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### **Value Chain Innovations for Technology Transfer in Developing and Emerging Economies: Concept, Typology and Policy Implications**

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**Abstract**

The adoption of modern technologies in agriculture is crucial for improving productivity of poor farmers and poverty reduction. However, the adoption of modern technology has been disappointing. 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. We argue that value chain organization and innovations can have an important impact on modern technology adoption, not just by downstream companies, but also by farmers. We provide a conceptual framework and an empirical typology of institutional innovations through which value chains can contribute to technology transfer to agriculture in developing and emerging countries.

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# **Value Chain Innovations for Technology Transfer in Developing and Emerging Economies:**

## **Concept, Typology and Policy Implications**

### **1. Introduction**

The adoption of modern technologies in agriculture is widely believed to be important for improving the productivity and welfare of poor farmers in developing countries and a key ingredient for achieving poverty reduction, food security, rural development and structural transformation. However, the adoption of modern technology, including improved seeds and chemical fertilizer, has been disappointing, particularly in Africa (Evenson and Gollin 2003; Sheahan and Barrett 2014). The existing literature has tried to find explanations for this phenomenon by looking at various factors, including credit market imperfections (Feder et al. 1985), learning processes (e.g. Lambrecht et al. 2014), the quality of technological inputs (e.g. Bold et al. 2015) and profitability (e.g. Suri 2011).

The role of value chains in technology adoption has been largely ignored so far. This is an important gap in the literature, as agri-food value chains have transformed dramatically in the past decades (Reardon and Timmer 2007). Privatization and liberalization in the 1980s and 1990s induced important transitions in the institutional organization of value chains (Swinnen and Maertens 2007). This has coincided with a major influx of domestic and foreign direct investment in wholesaling, processing and retailing and an increase in trade of high value agricultural products (Reardon et al. 2009). Urbanization and a global increase in consumer purchasing power resulted in an increased demand for high value and differentiated food products. Food safety and other quality aspects, such as convenience, diversity, branding and the sustainability of the production process have become increasingly important.

While the extensive literature on technology adoption in agriculture is largely ignoring the role of value chains, the emerging value chain literature has paid relatively little attention to the role of technology transfer – with some exceptions. Most value chain studies focus on the determinants of farmer participation in modern value chains and the welfare implications for small farmers (e.g. Maertens and Swinnen 2009; Michelson 2013; Andersson et al. 2015). We connect these two bodies of work and argue that (1) understanding the value chain in which a farmer is operating is key for understanding farmer technology adoption; and (2) understanding the role of technology is key in understanding the welfare effects of modern value chains.

This paper addresses the question how value chain organization and innovations can have an important impact on modern technology adoption, not just by downstream companies, but also by farmers. There is widespread evidence that food processors, marketing and retail companies in developing and emerging countries have upgraded their production processes using new technology in the past decades, often as a result of FDI and its horizontal spillover effects (Gow and Swinnen 1998; Reardon and Timmer 2014). This technological upgrading typically included a modernization of procurement systems for sourcing high quality raw material, necessary to meet new consumer demands. One important aspect of this modernization process was the introduction of private standards (with corresponding traceability, auditing and certification systems) to overcome information asymmetry, reduce transaction costs and as a marketing tool (Swinnen 2007).

This new demand on raw material often requires investments in new technologies by farmers, be it to improve productivity for minimum output, to upgrade product quality, or to satisfy other types of private standards<sup>1</sup>. Many studies have pointed at the challenges for small

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<sup>1</sup> Most standards, codified or not, either directly or indirectly prohibit the use of less costly technology (Swinnen et al. 2015). In fact many of the most visible standards for consumers directly prohibit or require the use of certain inputs. Examples of commonly prohibited inputs are child labor, chemical inputs (in accordance with organic

and poor farmers to satisfy these new requirements, and at the risk of further marginalization of this group. In this paper we argue that the same process and forces, which impose new challenges on these farmers, may also be a force of innovation, technology transfer, and thus inclusion for them. With imperfect (or non-existing) technology markets, various forms of value chain innovations have been introduced by up- and downstream companies to overcome constraints and enhance their access to and adoption of new technologies. Value chain innovations include smallholder contracting with interlinked technology transfer, triangular guarantee structures with technology suppliers or financial institutions, and special purpose vehicles.

To our knowledge this is the first article to systematically document and provide a typology of different institutional innovations<sup>2</sup> through which value chains can contribute to technology transfer to agriculture in developing and emerging countries. Moreover, we relate these different types of institutional innovations to external factors, such as the value in the chain, the nature of the technology investment (i.e. long versus short term, and contract specificity), factor market imperfections, etc.<sup>3</sup>

The remainder of this paper is organized as follows. The next section introduces a conceptual framework that explains under which conditions private-initiated value chain

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farming standards), or battery cages in the production of poultry. Examples of commonly required inputs are milk cooling equipment for dairy farmers and traceability systems for farmers supplying supermarket channels. Additionally, standards often require certain practices. For example GlobalGap certification requires Lychee farmers in Madagascar to use clean water for pre-harvest hand washing and to implement good picking and packaging practices for the transportation from the farm to the processing unit (Subervie and Vagneron 2013).

<sup>2</sup> Throughout the paper we use the concept of “value chain innovations” as institutional designs and models that deviate from the standard value chain structure (as illustrated in Figure 1) that have been introduced to address specific objectives.

<sup>3</sup> The extent to which buyers affect the production technology of their suppliers is a major topic within the international technology diffusion literature (Keller 2004). This literature primarily focusses on the vertical spillover effects of multinational firms in the manufacturing sector on their suppliers in developing and emerging countries, either domestically, through FDI. The consensus is that supplying to foreign owned companies can improve the productivity of local firms in developing countries (Havranek and Irsova 2011; Martins and Yang 2009), but these effects can vary substantially depending on country, sector and firm characteristics. This literature does, however, not focus on the nature of the value chain in which these companies operate.

technology transfer is expected to arise. In section 3, a variety of different value chain innovations for technology transfer are discussed and illustrated by empirical examples. In section 4, we draw some policy implications based on the theoretical and empirical insights and, in particular, discuss the role of governments in financing technology transfer programs.

## **2. Conceptual Framework**

### *2.1 Technology Adoption with Perfect Markets*

Consider a simple value chain (figure 1). With perfect markets, decisions to invest in technology are made independently at each stage of the chain<sup>4</sup>. Demand and supply for a product with certain qualities determines the price level and thereby the incentive to invest in necessary technology. A change in consumer demand for higher quality food, will in this way translate into a demand for high quality farm output and an incentive to upgrade technology by the farmer – and thus technology investments if profitable.

Notice that parallel to the flow of goods and technology in the value chain there is a flow of finance (in the opposite direction). Access to finance (in the form of own liquidity or loans) at each stage of this chain is crucial as production costs and technology investments are carried in full by the individual actors. Moreover, costs of technology investment are incurred at the start of the production cycle, while payment occurs at the end, making access to capital essential to bridge this gap. This is especially the case in the agricultural sector where the duration of the production process is relatively long.

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<sup>4</sup> Foster and Rosenzweig (2010) define technology as “the relationship between inputs and outputs”. And the adoption of technology as “the use of new mappings between inputs and outputs, and the corresponding allocations of inputs that exploit the new mappings”. In practical terms, technology adoption therefore refers to a transformation of the production process, which might result in enhanced efficiency (requiring less inputs to produce a given output) or in different product attributes (i.e. enhanced quality). This means, in practice, a firm can change its production technology by either combining its current inputs in a different way, or by applying new intermediate inputs (e.g. machinery) in the production process, with a certain technology embedded in it. A farmer for example, may change its production technology by combining his inputs (e.g. labour, land, seeds and water) in a different way, or by using a new intermediate input (e.g. high yielding seeds, chemical fertilizer, or pesticide) produced by an input supplier.

## *2.2 Imperfect Finance and Technology Markets*

It is not difficult to see why this form of technology adoption might not be working in the context of imperfect credit markets. It is well known that financial markets are often not working well in developing and emerging countries (Banerjee and Duflo 2014; Bardhan and Udry 1999). Poor farmers may simply not have the financial means to make the investment out of own savings and may not get loans from banks or other lenders. As a result, credit market imperfections and financial constraints will cause technology market imperfections, and the failure to adopt technology by farms.

These problems are reinforced when there are potential problems of payment for output at the time of delivery. In other words, the incentive for farmers to adopt technology may be reduced by the risk of buyer holdup (Klein et al. 1978). Relevant types of buyer holdup in value chains, include late payments, renegotiation of prices at product delivery and the absence of transparent and reliable quality evaluation procedures (which could lead to inappropriately rejecting produce). There is much empirical evidence that such holdup problems are important and widespread in agri-food value chains in developing and transition countries (e.g. Cungu et al. 2008; Barrett et al. 2012; Saenger et al. 2014).

## *2.3 Value Chain Innovations to Overcome Technology Market Imperfections*

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 high-quality consumer products; and consumers do not get the products they desire. All these agents have an incentive to make the farm adopt the technology.

Moreover, some of these agents may have better access to finance than the farms, because they have more liquidity, are more likely to get loans, or because they can draw on other commercial activities. These agents can then consider whether it is profitable to set up different types of exchange systems (rather than the spot-market model) to help or induce farms to invest in the required technology, such that they can benefit from the functioning of the value chain with technology adoption at the farm level.

The most straightforward model is that of “interlinked contracting” between farm and processor. The processor offers the farm either direct access to the technology, or to credit to purchase the technology, as part of a supply contract with payment conditions. Such interlinked contracts are well known in the traditional development literature for input provisions (e.g. P. Bardhan 1989; Bell and Srinivasan 1989)<sup>5</sup>. As we will explain in the next section these are widespread institutional mechanisms in modern value chains to stimulate technology adoption by farms.

However, they are far from the only model. In some cases it is not the processor, but other agents in the chain that set up the contract systems – such as the technology company itself. In other cases more than two agents may get involved in joint institutions. In some cases it may even require merging different agents into one organization. In section 3, we will provide a typology of different value chain innovations and empirical illustrations.

## *2.4 Determinants of Value Chain Innovations and Technology Adoption*

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<sup>5</sup> Bell and Srinivasan (1989) define interlinked market transactions as a transaction in which the parties trade in at least two markets on the conditions that the terms of all trade between them are jointly determined. Interlinked market transactions always include an element of credit as they involve exchange of current for future claims. Apart from interlinked credit and output transactions, interlinked transactions also exists in land markets (landlord who provide tenants working capital) and in labor market (employers who give advances to laborers in return for a claim on their labor in peak labor demand periods).



We already pointed at the fundamental role played by credit market imperfections as a motivating element for these value chain innovations. There are more factors which influence the specific value chain innovation to transfer technology to farms, including the financial and technical capability of the lead firm, the risk of holdup (contract enforcement problems), the value in the chain, and the type of technology being transferred.

Imperfect contract enforcement not only hampers relationship-specific technological investments by the farmer in a spot market-based value chain, like explained in section 2.2, but will also hamper the feasibility of technology transfer by the buyer, due to potential supplier holdup. Examples of supplier holdup include side-selling of produce after application of the transferred technology, applying the technology to non-contracted products, or selling the transferred technology. Imperfect enforcement of contracts necessitates private enforcement mechanisms, such as third party enforcement or self-enforcing contracts. These solutions are only feasible when sufficient value can be created by the transfer (Swinnen and Vandeplass 2011). This is because a contract can only be self-enforcing when it pays each party at least as much as their respective outside option (taking into account reputational costs). This might not be possible if too little value is created by the technology adoption. Technology transfer is therefore more likely to occur in high value market segments.

Another important factor affecting the risk of hold up, and therefore the feasibility of a transfer is the type of technology that is being transferred. Two dimensions of technology seem to be of particular importance here (Kuijpers and Swinnen 2016): the time dimension and, the specificity of the technology.

Technology embedded in short-run inputs (e.g. fertilizer, seeds, feed additives, detergent) are typically used up in the production process. Other technologies come in the form of assets and can have a long-term influence on the production process (e.g. transfer of knowledge or machinery). Short-run technologies are typically closer linked to the contracting

period. In contrast, long term technology may have effects beyond the contract period. These different time horizons influence the contract enforcement feasibility. This is because supplier holdup rewards for diverting technology are larger for technology with long-term benefits, while reputational costs are expected to be smaller – making contract breach more likely, and technology transfers less likely under standard interlinked contracts. Hence, in order to make long term technology transfers work, more sophisticated institutional mechanisms might be required which increase the costs of contract breach for the farm and which reduce the risk of contract breach for the contracting company. Alternatively, it may require a more stable macro-economic and institutional environment which contributes to reducing the risk of contract breach.

The other dimension of technology that is important for the feasibility of technology transfer is the specificity of the technology with respect to the relationship of the firm providing the technology (Klein et al. 1978; Williamson 1985). If the technology is 100% specific to the transaction (e.g. technology needed to comply with company specific private standards, such as a traceability system), it has no value outside the contract; if it (or its effects) are also valued by others (e.g. in the case of fertilizer) the technology is non-specific. Obviously, the benefits of diverting technology that is non-specific will more be beneficial than diverting technologies that are very specific to the relationship, which makes transferring non-specific technology more risky.

In summary, various factors will affect the value chain innovations for technology adoption. This means there is no one-size-fits-all solution, but that instead, we can expect a wide diversity in contractual designs – which is what we observe.

### **3. Value Chain Innovations for Technology Transfer: Types and Examples**

In this section we provide a typology of institutional innovations for technology transfer in agricultural value chains and give a series of empirical examples from various countries. All examples have in common that they are set in the context of imperfect financial and technology markets and weak contract enforcing institutions. Several of the examples come from technology transfer in the wake of liberalization process in Eastern European and the former Soviet Union (FSU). There are two reasons for this. First, the liberalization of markets and the privatization of firms in Eastern Europe and FSU in the 1990s and 2000s created a natural experiment where suddenly existing (state-controlled) value chain systems were abandoned. In the pre-liberalization-era, the technology applied at different stages of the value chain was primarily directed by the state. The shift to a market-led economy led to new competitive pressures, and created incentives for firms to improve quality and meet new consumer demand. Improving product quality in a context of failing capital and technology markets and imperfect contract enforcement, meant that the private sector was forced to come up with innovative contractual solutions to upgrade the technology in the chain. This unique natural experiment provided a series of very interesting case studies with rich implications.

The second reason is that the analysis of Eastern European institutional innovations for technology transfer can provide lessons and implications for developing countries. In many other parts of the world, the liberalization process led to a similar break-down of state controlled value chains (Swinnen et al. 2010). However, the Eastern European experience was different in at least two important aspects. First, per capita income at the time of the liberalization was much higher in Eastern Europe and FSU than in other areas that went through a similar liberalization process, such as Sub-Saharan Africa, and South East and East Asia. Second, Eastern Europe received a much greater influx of foreign direct investment (FDI) in the agri-food chains in the years after the economic reforms than Asia and Sub-Saharan Africa. The higher income of residents in Eastern Europe (as well as the proximity to wealthy Western Europe) increased

demand for high quality food after the transition and created an incentive to upgrade the technology at farms and elsewhere in the value chain, while the influx of FDI provided the necessary finance to implement technology transfer.

We increasingly observe other – poorer – parts of the world (Sub-Saharan Africa, Asia and Latin America) entering a phase comparable to Eastern Europe and FSU in the 1990s. Increasing urbanization and consumer purchasing power, increasing FDI in agri-food companies, the rise of supermarkets, and an increase in exports of high value crops, give rise to high quality and safety standards, also in these areas (Henson and Reardon 2005; Reardon and Timmer 2014). Similarly as in Eastern Europe in the 1990s, complying with these standards requires significant upgrading of production, transport and storage technology in a context of failing markets and weak governance, which induces private-sector-led institutional innovations for value chain technology transfer. Hence, the insights from value chain innovations in Eastern Europe and FSU are highly relevant to understand and to inform policy makers in countries that are currently experiencing similar developments.

We organize our discussion by different types of value chain innovations. In the last section we discuss the role that farmer cooperatives have played and can play.

#### *Innovation 1: Farm - Processor/Retailer Contracting*

Figure 2 illustrates the first value chain innovation. This is the case where the company that buys the farm product (be it a processing, a retailing, or trading company) finances the technology and then provides the technology to the farm as part of a contract.

The rationale behind such schemes is that the downstream firm may have better access to credit than farms, because it has more collateral or more cash flow for financing the technology, and faces lower transaction costs. The latter can be the case when the lead firm provides the technology to multiple suppliers (e.g. as part of an outgrower scheme) and benefits

from economies of scale. Another reason why a downstream firm may be in the position to assist its upstream suppliers is because they are closer positioned to the final consumer and therefore might have better knowledge on consumer preferences and how different types of technology used by the supplier are valued.

The contract typically specifies an obligation to comply with buyer standards and a transfer of technology (or credit, to make technological upgrading possible), linked to a purchasing agreement. Payment for these financial and technological services is generally accounted for at the time of product delivery. The technology that is provided can be rather simple such as specific seeds, fertilizer or animal feed. However, much more complex forms of technology transfer are also observed, especially in areas where product quality becomes more important and long term investments are required. More advanced forms of contract-farming can include the provision of long-term technological improvements through extension services, technical and managerial assistance, quality control, specialized transport and storage services, investment loans, and investment assistance programs.

Studies on horticultural export chains in Africa document the provision of specific inputs (as seeds and specific fertilizer) as well as elaborate systems of technical advice and extension services to contracted farmers (Henson et al. 2005). For example, Minten et al. (2009) show that access to technology was a major reason why poor farmers decided to sign up for the contracts with horticultural export companies.

There are several studies on Eastern Europe and Central Asia which document complex and elaborate value chain contracting systems in the 1990s and 2000s in various sectors including sugar, dairy, barley, cotton etc. Cotton gins in Kazakhstan, for example, not only provided seeds and fertilizer, but also water to the cotton farms, with water irrigation systems being a crucial technological input for farms (Sadler 2006). Dries et al (2009) summarize evidence on dairy contracting systems from various countries showing extensive technology

transfer. Important components are credit, animal feed, and technical advice, as well as investment loans for improved dairy cows and milk cooling tanks. Dries and Swinnen (2004; 2010) show, for the case of Poland, that interlinked contracting had a major impact on technology adoption (e.g. cooling tanks) and milk quality, both for small and larger farms.

Van Berkum (2007) documents the case of Danone, the large multinational dairy company, which invested heavily in the Romanian dairy sector. Their main customers were retail chains adhering to European Union standards. Initially, the dairy sector in Romania primarily consisted of small-scale farmers (96% owned one or two cows), who used very basic production technology and produced low milk quality. In response, Danone put in place a number of arrangements to upgrade the quality of their raw milk supply. This included pre-financing farm technological investments. The company would finance suppliers purchasing high-tech inputs, such as compounds (concentrates), and detergents (of milking equipment), as well as long-term technological investments, such as field machinery, cooling equipment and milk installations. Additionally, they offered a range of other services to their suppliers. For instance, field staff visited suppliers and advised them on hygienic practices, cleaning and fodder management). By 2010, as a result of the program, 90% of the raw milk sourced by Danone complied with European Union standards (Bruszt and Langbein 2014).

Another interesting multi-stage example of technology transfers in value chains is the Eastern European barley-malt-brewing value chains in the 1990s, as documented by Swinnen and Van Herck (2011) and Van Herck et al. (2012). All the major international brewing companies, such as Heineken, Carlsberg, Interbrew (now ABInBev) and SABMiller invested heavily in the privatized Eastern European malting and brewing industry<sup>6</sup>.

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<sup>6</sup> Eastern Europe was seen as an attractive destination for its beer drinking culture, relatively high incomes, and geographic as well as cultural proximity to Western Europe. Due to consumer preferences for local brands, the restrictive import tariffs in some of the countries, and the relatively high transport costs of beer, it was more opportune for these large multinationals to enter the European market through FDI, than by exporting their own international brands into the region (Van Herck and Swinnen 2011).

All of them however faced the problem of sourcing sufficient high quality barley and malt in order to produce high quality beer<sup>7</sup>. Enhancing the malt quality required technological upgrading of the entire value chain. For this purpose the brewing companies developed technology transfer programs, involving malting processors, barley farmers and seed companies (see figure 3). Assistance to farms included seed supply and selection schemes, investment assistance, and advice on post-harvest storage and treatment. These programs were successful in both improving quality, as well as in improving productivity. For example, in Slovakia, a World Bank (2006) study showed that the yields of barley farmers supplying to Heineken were consistently higher than the average yields of barley producers in Slovakia.

#### *Innovation 2: Farm – Technology Company Contracting and Leasing*

Technology companies can also be initiators of technology transfer. Like food processing companies, technology companies also have problems because financially constrained farms cannot afford to purchase the appropriate technology. To assist farms in purchasing the technology (and ensure payments), technology suppliers have engaged in a variety of, sometimes quite unconventional, forms of contracting. Institutional innovations have focused on reducing financial constraints of farms by introducing credit schemes, leasing arrangements, and by assisting farms in selling their products to improve their cash flow and liquidity.

One common initiative is finance provision by the technology company (i.e. another form of interlinked contracting), sometimes in combination with output purchasing, as illustrated by Figure 4. Foster (1999) describes how a multinational farm equipment manufacturer partnered with local farm equipment distributors to sell combines and tractors to

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<sup>7</sup> Initially, the foreign multinationals imported malt from their traditional suppliers in Western Europe. However, afterwards they started to invest in the development of a local supply base. Besides logistical and operational reasons, this was also due to high import tariffs and exchange rate uncertainty.

farms in Ukraine in the 1990s. Farmers could buy equipment from the distributor using a payment scheme. Initially they had to fulfil 25 percent down payment (in cash or kind). After three additional payments they received full ownership. To overcome financial constraints of the farms and to ensure payment to the technology company, the equipment dealer received the rights to a certain grain area as part of the payment by the farm. In addition, the equipment dealer was given the rights to harvest, transport, store and sell the grain. Hence, while the interlinked contracting by the food processing companies in Innovation 1 made the food company enter the technology market (vertically coordinating in the upstream part of the value chain), here the technology company entered in buying and selling the farms' products (vertically coordinating in the downstream part of the value chain).

A related contractual innovation by technology companies is leasing. Leasing is a specific kind of financial contracting, whereby the lessee (the farm) uses the equipment which is still owned by the lessor (the technology company) by paying a periodical fee. In essence it is an in-kind loan, whereby the equipment forms the collateral (since the lessor keeps ownership). Leasing is often used by suppliers of lumpy technological solutions, such as machinery to “sell” technology to farms that have no access to credit or cannot come up with the necessary collateral for loans.

Other value chain innovations where technology companies were part of, included more complex forms of contracting where they were part of an institutional design involving multiple partners. We discuss this next.

### *Innovation 3: Triangular Structures*

Many processors are reluctant to provide loans to farms for significant technology investments. The reasons are obvious: they require substantial amounts of finance and with the increase in the size of the outstanding loans, the risk of delayed re-payment or default increases too.



Processing companies have therefore reached out to financial institutions to see if they could collaborate in providing loans to farmers to make the technology investments.

We refer to such institutional designs and collaborations as triangular structures (illustrated by figure 5). The processing company typically offers a guarantee to the financial institution if it provides a loan to a farm which has a supplier contract with the processor. The guarantee is basically a promise by the processing company that it will assume the debt obligation of the supplier in case of default. The underwriting is for specific loans for technological upgrading, related to the contract, and restricted for contracting farms. Triangular structures require a smaller financial commitment from the processor as the financing (loans) is now (at least partially) covered by the financial institution. The guarantee is also likely to reduce the interest rate for the farmer, as the guarantee lowers the risk for the financial institution.

So far we discussed the “triangular structure” as between the farm, the processor and a financial institution. However the third party can also be the technology company itself. In this case the processor provides a payment guarantee directly to the company that sells the technology. The logic is very similar to the case with the financial institution.

In practice both models have been observed. Guarantee programs within triangular contracting structures were implemented, for example, by sugar processors in Slovakia (Gow et al. 2000), by retailers in Croatia for fruit and vegetable supplier investments in greenhouses and irrigation (Reardon et al. 2003), and by dairy processors in several East European countries (Dries et al. 2009). We will briefly discuss two of these examples in greater detail as they have been well document and because their effects were quite dramatic.

The first case is Gow et al.’s (2000) analysis of value chain innovations in the sugar sector in Slovakia in the 1990s. They document how foreign investors in Slovakian sugar processors introduced several institutional innovations aimed at stimulating technological

upgrading by their sugar beet suppliers. As a result of decades of socialist rule and the disruptions caused by the economic transition, productivity and product quality were low and falling even further, throughout the value chain. After upgrading the sugar processing plants, these investors set up a triangular contractual arrangement between themselves, the farms that produced sugar beets and a select group of companies providing technological inputs, such as seeds, chemicals and fertilizer. The processing company (Juhocukor) negotiated prices with these input companies and guaranteed payment of the purchases. For longer term technological investments (such as for machinery) they set up a similar triangular structure, but, instead of including the technology company, they included a financial institution (Polnobanka) through which the sugar beet farms could get loans to finance these investments. Juhocukor provided Polnobanka with a guarantee for the repayment of the loan and subsidized the interest rate.

Gow et al. (2000) emphasize that the guarantee provided by the processor served two purposes. First, it reduced the risk for the technology companies and the bank to supply technology and credit to the farms – as explained above. Second, it also signaled to farms that the processor was committed to the contracts and planned to honor them – otherwise it would hurt itself. This second element was important in an environment where contract breach and delayed payment by sugar processors were widespread, causing financial strains on the farms and making them reluctant to contract and invest<sup>8</sup>.

This package of contractual innovations<sup>9</sup> was highly successful. Not only did Juhocukor provide sugar beet suppliers with improved access to advanced technologies, but by investing themselves in the triangular structure with their farms, they reduced the farms' risk of investment. The result was (a) a substantial increase in beet yields (tons/hectare), (b) a

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<sup>8</sup> On the impact of holdups and payment delays on farm investments see Cungu et al. (2008).

<sup>9</sup> In addition Juhocukor launched a media campaign and supported its farms by technical advice and extension services. This included agronomical advice, soil testing, extension services on integrated pest management, and management support (see Gow et al. (2000) for details).

significant improvement of quality (sugar content) on the farms they contracted with; and (c) a growth of the supply base as other farms wanted to contract with them.

Another important conclusion was that the innovations not only induced vertical technology spillover effects, but also horizontal technology spillovers, as other sugar processing companies were forced to offer similar contractual arrangements to attract farms to supply to them. Interestingly, this contractual convergence and subsequent wave of technological upgrading was not confined to the sugar sector. Other sectors that competed for the same resources (land and farms) started to offer similar contracts. Another interesting institutional spill-over worth mentioning is that Polnobanka later standardized and extended this contractual model into a range of financial instruments offered to the entire agricultural sector.

Similar triangular structures were introduced in other countries. One sector which was analyzed in detail by Dries and Swinnen (2004; 2010) is the polish dairy sector. Their analysis shows that triangular contracting schemes between dairy processors, dairy farms and polish banks lead to a significant increase in (higher quality) dairy cows and on-farm cooling equipment. As a result, milk quality and dairy productivity increased strongly.

Finally, it should be mentioned that these triangular structures to stimulate longer term technology investments did not occur everywhere in the transition countries. For example, studies by Sadler et al. (2006) on the cotton sector in Kazakhstan and by White and Gorton (2006) on agri-food companies in five FSU countries (Russia, Ukraine, Moldova, Armenia and Georgia) found that many of these companies provided basic inputs and technology (such as seeds, fertilizer etc.) under contracts as discussed above, but not long term investment loans. Neither did they engage in triangular structures. This suggests that certain conditions may need to be fulfilled before these more complex value chain innovations may emerge. These conditions could relate to the overall economic and institutional environment or to the nature and structure of company ownership, or other factors. There is no clear evidence on this.

#### *Innovation 4: Special Purpose Vehicles*

An even more complex form of value chain technology transfer, is the use of so-called “special purpose vehicles” (SPVs). A SPV is a stand-alone company jointly owned by, for example, a processor, a technology provider and a bank (see figure 6). Typically, the SPV will then contract with the farms. The contract can include provisions on output, technology, and credit.

An important advantage of such institutional solution is that the partners in the SPV now share the risk of contract breach. When a processing company by itself implements technology provision programs, the processor carries the entire risk of farms’ breaching contracts, although both the technology provider and the financial institution benefit from these contract innovations. Institutions such as SPVs allow sharing of the risk between various agents, and hence, will stimulate investments by companies who otherwise may be deterred by the risk<sup>10</sup>.

An example described in the literature is the case of the collaboration between the Russian dairy processor Wimm Bill Dann (WBD) and the Swedish dairy equipment seller De Laval (Top Agrar 2004). The goal of the joint project “Milk Rivers” was to upgrade the technology used by Russian farms. They created a jointly owned “project”, an SPV, which leased combine harvesters, milking and cooling equipment. The farmers had to cover about 20% to 30% of the costs themselves and received the equipment (provided by De Laval) based on a three to five year leasing basis. The leasing costs were being paid off by the farmers by delivering raw milk to WBD. The main condition for suppliers to take part in the program was compliance with WBD quality standards and motivation to improve quality and productivity.

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<sup>10</sup> In some cases such structures have developed with farmer participation. For example, Gow and Swinnen (2001) report that in Eastern Hungary a group of sheep farmers set up a producers’ co-operative through which they participated in an SPV-like joint company.

Although the project was considered a success, at times the enforcement of the contracts proved difficult, as some of the supported farms started to supply their milk to competitors who offered a higher price. These holdups endangered the feasibility of the scheme (World Bank 2005).

Also with these innovations there were horizontal spill-over effects. Serova and Karlova (2010) found that a few years after the WBD-DeLaval project took off, competitors of WBD, started copying the scheme to stimulate dairy farm investments. They used a similar construction (also with DeLaval), whereby farms received milking equipment under a leasing contract as part of a one- to five-year instalment plan, as well as calf milk replacers (CMRs) and feed additives.

#### *Innovation 5: Vertical Integration*

In some cases companies have gone as far as taking over the farming activities, i.e. by “vertically integrating” the supply of raw materials in their company. There are several motivations to do so. One is high transaction costs of market exchanges or high risks of hold-ups in contracting (Klein et al. 1978; Williamson 1985). Increasing private and public standards may increase these transaction costs, in particular when monitoring is costly (e.g. restrictions on the use of pesticides and child labor). These costs of technology transfer and monitoring are amplified when the capability of farmers is low, when standards are complex, and when required technology is difficult to codify in a set of well-defined practices (Gereffi et al. 2005).

There are several studies which show how the rise of standards in high value chains and the associated requirement for farmers to invest in modern technology, has led towards vertically integrated production systems. Several studies have documented this for Africa. For example, Maertens and Swinnen (2009) and Maertens et al. (2011) document how, in the Senegalese horticulture sector, the combination of available land and a tightening of public and

private standards (such as HCCP and EurepGAP) induced exporters to move from smallholder contracting to integrated estate production. Similar shifts to vertical integration and large estate sourcing have been observed in other parts of Africa as well, such as in Ghana (Suzuki et al. 2011), Zimbabwe (Henson et al. 2005) and Kenya (Dolan and Humphrey 2000).

Note, however, that in almost all of those cases, the shift towards vertical integration has only been partial, as processing companies maintained a mixture of sourcing channels. There are several motivations for this strategy. First, it might simply be difficult to acquire land, due to practical (e.g. high population and farm density in fertile areas) or legal constraints (e.g. foreign ownership of land not being allowed). Second, social pressures (e.g. from surrounding communities or international civil society) might induce large reputational costs from being associated with “land grabbing”. Third, maintaining multiple and diverse types of suppliers is part of a risk management strategy (Swinnen, 2007). Suzuki et al. (2011) explain why Ghanaian pineapple exporters combine own-estate production with smallholder-sourcing to anticipate unexpected fluctuations in demand.

Interestingly, in the large grain producing areas of the former Soviet Union (Kazakhstan, Russia and Ukraine) extensive vertical integration has developed not so much to address product standards, but to overcome farms’ constraints in financial and input markets (Gataulina et al, 2006). Large agro-holdings have taken over farms, sometimes up to hundreds of thousands of hectares. However, this type of vertical integration, while fully in line with the logic of financial constraints as explained above, appears to be a product of the specific conditions of the transition conditions (including extreme financial constraints and privatization through voucher systems) which are unlikely to occur in other countries (Serova, 2007; Rozelle and Swinnen, 2004).

#### *Innovation 6: Integrating Farm Organizations in Value Chains*

Theoretically, there are several reasons why cooperatives can enhance technology adoption. First, a collective marketing agreement with a processor or trader might secure a market outlet for their products, reducing the risk of relationship specific investments. Second, through collective bargaining cooperatives might be able to obtain higher output prices, increasing the return on investment and obtain discounts on equipment, inputs and services. Lumpy investments (e.g. harvesting machinery) might be collectively purchased and hired out to members for a fee. Third, cooperatives might enhance access to credit. Collectively taking a loan can reduce transaction costs, and collectively guaranteeing repayment reduces the risk of default following idiosyncratic shocks. Fourth, cooperatives may reduce transaction costs for retailers and food processing companies in sourcing from (small) farmers by pooling supplies, controlling quality, etc. Fifth, cooperatives may also play a role in joint quality control systems. As prices are typically related to quality in modern supply chains, transparency of quality control is a crucial factor to prevent holdups in contracting and, therefore, to make value chains function effectively. Involvement of farm organizations in the quality controls may help in this.

In summary, there are many reasons why farm organizations could play an important role in value chains and innovations. Reports by development organizations, such as FAO, the World Bank, and NGOs, invariably point at their importance. Moreover, the empirical evidence that is available from value chains in Africa show that cooperative membership is indeed associated with higher rates of technology adoption (e.g. Verhofstadt and Maertens 2014; Abebaw and Haile 2013).

However, in reality participation by farmers' organizations in these value chain innovations appears rather limited. Gow and Swinnen (2001) document how a sheep farmer organization in Hungary in the 1990s participated as a partner in an SPV structure, and thus increased farmers' bargaining power in the contract design. Van Berkum (2007) and Bruszt and Langbein (2014) describe how a dairy farmers association (ISPA) in Romania became a

shareholder in the private milk processor (ProMilch) in the late 1990s. ISPA supported their members in upgrading their technology in several ways: (a) by investing in milk collection centers; (b) by supplying high-quality inputs (feed, medication), which were financed by deducting milk payments; (c) by offering on-farm technical assistance (on a range of topics); and by providing loans to their members (in collaboration with a financial institution (Rabobank)) to invest in equipment, animals, or (re-)construction of stables. Farmers did not have to provide any collateral, but needed to have a durable relation with ISPA, and continue milk delivery to the cooperative.

#### **4. Discussion, Implications and Conclusions**

The adoption of modern technologies is crucial for improving the productivity and welfare of poor farmers in developing countries but technology adoption has been constrained. Many factors have been identified, but the role of value chains has not received much attention so far. In this paper we have explained why value chains and institutional innovations may play an important role in agricultural technology adoption. With imperfect technology markets, various forms of value chain innovations have been introduced by up- and downstream companies to overcome constraints and enhance farmer access to and adoption of new technologies. We have systematically documented value chain innovations including smallholder contracting with interlinked technology transfer, triangular guarantee structures with technology suppliers or financial institutions, special purpose vehicles and vertical integration.

Several conclusions can be drawn from our analysis and empirical cases. First, value chain technology transfer programs are often driven by a need for quality upgrading. This was particularly clear after the economic reforms in Eastern Europe, where due to sudden and strong competitive forces and Western European FDI, the demand for high quality products was



outpacing supply. Similar market developments are now occurring in Sub-Saharan Africa and other developing parts of the world, following the growth in high value exports, urbanization and a rise in domestic purchasing power.

Second, these technology transfer programs have been set up in complex environments. Successful programs create the right conditions for successful and self-enforcing contracting, and are based on extensive knowledge of the sector and of local conditions. Moreover, these programs need to be flexible enough to adjust the contractual terms to changing circumstances – an often occurring situation in developing and emerging economies.

Third, many institutional innovations for technology transfer use both a *pull* and *push* strategy. The push strategy consists of improving access to technology. Different modalities are often used for different types of technologies. Intermediate inputs are often provided through interlinked contracting or guaranteeing payment in a triangular system with technology providers. Longer term investments, such as machinery, often required a more sophisticated contract design, either involving a triangular guarantee structure with a financial institution that would provide the loan to the supplier to buy the equipment, or special purpose vehicles in which both the buyer and technology company collaborate. Knowledge, training and assistance is often directly provided by the downstream lead firm. One advantage of this direct contact is the possibility for the downstream lead firm to monitor the production process of the supplier – and thus to contribute to contract enforcement.

The pull strategy consists of providing better incentives for investments in technological upgrading. The most obvious way this was achieved was through price premiums for higher quality. Other strategies involved improving trust (e.g. by providing prompt payments) and relationship-specific investments by the downstream lead firm to enhance the “private enforcement capital”. This made relationship-specific technology investments for suppliers less risky.

Fourth, access to finance by the initiator of the technology transfer program is essential. In all of the cases discussed, the firm that initiated the technology transfer innovation either received financial input through FDI or had significant financial sources. This is because interlinked contracting, pre-financing and guarantees require large upfront investments, or sufficient collateral.

Fifth, the effects of these programs can be very substantial as they can move the entire value chain towards a higher equilibrium, with impacts for all agents. Spillovers are not restricted to vertical interactions, but can also be horizontal. Competing companies or firms that initiate a technology transfer program may introduce similar contractual arrangements, either to stay in business (as farms will otherwise shift to supplying other companies) or because it is profitable for them to do so once they observe the success of the innovations elsewhere – or both. Such type of contractual convergence may go beyond sectors in which the transfer program was initiated. Other sectors that compete for the same resources (e.g. land) might offer similar contracts as well – or financial institutions may standardize the approach for other farms.

Important questions relate to the policy implications of our analysis. The most straightforward implication relates to recognizing the importance of value chains as an engine for technology adoption, and to the need for allowing this engine to work its best. A key policy to stimulate technology transfer and adoption in the agricultural sector of developing and emerging countries is therefore to improve the enabling environment for companies to operate in. Enabling environments encompasses various macro-economic and macro-institutional elements.

Macro-economic stability is a key condition for financial markets to function properly. Instability may increase the risk of holdup, as unexpected changes in economic conditions might make it more attractive to default on the contract. Hence, macro-economic stability is

not only necessary for the functioning of more traditional finance systems, but also for technology transfer as it reduces the risk of investments.

Improving contract enforcement is another promising avenue for improving the enabling environment for technology adoption, as it can reduce the risk of hold-ups. As it is generally either not possible or too costly to resolve disputes in courts, alternative dispute settlement institutions can play an important role. Other measures can include increasing transparency of contracts, supporting alternative dispute settling arrangements, training farmers in their rights/obligations as contractors etc.

One of the key findings of our review is that there exists significant variation in private sector technology transfer schemes across countries and sectors. Hence, one should be careful with interventions that may hamper the flexibility of companies to address different circumstances.

Private sector technology transfer might only be feasible for high-value market segments and for certain types of technology. In particular, there is less incentive for transferring long-term oriented technology that is not to some extent relationship-specific, due to a higher risk of supplier hold up (e.g. training on how to increase yields). One could therefore consider public interventions which focus on those firms or farms being excluded from private sector programs, those low-value market segments for which technology transfer is unlikely, and those technologies that are not provided by the private sector. These public programs could learn from the institutional design of the private sector in bringing different partners to the table.

Another option is to leverage the private sector's resources and use value chains for transferring technology to farms. As we showed, access to finance is essential for technology transfer. Therefore, one way to facilitate technology transfer is by offering government finance for private-sector-led technology transfer programs that could otherwise not be financed. This can be achieved through different modalities, such as public-private partnerships. Governments

could possibly use such funding for value chain technology transfer to address certain objectives which may otherwise not be reached, such as inclusion of specific farm groups (e.g. smallholders), adherence to certain environmental sustainability and labor condition standards.

Alternatively, governments (and NGOs) could directly assist suppliers in upgrading technology (e.g. through training, improving access to essential inputs, and facilitating certification) in anticipation of increasing market demand for high quality produce, or, more actively, in close collaboration with the private sector. Unlike traditional technology adoption programs, these initiatives complement a government initiated productivity push, with a private “market pull”. Waddington et al. (2014) review the effectiveness of public agricultural extension services and find effects are particularly large when they are implemented alongside complementary upstream or downstream interventions (access to seeds and other inputs, assistance in marketing produce).

In fact these type of value chain development projects have become increasingly popular among donors active in rural developing areas. A recent example is a joint World Bank – World Food Programme project to set up a staple food sourcing program in East Africa in which it collaborates with private sector input suppliers (seed, fertilizer and pesticides) in an SPV-like institutional organization with smallholder farmers to source staple foods (cereals) from them.

The effectiveness of these programs is, however, only rarely evaluated “rigorously”, and most of those studies have appeared in the “gray literature”. An exception is Shayonan et al. (2014)<sup>11</sup> who document how a public-private-partnership for technology transfer in Armenia, led to a sustainable upgrading of supplier technology. An international aid program (the USDA Marketing Assistance Program) facilitated linkages between dairy processors and dairy farmers, stimulating technology upgrading and investments in dairy cows, dairy husbandry facilities and milking equipment, even after the program ended.

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<sup>11</sup> Another exception is Waarts et al. (2012).

However, as all public interventions, also this type of selective government involvement in markets carries a number of risks. For example, the government financing might not be “additional” to private sector initiatives, or the project may not be sustainable beyond the public funding (DCED 2014; Shepherd 2007).

As still little is known about what type of intervention works best in what type of context, further research on this topic, as well as, rigorous monitoring and evaluation of initiated programs is needed. As the impact of the value chain innovations that we have documented here are potentially very significant, these are research areas with a potentially high pay-off.

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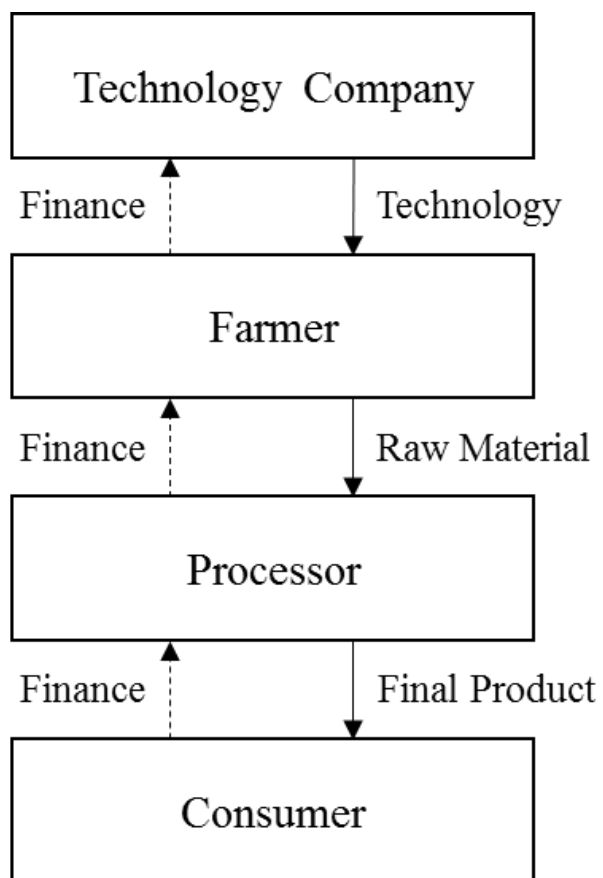


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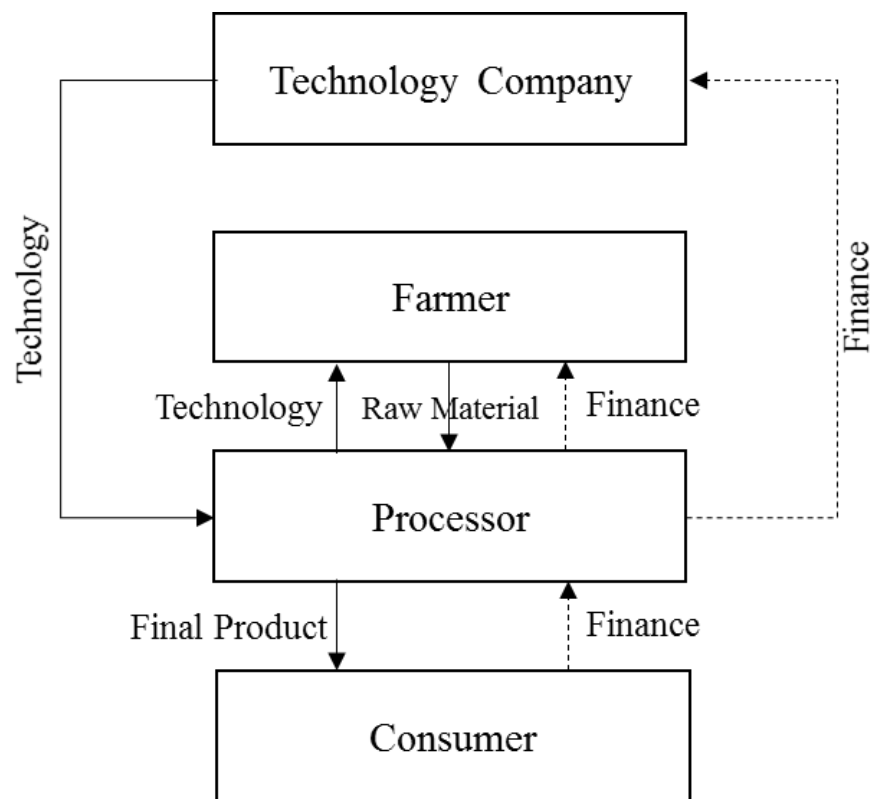
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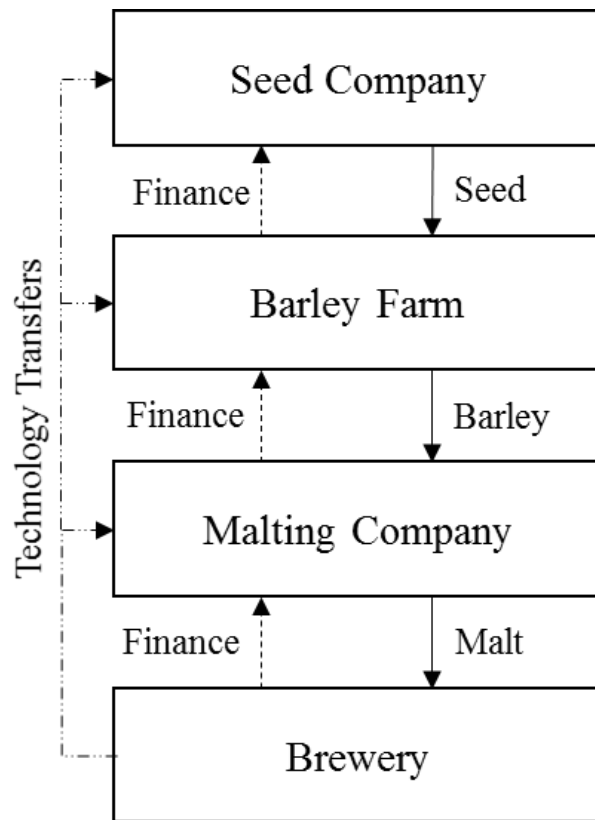
**Figure 1: Value Chain and Technology Transfer with Perfect Markets**



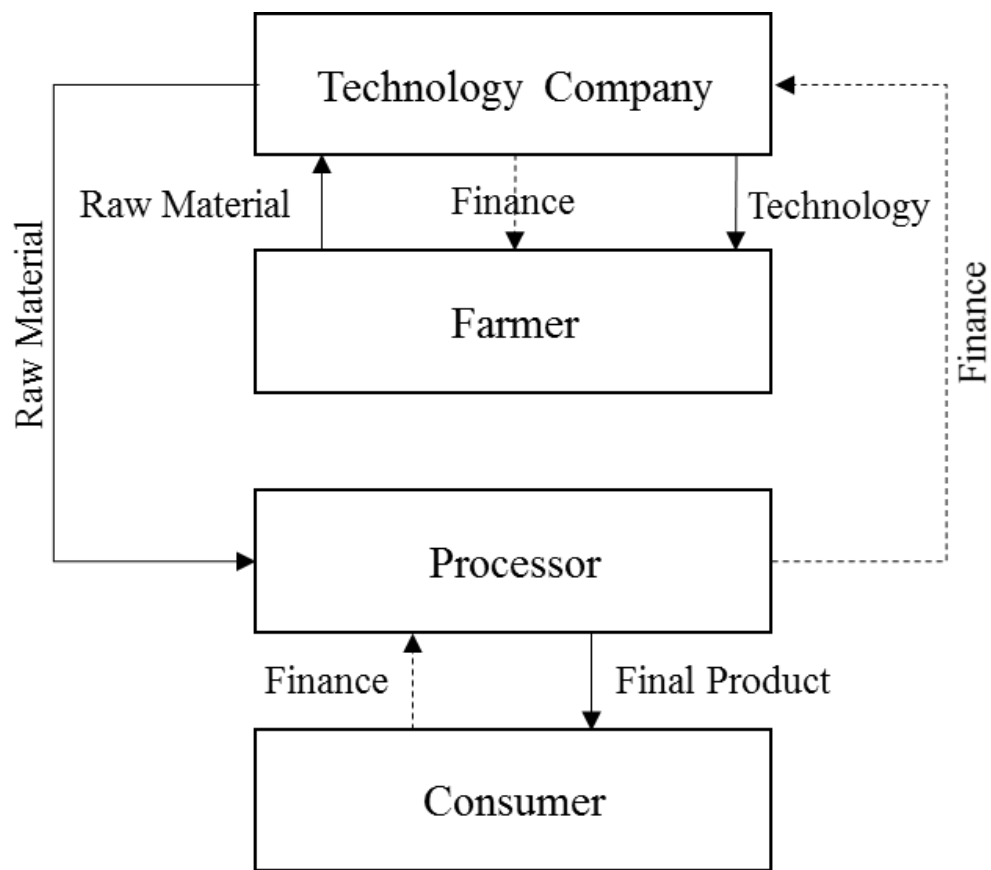
**Figure 2: Farm – Processor Contracting**



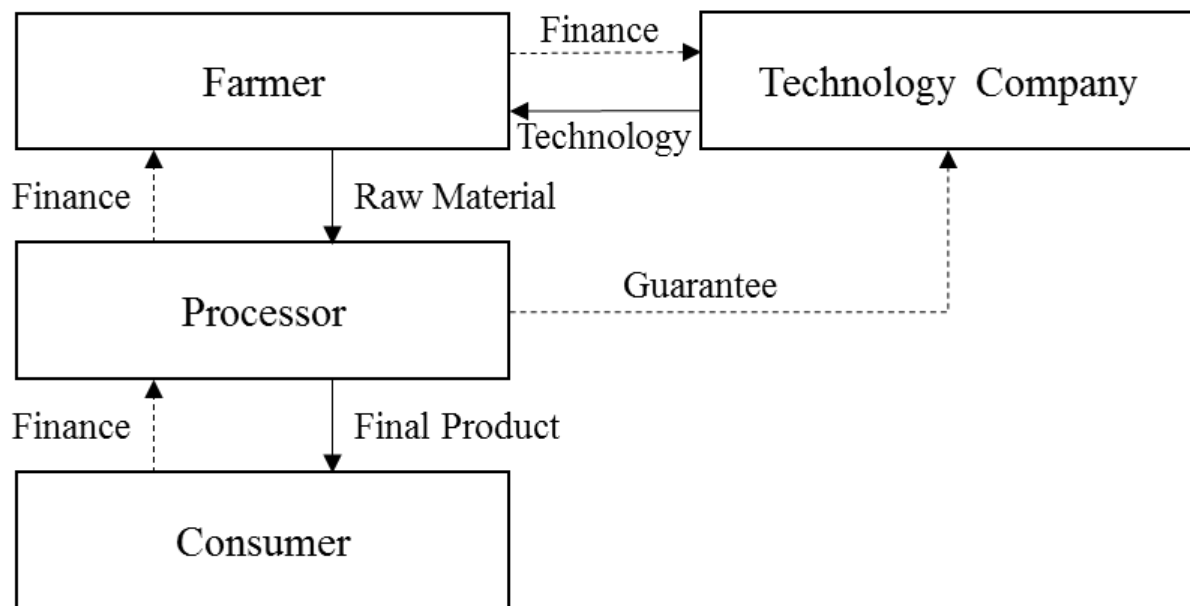
**Figure 3: Multi-stage technology transfer in the brewing sector**



**Figure 4: Farm – Technology Company Contracting**



**Figure 5: Triangular Value Chain Structure**





**Figure 6: Special Purpose Vehicles for Technology Transfer**

