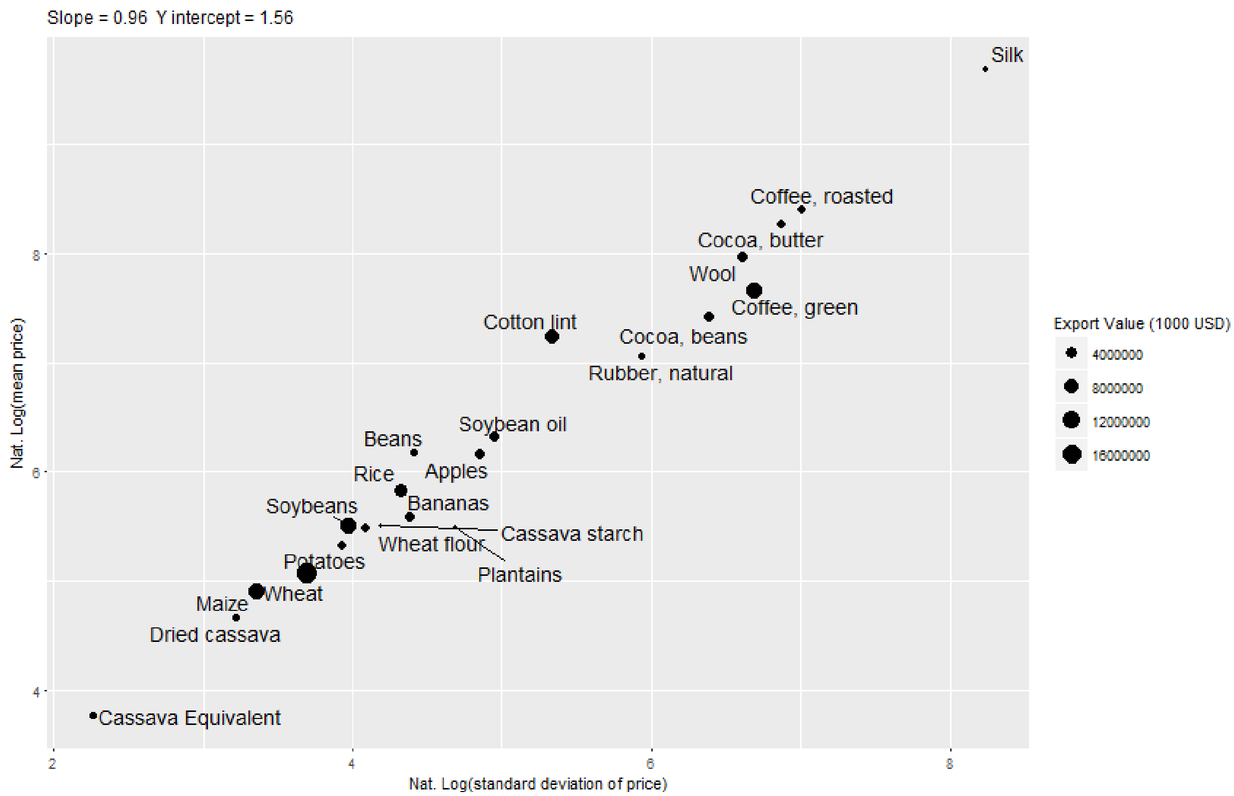
One of the key lessons learned from Belo Horizonte is that politics matters (Morgan, 2009). Successful politics, however, require stakeholders and policy makers who are both mobilized and motivated. These individuals and groups emerge from the institutions, formal and informal, public and private, governmental and non-governmental, that all have a stake in the agrifood system. The importance of a motivated base is similarly illustrated in multi-stakeholder platforms for potato. Again, synergies between productivity enhancing investment and local empowerment are realized, offering greater benefit to the smallholder as well as the overarching agri-food system (Thiele et al., 2011). The approach illustrated by Thiele et al. in Bolivia, Ecuador and Peru shows the importance of mobilizing multiple sets of actors and how this can lead to new value chains and even trademarked high value products (2011). This type of institutional-based intervention promotes interaction and creates interdependence among different stakeholders and actors, including farmers, processing companies, restaurants and supermarkets, in order to achieve outcomes that would not be possible by any one actor on their own.

The foresight modeling scenarios presented earlier offer some additional quantitative perspective regarding the potential relevance of multi-stakeholder platforms for potato in Bolivia, Ecuador and Peru. By 2050, population in these three countries is expected to grow on average by more than 30% compared to 2010, also increasing potato demand by a similar percentage. However, projections of the IMPACT model suggest that potato production will almost triple, making the three countries net exporters of potato, and thus creating further opportunities for all stakeholders to cover multiple types of demand across different world regions. To benefit from these new opportunities, a scaling up of the platform mechanism would be required, accompanied by investments in agricultural research for bringing about innovations in both production and marketing of potato. For smallholders outside the platform to be able to take advantage of such value-added opportunities requires access to crucial information, sufficient countervailing power relative to stronger value chain agents, and the ability to participate in these markets. Though platforms may present barriers to entry that prevent smallholders from attaining or demonstrating required quality standards, the platforms can play an important role in mitigating economic losses for all stakeholders by facilitating innovation processes and linking them with previously unreachable markets.

In some sense, interventions such as multi-stakeholder platforms are investment agnostic and adaptive in nature. That is to say, they are well positioned to complement or accommodate the outcomes associated with nearly any policy approach driving investment in agriculture. Even so, key institutional arrangements for developing value added opportunities hinge on trust in the value chain, information availability and reliability, and both demand and supply of the required commodities.

Less obvious, however, is that engaging in more profitable but more specialized value chains entails higher risk (Figure 4). Both high value commodities as well as the value-addition process result in higher expected return for the smallholder, but with more volatility in prices. Smallholders must therefore also have the *risk* capital necessary to pursue these opportunities. Government price support plays a role in risk mitigation, but the same protection can be achieved by diversifying the smallholder's options. This diversification can often be built around a flex crop like cassava, which can be cultivated at low cost and consumed for subsistence or transformed into multiple higher value products for downstream food, feed, and industrial markets (e.g., as cassava, dried cassava, and cassava starch). Diversifying production is not only related to risk but also depends on the entrepreneurship culture, the institutional support from the government in the form of incentives (not necessarily price support), and investments in adequate infrastructure (e.g. foreign direct investment in storage facilities, food processing facilities) to support activities that add value to existing practices (Gulati et al., 2007, p. 93). Although the above constitute a direct type of support to promoting agricultural entrepreneurship, the public sector also plays an indirect role in alleviating a series of institutional, structural and cultural constraints that may exist among rural communities (Byerlee et al., 2009).

Figure 4: The value-volatility relationship. Source: FAO 1974-2008 Data. "Price" = World Export Value / World Export Quantity.



Investment in productivity must be paired with strategic complementary investments. This should not be mistaken, however, for producer and consumer subsidy equivalents, which are often inappropriately implemented to prop up specific segments of domestic producers, resulting in price distortions, non-competitive markets, and even potential declines in overall food security (Brooks, 2014). Properly implemented, market price supports, stockholding, and redistribution of subsidized food actually have the potential to bolster smallholder livelihoods, though these may be inhibited by trade agreements (Fritz, 2014). Out of necessity, policy interventions are also designed to mobilize improvement in wellbeing at the regional to national scale. Examples such as the removal of a food rationing program and the implementation of a food-for-school program (wherein school-going children received rice and wheat) help improve food efficiency and build long-term human capital (Babu and Dorosh, 2017). This latter example is particularly interesting in the present context as it creates synergy between productivity enhancing investment and policy related to child welfare and human capital development.

There are several important cultural constraints that also relate to the perception of the potential value in the agriculture sector. Young people and women are especially affected. Young people have been leaving farming for urban jobs, in lieu of exploring agriculture for "higher value opportunities"; agriculture should be able to ensure a high and secure stream of income, as these are the main economic criteria that distinguish a “bad” from a “good” job in rural areas (Brooks et al., 2013). Young people who opt to stay in farming will need to be supported by appropriate education structures which will allow them to develop the necessary skills to explore value added opportunities. The role of the public sector in the organization of agricultural education services that aim at improving the human capital in rural areas is again important, since farmer schools not only improve productivity and income of small-scale farmers (Davis et al., 2012), but also contribute to the cultivation of a culture for entrepreneurship and collective action and, especially, the empowerment of women (Friis-Hansen and Duveskog, 2012). This latter point is especially important as many local crops are already viewed as "women's crops" and if linked to high-value addition products, represent an important opportunity for women.

4.2 Markets

In many less developed countries, smallholders are confronted by a lack of access to adequate markets for many of the products that they can most readily produce. This is pointedly illustrated in Mozambique where, for many years, chicken broilers (e.g., from Brazil and South Africa) were imported and sold at prices lower than local producers could match. In order to access the market, the local producers needed to either improve the perceived quality of their product, lower prices, or both (Karnani and McKague, 2014). After an extensive set of interventions, ranging from improving the relationship between commercial chicken processors and smallholders to improving the availability and cost of chicken feed, the poultry industry in the country grew to US$ 165 million in 2010 (Karnani and McKague, 2014). This latter issue, the increased production of soybean, has resulted in an expanding agricultural frontier in Mozambique and elsewhere in southern Africa. The result could lead to a "south-south" tele-coupling wherein transfer of agricultural technology between South America and Southern Africa could also transfer various conservation challenges (Gasparri et al., 2016).

According to the scenario analysis results, investing in only one section of the value chain for soybean would not be enough to spur production. More specifically, increasing soybean yields on farmers' fields through improved technologies or even reducing marketing costs including transport costs for soybean grain would not be enough to substantially reduce import dependency for soybean grain and processed soybean products in southern Africa. Processed soybean products such as cooking oil and soybean meal currently dominate the consumption of soybean-based products in southern Africa; they are also expected to maintain their dominant position by 2050 under a hotter and drier climate. To reduce soybean import dependency in southern Africa by 2050, additional policies would be needed to strengthen the processing sector in the region so that it can produce the bulk of processed soybean products and in the process act as a powerful pull for soybean grain production by smallholder farmers. Using strategic foresight and IMPACT modeling approaches will allow us to understand the extent to which different agricultural technologies can be used to sustainably intensify soybean production while avoiding conservation challenges. With these insights, strategies can be developed to both understand the potential of soybean for agricultural producers as well as understand potential future impediments to market expansion in the poultry industry.

Another interesting model emerges from food industry motivation to assure supply of key inputs. Maize, for example, is one of the crops facing serious potential consequences related to climate change (Challinor et al., 2014; Gbegbelegbe et al., 2014). Given the all but inevitable impact to maize production, private sector consumers are motivated to invest in local and sustainable sourcing to ensure supply (see https://lnkd.in/e26pScN). In this example, the International Center for Improvement of Maize and Wheat (CIMMYT) helped broker an agreement in between Kellogg's Company and yellow maize producers in Sinaloa, Mexico, with active participation and enthusiasm from a mixed audience, including producers, farm advisors, businessmen, scientists and politicians. This approach requires research investments to develop appropriate varieties and technologies that meet the requirements of both the market and the producers, but also requires national innovation hubs where stakeholders can interact. Quantitative foresight modeling not only offers insight with respect to potential return on investment, but also potential exposure to impacts of climate change, pest and disease, and long term potential of these types of localized partnerships given the global context.

The maize example reflects the potential value of different scenario results and how different investment scenarios may benefit different sectors and different scale producers. Local agreements such as that in Sinaloa could substantially benefit from focused investment in NARS that promote innovation hubs, and from investments that enhance market efficiency through improved infrastructure that lowers margins. While the processing industry is increasingly interested in locally sourced inputs, they have to be competitive relative to imported raw material. Making the right types of investment to create a conducive environment can ultimately lead to stronger public-private partnerships and greater market engagement for local producers. Global partial equilibrium models such as IMPACT can only partially capture these developments as major commodities in these models do not distinguish between different quality traits. The maize produced for an integrated value chain for breakfast cereals is a yellow maize where the producers in Sinaloa are currently growing white maize for the tortilla market. Thus, while quantitative foresight offers a broad perspective, consideration of local context and requirements for complementary investment is a critical element in promoting smallholder prosperity.

5 Closing the loop on investment for smallholder prosperity

In an ideal world, investments in agricultural research would rapidly transcend from theory, to investigation, to practice, with poor famers equitably and efficiently benefiting from research investment outcomes. The reality is much more complex, however, and assessments of economic benefits associated with agricultural research only offer limited diagnostics for improving research related outcomes (Hall et al., 2003). If ex post economic impact assessment offers little in the way of diagnostic value, what we can really expect to learn from ex ante strategic foresight approaches that incorporate numerous assumptions regarding potential future trends?

First, we can immediately discern that the structure of investment matters. The scenarios presented in this review illustrate multiple potential futures and show, clearly, that different investment scenarios have different implications across both crops and geographies. By extension, this also yields insight into who are the potential beneficiaries of different investment strategies. In this work, we use the foresight scenario results to provide insights into how different investment strategies may or may not affect smallholders, with a goal of understand when and how creative complementary investments can serve as a boost to more traditional investment strategies.

Large scale foresight analyses can only take us so far. Foresight analysis serve as a key input into more specific conversations around the requirements for new policy, institutional innovation, and creative thinking in terms of markets. When we contextualize the macro-level results from the scenario analysis with an exploration of the instruments required, we work towards helping to transfer outcomes of agricultural investments to smallholders. The presented cases, positioned around interventions related to policy, institutions and markets, illustrate that investments in productivity enhancement are only one step toward improving smallholder prosperity, and that these investments must be accompanied by complementary investments in social systems to facilitate transfer and uptake of innovation in a way that builds equity in the smallholder population. At the most fundamental level, labor productivity must increase in agriculture systems; without increased labor productivity, the chronic cycle of investments serving as partial solutions to complex, system level problems will only continue.

The point of quantitative strategic foresight is neither to predict nor to prescribe action relative to a specific outcome. Foresight approaches are intended to facilitate dialog and promote evaluation of, and planning around, uncertain futures (Cook et al., 2014). As was illustrated, a small amount of foresight can provide us with a great deal of information regarding the volatility of potential investment options; investments in futures with higher potential volatility should be accompanied by the corresponding safety nets required to allow smallholders to mobilize their assets and adjust their livelihood strategies according to their individual situation. These types of interventions would allow smallholders to take on the risk associated with higher value opportunities. Ultimately, the investments presented in the scenario analysis are the first step in this direction; with future strategic foresight specifically oriented to transfer of investment benefits to smallholders, we will be well on our way to ensuring a positive future for all participants in the global agrifood system.

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