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Making the value chain work – analysing the impact of Intellectual Asset and Property Management for seed sector development in West Africa

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The role of Intellectual Property Management in facilitating the agricultural transformation process in developing countries is unknown and discussed in a very controversial way. This paper conceptualises a framework for assessing the impact of Intellectual Property Management on the seed sector in West Africa. At the core of such assessment are a number of system dynamics models that describe the dynamics of a seed value chain at different levels of aggregation. We use data from interviews with multinational seed companies, research institutions and private sector actors in Ghana for developing conceptual simulation models and for specifying the impact assessment framework. Simulation runs reveal the potential of Intellectual Property Management to boost research and thus the development of new, improved seed varieties. The timing of the introduction of intellectual property influences both the eventually achievable capacity of national and international research institutions but also the transition pattern towards this capacity.

Introduction

West African economies depend heavily on agriculture. Agricultural earnings accounted for almost 41% of GDP in 2006 in Ghana (Alhassan and Bissi 2006). At the same time, the majority of West African agriculture is at a subsistence level, and most of the land is cultivated by smallholder farmers who are particularly vulnerable to production risks caused by climatic variability, pest plagues, environmental degradation, and other factors (Lobell, Burke et al. 2008), (Brown and Funk 2008). Poor transportation infrastructure and limited availability of agricultural inputs such as seed of high-yielding varieties and fertilizer contribute to low production levels. In the case of maize less than 30% of the maximum achievable output is generated (Ministry of Food and Agriculture 2003). Among other factors, this can be explained by the fact that 85% of the maize seed is obtained from informal sources (on-farm saved seed or seed exchange with neighbours). Informal seed supply tends to be inconsistent in terms of quality and such seed is vulnerable to new pests and diseases. Only 15% of the maize seed in Ghana is of certified, improved varieties (Morris, Tripp et al. 1999).

Seed of improved varieties and other inputs (fertilizer and crop protection products) are imperative to the transformation of the agricultural sector from subsistence farming to small-scale commercial agriculture. Quality seed can play a critical role in increasing agricultural productivity and thus food security as well as farmer incomes. It determines the upper limit of crop yields and the productivity of all other agricultural inputs into the farming system (Maredia, Howard et al. 1999). The development of new crop varieties is also a key factor to shape the future severity of climate change impacts on food production (Lobell, Burke et al. 2008). However, the transformation of the agricultural sector will take time. This means that quality seed will need to be available and that farmers will need to be able to use this seed. Until small producers are linked to reliable input and output markets, they will hesitate to take the risk of investing in improved inputs.

Improved seed varieties developed by the national and international agricultural research centres very often fail to be adopted by the smallholder farmer (Morris, Tripp et al. 1999). Although the public crop research institutes have breeding programs, the subsequent, private sector stages of the seed value chain such as foundation seed production, seed production and extension or agro-dealer networks are underdeveloped. The lack of private sector investment in the provision of improved seed has several reasons (Tripp 2003).

- Poor communication and transportation infrastructure and low revenues in the agricultural input businesses. There is therefore little incentive for entrepreneurs to enter this business. Consequently, large areas are not served by agro-dealers at all. In order for national and international companies to invest into infrastructure a proper regulatory and juridical system needs to be in place and grant security.
- Lack of financial capital for seed producers to produce hybrids. The cultivation of hybrids is costly due to irrigation, land preparation and use of fertilizer.

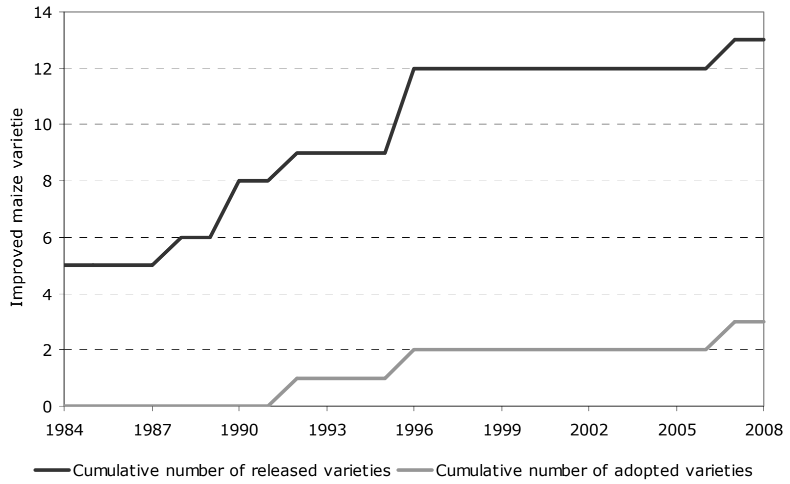
- Lack of trust. Even if improved seed varieties are available they might not be purchased since the problem of imitations of certified seed erodes trust in the premium price product. Branding and certification policies, if effectively enforced, can help to overcome these problems in creating quality standards that signal trustworthiness for the consumer.
- Government and donor seed schemes. It has repeatedly been shown that ad-hoc public sector interventions frequently impede or set back efforts to develop a sustainable agricultural inputs supply system. Public seed production and distribution tends to be both expensive and ineffective because parastatal seed organisations, among other reasons, only supply a narrow range of varieties that fail to meet smallholder needs and that, as a consequence of lack of competition, are inconsistent in their quality (Maredia, Howard et al. 1999).

These findings lead to our first research proposition:

The private sector in the seed value chain is crucial for farmers' adoption of improved varieties and thus for an increase in agricultural productivity, food security and farmers' income in West Africa

In every stage of the development, production and distribution process there is space for investment and improvement by the private sector. During the last 25 years, the national agricultural research system in Ghana has released 13 improved maize varieties, a number that could be much higher with more private sector involvement. Out of the 13 released varieties only three have ever been adopted by farmers. Local, decentralized breeding could yield varieties that are locally adapted and satisfy local demand. Private investment could also overcome budget constraints for foundation seed production and seed production that currently hinder the dissemination of varieties to the farmer. An increased number of agrodealers would improve the supply of varieties for the farmer, which would stimulate the adoption of improved and certified seed. The involvement of large multinational enterprises can establish new sales channels that local companies later can benefit from by promoting new varieties in field days, demonstration plots and through other services. Thus the whole value chain would benefit and could be raised to a higher level where the profitability of the seed business would draw more investors and entrepreneurs into the sector and thus trigger even more investment.

Figure 1: Maize sector performance in Ghana 1984-2008 (updated after (Morris, Tripp et al. 1999))



The question then is how investment in all stages of the seed value chain can be increased. In this context, the improvement of the regulatory environment and the introduction of intellectual property laws are often mentioned. Intellectual property right (IPR) regimes can play a part in agricultural development, but the challenge is to strike the right balance between incentives for innovation and access to productive resources.

IPR regimes stimulate disclosure of new innovations (Chen 2006), provide security for the outcomes of investment (i.e. the development of new, improved varieties), influence material transfer between actors in the seed market, and generate revenues from licensing fees, for private as well as for public organizations (The World Bank 2006). Plant breeders' rights and patents are the most important instruments in the plant breeding context, but also marketing instruments such as geographical indications and trademarks are used. Intellectual Property Rights in the age of biotechnology are an increasingly important policy around the development of new varieties. It is not difficult for competitors to determine the molecular composition of biotechnological inventions and to develop imitative products (Maskus 2000).

A number of further instruments support the effectiveness of intellectual property right regimes. Seed laws regulated variety registration, declaration of genetically modified seed and seed certification. Seed certification schemes generally promote the quality of the seed sold on the market. Biosafety regulations are intended to provide for proper handling of genetically modified material.

In industrialized countries there is a clear correlation between IP protection of plant varieties and the willingness of companies to produce varieties. Without strong protection, there would be few new varieties available for the public benefit (Price and Lamola 1994). In addition, if national legislation allows public institutions to retain property rights, the number of patents increases since these facilitate licensing agreements. There are expectations that new or strengthened IPR regimes for plant breeding in developing countries will provide increased incentives for private seed sector activity

(The World Bank 2006). Strengthened IPR regimes also motivate national agricultural research centres to consider strategies for generating revenue. The accessibility of technology and materials is a critical issue that needs to be resolved because the future rate of technological progress generated by public sector institutions may depend nearly as much on their ability to negotiate access to existing component technologies as it does on the scientific capacity to assemble the components (Trigo, Traxler et al. 2000).

Our second research premise therefore is:

Intellectual property law and regulatory frameworks positively contribute to the development of a formal and sustainable seed value chain in West Africa

So far, little empirical analyses exist on the impact of IPR on food and agriculture, especially in developing countries. In Mexico, a technologically advanced developing country, IPR was not a necessary precondition for maize breeding since viable maize breeding industries had existed before the presence of enforced IPR (Léger 2005). For India, non-IPR mechanisms such as biological protection, trade secrets and contracts will remain major instruments of the strategy of private seed companies in India. Plant Variety Protection and Farmers' Rights Act, on the other hand, had modest impact on plant breeding priorities, relations of public research with private seed companies and farmers, transfer of technologies by multinational companies and seed prices (Pal, Tripp et al. 2007). Similarly, Plant Variety Protection has had modest immediate impact on plant breeding and seed production in China, Colombia, Kenya, and Uganda. Plant Variety Protection should instead be seen as a part of a broader strategy for the development of commercial seed provision. Such broader strategy includes compatibility with other seed law, efficient and transparent management of seed marketing regulations, variety registration, and seed certification and quality control (Louwaars, Tripp et al. 2005);(Tripp, Louwaars et al. 2007). In the case of India, indirect costs of regulation were found to be large ((Pray, Bengali et al. 2005) for the case of India), a fact that has to be taken into account in designing regulation. Opportunities arising from an increased availability of information and from little obstruction by patents in the developing world most often do not compensate for the lack of capacity and infrastructure to absorb the technologies (Mayer 2003). Overall, there is considerable uncertainty about the effects of strong IPR regimes in developing countries (Tansey 2004). The question remains how important IP is for stimulating innovation in developing countries (Commission on Intellectual Property Rights 2002) and whether developing or industrialized countries eventually benefit from strengthening IPR regimes (Panagariya 1999).

Assessing the impact of a given IPR regime as well as harmonization of IPR regimes across countries on the seed sector in specific and the agricultural sector in general can be facilitated by the use of computer based simulation models. In the seed industry simulation models already have been applied for production planning. (Jones, Kegler et al. 2003) developed a model that mitigates demand uncertainties by calculating the seasonal seed demand as a function of the last years seed demand. As a consequence they observed an improvement in the production planning process. Such models do, however, not support a longer term analysis of the emergence of a viable seed sector and the impact of intellectual property on this process.

Objectives and methodological framework

The two research promises formulated in the previous section lead to two main research objectives:

- Understand the emergence of a seed sector that is able to provide farmers with high quality products on a continuous basis: Which processes and actors are involved in such emergence and what kinds of decisions do these actors take? What kinds of behaviour patterns arise out of the combination of the processes and actors' decisions?
- Assess the dynamic impact of intellectual asset and property management in this process: What is the effect of IP management on the development, production, distribution and adoption of improved seed varieties?

The emergence of a viable seed sector is a process in which a variety of actors are involved. The process and its actors can best be described as a value chain. A first step therefore consists in adapting the supply chain or value chain concept (Sterman 1989); (Sterman 2000) to the seed context in West Africa. For this purpose we follow an iterative procedure that balances theoretical and conceptual work with actual data collection and analysis in West Africa.

The central question underlying the value chain analysis is the question of how the impact of intellectual asset and property management can be assessed. For this purpose different sectors (research, seed production, farmers) and scales (international treaties and conventions, regional laws and regulations, national contract and IP law) have to be distinguished. In order to be able to assess the impact of IP on seed market dynamics a first step is to identify the variables in the seed value chain that are affected by IP management and protection.

To facilitate the research objectives we design a series of assessment tools of the seed value chain based on the development and implementation of computer simulation models. The simulation models describe the dynamics of the seed value chain in West Africa with its relevant processes, actors and decisions and allow testing different policy interventions and assessing the impact of intellectual asset and property management on agricultural development.

This paper illustrates the methodological framework with two simulation models of different scales. The first model captures the entire seed value chain and its basic dynamics on a very aggregate level. The second model goes into more detail in the research sector and contains the rest of the value chain in only very aggregate form. Though both simulation models are currently conceptual in nature their structure and usefulness are based on several empirical sources:

- Multinational seed companies (Pioneer HiBred). These interviews helped understand investment decisions, preconditions for investment in a country such as Ghana and the role of regulatory frameworks and IP laws for investment.
- International agricultural research sector (CGIAR Centres). These interviews contributed to an understanding of the public sector's attitude towards and experience with IPM.
- National agricultural research sector in Ghana, local seed producers, agrodealers and farmers in Ghana. These interviews helped elicit the stakeholders' perceptions of the problems in maize seed production in Ghana and of the potential role and entry points of IPM.

Thus, the first, aggregate model helps explain the low number of adopted maize varieties in Ghana over the last 20 years. The second simulation model, in turn, provides a conceptual explanation of the number of developed maize varieties over time (see Figure 1).

Model overview

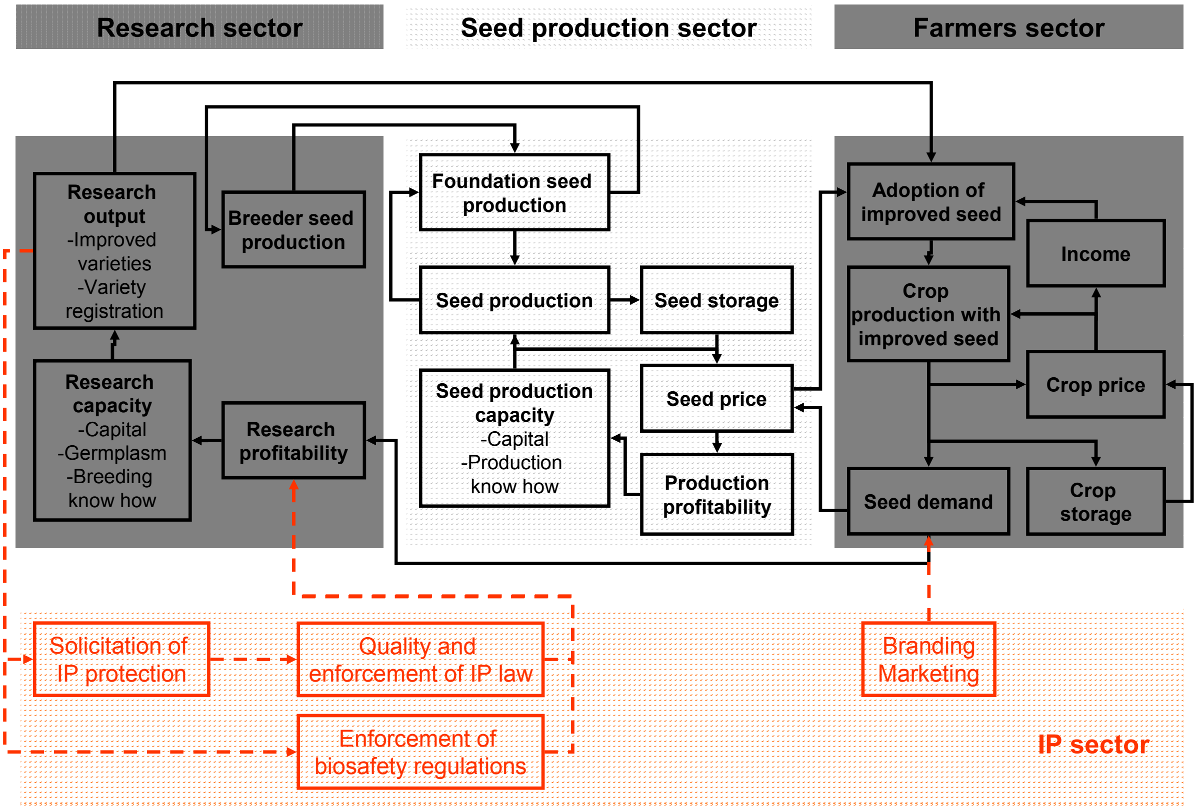
In the seed context the value chain includes processes from breeding, seed production to seed use in crop production (Figure 2). The seed value chain develops and delivers new varieties and the corresponding seed upstream (breeder seed production, foundation seed production, seed production, crop production with improved seed). This flow is driven by demand for seed and improved varieties that works in the opposite direction.

In order to capture the process of the emergence of a seed value chain as opposed to the management of an already existing value chain two elements have to be included in the model:

- Capital and skills: Capital and skills are important for seed production (capital, production know-how) and for research (capital, germplasm, breeding know-how).
- Innovation adoption structure: The central pull force in the value chain is farmers' demand for improved seed. Such demand stimulates both seed production and breeding of yet newer improved seed varieties. Demand depends on a number of factors, availability of various improved varieties and price of improved seed being only two of them.

Intellectual property management supports both pull and push forces (Simchi-Levi, Kaminsky et al. 2007) to the central flows in the seed value chain (red boxes in Figure 2). Since demand for modern improved maize varieties is currently very low, the initial stimulus for the value chain to work will be provided by a push of new varieties that the farmer will be able to experiment with. Intellectual property management will support the pull factors by reducing some of the demand uncertainties e.g. by enhancing the quality and thus the image of seed varieties via branding and trade marking strategies. Thus a market for improved varieties is created and their profitability increased. IPM also has the potential to enhance the push factors by providing greater incentives for investment into R&D of new maize varieties.

Figure 2: Seed value chain with the main processes and actors and IPM entry points



In the next sections we report on the structure and preliminary simulation runs of two models that cover parts of the overall seed value chain and its interactions with the IP sector. While the purpose of the section on the aggregate model will be to demonstrate that the basic seed value chain exhibits plausible and characteristic behaviour the research sector model will be discussed in more detail. In this second model explicit intellectual property management policies can be tested.

Aggregate model – seed production and use

The first model develops an aggregated overview of the seed value chain with no specific intellectual property entry point. The purpose of this model is to provide a solid background for all further model developments and analyses by capturing the basic seed value chain dynamics. Figure 3 sketches the major feedback loops that link foundation seed production, seed production, seed distribution through agrodealers and the use of improved seed by farmers. The figure shows a number of reinforcing feedback loops that describe how an increase in seed demand by farmers can travel through the value chain, boost seed production and positively feed back into farmers' demand. These reinforcing feedback loops are controlled by balancing loops that regulate demand changes through corresponding changes in seed price and seed production.

Figure 3: Causal loop diagram for the production, distribution and use of improved seed

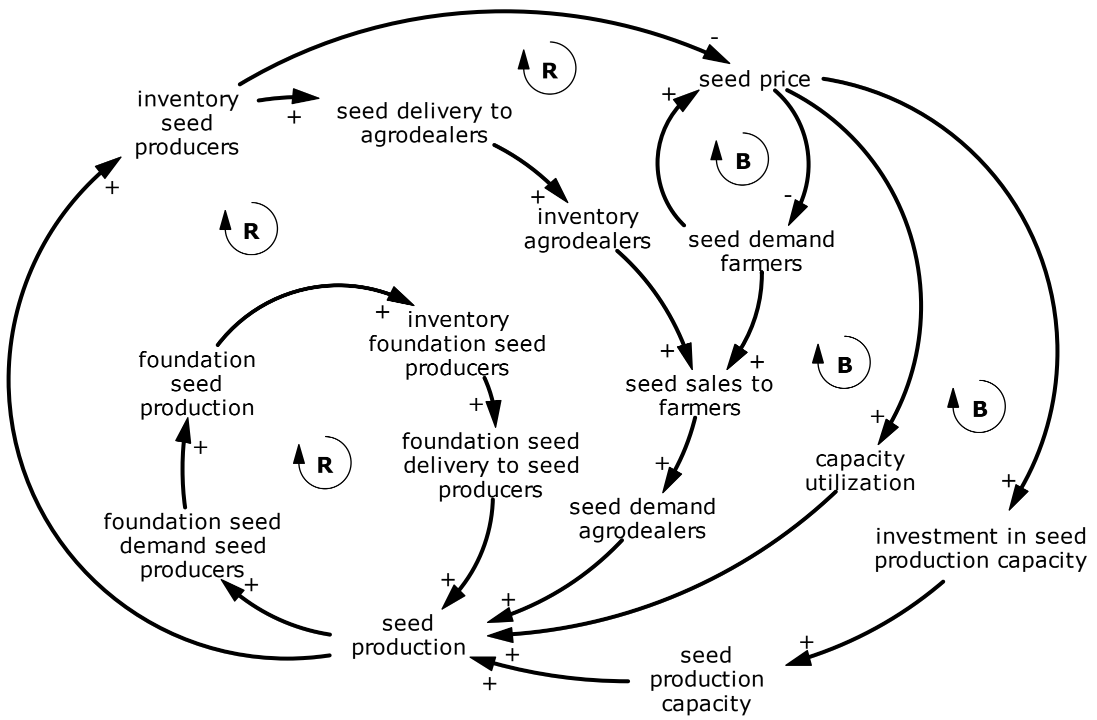
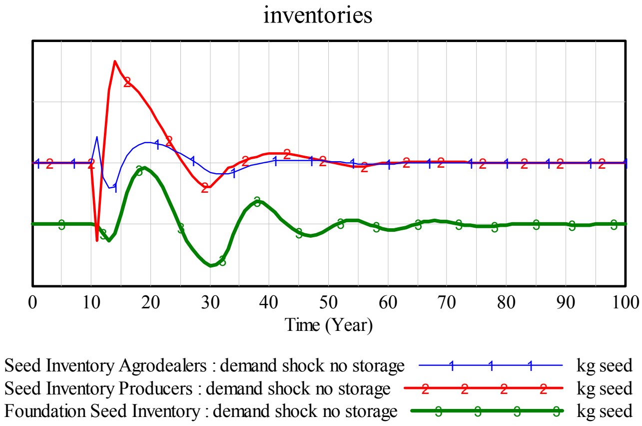


Figure 4 illustrates the behaviour patterns that are generated by such structure for the case of foundation seed producers' inventories (line 3), seed producers' inventories (line 2) and agrodealers' inventories (line 1). For the interpretation of the graph it is important to note several things:

- The underlying simulation model is of conceptual nature. It is not based on empirical data although most of the parameter values and especially the relationships in terms of scales between parameter values and initial values are clearly based on initial field work in Ghana for the case of maize.
- The model is initialized to equilibrium. It therefore does not reproduce or try to reproduce some kind of reference mode of behaviour such as shown in Figure 1. Instead, it highlights the basic dynamics that result from the model structure without any noise created by data trends.
- The model is hit by a pulse increase in farmers' demand for improved seed in the year 10. The pulse increase doubles farmers' demand which can easily happen in times of drought or other cases of drastic meteorological changes.

Figure 4: Reaction of actors' inventories to a pulse increase in seed demand by farmers



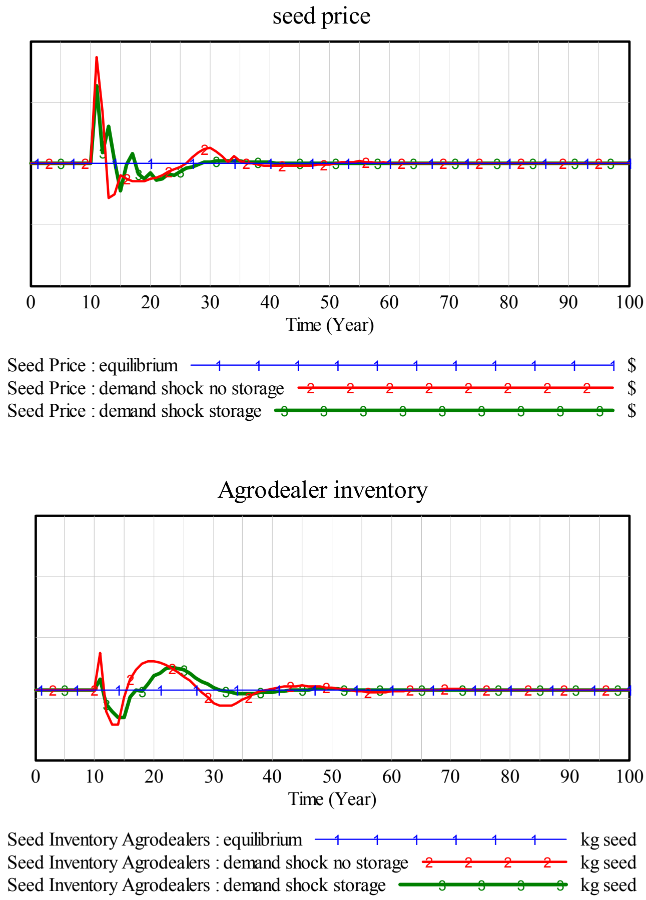
The basic conclusion that can be drawn from Figure 4 is that the seed value chain produces plausible behaviour that is typical for supply chains (see (Sterman 1989)). First, changes in farmers' demand destabilize the system and create oscillations. These oscillations are amplified downstream and there is a clear phase lag between the oscillations for agrodealers, seed producers and foundation seed producers.

While seed producers' and foundation seed producers' inventories drop as a consequence of demand increase the opposite holds true for agrodealers' inventories. The initial increase of these inventories is caused by the fact that there are virtually no delays for shipping seed from seed producers to agrodealers when they need more seed to satisfy farmers' demand. This shipping delay is especially negligible because of the much longer delays involved in producing more foundation seed or seed.

Figure 5 reports on a policy analysis that consists of building storage facilities for foundation seed producers, seed producers and agrodealers. Storage plays an important role for balancing demand oscillations on the market because seed can be retained in times of low demand and put on the market in times of high demand. For this analysis the model is hit with the same pulse demand increase. Contrary to the previous simulation runs we added storage structures to the model so that behaviour with (line 3) and without storage facilities (line 2) can be compared. We report on behaviour patterns in seed price (upper half of Figure 5) and agrodealers' inventories (lower part).

Figure 5 confirms some of the expectations usually tied to storage. The amplitude of oscillations both in seed price and agrodealers' inventories is damped through storage. However, storage introduces some instability to the behaviour by adding minor oscillations to the bigger behaviour pattern. This is especially visible for the seed price. While seed can be stored for a while it depreciates quite quickly after a couple of years and looses its superior characteristics such as higher yield per hectare. Thus it cannot be retained in storage facilities infinitely but has to be sold on the market with a delay of approximately two years.

Figure 5: Reactions of seed price and agrodealers' inventories to a pulse increase in seed demand by farmers with and without storage facilities



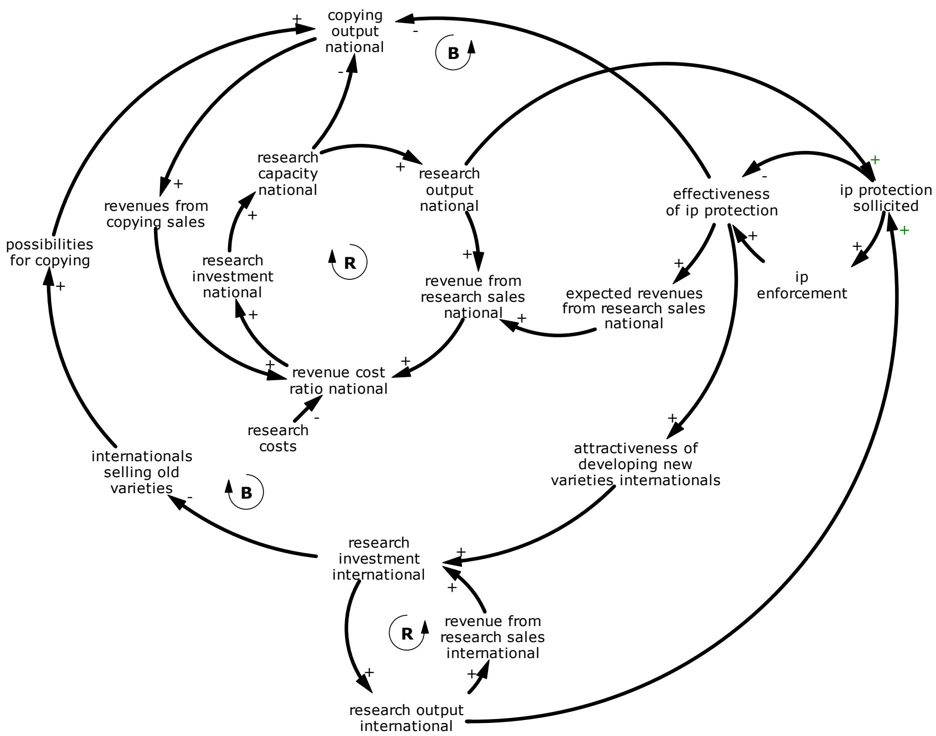
Research sector model

The second simulation model takes a much deeper look at one of the sectors in the seed value chain. It studies the process with which new varieties are generated through research activities by both the national and internationals research institutions (Figure 6). National research institutions refer to public agricultural research institutions and possible (though at least in Ghana not existing) private sector research activities. International research institutions in this context are constituted by multinational seed companies who either decide to produce, distribute and sell existing varieties that they developed for other countries or to invest into country-specific research. Country-specific research means that multinationals either develop new varieties or develop their existing material further by adapting it to the country's specific climatic and cultural conditions. Usually, multinational companies pose the existence of a stable IPR system as a precondition for investment in country-specific research and development to protect their parental lines.

Research, whether done by national or international institutions, depends on available material (germplasm), breeding know-how and breeding infrastructure. These three inputs are summarized into the term research capacity. Research is enabled by investments which depend on the revenue generated by the sales of research outputs (improved varieties).

As long as no intellectual property law is in place or effectively enforced national research institutions have the possibility to copy old varieties sold by multinational companies. Copying also generates revenue that can be further invested into research and thus gradually builds up the capacity to develop own varieties. With the introduction and enforcement of intellectual property law this activity is made more and more impossible in two ways. On the one hand multinational companies shift from selling old varieties to developing their own, country-specific varieties thus depriving the national research institutions of the possibility to copy existing material. On the other hand an effectively implemented intellectual property law punishes copying of existing material. National research institutions thus have to shift their activities from copying to developing their own material.

Figure 6: Causal loop diagram for the interactions between research and intellectual property management



Intellectual property law takes time to become effective. Only over time will intellectual property rights be properly enforced and thus provide stable investment incentives both for national and international research institutions. In our simulation runs we therefore distinguish three different scenarios:

- No intellectual property law. In this scenario intellectual property law is not introduced during the entire time horizon. This implies that the international research institutions restrict themselves to selling old varieties. National research institutions can gradually develop their own research capacity through both copying of old varieties and generation of their own improved varieties.

- Early intellectual property law. In this scenario intellectual property law is introduced to the country in the simulated year 10. During the time before the introduction the same processes occur as in the no intellectual property law scenario. After introduction copying is not possible any longer and multinational companies start investing in country specific research.
- Late intellectual property law. This scenario introduces intellectual property law much later (year 25) to the country than in the early intellectual property law scenario.

As in the case of the aggregated value chain model the research sector model has a number of characteristics that are important for the interpretation of the simulation runs:

- The underlying simulation model is of conceptual nature.
- The model is initialized to equilibrium.
- The model is pushed out of equilibrium by a step technology transfer to national research institutions in the simulated year 5. Such technology transfer can for example be understood as the launch of a seed variety development programme as it was implemented in Ghana in the 1980ies (Morris, Tripp et al. 1999).
- Research capacity is measured in number of new, improved varieties that can be generated per year.

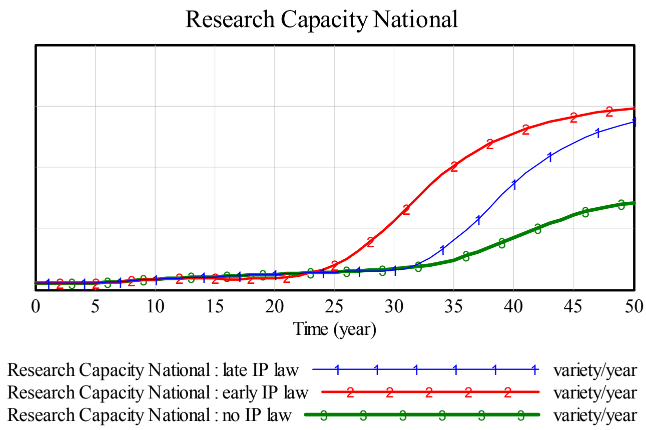
Figure 7 compares the reaction of research capacity for national and international research institutions to the above described three scenarios. In the absence of other forces the graphs show that IP has the potential to trigger some very dynamic development in the research sector.

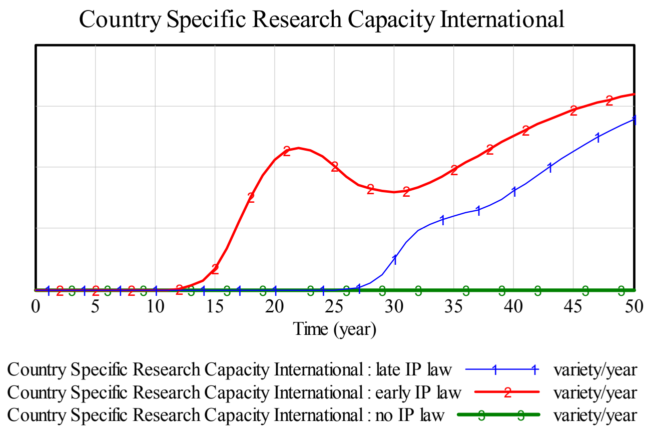
In a scenario without intellectual property laws (line 3) multinational companies restrict themselves to selling old varieties in the country. By copying these varieties national research institutions slowly accumulate research capacity until they are able to develop their own varieties. Starting from this point (around year 35) the accumulation process works much faster as they are able to design locally adapted and differentiated varieties with which they can increase farmers' adoption and thus their own revenue.

The same mechanism can be observed for national research institutions in the two scenarios with intellectual property law. Intellectual property low, however, increases research capacity considerably. It does so because demand uncertainties on the farmer side are reduced and higher revenues are possible. Especially in the early introduction of IP law scenario (line 2) there is a slight tendency towards worse-before-better behaviour for national research capacity. In the initial phase after the introduction of IP law copying is not possible any longer and national research institutions first have to shift their research priorities and build up sufficient capacity for developing their own varieties.

Multinational companies' country specific research capacity starts growing after the introduction of intellectual property law. In the early introduction scenario capacity experiences a notable overshoot which can be explained by the fact that although IP law is implemented, it takes much longer to enforce such law properly (cf. (Pal, Tripp et al. 2007)). After an initial phase with intensive research activities they are slowed down until enforcement is on an appropriate level. This overshooting tendency is much less pronounced in the late introduction scenarios where national research institutions have accumulated more experience with generating their own varieties at the time where IP law is introduced. Because national research institutions are at this point more interested in the proper enforcement of IP law for their own interest the enforcement delay is much shorter than in the early introduction scenario.

Figure 7: Reaction of research capacity to timing of introduction of intellectual property law





Conclusions

The purpose of this paper was to present a methodological framework to assess the impact of intellectual property rights regimes on the emergence of a private seed sector and on agricultural development in developing countries. For this purpose we developed initial simulation models and ran a number of policy analyses. Although the models are currently conceptual in nature and are not calibrated to empirical data about the maize value chain in Ghana they are still grounded in stakeholder interviews and field visits in Ghana. The interviews we conducted suggest that there is local demand for such an overview analysis and the discussions we had about our approach indicated an immediate contribution to the understanding of the entire seed system.

The seed value chain model demonstrated the usefulness of the value chain approach to understand the basic dynamics of private sector emergence. Without an explicit structure that describes farmers' adoption of improved seed this model is currently not capable of explaining the characteristics of the empirical data time series about the adoption of improved maize varieties in Ghana. Issues such as trust and word of mouth will have to be explicitly included in the model.

The research sector model helped understand the basic dynamics of research activities that generate new, improved seed varieties. It illustrated that intellectual property management, in the absence of other framework conditions or processes can substantially boost research. This is not only the case for international research institutions. Instead, national research institutions also benefit from IP protection. The timing of the introduction of intellectual property laws determines the level of research capacity that can eventually be reached. In addition, it affects the transition pattern towards this achievable research capacity as shown in the overshooting tendency in the early introduction scenario. The research sector model illustrates how research capacity of national institutions slowly develops on a rather low level and how capacity can be boosted as a consequence of IP. The model is thus able to provide one possible explanation for the comparatively low number of developed maize varieties in Ghana in the last 20 years.

Working on several models simultaneously has so far proven to be an effective approach for working on a big issue such as the impact of intellectual property management on the seed sector in specific and agricultural development in general. Breaking the whole value chain down into smaller substructures that contain the rest of the value chain in an only very aggregate way creates feasible work steps. An overall model that covers the entire spectrum of actors and processes with a low level of detail, on the other hand, ensures that important cross sector feedback relationships are included. It also studies the basic dynamics that can arise from the overall structure.

A final implication of the modelling work so far is that intellectual property management is feedback richer than might initially be expected. This has, for example, become obvious in the case of solicitation of intellectual property protection and effective enforcement of such protection. Consequently, impact assessment, especially with regard to smallholder farmers, becomes even more difficult.

Reliable impact assessment and decision support for seed sector development in West Africa, in any case, need to be based on simulation models that are more advanced than the ones reported on in this paper. In a first step the currently conceptual models will have to be calibrated to empirical data and to the specificities of the maize sector in Ghana. In order to be able to compare case specific to more generic insights and policy implications the models will also be calibrated to other crops such as rice and other West African countries such as Mali. For concrete policy analysis more details about patent requirements (utility, non-obviousness, and inventive step) will have to be included as well as issues such as disclosure, access to knowledge, innovation, and commercialization.

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