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A classification of “public and private” technologies in agriculture: an introductory framework.

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I. Problem statement

Most of the private investment made in Argentina until the beginning of the 1970's was concentrated on the area of machinery and post-harvest techniques, whereas the public investment was mainly made in such areas as biological innovation, plague control and natural resources. At present, the private sector is developing important capacities in areas previously dominated by the public sector, genetic breeding being the most relevant.

The Argentine government has privatized many public companies over the last years, and it has been controlling and cutting down on the public expenditure of the central administration and decentralized agencies, which in some cases, such as the National Institute of Agricultural Technology (INTA), meant eliminating and/or cutting down very important agricultural research and extension commitments.

This “retreat” on the part of the state -together with the significant advance of the private megacompanies of agricultural inputs, with strong investments in R & D, (i.e. seeds)- has made it necessary to pose some questions, such as the following ones: What kind of research and/or extension work should public institutions carry out in an increasingly private world? Are there public good technologies that private companies are not willing to pursue? How could these “public good” technologies be defined? If so, in what field of research and/or extension?

Could public institutions coordinate their actions with the private sector, or should they reallocate their resources on those research areas where the private sector does not seem to have commercial interest, e.g. basic research?

The last question is closely related to the issue of property rights (Boehlje, 1998). Other authors have also made good comparisons concerning the way the public and private sectors work jointly in the development of new knowledge in plant biotechnology (Theodorakopoulou and Kalaitzandonakes, 1999).

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II. Aims

To develop an introductory framework to classify and analyze the different public/private technologies generated on a public institution-private firms network basis.

III. Procedures

Public institutions are commonly thought to offer only public goods, whereas private companies are generally believed to be mainly “private good” suppliers.

This assumption is **incorrect**, since the nature of goods –whether public or private- is not determined by the kind of institution or company that produces them, but by their intrinsic characteristics in terms of rivalry and excludability. *“The degree of rivalry is a purely technological attribute. Purely rival goods are those precluded from being used by more than one company or person, whereas purely non-rival goods, on the contrary, are by no means confined to being used by only one firm or person. As to excludability, it is a function of both technology and legal systems. A good is excludable if the owner can prevent others from benefiting from its use”*(Traxler,1999).

However, in Demsetz’s words (1970) *there is nothing in the concept of public good that disallows the ability to exclude. Frequently, there is confusion between the concept of public good, such as I understand it, according to which it is possible for additional people to enjoy **the same unit** of a public good at no cost for additional persons to enjoy the same unit of a public good, and a different concept that might be identified as a collective good, which imposes the stronger condition that it is impossible to exclude non purchasers from consuming the good”*.

The **knowledge** -that is theory, basic and applied research, inventions and designs and others which are made available to the society at large.- makes up a public good and is, in general, the main input for the generation of new technology or goods(Liebowit, 2000). This proves so in the case of cutting-edge agricultural technologies, since the cost of generating and applying knowledge generally represents the major portion of production cost. In fact, all intermediate and finished goods are based on **knowledge**. In many cases, knowledge in itself may be separated from its incorporation into specific goods. For instance, the technical stages leading to the attainment of a new variety of transgenic soybean may be commercialized in the “variety market”, irrespective of who will use this knowledge for the production and trading of the transgenic seeds.

Private supply of public goods is possible as long as exclusion makes up a feasible alternative, (e.g. a legal system protecting property rights). So, in order to profit above the opportunity cost, those who produce a certain technology considered to be a public good need a legal system to be protected.

On the other hand, the private production of collective items in those cases where the exclusion cost is very significant does not seem to be feasible. Nevertheless, inferring that collective goods cannot be produced in sufficient amounts by private companies is an extreme conclusion. In many cases the consumption of a collective item can be “tied” to the consumption of a second one, and then incentives for private production are likely to appear (Demsetz,

1970). TV and radio shows can be cited as examples of this case. No one can be precluded from consuming them -furthermore, there is no rivalry among consumers; nevertheless there are at least two groups involved in the program broadcast: advertisers and producers of TV and radio sets.

In agriculture, an example of that can be found in the extension work involving certain agricultural technologies aimed at improving productivity or lowering the plowing cost (for instance direct drill), which on many occasions are carried out by private firms -despite the fact that this type of technology makes up a public good-, since the spread of them is linked to the trade of transgenic seeds and certain agrochemical products (ej Glyphosate).

A proposal to classify public and private technologies

A four-cell matrix are usually used to classify goods in terms of their rivalry and excludability. This sort of classification categorizes goods as follows:

- Public goods: Absence of rivalry in terms of consumption – Absence of excludability among consumers.
- Private goods: Existence of rivalry in terms of consumption – Existence of excludability among consumers.
- Semipublic goods: Existence of rivalry in terms of consumption – Absence of excludability among consumers.
- Semiprivate goods: Absence of rivalry in terms of consumption – Existence of excludability among consumers.

In this paper, however, we propose a classification of “private and public technology” which consists of six combinations and incorporates two more categories (Table 1):

- Semiprivate/public goods: non rivalry in consumption, with excludability among consumers at the first sale, however, with non excludability later on if the good could be duplicated at low cost.
- Private/Semi-public good: rivalry in consumption, with excludability among consumers at the beginning, however non excludability later on.

The “pure knowledge” of a new soybean variety, for example, without property rights is a public good technology (Cell 01). In this case, the market demand is the *vertical sum* of the demand of all users of such technology. For such a variety it is possible to know the price that each individual would be ready to pay. If we add of all these prices it possible to determine the total amount that the market is ready to pay for such “public technology”.

This variety arises from the combination of basic agricultural and applied sciences. Within the former we could mention: a) ecophysiology of crops (i.e. the determination of Maturity Groups in soybean) and b) genetic breeding (i.e. obtaining soybean varieties with high yield per hectare, growth cycles and types adapted to specific management situations, rich in proteins and oil ,and disease resistant).

Table 1. A classification of Public and Private technologies

	<u>NON EXCLUDABILITY</u>	<u>INCOMPLETE EXCLUDABILITY</u>	<u>EXCLUDABILITY</u>
NON RIVAL IN CONSUMPTION	Cell 1. <u>Public Goods</u> Varieties without property rights Soybean basic research: Ecophysiology; genetic improvement, etc. Applied research in soybean Germplasm Bank Open Extension System	Cell 2. <u>Semi -Private/Public Goods</u> Closed grupal extensión(INTA) CREA Groups(private firms)	Cell 3. <u>Semi-Private Goods</u> Registered varieties: transgenic soybeans and Open polinization (in case of wheat) Registered Hybrids(corn and sunflower)
RIVAL IN CONSUMPTION	Cell 4. <u>Semi - Public Goods</u> Underground irrigation water.	Cell 5 <u>Private/Semi- Public Goods</u> Soybean transgenic seeds in Argentina. Wheat seed .	Cell 6. <u>Private Goods</u> Soybean transgenic seeds in the US. Hybrid seeds (i. e.. Corn and Sunflower)

Source: own elaboration.

Within the applied sciences we find: choice of varieties, crop management, use of water resources and irrigation systems, laboring and crop sequences, weed control, etc. (Giorda y Bai-gorri, 1997).

In the extension field, any open extension of agricultural practices related with crops is also considered a public-good technology (i.e. Direct drill), since its utilization is feasible for all and there is no rivalry.

When the new variety has a **property right** (cell 03), it is then feasible to exclude some of the potential users and it is considered as semi-private good-technology. According to Table 1, in the case of the seed (cell 06) that have “incorporated” a new soybean variety, its market demand is simply the horizontal sum of individual demands. Seeds have the characteristics of private technology: utilization is rival and excluding. So, it is important to differentiate between **variety and seed**: variety is the production of applied genetic knowledge that originates in the work of breeders. Seed is an agricultural input that “incorporates” said technology and can be produced by the breeder or by multipliers.

Transgenic soybean in the United States is a private-good technology since there is a legal protection system for property rights and farmers are required to buy original seeds every year (Cell 06). In Argentina, however, it is a private/semi-public technology (Cell 05) since farmers can multiply the seed without buying the original seed. The Argentine Association for the Protection of Vegetal Breeders (ARPOV) estimated that in the 1999 season, 40% of the seeds were acquired illegally (Clarín journal, 04/01/2000). This does not necessarily imply low profit for the breeder but a loss of income that could be obtained should there be a legal protection system in place.

An agricultural extension system that may disseminate new technology may, in principle, exclude some users through closed learning groups. But it would be impossible to make future exclusions since the techniques taught to the first groups can be easily disseminated to other farmers (Cell 02).

Finally, an example of semi-public good technologies is the utilization of underground water for irrigation purposes. There is rivalry among users that cannot be excluded (Cell 04). If the state charged a cannon for the use of water, this technology would be a private one (Cell 06).

The classification of the different kinds of technology which appears on Table 1 facilitates the analysis of the possible complementation or competition between the public and private sectors in the generation and/or diffusion of agricultural technologies. Such classification, moreover makes it possible to determine the presence of “market failures” with respect to the private supply of technologies. The following are some examples of such “market failures” related to research and technologies:

- Asymmetries: small and medium farmers/processors who are out of the international circuit of information about technologies.
- Negative externalities, i.e. the impact of chemicals on the environment.
- Absence of supply of “public goods”, i.e. certain products or technologies which private companies are not interested in producing them by reason of low profitability,

- Formation of oligopolies: companies dealing in private research, agrochemical products, feed, and food are merging more and more, which may give rise to future oligopoly power.

Below are discussed some cases where interaction between the public and private sectors appears feasible.

Case 1: Complementation of the public and private sectors' activity

Taking into account what was discussed above, let us consider the case of a private breeder that sells a new variety of soybean to a multiplier—either a private company or a public institution involved in research and extension. In this case, the multiplier's business simply consists in multiplying the seeds, even though the public institution could also run research programs (i.e. soybean genetic). The multiplier may indeed exercise its property rights through a license therefore having a legal monopoly of the market of such a seed.

Traditional economic analysis tells us that this monopolist will determine the optimal production level by producing up to the point where marginal cost and marginal income are equaled and by verifying that at this break even point the benefit of the monopoly is higher than or equal to the royalty paid. If so, the multiplier will have enough incentive to purchase the rights; otherwise, the company will offer nothing, since the total cost is higher than the potential benefit.

Seed production under conditions of monopoly means that the amounts sold will be lower (and the prices higher) than considered optimum in social terms. Nevertheless, it is precisely this situation that encourages production, since should there not be monopoly-type profit there would be no economic incentive for the breeders because of the large scientific and technical investment that the generation of new varieties demands. In such a situation multipliers would be working in conditions of perfect competition -or monopolistic competition- where the individual profits of each company would be lower, which would in turn be reflected backwards in the reservation price they would be willing to pay for royalties on the varieties.

If the breeder gets a lump sum payment for each license sold, the highest price obtained would not be the price paid by each consumer of seeds, but it would be the total income -net of the seed multiplication costs- provided that the seed multipliers get a normal return for the investment that is included in the cost.

The following question could arise: If the multiplier gets a quasi-rent, then why does the breeder not take up seed multiplication? That decision will depend on the transaction costs that the vertical integration process may entail, as well as on the seed market size. If the market is small, the high costs of research and development for the breeder may not allow for the addition of new costs for the production of seeds, including market distribution. In this case, it would be advisable for the breeder to partner with independent multipliers.

In summary, a private breeder may partner with:

- a) Farmers -for multiplication of seeds- or with farmers organizations for commercialization, or,
- b) Public institutions of research and extension, such as I.N.T.A. in Argentina. An example of the relation between public research and private activity is the research and marketing agreement between I.N.T.A., the Argentine Agrarian Federation (FAA), one of the farmer unions, and the Federated Argentine Farmers (AFA). According to this agreement I.N.T.A. runs the research on cultivars, charging the FAA a royalty for its work on genetic breeding, whereas both private entities deal with the commercialization.

Another good example of this kind of partnership is made up by the agreement between I.N.T.A, Monsanto, the FAA and the AFA, according to which Monsanto introduced four transgenic soybean varieties from the States, I.N.T.A. dealt with adapting such varieties in its experimental stations for two years and the unions were in charge of the commercialization process. The varieties achieved were registered under the provisions of Argentine Seed Law.

Nevertheless, the characteristics of these partnerships varies according to whether the partners are farmers or a public institution of research and extension. In the first case, the farmers do their economic and financial business, the seed multiplication being part of their total income, and the breeder carries out the supervision and technical analysis of multiplication itself. In the second case, a public institution of research may or may not want to multiply and commercialize the seeds, but it is likely to be interested in offering the breeder its technical service concerning the analysis of the seed adaptation to the different regions of the country .

Case 2: Concurrence between the public and private sectors

In the preceding case we pointed out that when the seed production is controlled by monopolists the market price is fixed at a level above which is considered optimum in social terms. However, there exists the possibility of increasing the level of production through the generation of new seed varieties on the part of the public sector. It should be taken into account that public institutions are enabled to generate private technology. Although in such case the objective of increasing the whole production is achieved, there will surely be a decrease in the level of the private sector's participation. The public and private sectors compete with each other. Then, it is obvious that, given the lack of information on individual and market demand, the cost-benefit outcome may be ambiguous in social terms.

Whether or not the public sector should compete in the area of genetic technology generation and dissemination has to do with a political decision. However, it is important for a society to have a germplasm bank available to all researchers like some sort of library, especially when it comes to food and medicines, where science is making breakthroughs. Although a variety (cell 03) may be protected by law, the specific knowledge that generated it will be available to society only fifteen or twenty years after being registered (cell 01), which means a long time, especially at present.

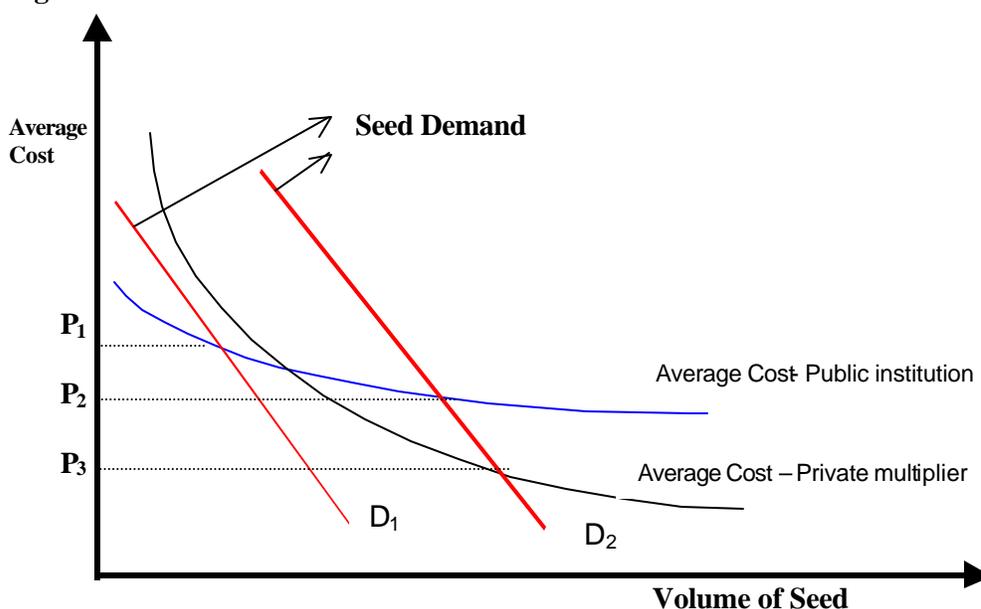
Furthermore, there should be rules which protect private activity so that this should be able to get profitability in accordance with the high investments made. So, how to solve this conflict? The government should do research on basic genetics and could also compete with the private sector. The varieties created by both sectors will be legally protected, though those

generated by state institutions could, if necessary, be incorporated to the list of public technologies (cell 01) .

There is a case, however, where the private sector is likely not to be able to compete with the state. Let us think of a public institution which does not specialize in the research/diffusion of any specific crop, e.g. soybean; that is, it works on several species at a time. This institution, moreover, has several experimental stations in different regions of the country, as well as laboratories, experimental farms, research staff, etc.. If the soybean market is small, the average costs of research and multiplication of this institution are likely to be lower than those of a private company with high technological standards that specializes in certain crops. For the latter the necessary investments will mean a higher number of tests in different areas with different environmental characteristics, involving more specialists, etc.. As a result, the specialized company will have higher average costs of production when the volume of production is low, since it is not possible to dilute the initial overhead costs in the same way as in the case of a public institution . (Fig. 1).

Generally speaking, companies that specialize in certain activities can profit from economies of scale, which makes it possible for them to operate with lower unit costs. Such economies of scale is a result of the fact that the investment in specialization basically makes up an initial sunk cost. This reasoning assumes that the specialized firm makes the necessary investment and produces large volumes. This possibility is shown in fig. 1, where D_2 (demand generated by economic growth, development of new crop areas, etc.) allows the rise of specialized production. When the price is equal to P_3 , the average costs of the private companies will be lower than those of the public institution.

Figure 1



In the case of autogamous seed production (wheat, soybean) the characteristics of incomplete excludability can, moreover, determine a smaller-sized market which restrains specialization. In such cases the public sector can play at least two possible roles. On the one hand, it could produce more differentiated seeds in order to enter a segment of the market where the private sector does not compete. This could mean, of course, selling at a price which is lower than the unit cost, a situation justifiable by non-strictly-economic reasons, such as achieving equitable distribution and social considerations. On the other hand, the public sector could introduce institutional changes for encouraging a higher degree of exclusion, e.g. an improvement in the mechanisms which allow breeders effectively exercise their property rights.

Case 3: Private production of public goods (not involving rivalry and excludability)

In many cases the consumption of a private good can be “tied” to that of a public one. Consequently, there may be private incentives which encourage the production of the “tied” good, since exclusion is possible. Cases of research in agricultural technology and extension (non-rival/nonexcludable ones) can be found in the agricultural sector. For instance, research and diffusion of direct drill makes up a case where the private sector takes part actively. The research done on this technique -as well as its diffusion- is essentially a nonexcludable public good (Cells 01 or 02 in Table 1). However, the more farmers adopt it the more the consumption of certain agrochemical products –such as glyphosate- elaborated by the same companies that do research on transgenic soybean varieties and seeds (combination of Cells 01 or 02 with cell 06). So, the use of public technologies is “tied” to the use of private ones –and to the use of private inputs.

In Argentina, many private companies sign up cooperation agreements with institutions which are linked to extension technologies. For instance, the Argentine Association of Direct Drill Farmers (AAPRESID) organizes congresses, which are sponsored by Dekalb, Monsanto, etc.. Moreover, I.N.T.A. and some universities are running direct drill research programs that farmers then incorporate to their production methods. Another private institution, the Agricultural Experimentation Regional Consortia (AACREA) has celebrated agreements with I.N.T.A. and private companies to work on specific projects of research and extension.

Of course, attaching technologies to make it possible to bring together the public and private sectors does not guarantee by itself an optimum supply in terms of volume. The determination of efficient supplies exceeds the purpose of this paper; however, it is clear that the cooperation between both sectors in this matter is feasible.

Case 4: Incomplete exclusion owing to the ease of duplication: autogamous species seeds (wheat, soybean)

Autogamous or open-pollination seeds can be multiplied by users and this cannot be avoided by breeders. Original multipliers sell a certain volume of “authorized” seed, and then unauthorized duplications are made (Cell 05). This means that the breeder of a variety cannot receive the whole potential income from the sale of such a variety, which would determine a lack of economic incentives for private technological innovation.

However, even in the absence of the possibility of full exclusion, multipliers can still get income for the use of their products. For instance, it could be thought that the fact of being the first to introduce a seed in the market enables the breeder to catch a significant part of the potential benefit. The introduction of a new seed and its diffusion will mean for its breeder an important initial volume of sales; moreover, it might take unauthorized users some time before they are able to deteriorate this monopoly position in the market.

Another potential way in which original multipliers can seize benefits is by indirectly appropriating the payments made by users who purchase unauthorized duplicated seeds. Those farmers who make unauthorized multiplication of seeds could indirectly pay the breeder if the multiplier that buy authorized duplicated seeds, took into account the resale value when they buy the original seed.

At this point, some problems are likely to arise. The power of indirect appropriation may become weakened when different numbers of copies out of each original are made. Breeders have difficulty in appropriating duplicator's benefit when duplications are made only out of some original varieties, since this alters their relative value. In such cases, the breeder should have some way to detect those users who are likely to duplicate the originals and those who are unlikely to do so. If the breeder is unable to discriminate prices, the price of all original seeds should be increased, since they are potentially duplicable. Consequently, only those who really intend to duplicate the seeds will buy them.

Another alternative consists in lowering the price in order to sell larger amounts. So, the seed will be bought by both kinds of users, which will mean a lesser appropriation of the economic surplus by those users who intend to duplicate the seeds.

Let us imagine an extreme situation where there are only individuals who want to make unauthorized duplication. If the monopolist appropriation of income originated in the introduction of the variety were reduced, then the possibility of getting benefits on the part of private producers would be almost non-existent. This case does not seem to be a very usual one, since, for instance in Argentina the development of wheat varieties was led by only one private company -Klein- in spite of the ease of duplication and of a legal context which made it difficult to exert property rights.

This suggests -even though there is no detailed empirical evidence- that the benefits proceeding from the introduction and sale of the variety along with the possibility of indirectly appropriating the unauthorized duplicator's surplus probably constitute enough incentives for the development of the private sector in this area.

IV. Concluding comments.

It is generally accepted that, at present, the public sector should devote most of its resources to the study of basic agricultural sciences, whereas the private activity should devote its efforts to the application of knowledge in the development of products. The relationship between both sectors would be given through a “natural” complementation between these two research areas in a unidirectional manner, either from basic sciences to applied sciences or viceversa, from applied sciences (the world of “business”) to basic sciences.

Although in many cases this is true, the public/private relationship is much more complex than a simple lineal relationship. However, this relationship acquires a much greater potential when seen from the angle of the complementarities between both sectors: a private good, generated by a private company may have a much broader market if it is “tied” to a public good. In fact, the latter acts as an ally rather than like an enemy. For example, the case of glyphosate and transgenic soybean (both private goods) and direct drill (public good).

Likewise, private breeders of new varieties could improve their marketing strategies if they related with a public system of agricultural extension. Regional extensionists have valuable technical information on farms but also, and this is the most relevant part, they are acquainted with the production systems and the idiosyncrasy of farmers. Genetic tests are usually done in plots but in fact farmers work with a production system.

The public sector is qualified to compete with the private sector in the field of genetics. With a patent law to protect both sectors, the government can, a) cause a drop in the real price of seeds; b) guarantee the availability of genetic “public knowledge” to be used at any time to obtain new varieties offering better quality and higher yield per hectare, or else containing genes that could be utilized for the treatment of human diseases. In this way the government would stimulate competition in this research area to the benefit of society as a whole.

If the size of the seed market is small, then the public sector is likely to have the exclusiveness in the generation of varieties since for a private breeder it may not be profitable to enter this business. On the other hand, the greater the market, the greater will be the cost advantage to the private breeder in connection with the public sector, unless the latter is constantly updated.

The key areas to be considered in order to create a successful relationship between the public and the private sectors in the area of research/agricultural extension would be, a) a law to provide for legal protection of the varieties obtained by both sectors, b) an efficient public research/extension system (with researchers of excellent level and “high” salaries) since no private sector will be willing to partner with a public institution without sufficient human and financial resources which, as such, is not prepared to act as a counterpart in the long term research, and c) a funding system for the public sector to determine **who** covers the research expenditures: consumers and/or agroindustries and/or private breeders.

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