Chapter 10. Hybrid potato breeding for smallholder farmers in developing countries: four models for public-private collaboration

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Abstract

We explore how the potential of hybrid potato breeding can be harnessed for smallholder farmers in low-income countries, using economic theories developed for the governance of commons (or common-pool goods). Despite the great potential of hybrid potato breeding, it comes with major challenges that need to be overcome by public-private collaboration. We explore the strengths and challenges of four possible models for public-private collaboration of how hybrid potato breeding can be made available for smallholder farmers in low-income countries: the charity model, the pre-competitive research model, the breeding consortium model, and the project model. It should be noted that these four models are not mutually exclusive. The four models show that there are different ways of institutionalising public-private partnerships while each of these models have specific strengths and weaknesses when it comes to ensuring smallholder access to innovation. It can be argued that the project model is most likely to ensue if no concerted action is taken to institutionalise the access to hybrid breeding for smallholder farmers. This exploration of the four models of public-private partnerships can be used as a starting point for the public and private sectors to come together and discuss how they can combine their forces for the benefit of smallholder farmers around the world. We are convinced that the way these models will be operationalised will result in much more complex and nuanced collaborations, and involve other aspects that we have not taken in consideration.

Keywords: commons, charity, pre-competitive research, breeding consortium, project

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10.1 Introduction

This chapter explores how the potential of the powerful new approach of hybrid potato breeding can be harnessed for smallholder farmers in developing countries through public-private collaboration. Potato (*Solanum tuberosum* L.) is an important staple and/or cash crop for many smallholder farmers in Africa, Latin America, and Asia, and it is widely expected to gain greater importance thanks to its relatively healthy nutrient content and ease of cultivation (Haverkort and Struik, 2015). However, the importance of potato for smallholder farmers is held back by the complexity of incorporating the many characteristics they need into a single variety, and by significant constraints to the availability and access to high-quality planting material.

Inbred diploid hybrid breeding in potato (henceforth: hybrid breeding) promises to overcome several of these constraints (Beumer and Edelenbosch, 2019; Beumer and Stemerding, 2021; De Vries *et al.*, 2016). Firstly, this innovative breeding method makes it possible to include new traits faster (Lindhout *et al.*, 2011; Jansky *et al.*, 2016). This enables the development of high-quality varieties with traits that are specifically relevant for smallholder farmers. Secondly, this innovation will enable the multiplication of potato varieties through true botanical seeds. These have significantly lower disease loads as compared to seed potatoes currently used by farmers. As such, the technology has the promise to increase the productivity and income of smallholder farmers, lower the risk of disseminating destructive diseases through tuber seed, and significantly decrease the costs of storage and transport of planting material to remote areas.

It is far from certain, however, that this promise will be realised. Current progress in hybrid potato breeding is already highly promising for smallholder farmers, for example with stacking *Phytophthora* resistance genes (Su *et al.*, 2020). Yet there remain important challenges in ensuring that smallholder farmers in developing countries (henceforth: smallholder farmers) will have access to the benefits of this innovation. Hybrid breeding activities in public sector institutions that target smallholder farmers are currently modest and focus mostly on fundamental research. Hybrid variety development efforts are currently largely concentrated in the private sector and it cannot be taken for granted that traits that are specifically interesting for smallholder farmers, but that hold little commercial relevance otherwise, will be targeted. Nor can it be taken for granted that varieties that do include such beneficial traits will reach smallholder farmers who are often poorly connected to formal seed systems.

In this chapter, we turn to public-private collaborations as a way to overcome these challenges. As we will argue in more detail below, neither the private sector nor the public sector can fully harness the potential of hybrid diploid breeding alone. This raises the question how public-private collaborations can best be organised to enable access for smallholder farmers to the benefits of hybrid potato breeding. We will explore this question from the perspective of the commons, which is especially fruitful in drawing attention to the institutional arrangements for ensuring access. We will explore four models for institutionalising public-private partnerships and will assess the potential of each model in overcoming the challenges of access for smallholder farmers. This is an essential step towards identifying how best to realise the potential of hybrid diploid breeding for smallholder farmers.

The focus on institutional arrangements for public-private partnerships implies that several other important aspects for ensuring access are not addressed. For example, access to improved starting material is also informed by factors such as national regulations for importing true seeds instead of tubers; by cultivation practices that are mediated by ethnicity and gender and class; and by infrastructures and skills that shape whether hybrid potatoes can best be supplied as seed tubers or true seeds. These challenges lie beyond the scope of this chapter. In this contribution, we focus on the innovation of hybrid potato breeding as the resource.

10.2 Commons

In a narrow economic sense, commons, or common-pool goods are defined as goods or resources that are both subtractable and non-excludable (Ostrom, 1990). Goods are subtractable (or rivalrous) when they can be depleted: the use or consumption of the resource by one actor limits the possibility for use or consumption by another. Goods are non-excludable when other actors can access the resource with relative ease.

For decades, economists have assumed that goods that are both subtractable and non-excludable would fall victim to the so-called 'tragedy of the commons' (Hardin, 1968), whereby self-interested individuals would take what they could and soon deplete the resource. The solution to this collective-action problem, so economists argued, was to either fully privatise the resource or make it subject to public regulation. Yet since the 1980s a large number of studies has emerged that demonstrated that such common-pool resources can be sustainably governed by communities themselves (Van Laerhoven and Ostrom, 2007; Ostrom, 2002; 2009; Stern, 2011). This has renewed academic interest in the governance of resources outside government or market structures.

This literature has offered a broader understanding of the commons, where the commons are understood as resources that are: (1) governed by a community of users; (2) in a way that 'exceeds the division between public and private' (Terranova, 2015, p. 9). This perspective is especially helpful in understanding situations where fully public or private ways to ensure access to resources fall short.

This is also the case when it comes to access to hybrid potato breeding for smallholder farmers. On the one hand, we consider that fully privatising hybrid breeding is unlikely to ensure the optimal use of this innovation for smallholder farmers. These farmers are often poorly connected to markets and can hence not be easily reached through conventional market channels that companies are connected to. Smallholder farmers furthermore engage in informal markets where they freely exchange seed, thus violating conventional markets rules in ways that may disincentivise the private sector. Finally, and as a consequence, the private sector has little to no incentive to use hybrid breeding to target traits that are specifically interesting for smallholder farmers, but that hold little to no commercial interest otherwise. Making hybrid potato breeding fully public, on the other hand, is equally unlikely to ensure that it is optimally used to the benefit of smallholder farmers. International and national public institutes (both in the North and the South) have very broad mandates and, at least in the foreseeable future, are unlikely to have

sufficient resources to develop the experience, expertise, and institutional capacity in hybrid potato breeding, as some private sector actors do (Beumer and Stemerding, 2021).

In this context, the perspective of the commons helps to draw attention to arrangements where the public and the private sector can form a community to govern the innovation of hybrid breeding according to their own rules and norms. The question, then, is what rules and norms work best to enable and incentivise the community of users from the public and the private sector to optimally use hybrid breeding for smallholder farmers. Or phrased differently, what institutional arrangements ('rules and norms') can be devised to enable the use of hybrid breeding for smallholder farmers?

The importance of institutions in governing access to resources is recognised both in literature on the commons (Ostrom, 1990, 2002) and in literature on technology governance (Khandekar *et al.*, 2016). The latter also highlights that in exploring these institutional arrangements, we should also pay attention to the constitutive role that technological innovations play. A recent article highlighted that innovations like hybrid breeding are both shaped by the institutional arrangements that ensure access, and simultaneously shapes those institutional arrangements as well (Beumer *et al.*, 2020). The institutional structures for ensuring access both enable and constrain what types of innovations can be developed, while innovations like hybrid potato breeding may, in turn, both strengthen and undermine the institutions that enable access for smallholder farmers. This should hence be taken into account in exploring public-private collaborations from a commons perspective.

The public-private partnerships described below are situated in broader institutional structures that can either enable or constrain access to hybrid breeding and its intermediate and end products-principally parental lines and hybrid varieties. The commons literature refers to this as 'multiple layers of nested enterprises' (Ostrom, 1990). For hybrid breeding this includes institutions for intellectual property such as the International Union for the Protection of New Varieties of Plants (UPOV) for breeders' rights and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS agreement) for patents. This also includes various phytosanitary regulations for ensuring the health and safety of potato cultivation and consumption; international agreements and organisations that enable access to potato genetic material like the gene banks and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA); funding instruments from national governments and international organisations like the European Commission; and more informal institutions for sharing information and materials.

These institutions affect the accessibility of the benefits of hybrid potato breeding and these institutions themselves may also be subject to change. In what follows, however, we focus on the public-private partnerships and draw upon these other institutional layers only when this is necessary for understanding the public-private partnerships.

10.3 Four models of public-private collaboration

We will explore how hybrid potato breeding can be made accessible for smallholder farmers by describing four different models for public-private collaboration. This exploration addresses situations in which smallholder farmers require other or additional genetic traits to be incorporated by hybrid potato breeding and that this is insufficiently commercially attractive and therefore does not constitute an interesting market segment for the private sector. In such conditions, the private and public sector play complementary roles. While smallholder farmers themselves can play a role in each of these models, the focus of the current paper is on the roles of public and private actors.

The four models are distinguished along the lines of breeding (who profiles the products and develops varieties) and dissemination (who disseminates planting material of these varieties) (Table 10.1). Each of the four models potentially enables smallholder farmers to access the benefits of hybrid potato breeding in different ways. We will assess the strengths and weaknesses of each model in overcoming the challenges of access by smallholder farmers.

It should be noted that these models – simplified representations – are not mutually exclusive: elements of the different models can be combined. We have nevertheless chosen to present these models as neatly distinguished entities as this helps to bring the benefits and drawbacks of each model into sharper focus. These simplified representations are helpful tools for thinking through how to ensure that the benefits of hybrid breeding are accessible to smallholder farmers.

10.3.1 The charity model

In this model, the breeding of hybrid diploid potatoes is concentrated in the private sector, while the dissemination of starting material to smallholder farmers is taken up by the public sector and non-governmental organisations (NGOs). Companies have developed homozygous parental lines that form the basis for their hybrid breeding programmes. Varieties that are potentially beneficial for smallholder farmers are then brought to smallholder farmers by government organisations and NGOs, which use their networks to reach smallholder farmers in and outside formal seed systems and offer the hybrid potato either at a reduced rate or even for free – as a form of charity. This model is similar to institutional arrangements for genetically modified crops, where companies develop and own specific crops, which are then made available to farmers in developing countries with the help of public research organisations and NGOs (Rock and Schurman, 2020).

Table 10.1. Key features of four models of public-private partnerships for access to benefits of hybrid potato by smallholder farmers.

Model	Breeding	Dissemination
Charity model	Private	Public and others (NGOs)
Pre-competitive research model	Public	Private
Breeding consortium model	Public and private (structural)	Public and private
Project model	Public and private (projects)	Public and private

The success of this model partly depends on the extent to which traits that benefit smallholder farmers will be part of commercial breeding activities. Companies are driven by profit and hence have most incentives to target those traits that are commercially most interesting. In many cases, such traits are also interesting for smallholder farmers, who can for example also benefit from robust varieties with *Phytophthora* resistance. There may also be smallholder relevant traits that are relatively simple to incorporate – i.e. controlled by one to two genes. In such cases, this model can also function well for smallholder farmers, as the underlying commercial variety can remain the same. This may for example be the case for increasing resistance in potato to diseases caused by viruses or nematodes, assuming such traits are relatively simple to genetically incorporate. The relatively modest work to include such traits may for example be part of corporate social responsibility programmes or funding by philanthropic organisations.

The main strength of this model is that breeding and dissemination to smallholders are each taken up by those actors that currently have the most comparative advantage in these activities. The actors thus complement each other well. Activities with hybrid diploid potato breeding are currently largely concentrated in the private sector, with various companies having gained valuable expertise and experience in developing homozygous parental lines, including novel traits, and developing true botanical seed hybrid potatoes.

Public organisations and non-governmental organisations, in turn, traditionally have mandates in disseminating potato varieties to smallholder farmers. Public organisations like the International Potato Center (CIP) and national agricultural research institutes, as well as NGOs like Asociación Andes and Seed Savers Network Kenya have connections with or represent extensive networks of extension services, farmer organisations, and farmers. These networks can be harnessed to help assure that diploid hybrid potatoes meet the needs of smallholder farmers and are accessible to them.

One main challenge to this model is that the institutional context that shapes private breeding activities mostly provides incentives to focus on traits that are commercially interesting. As mentioned, this does not always coincide with traits that are most beneficial to smallholder farmers. In some cases, smallholder farmers may need traits that are not relevant for farmers that participate in commercial markets or traits that cannot easily be incorporated in commercial varieties, such as traits for cultivating potato in lowland areas in the tropics. While hybrid breeding is certainly a promising avenue for including such traits, when private companies have little incentive to invest money and time in targeting such traits, alternative institutional arrangements are needed. This can involve corporate social responsibility schemes and philanthropic funding.

Related to this is the challenge of identifying what traits are relevant for smallholder farmers in the first place – such as culturally dependent culinary traits, storage traits like dormancy, and resistances against diseases that are mostly prominent in the Global South or those that slow down degeneration. Even if the private sector is willing to work on traits that are only relevant to smallholders, they may not be in the best position to identify what traits are most needed and wanted by smallholder farmers (and in what varieties). To be sure, this is a challenge for the public and private sector alike (Almekinders *et al.*, 2019), but the lack of incentives that breeding

companies have to target the needs of smallholder farmers, who are not their target-clients makes this especially difficult. Hence this requires dedicated efforts to elicit the needs of smallholder farmers.

A final challenge in this model lies in clearly distinguishing smallholder farmers targeted by public institutes and NGOs, from the farmers that can be targeted by private companies themselves through their commercial activities. In many cases these distinctions are rather clear, with companies targeting any farmer with access to formal seed markets, while public institutes and NGOs focusing their activities also on the informal sector. Yet this is complicated when formal and informal markets intersect, which is the case for the majority of smallholder farmers: they occasionally purchase seed tubers from formal markets while usually relying on informal channels (Almekinders *et al.*, 2019). Is the public sector in such cases allowed to share hybrid potatoes with these farmers or not? And are farmers allowed to share hybrid potatoes among themselves? These issues may be addressed by making clear agreements that define and delineate smallholder farmers that can be targeted by public institutes and NGOs from the farmers that can be targeted by the private sector through commercial activities (e.g. De Jonge and Munyi, 2016).

The private breeding, public dissemination model builds on the current strengths of the private sector in developing and using homozygous parental lines for hybrid potato breeding and leverages the connections of the public sector with smallholder farmers. Major challenges for this model are to ensure that traits are targeted for which there is no commercial interest, that the needs among smallholders for these traits are identified, and that commercial and non-commercial interests remain clearly delineated (so that they do not dwell in the same waters). Possible solutions to these tensions include public funding for private companies to promote the use of hybrid breeding to target traits for smallholder farmers, giving private money to public institutions to test and deliver quality seed to smallholder farmers, and to elicit knowledge from public and other organisations about farmer demand to private breeding efforts. Finally, clear agreements need to be made about the way hybrid potatoes can be disseminated by public and other institutions to exclusively smallholder farmers.

10.3.2 The pre-competitive research model

In this model, the early stages of hybrid potato breeding are concentrated in the international and/or public sector, while the further selection and dissemination of hybrid potato to smallholder farmers is taken up by the private sector. This can be understood as a form of 'pre-competitive research' or 'pre-breeding'. Here, the public sector could take responsibility for developing homozygous parental lines – perhaps the most expensive part of the hybrid diploid breeding process – which can then be shared either for free to everyone, or to a selected group of companies that made a contribution to finance the pre-competitive research. This model is regularly used for cereal crop varieties from international breeding programmes that are subsequently licensed to predominantly nationally and locally operating companies (Donovan *et al.*, 2021; Yigezu *et al.*, 2021). The model was also used in potato breeding in the Netherlands after World War II (Van Loon, 2019).

Besides decreasing private sector breeding costs, the main strength of this model is that beneficial traits for smallholder farmers are not limited to specific varieties of individual companies who make a dedicated effort at including such traits but that they are included in all the varieties that companies subsequently develop on the basis of the public parental lines. That way, beneficial traits for smallholder farmers can become an integrated part of all hybrid potato varieties.

This model is especially promising for developing parental lines with complex multi-gene determined traits. While companies may take the effort to include one or two more simple traits that are especially relevant for smallholder farmers, including a broad range and more complex traits may require too high an investment for companies who could put those same resources to develop commercially relevant traits. In such a situation, this model offers an attractive solution by letting public organisations develop homozygous parental lines that include such complex traits, which can then be taken up by private companies.

In the case of potato, this model would constitute a relatively stark reversal of the current task distribution, where the private sector is most active in breeding and the public sector is modestly engaged with pre-breeding and dissemination. In other words, this model requires the national or international public sector partners to develop the resources and capacity for hybrid breeding. A recent paper that outlines the steps required to develop diploid parental lines (Zhang *et al.*, 2021) takes a step in this direction by opening up the opportunity for new players to engage in hybrid breeding, including the public sector. Yet in the near future only significant and structural investments could enable the public sector to develop parental lines.

Another challenge in this model is to make sure that varieties with these beneficial traits reach the smallholder farmers. Currently, in most countries the formal private potato seed sector is small and not functioning optimally. Smallholder farmers can certainly constitute an interesting market for the private sector. But large numbers of smallholder farmers source their starting materials from informal seed systems (Almekinders *et al.*, 1994) and hence do not engage in the formal markets that are served by the private sector. Hybrid potato may eventually come to circulate in informal seed systems as well but by that time the starting material will have decreased in quality (while the traits that benefit smallholder farmers may at the same time support longer recycling of the seed). One way to address this is to expand the reach of formal seed systems and the accessibility of quality seed, which is by no means an easy task.

Another way to address this challenge could be for the public sector to share parental lines on the condition that the starting material that is subsequently developed by the private sector is made available to smallholder farmers outside formal markets. A suitable model for this can be found in public health. For example, in the case of avian influenza viruses, the World Health Organization (WHO) coordinates a global network of public sector institutions that monitor the evolution of influenza viruses and prepares materials for vaccine development – a form of pre-competitive research. This is made freely available to the private sector on the condition that a certain percentage of the vaccine produced is made available at cost price or for free to low-income countries (WHO, 2018). Similarly, parental lines developed by the public sector could be shared

with the private sector on the condition that a certain percentage of starting material is (freely) shared with smallholder farmers that do not have access to formal markets.

10.3.3 The breeding consortium model

In this model, parental lines are developed by the private sector and are then shared with the public sector under the restrictive mandate to use these exclusively to develop varieties with traits that are specifically relevant for smallholder farmers. This can be understood as a 'breeding consortium' – which has recently been proposed in Nature Plants (Beumer and Stemerding, 2021).

In such consortia, agreements are made about who can make use of the outcomes of the public breeding activities (using private sector parental lines). One common agreement is that the public sector can disseminate the varieties they developed to smallholder farmers at reduced rates or even for free, while the private companies that provided the parental lines will have exclusive access to these varieties for more conventional commercial activities. Like the previous model, this model is specifically suitable for developing varieties with larger numbers of relatively simple traits for smallholders. After all, the variety that includes those traits will strongly resemble the commercial variety whose parental lines were used.

The benefit of this model is that the public sector can make use of the broad range of different parental lines that are developed by companies. The public sector subsequently can concentrate its breeding activities on inserting those traits that make varieties specifically suited to the complex and diverse realities of smallholder farmers. By gaining the exclusive rights to commercialise any variety that is developed using their parental lines, the private sector, in turn, can benefit from public breeding activities without running financial risks themselves. For dissemination and supply of the planting material to smallholder farmers, both public and private sector actors can play a role, as indicated in the former models.

One challenge of this model is that it requires the public and private sectors to agree on clear conditions under which the varieties can be shared with smallholder farmers for free or at reduced rates. In essence, this requires agreement on a clear distinction between smallholder farmers who in principle can access formal seed markets, and smallholder farmers who exclusively rely on informal seed markets and cannot reasonably be said to constitute a market opportunity. However, as was described previously (Section 10.3.1), this distinction is not always so clear-cut. Recent work by De Jonge and Munyi (2016) offers some interesting pointers for how this may be achieved nonetheless.

Finally, this model stands or falls with the ability for private companies and public sector organisations to share parental lines in a confidential and secure way. Therefore, clear agreements need to be made about the way these parental lines (and information about these parental lines) are stored and used. This is arguably easier to manage if various private sector parental lines are shared with one (international) public sector institute instead of many.

10.3.4 The project model

In this model, public and private institutes collaborate on an *ad hoc* basis to tackle specific breeding challenges when there is a shared interest. This can be understood as a form of 'project-based work' and may apply to any of the three former models of collaboration. These collaborations are often initiated by project funding from national governments or large philanthropic organisations, who often require some form of co-funding from companies, and who often focus on urgent issues. The results are then usually partly made public and partly shared exclusively among the participating stakeholders. Dissemination can have a mixed form as well.

This model has been followed in tackling *Phytophthora* with the use of genetic modification techniques in the Netherlands. In the mid-2000s, the Dutch government funded a major joint research project involving several universities, companies, and other stakeholders to use genetic modification to develop late blight resistance (Haverkort *et al.*, 2009).

This model works best in cases of breeding challenges that are specific, that require a certain scale to succeed (i.e. that cannot be tackled by individual companies alone), and that are perceived as urgent by both the public and private sector. This was for example the case with the *Fusarium* fungus (*Fusarium* wilt tropical race 4 or TR4) that may threaten the Cavendish banana with extinction ('Bananageddon'). This challenge is specific (it is one disease), it is urgent, and it threatens both public and private interests. For hybrid potato breeding, it can be envisioned that this is the case for urgent challenges like drought resistance, climate resilience, and other cases whose complex nature may make it too complicated for individual companies to tackle, and where the needs of private parties align to the (public) needs of smallholder farmers.

As should be clear from the examples above, these conditions do not require that the targeted traits are genetically simple. Drought resistance and climate resilience, for example, are complex traits, and it can be envisioned that this model also works for developing a lowland potato for the tropics. Varieties with these traits would then be further developed and disseminated by companies that participated in the project. More important is the distinction between traits that are also interesting for existing commercial markets, like drought resistance and climate resilience, and traits that do not neatly align to existing commercial markets, like those for lowland potato in the tropics. In the latter case, projects are only likely to attract private partners who see sufficient commercial potential for creating new markets in such areas.

One downside of this model is that no institutional changes are made to structurally secure access of smallholder farmers to the benefits of hybrid breeding on the long term. The relatively short time span of projects (usually between 2-10 years) is not always sufficient for tackling certain breeding and dissemination challenges. Moreover, the *ad hoc* nature of the collaborations requires stakeholders to be mobilised around urgent issues time and time again. This makes these collaborations especially vulnerable to both economic downturns and 'apocalypse fatigue'. And finally, the lack of structural institutional changes also has the potential downside that no institutional memory is built up. Know-how and routines that are developed in collaborations are at risk of being lost once projects end and new projects thus face relatively high transaction costs

as partners have to learn about one another's expertise and way of working time and time again. Neither of these issues is easy to solve without falling back on more long-term institutionalisations of collaborations, which, in the end, would turn the project model in one of the other models.

Another downside of the *ad hoc* nature of project work is that there are no guarantees that sufficient capacity has been built up in preceding years when no project funding was available. For example, the project to develop Covid-19 vaccines succeeded in part because in earlier years actors kept working on mRNA techniques as well as on coronaviruses, even though at that time there was no widely shared sense of urgency. Similarly, in potato, smallholder farmers may come to face urgent challenges related to new potato diseases or climate change that cannot immediately be tackled with project-based collaborations if no capacity has been built on these topics in the preceding years. This underscores the need to strengthen the institutional knowledge base.

10.4 Discussion and conclusions

Hybrid diploid breeding has the potential to benefit smallholder farmers around the world as it can help overcome challenges associated with climate change, poverty, and food security. This requires that hybrid breeding will be used to develop varieties that are suited to the specific contexts and needs of smallholder farmers and that concerted efforts are taken to disseminate those varieties to farmers.

We began this chapter by observing that this does not happen by itself, and that neither the public sector nor the private sector can do this alone. This raises the question of how best to institutionalise public-private partnerships to enable smallholder farmers to gain access to the benefits of hybrid diploid breeding.

By drawing upon the perspective of the commons, we identified four different models for institutionalising public-private collaborations in order for hybrid breeding to benefit smallholder farmers. We called these models the charity model, the pre-competitive research model, the breeding consortium model, and the project-based work model. The four models and their respective strengths and challenges for making hybrid breeding work for smallholder farmers are summarised in Table 10.2.

It can be argued that the project model is most likely to ensue if no concerted action is taken to institutionalise the access to hybrid breeding for smallholder farmers. We believe this will produce suboptimal outcomes for smallholder farmers. Under such institutional arrangements, the incredible potential of hybrid breeding for smallholder farmers will be underused.

As we mentioned before, these models to ensure that hybrid breeding also benefits smallholder farmers are not mutually exclusive and elements of different models can be combined in practice. We have nevertheless chosen to clearly distinguish them in order to bring the relative and potential strengths and weaknesses of each model into sharper focus. The models show that different ways of institutionalising public-private partnerships each have specific strengths and weaknesses when it comes to ensuring smallholder access to innovation. It is our hope that this can be used

Table 10.2. Strengths and challenges of models of public-private partnerships for access to benefits of hybrid potato by smallholder farmers.

Model	Strengths	Challenges
Charity model		
Private sector breeds, public sector disseminates	• Builds on existing strengths of public and private sectors	• Identifying beneficial traits • Distinguishing smallholders with and without market access
Pre-competitive research model		
Public sector develops parental lines, private sector breeds and disseminates	• Decreases private sector breeding costs • Inclusion of beneficial traits across commercial varieties	• Reversal of existing competitive advantages • Dissemination to smallholder farmers in informal markets
Breeding consortium model		
Private sector shares parental lines, public sector breeds and disseminates	• Combining private sector parental lines for public use • Private sector profits from public sector work	• Distinguishing smallholders with and without market access • Ensuring confidential and secure use of parental lines
Project model		
Public and private sector jointly address specific breeding challenges	• Tackling urgent specific challenges that require scale • Suitable for both simple and complex traits	• Ensuring structural attention to smallholder need • Building institutional memory and capacity

as a starting point for the public and private sectors to come together and discuss how they can combine their forces for the benefit of smallholder farmers around the world. We are convinced that the way these models will be operationalised will result in much more complex and nuanced collaborations, and involve other aspects that we have not taken in consideration.

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