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Can the private sector help deliver improved technology to cassava smallholders in South East Asia?

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The cassava sector in South East Asia is a multi-billion dollar industry, with smallholder producers connected to final consumers via complex and diverse value chains. Public sector research conducted with farmers over several decades has generated technologies with the potential to improve farmer livelihoods. However, translating these research outputs into widespread adoption by farmers, with scaling beyond intervention sites, has had mixed success. This has prompted the question whether private sector actors in the cassava industry can have a greater role in knowledge transfer. We develop a framework in which value chain characteristics, as well as the inherent characteristics of technologies and farming communities, affect the potential for scaling of research outputs and widespread adoption by farmers. We apply this framework to an analysis of six contrasting case studies in four South East Asian countries, ranging from underdeveloped value chains around small-scale processing of animal feed to highly-commercialised international value chains for starch. We find that, in particular contexts, such as when farmer adoption of a technology generates increased supply to a single processor, the processor has an incentive to invest in the extension of research outputs to farmers in its supply zone. In other contexts, however, such as when there is intense competition among processors for smallholder output or where the benefits of the technology are not immediate, there is little incentive for private sector involvement. In all cases, we find that support from a knowledge broker, such as a public sector or non-government actor with the capacity to work with farmers, is also required. Hence, the private sector is not a panacea for generating research impacts at scale.

Keywords: sustainable production; agricultural production; value chains; technology adoption; extension; scaling; cassava; smallholders; South East Asia; Cambodia; Indonesia; Laos; Vietnam

Introduction

Cassava (*Manihot esculenta*) is a root crop of South American origin that has long been cultivated by smallholders in South East Asia as a supplementary subsistence crop. Over the past four decades, cassava cultivation has expanded throughout the region into a multi-billion-dollar industry, supplying food, animal feed, starch, and a range of starch-derived products (Lefroy, 2015). Fuelled by expanding market demand, the global supply chain for cassava has extended across borders and deeper into increasingly marginal agro-ecological zones (De Koninck & Rousseau, 2012). Producers are connected to final consumers via a complex and diverse set of value chains involving traders, agents, primary processors, commodity traders, deep-processors, feed companies, livestock farmers, fuel and energy companies, and global multinational food and beverage companies.

Despite being connected to these dynamic global markets, cultivation of cassava in South East Asia continues to be dominated by smallholder farmers, many of whom have low rates of adoption of improved practices and limited access to technical advice. Research conducted over several decades, largely by national and international public agencies with donor funding, has generated a range of improved technologies, including higher-yielding varieties, more appropriate chemical fertilizer formulations, soil conservation measures, and improved methods of pest and disease management. Participatory research trials on a local scale have shown that the adoption of improved cassava production technologies by smallholders can lead to enhanced productivity and sustainability of the sector, contributing to improved livelihoods and economic development (Howeler & Aye, 2014). Nevertheless, the process of translating research outputs into widespread adoption by farmers, with scaling up beyond project intervention sites, has had mixed success.

Although the developmental case for improving smallholder cassava production appears compelling, government policies in South East Asia have not prioritised the cassava sector. Hence, research agencies working on cassava have turned to the private sector as a potential "next user" of research outputs, seeking to partner with agribusiness actors to develop and share useful knowledge with farmers. This change in strategy also follows the currently fashionable emphasis of many donor agencies on engaging with the private sector to achieve development outcomes. For example, the Australian Government's Aid Policy Framework asserts that "through increased collaboration and partnering, business can deliver sustainable social impact in developing countries while delivering commercial returns. The private sector drives productivity and participation which in turn creates economic growth" (DFAT 2015, p. 5). However, there has been limited analysis of the incentives and preconditions for this kind of knowledge partnership to be viable. Does the private sector have the motivation and capability to enter into knowledge partnerships for smallholder development? If so, in what circumstances and with what support? Has the potential for partnering with the private sector been overstated in agricultural development strategies?

An action research project was undertaken from 2016 to 2020 in four South East Asian countries (Cambodia, Laos, Vietnam, and Indonesia) to examine the circumstances promoting and obstructing effective partnerships between public research agencies and private sector actors in developing and disseminating improved technologies to cassava smallholders. Six contrasting case studies were undertaken in which government and university researchers sought to partner with private sector actors and networks in testing and disseminating a range of improved cassava technologies. The six case studies represented a variety of cassava value chains with different structural characteristics, ranging from localised value chains for small-scale processing of animal feed to highly commercialised international value chains producing starch for various industrial end-uses. In each case-study site, industry stakeholders were identified and engaged through a sequence of activities. These included semi-structured interviews with farmers and value-chain actors at the outset of the project; involvement of these stakeholders in project meetings, the conduct of field trials, and field days; interviews with stakeholders about the results of the research and how to make them more widely available; and informal conversations with key informants. Together, these sources of data enabled researchers to examine the motivations for and constraints to private sector participation in technology development and dissemination in each setting.

In this paper, we present a comparative analysis of the case studies to assess the factors affecting the type and extent of private sector involvement. We first discuss the need to broaden the conventional framework for analysing adoption of farm technologies to include the attributes of value chains affecting the potential for private sector participation in the extension or scaling process. We then use this broader framework to characterise the cassava technologies, farming populations, and value chains examined in each of the case studies. This is followed by a cross-case comparison to highlight the key variables affecting private sector participation. We conclude with some reflections on the scope for effective knowledge partnerships with the private sector.

Conceptual framework

The term “technology” as used here refers to the knowledge incorporated in farming systems, whether as farming practices (such as cropping patterns) or embodied in material inputs (such as crop varieties and fertilisers). We recognise that technology has multiple sources and is not simply transferred uni-directionally from researchers to farmers (Biggs, 1990; Cramb, 2003; Williams and Cramb, 2020). However, there is often a case for taking technologies that have been co-produced in a particular location by farmers, researchers, and others and transferring them to new locations where they appear to have potential for widespread adoption. Given the high degree of location-specificity of agricultural technologies, these transferred technologies still need to be tested and adapted before broad-scale adoption is likely to occur. It is this more nuanced process of technology transfer, adaptation, and adoption that is assumed in this paper.

Research on the adoption of innovations or new technologies by farmers has focused on the characteristics of the technology in question in relation to the characteristics of the population of potential adopters (Pannell et al., 2006; Pannell & Zilberman, 2020; Rogers, 2003). These two sets of characteristics combine to influence the peak level of adoption within the specified population and the time to reach peak adoption – outcomes that are critical to assessing the overall impact of a new technology. The ADOPT model has been developed to formalise these influences with the aim of predicting adoption outcomes (Kuehne et al., 2017; Llewellyn & Brown, 2020). Within this framework, the key characteristics of a technology are synthesised into two variables – relative advantage and learnability (Kuehne et al., 2017; Llewellyn & Brown, 2020). The relative advantage of a technology encompasses its investment cost, profitability, risk, ease and convenience, environmental impacts, and other attributes. The learnability of a technology encompasses its complexity, observability, and the ease of testing it on the farm (trialability).

The key characteristics of the population of potential adopters are also viewed in terms of relative advantage and learnability (Kuehne et al., 2017; Llewellyn & Brown, 2020). The relative advantage of a technology to a heterogeneous population of farmers will depend on farmers' profit orientation, risk orientation, environmental attitudes, scale of operation, and planning horizon, as well as short-term constraints such as access to credit. Specific influences on the ability of a population to learn about a technology include existing skills and knowledge, farmer groups and networks, and the level of advisory support or extension. The ADOPT framework implicitly assumes the central role of a public extension service, the quality of which strongly influences a farming population's ability to learn about a technology. However, as Norton & Alwang (2020) observe, a number of factors have led to changes in the way extension services are organised and financed. The overall result has been a decline in public extension activities since the 1990s. As Norton & Alwang (2020: 13) remark, "the hope was that the private sector would step in." However, the involvement of the private sector in technology transfer has been very uneven, raising questions about the incentives and capabilities of actors in different value chains.

The globalization of value chains has meant that both farmers and value chain actors have needed to upgrade technologies, often in response to the requirements of lead firms within a contracting arrangement (Reardon & Timmer, 2014). Yet Swinnen & Kuijpers (2019: 298) observe that "the role of value chains in technology adoption has been largely ignored so far, despite the dramatic transformation and spread of modern agri-food value chains." They point out that "the failure to adopt the technology not only affects the farm but also all other agents in the chain. Technology companies have lower profits since they cannot sell their technology; processors do not get the raw material they need for producing consumer products; and consumers do not get the products they desire. All these agents have an incentive to make the farm adopt the technology" (Swinnen & Kuijpers, 2019: 300). However, we argue that the discussion of value chains as conduits for the transfer of technology to farmers often lacks a nuanced appreciation of the varying incentives and capabilities of actors in different value chains. Not all value-chain actors will be aware of or interested in all technologies, or have an incentive to invest in adapting and transferring these technologies to farmers. Hence, in addition to the attributes or characteristics of the technology and of the population of potential adopters – the key variables considered in the ADOPT model – it is necessary to consider the *characteristics of the value chain in which the potential adopters are embedded*. These characteristics will influence both the relative advantage of farm-level adoption to different value-chain actors and the learnability of the technology in question, that is, the ability of value-chain actors to learn about and communicate the technology.

The relative advantage to a firm of investing in technology transfer to farmers will depend not only on the technology's relative advantage to farmers but also on the firm's individual situation (e.g., size, spare capacity, and access to capital). For example, a processing firm with unused capacity will have greater incentive to promote yield-increasing technology to farmers, such as a higher-yielding crop variety, in order to achieve greater throughput and lower fixed costs per ton of processed product. Relative advantage to the firm will also depend on the industry structure (e.g., number of competitors, degree of industry coordination, and the strength of ties to farmers), affecting the firm's capacity to capture the benefits generated. For example, while the processing firm may potentially benefit from increased farm production, it may not be able to prevent competitors from also benefiting from its investment in technology adoption. This inability to capture the full benefits of technology transfer may reduce the firm's perceived relative advantage.

The learnability of a technology to a value-chain actor will be influenced, not only by its inherent complexity, observability, and trialability, but also by such factors as the actor's existing skills and knowledge, their awareness of current farming practices and available technologies, their industry networks, and their access to technology providers in both public and private sectors (Kuehne et al., 2017). Given the potential benefits to value-chain actors, Swinnen & Kuijpers (2019: 300) argue that these actors can "consider whether it is profitable to set up different types of exchange systems … to help or induce farms to invest in the required technology." They report that, while interlinked contracting between farm and processor (i.e., "contract farming") has been widely studied, it is possible to "observe many different forms of value chain innovations with successful technology transfer" (Swinnen & Kuijpers, 2019: 300). They present a typology with five models of innovative contractual arrangements, all involving the financing of technology adoption. These range from a buyer (e.g., a processor) financing the farmer's adoption of technology as part of contracted product delivery, through to complete vertical integration. While this typology is a useful starting point, it does not encompass situations where there is no formal contracting or financing involved. Nor does it address the issue of competition between value-chain actors.

In this paper we build on the ADOPT framework by examining the relative advantage and learnability of a range of cassava technologies to value chain actors in six different market contexts. In the process, we also extend the typology of Swinnen & Kuijpers (2019) to encompass contexts with different degrees of competition and the absence of formal contracts and finance.

Case studies

Our extended framework considers the influence on the rate and level of adoption of the attributes of (a) the technologies, (b) the population of potential adopters, and (c) the associated value chain. Each set of attributes is analysed in terms of (a) learnability and (b) relative advantage. This framework was applied to each of the cases. As the available technologies were common to all the case studies, their attributes can be examined first (Table 1).

Attributes of cassava technologies

Of the four types of technology, improved varieties are the most adoptable, given their high learnability and relative advantage. Optimising fertility management through the use of a balanced fertiliser regime is a somewhat less adoptable technology, with moderate learnability characteristics but a high relative advantage. Soil conservation practices are inherently much less adoptable, given their low learnability and the long-term nature of the benefits, which accrue to the wider community as well as the individual adopter (Howeler & Aye, 2014). Similar comments can be made about pest and disease technologies, which require collective action to implement and provide community benefits.

These inherent attributes can be expected to feed through, not only to the population of potential adopters, but also to the value-chain actors who might be motivated to invest in disseminating the technologies to farmers.

Table 1. Attributes of cassava technologies

Technology	Learnability characteristics	Relative advantage
Improved varieties	• Easy to trial given access to planting stakes • Low complexity – little change in farm practices • Observability high at each stage but main evaluation at harvest • Observing starch content more difficult	• Upfront cost low; farmers subsequently use own stakes through vegetative propagation • High reversibility • Impacts realised from first year of use • No community benefit • Relatively low risk; may have higher susceptibility to some pests and diseases • Little or no change in level of convenience
Fertility management	• Moderately easy to trial – but there is low awareness and access of NPK fertilisers suited for cassava and appropriate rates • Moderately complex – fertilizer application depends on type of fertilizer, timing, and location • Observability is good at different stages, but main evaluation at harvest • Observing starch content more difficult	• Moderate upfront costs • Relatively good rate of return • Immediate impact can be high; long-term impact unclear • No community benefits – potential negative environmental externalities • More exposure to risk • Less convenient than no fertility management
Soil management	• Difficult to trial as may be long lag between implementation and observable impacts • Complex – many options including intercropping, soil conservation techniques • Low observability until critical threshold reached	• High labour input in initial years • Higher labour demand throughout the season for intercrops, reducing opportunities for stable off-farm employment • Some benefits in first year of intercropping • Added price and production risk/uncertainty for intercrop • Other impacts have long time horizon • Positive community benefits • Less convenient than no soil management
Pest and disease management	• Difficult to trial due to externalities requiring collective action (e.g., cannot treat one	• Moderate upfront cost • Uncertain private benefits in first year

	field if surrounding fields not treated) • Complexity can be high • Observability may be low as often difficult to connect pest/disease control with yield; no 'with' and 'without' cases to observe	• High community benefits if community-based treatment undertaken

Case 1: Simalungan, North Sumatra, Indonesia

Simalungan is a district in the Indonesian province of North Sumatra, centred on the city of Pematang Siantar. The city and district combined have a population of 1.1 million and a density of 253 persons/km^2. The terrain is undulating to hilly and the climate is humid tropical, with an annual rainfall of 2,894 mm distributed evenly throughout the year. Smallholders plant a variety of field and tree crops for subsistence and sale, making use of credit for inputs. Cassava farmers rely on a few traditional varieties of unknown origin and apply sub-optimal amounts of inappropriate fertilizer, averaging around 30 metric tons per hectare (t/ha). Cassava is not designated as a priority crop for the government extension service, which consequently had little involvement in the project.

The project worked with a starch factory established in 1974 in Pematang Siantar that is the sole buyer of fresh roots for most cassava smallholders in the district. The factory produces starch for the domestic market and is not well connected to R&D agencies, concentrated in Java. The company works through seven or eight agents who coordinate supply through a network of local traders, each of whom has their own network of farmer-suppliers. Credit for production inputs is channelled through these networks but there is no formal contracting. Side-selling is minimised by the monopsonistic nature of the local processing market, the high transport costs, and the high degree of personal trust among traders. If the factory has excess supply, it will allow its traders to sell elsewhere but, during the research, the factory was operating at only 40% of capacity.

Given these attributes, the company's management was very interested to cooperate with the research team, particularly in varietal trials to increase farm yields and hence the supply of cassava roots to the factory. The company provided land for the first set of varietal trials, which were managed by a lead-agent who was also a cassava farmer. Traders and farmers inspected these trials during field days and evaluated varieties for subsequent testing. The company paid for additional planting material to be shipped from Java, and some agents and traders took stakes of the new varieties for testing and multiplication on their own land, with subsequent dispersal to farmers.

The company was also supportive of fertilizer trials conducted in combination with the varietal testing, again expecting increased yields. However, problems with sourcing an appropriately formulated commercial brand and a bias in government policy towards subsiding fertilizers for rice made it difficult to translate the fertilizer trials into farmer adoption. The company also supported the intercropping trials proposed by researchers, not for reasons of improved soil management but in the expectation that, with a productive intercropping system, farmers might continue to grow cassava in times of low prices.
The factory's agents played a critical role in transmitting knowledge from the central node to farmers via their trading networks. However, the agents differed in their commitment to this process, based not on differences in their ability to capture profits but on individual attributes. More generally, late in the project, when financial pressure on the company was resulting in delayed payments along the value chain, the loyalty of some agents to the factory was tested, inducing them to seek out a more distant starch factory to supply.

In sum, the company was willing to invest in a research partnership to generate and disseminate highly adoptable technologies (varieties, fertilizer-use) that would increase farmers' productivity and hence factory supply, knowing that it could both disseminate the technologies and capture their benefits through its informal but stable supply network and its position of effective monopsony. However, even in this case, financial pressures could disrupt the process of knowledge transfer.

Case 2: Son La, Northwest Region, Vietnam
Son La is a province in the mountainous Northwest Region of Vietnam, centred on Son La City. The province had a population of 1.2 million in 2018 and a density of 85 persons/km^2. Farming is carried out on steeply sloping land that is susceptible to erosion and declining yields, especially with the recent transition to continuous cropping of field crops like maize and cassava. Son La has a humid sub-tropical climate, with an annual rainfall of 1,434 mm, 85% falling in the summer months (April-September). Because of this strong seasonality, cassava processing only occurs for five to six months of the year. Farmers grow traditional landraces with low tuber yield (averaging 12 t/ha in 2013) and low starch content, partly a function of the steep terrain and rudimentary management. The association of cassava with land degradation on the sloping lands has resulted in the local government supporting a transition to tree crops such as coffee and fruit trees rather than the development of sustainable cassava systems. Despite this, cassava has remained a critical source of livelihood, both for cash income and on-farm utilisation as livestock feed.

At the outset of the research, there was one company with a starch factory but many processors of dried chips (used for livestock feed). Hence farmers were not committed to supply the factory, as they were in Case 1. Now there are two starch factories and two more planned, increasing the degree of competition for cassava roots. Although the company was interested in collaborating in the research project, its factory was operating at full capacity. Hence the company's management was mainly interested in developing technologies for farmers to extend the harvesting period beyond the current six-month window (which was as much a financial as a technical question), and in varieties with higher starch content that would improve processing efficiency. The company was interested in disseminating improved varieties with higher starch yields through its trader network, but only if someone else incurred the cost of multiplying the planting material. There was a constraint in that, while local management was interested in a research partnership, the company's head office, which controlled spending, was in Ho Chi Minh City, remote from conditions on the ground. The company had little incentive to promote more appropriate fertiliser use because of the steep terrain (reducing the effectiveness of fertilizer outlays), its lack of capacity to process more roots if yield was increased, and the risk of side selling, given the number of alternative buyers. Likewise, there was little incentive for farmer adoption or factory promotion of conservation agriculture, given its low ranking in terms of learnability and relative advantage (Table 1). However, there was evidence that the project's on-farm demonstrations had encouraged farmers to take more care in planting the cassava stems, providing a low-cost improvement to yields. There were also positive signs that local government would strengthen its cassava extension in recognition of the importance of the crop to ethnic minority households, thus compensating for the limited capacity of the processing company to take on this role.

Case 3: Dak Lak, Central Highlands, Vietnam

Dak Lak is a province in the Central Highlands Region of Vietnam with a population of 2.1 million in 2019 and a density of 160 persons/km^2. The terrain is undulating to hilly and the province has a tropical savanna climate, with annual rainfall of 1,600 mm concentrated in the summer months (May-October). The farming system includes a range of annual and perennial crops and livestock, with a steady increase in perennials such as coffee and pepper. However, poorer farmers still plant cassava because it is easy to grow and requires a low investment.

There are many starch factories in the province, processing cassava roots during most of the year. At the start of the project there was less competition, with factories able to draw on a specific catchment. Factory numbers have now increased to 11, with overlapping supply zones. All factories are short of supply and purchase roots from further afield to increase their throughput. Competition for roots is intense and margins are small. However, there is one ethanol factory that produces its own supply. In this case, company management was more interested in cooperating with researchers in knowledge development. The starch factories clearly had limited incentive to invest in collaborative research and dissemination for any of the technologies listed in Table 1 due to the extreme competition, lowering the relative advantage to each actor. Investment in yield- or starch-increasing technology by one firm would potentially provide benefits to all other firms, all of whom were seeking to better utilise their capacity. There was also a perception, given that a government extension system is in place, that disseminating technologies to farmers is "not their responsibility" (as stated by a factory manager at a stakeholder consultation).

Nevertheless, in the past, networks of factories from this region were buying newly-released cassava varieties from Tay Ninh Province to the south to distribute these to farmers. There is likely a good business case for the formation of a processors' association that could levy its members for such research and dissemination activities. This becomes even more urgent now that diseases such as Cassava Mosaic Virus (CMV) are contaminating the value chain, causing potential economic hardship to both farmers and processors.

Case 4: Xayabouly, Northern Laos

Xayabouly is a province in Northern Laos west of the Mekong River, bordering Thailand. The population in 2005 was 381,000 and the density, 23 persons/km^2. The terrain is flat along the narrow floodplain, but much of the province is undulating to hilly. The province has a tropical savanna climate, with an average rainfall of 1,282 mm, concentrated in the summer months (May-September). Rice-based farming systems predominate but farming has become more intensive and commercialised in recent decades, supplying cross-border trade with Thailand during successive crop booms, including for maize and cassava. Cassava production is undertaken by independent smallholders who supply fresh roots over a six-month period (November-April) to a foreign-owned starch factory in Paklai District and to dried chip processors. Cross-border trade in fresh cassava roots has been blocked by provincial regulation to encourage value-adding and maintain the viability of the single starch factory.

The project worked with the foreign-owned starch factory, which is directly supplied by surrounding farmers. This factory operates at full capacity early in the harvest season, but then has spare capacity. It has an incentive to support existing knowledge networks to promote yield-increasing research and dissemination, particularly if it can purchase more roots over a longer period and prevent leakage in its supply to dried-chip processors.
The research found scope for farmers to adopt simple improvements in management practices (such as the selection of disease-free stems for next season's planting) that were low-cost and yield-increasing, while maintaining starch content and processing efficiency. Similarly, despite recognising declining yields, no farmer surveyed was using any fertiliser. A series of demonstrations showed good rates of return to low levels of fertiliser application, even at low cassava prices. This information could be provided by the company at little cost, given its direct link to farmers.

The company already pays a levy to the District Government based on the weight of roots processed. The possibility of directing part of the levy into extension activities was being explored with the processor and the local government at the time of writing. Concerns over leakage of into the chip market was the main issue being discussed.

Case 5: Kratie, Eastern Cambodia

Kratie is a province in eastern Cambodia, spanning the Mekong River and bordering Vietnam in the southeast. It had a population 372,000 in 2019 and a density of 34 persons/km^2. The climate of Kratie is tropical monsoonal, with an annual rainfall of 2,095 mm concentrated in May to October. Farming is concentrated along the Mekong corridor, phasing into thick forest in the east of the province. The terrain is flat and soils are sandy. Farming systems are rice-based, with increasing areas of forest being cleared for field crops like cassava, often followed by perennial crops like cashew and pepper. As in other cases, however, poorer farmers continue to be reliant on cassava.

The province has been a frontier for the expansion of cassava production, supplying fresh roots to starch factories in Vietnam’s neighbouring Tay Ninh Province. There is a large processing capacity in Tay Ninh, with over 60 large starch factories supplied by Vietnamese growers. High demand pushed the extensive margin of cultivation across the border into Kratie. When prices slumped, a significant proportion of Kratie’s production was diverted as dried chips to Binh Phuoc Province in Vietnam. With the recovery in prices, the extensive margin for suppliers of the Tay Ninh starch factories has been pushed beyond Kratie to provinces to the north and west.

The cross-border trade involves a value chain with a break at the border. Cassava roots are transported by Cambodian traders to the border, where they are reloaded onto Vietnamese trucks. Hence, in contrast to Cases 1 and 4, there is no direct relationship between the Cambodian farmers and the Vietnamese processors or their agents. There have been attempts to develop a processing sector within Kratie. A factory was established close to Kratie town at a time when world prices were low and demand from Tay Ninh was reduced but, with resurgent demand from across the border, it cannot compete with traders selling into Tay Ninh. Traders have low overheads and can offer farmers a better price, despite the transaction costs at the border. A second company has recently opened a factory within Kratie Province and is contemplating contract farming to tie in its suppliers.

The project could not identify a private sector knowledge partner in this situation. There was no interest or awareness in partnering from the processors in Vietnam due to the break in the flow of information and connections at the border. Processors in Tay Ninh were aware that, during the local off-season, around 80% of the fresh-root feedstock was coming from Cambodia, but they had no direct connection to Cambodian farmers. Traders were only interested in filling short-term orders passed down the chain. Public sector agencies also had limited capability to work with cassava farmers, restricting the effectiveness of the project. In

Cambodia, non-government organisations (NGOs), including microfinance institutions, have proliferated to fill the gap left by the public sector, but their activities are fragmented and mainly concentrated on upstream activities rather than linking with downstream actors. There is an urgent need in Cambodia to coordinate the supply of planting material that is not only high-yielding but also disease-free, due to the spread of CMV and Cassava Witches Broom Disease (CWBD). In theory, processors should be interested in ensuring farmers use clean planting material as this will increase root yields and starch content. However, in the short term, if CMV reduces yields, they can simply source roots further afield to maintain their throughput. Moreover, if one firm supplies disease-free stakes it has no guarantee that this will control the spread of the disease, nor that it will benefit from the higher yields and starch content. The first step is for a public agency to establish a source of clean planting material and then supply this to accredited private sector actors for multiplication and sale. As technology suppliers, it would be in the interest of those actors to increase farmers' knowledge about the general benefits of disease control. The same argument would apply to a private supplier of an appropriately-formulated fertiliser for cassava growers.

Case 6: Sikka, Nusa Tenggara Timur, Indonesia

Sikka, on the island of Flores, is a district in the province of Nusa Tenggara Timur (NTT) in eastern Indonesia. It had a population of 300,000 in 2010 and a density of 173 persons/km^2. The climate is tropical monsoonal, with an annual rainfall of only 1,139 mm concentrated in the summer months (November-April). There is a narrow flat coastal plain in the north, rising sharply to steep, mountainous terrain. Conventional dryland farming of maize, cassava, and pigeon pea is practised on the plain, while the sloping uplands support a highly diverse agroforestry system, with field crops such as upland rice, maize, and cassava interspersed among tree crops such as coconut, cocoa, coffee, cashews, and tamarind.

Here cassava is grown as a major staple food for home-consumption and trade in local food markets. Hence traditional "sweet" eating varieties are utilised, with few or no inputs. Farmers practise piecemeal harvesting when they need food or cash. The price of these eating varieties in the market is higher than that of industrial ("bitter") varieties. There is a small-scale cottage processing industry producing cassava-based food products for local purchase but no processing for animal feed or starch. The project experimented with introduced varieties and alternative multi-cropping systems on farmers' land. The research conducted with farmers demonstrated that increasing the density of cassava within the traditional maize-cassava system could improve the yield and income generated from cassava, without a decline in maize production as feared by farmers.

In partnership with the project, an entrepreneur established a pilot processing plant for animal feed and invested in distributing a new, high-yielding industrial variety (Malang 4) to farmers in both upland and lowland locales in Sikka and a neighbouring district. The transaction costs associated with the dissemination of technology to a relatively small number of farmers resulted in the price he was offering being substantially lower than the price farmers could get from the piecemeal selling of their cassava to food traders. Though Malang 4 is considered an industrial variety, it can also be consumed as a food crop with some additional processing (i.e., soaking in water). The extensive opportunistic side-selling was thus threatening to undermine the viability of the pilot project and ongoing expansion of the processing capacity.

In this case, stakeholder consultations indicated a strong argument for a public-private partnership to lower the cost of knowledge transfer, with the local agricultural office providing initial support in introducing suitable varieties and multiplying them while the processor distributes them to farmers. An NGO or development project could catalyse and support the process.

Discussion

The degree of private sector interest and involvement in the project's research agenda in each case varied with the characteristics of the technology, of the farming population, and of the value chain. Both farmers and value-chain actors were most interested in utilising cassava varieties that gave higher tuber and starch yields and, to a lesser degree, in managing soil fertility through application of appropriate fertilizer doses. These technologies had high learnability and relative advantage. However, although there was a degree of interest in and awareness of the impact of cassava diseases, the low learnability and (individual) relative advantage of disease control measures discouraged adoption and dissemination. Technologies for soil conservation were also characterised by low learnability and (individual) relative advantage; hence there was little or no interest in these technologies, even for the steeply sloping land of Northwest Vietnam where they are most relevant.

The attributes of the farmers in each case also influenced the degree of private sector involvement. In all sites but Sikka, farmers grew cassava purely as a commercial crop and were motivated to adopt technologies that could be demonstrated to increase their farm income in the short run. Mostly operating with trader credit on an annual planning horizon, they were understandably less interested in more complex technologies involving up-front investments with long-run benefits. Even in Sikka, where cassava was grown primarily for home consumption, farmers were sensitive to relative market prices for food and industrial end-uses, undermining their commitment to supply a pilot feed industry. Though public extension services varied between cases, being better resourced in Indonesia and Vietnam than in Laos and Cambodia, in no case was there adequate provision of extension for cassava smallholders.

Overlying these two sets of characteristics were the characteristics of the value chain. In all six cases, the focus was on the role of the processor and of the traders linking the processor to the farmers. This is closest to Model 1 in the typology of Swinnen and Kuijpers (2019: 301), in which "the company that buys the farm's product (be it a processing, a retailing, or trading company) finances the technology as part of a contract." However, in none of our cases was formal contracting involved. Rather, processors interacted with farmers through informal networks of traders with varying degrees of social capital. In the absence of enforceable contracts, the strength of these networks was a function of the degree of competition in the value chain and of the number of links in the transfer of product and information from farm to processor, particularly with respect to cross-border trade. Moreover, the flow of finance in these networks provided the working capital for farmers to purchase inputs and traders to purchase the harvest. This credit was not tied to technology transfer as such, though processors and traders did in some cases provide improved planting material to "their farmers", and the project explored the feasibility of using these channels to supply appropriate fertilisers.

The types of value chain structure reported in the case studies are characterised in Table 2. The Simalungan case provides a baseline with regard to value-chain attributes. It can be regarded as an "embedded monopsony" in that it was the sole buyer in the district and had long-established links to its farmers through a network of agents and collectors. In addition, the factory was operating at below capacity. Hence the company was very supportive of collaborative efforts to test and disseminate improved varieties and fertiliser practices, contributing land, manpower, and finance. However, both the strength of the company's supply network and the degree of support for the project did vary with the market price of starch and other financial pressures. Thus, even in the case of an embedded monopsony, relying on a single company as a partner in technology transfer entails risks.

Table 2. Types of value chain found in the case studies and implications for private sector knowledge partnership

Structure of value chain	Cases	Involvement in knowledge partnership[1]
Embedded monopsony	Simalungan, Indonesia	High
Connected competitor	Son La, Vietnam Paklai, Laos	Moderate
Competitive linking	Dak Lak, Vietnam	Low, requires assured coordination
Disarticulated	Kratie, Cambodia	Absent
Self-contained	Sikka, Indonesia	High, but unsustainable

Note 1: "High" refers to involvement in project interviews and meetings, and investment in field activities over successive years. "Moderate" refers to involvement in project interviews, meetings, and some field activities. "Low" refers to involvement in project interviews and some meetings. "Absent" is self-explanatory.

The two sites in Vietnam show the potential for processors to collaborate in disseminating the more adoptable technologies. The factory in Son La was initially the sole starch processor, with direct links to farmers, but faced stiff competition from the many dried chip processors. Moreover, its factory was operating at full capacity. Nevertheless, there was genuine interest in research collaboration, particularly in extending the seasonal window for harvesting and processing. It can be regarded as a "connected competitor". The starch factory in Paklai, Laos, was in a similar situation in that it operated at full capacity for a short period and was interested to collaborate in disseminating technologies to extend the processing period. Though directly linked to farmers and protected from cross-border competition, it too faced the leakage of supply to dried-chip processors. There was potential to involve this factory further in disseminating low-cost improvements to farmers.

In Dak Lak there was more intense competition between the many starch factories, hence less incentive to collaborate in disseminating yield-increasing technologies, despite the prevalence of spare capacity. Nevertheless, networks of factories had collaborated in buying and distributing planting material in the past. This case pointed to the need for industry coordination, or "competitive linking", such as through a processors' association that could levy its members for research and dissemination activities, thus overcoming the free rider problem.

The case in Cambodia illustrates the additional problems associated with value chains that span borders, reducing the informal ties between processors, traders, and farmers. This can be characterised as a "disarticulated value chain". The Vietnamese processors saw no relative advantage in disseminating technology to Cambodian farmers, with whom they had no relationship, formal or informal. Likewise, the traders on both sides of the border were only interested in making spot transactions in a volatile market. Hence the project could not identify a private sector knowledge partner, and government and non-government agencies were ill-equipped to step in. To meet the urgent need for a supply of disease-free planting material will require a public agency to take the lead, perhaps then linking to private sector technology suppliers who would thus have an interest to increase farmers' awareness and knowledge about disease control.

The Sikka case in eastern Indonesia reflects a "self-contained" value chain, where farmers produced for household and local consumption. Here the private sector actor was operating much closer to Model 1 of Swinnen & Kuijpers (2019), financing the testing and dissemination of high-yielding industrial varieties in order to create a new value chain in which he would be acting as a monopsonist. However, in the absence of a contract or the social capital seen in the North Sumatra case, and with farmers having the option of side-selling into the existing value chain, the private investment in technology appeared unsustainable.

The comparison of cases shows that different incentive structures for engaging in knowledge partnerships exist within each value chain, depending on the type of technology, the farming population, and the potential for value-chain actors to capture benefits from the dissemination of the technology. This potential is in large part a function of the structural characteristics of the value chain, though the personal attributes and relationships of individual actors played an important role. This implies that private sector actors can be powerful partners in technology dissemination if the incentive structure is in place, but in other cases the private sector has little or no incentive to get involved.

It is important to note that the research did not find a case where the private sector had spontaneously become involved in research-based technology dissemination. Hence, even where there is an underlying business case for such involvement, there needs to be facilitation by a public sector (or NGO) actor. Successful knowledge partnerships can often be traced to the activities of one or a few local "champions" in business, government, and/or research who spark the process and keep it going. Moreover, the private sector partner may face constraints due to lack of knowledgeable staff, high turnover of staff, lack of capabilities to undertake participatory research, or language and cultural barriers (especially with foreign ownership), again pointing to the need for public-private partnering. Also, it cannot be assumed that private sector actors will have the necessary sensitivity to equity issues. A further point that underscores the need for public sector involvement is the need to coordinate contributions from value-chain actors that benefit the whole industry, as in the case of distributing disease-free planting material. While there are some examples of spontaneous coordination, it is likely that government regulation is needed so that participants are assured of mutual compliance.

Table 3. Key conditions for effective knowledge partnerships with private sector actors, based on results of cassava case studies

A fund of adoptable technologies (i.e., with moderate to high relative advantage and learnability) requiring no more than local adaptation
A commercially-oriented farming population, experienced in repeat-dealing with stable agribusinesses
An articulated value chain that establishes strong, enduring links between farmers, traders, and processors
A market structure OR industry regulation that assures agribusiness actors of capturing the benefits of investing in improved farm productivity
Absence of policy constraints such as distortions in fertilizer pricing or sudden changes in cross-border trade restrictions
Involvement of a knowledge broker to catalyse and support the partnership (e.g., a public agency, a university, a development project, or an NGO)
Individual actors with the interest and capabilities to pursue these partnerships

These requirements for partnering with the private sector are summarised in Table 3. The "key conditions" listed can be regarded as provisional generalisations arising from the cross-case analysis and are not intended as a simple recipe for knowledge partnerships. As we have emphasised, there are many case-specific factors that restrict our ability to make such firm generalisations. Nevertheless, these key conditions can serve to delimit situations where private sector partnerships are more likely to succeed.

Conclusions

The research reported here sought to examine the circumstances giving rise to effective partnerships between public research agencies and private sector actors in disseminating improved technologies to cassava smallholders. We found that favourable circumstances depend on the attributes of the technology, the attributes of the farming population, and, crucially, the attributes of the value chain. In particular contexts, private sector value-chain actors have incentives to invest in the extension of research outputs to smallholder farmers, even without formal financing and contracting, but generally not without initiation and support from public sector actors or other knowledge brokers. In other contexts, however, there is little incentive for private sector involvement, and public sector or non-government actors will need to take responsibility for supporting smallholders with their technology needs. Thus the private sector cannot be seen as a panacea for generating research impacts at scale.

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