Economic impact of farming innovations: Arbitration between hybrid and inbred line in the seed sector

Innovations concerning crop seeds essentially stem from private research. Seed companies may appropriate a larger part of the economic profits from innovation by choosing to create hybrid seeds rather than inbred line seeds. Yet this technological choice also has an impact in terms of efficiency since production costs differ according to the type of seed. This text surveys research work in which we show that, from an economic viewpoint, in some cases, firms’ technological choices may entail a loss. We also show that this loss is reduced by implementing a tax on on-farm-produced seeds from inbred-line seeds, like the “contribution volontaire obligatoire” (compulsory voluntary contribution) (CVC) in the case of wheat in France.

Introduction

The competitive advantage of the firms in the seed sector mainly depends on the technological innovations they develop and incorporate into new seed varieties. For various reasons, these technical changes may give rise to controversies. Particularly, as far as economics are concerned, controversies are about the idea that, in the first place, certain technical choices are made to increase seed companies’ profit at the expense of farmers.

For instance, this is the issue in the case of hybrid seeds. At each year, the farmer who uses that type of seed must buy it again. Conversely, with the other main type of seeds (inbred line seeds), the farmer may produce his seeds from his own crop. It is understandable that the seed company’s interest is to switch from inbred line seeds to hybrid seeds to extract a larger part of the profits linked to innovation. However, these technologies also have an impact on production costs. Hybrid seed production implies additional production operations (for instance, maize castration), which increase production costs.

We analyse the seed company’s interest in switching from inbred line seeds to hybrid seeds, and the impact of this switch on collective surplus. How is it that a seed company may have a stake in switching to hybrid seeds even if these are more expensive to produce? Are there cases when surplus would be higher with inbred line seeds than with hybrid seeds? Are there any economic tools, which would prevent such a situation?

Firstly, we present the different ways of appropriating the benefits implemented for major crop seeds. Then we present the main results of a normative analysis, the purpose of which is to examine the conditions in which switching to hybrid seeds is favourable from a social point of view. In the conclusion, we debate the potential enlargement of this type of analysis to other types of technological change, in particular GMO.

Ways of appropriating benefits linked to seed sector innovation

In France, seed sector innovations are protected by the Plant Breeder’s Rights (PBR). This is an intellectual property right (IPR) which, like a patent, grants the plant breeder exclusive marketing rights to a new variety of seed. PBR have two particularities, which differentiate it from patents. The first is the exemption for research: it allows any agent to use the variety protected by PBR as a vegetal material source in their research program. The second particularity, which is important for our purpose, is the farmer’s privilege: it allows every farmer to self-produce seeds from the previous year’s crop, as long as these seeds are used inside the farm.

Beyond the general PBR framework, which applies to all crops, there are some restrictions on the farmer’s privilege, these restrictions being partial or complete, and different according to crops.

The first restriction is of a technical nature. Seed producers may develop various types of seeds, the quality of which may deteriorate from one year to the next when they are self-produced by farmers. For instance, this phenomenon happens with hybrid varieties. These varieties stem from two different parents. The complementarities between both parents give a better hybrid than the better of the two parents but this advantage disappears when hybrid seed is self-pollinated. The farmer who has hybrid seed without parents cannot produce such a good seed as hybrid seed.

Hybrid seeds were developed with success for several species, the biology of which could be fairly well adapted to
this type of genetic engineering. Table 1 shows the present situation for five main species cultivated in France. The first hybrid maize was developed in the United States in the 1930s and spread in France in the 1950s and 1960s. Hybrid sunflowers were released in the seventies. Nowadays, all maize and sunflower varieties are hybrid and all farmers buy their seeds. In this case, the farmer’s privilege restriction is complete.

Straw cereals (wheat, barley) do not lend themselves easily to the manufacture of hybrids. Since the 1980s, several seed producers have tried to develop wheat hybrids but the release of such varieties has never been very large-scale because they do not offer very significant benefits. In the case of barley, certain hybrid varieties were developed in recent years, but not enough time has elapsed to assess their impact. The share of hybrid seeds in straw cereals is insignificant. A large share of the straw cereal area is sown with on-farm-produced seeds (20% of barley, and more than 40% of wheat).

The case of rapeseed is intermediate. Various hybrid types have been developed since the middle of the 1990s and are now used on one third of the area. This proportion has remained relatively stable over the past few years. The share of on-farm-produced seeds in the rest of the areas sown with inbred line varieties is equivalent to what was observed for wheat and barley.

The second restriction is of an economic nature. Article 14 of European directive 2100/94 related to PBR stipulates that farmers self-producing their seeds (except for small farms) are compelled to pay a fair fee to seed producers. Nevertheless, this measure requires the implementation of a specific device to collect that fee. Since 2001, this device has only been implemented for soft wheat in France, on the initiative of SICASOV (a French seed producers’ cooperative). At cropping, a tax called “contribution volontaire obligatoire” (compulsory voluntary contribution (CVC)) of 0.5 €/ton is collected over the whole production, that is to say less than 5 €/ton for CVC, to be compared with the royalties paid by farmers buying seeds at more than 10 €/ha. The CVC is repaid to farmers who buy seeds. Most of the tax (85%) is transferred to seed producers, representing average additional income of 6 millions Euros/year over the past five seasons, that is to say 20% additional income compared to royalties.

To sum up, the appropriation allowed by intellectual property rights in the seed sector is incomplete, in particular, because farmers can self-produce seeds. Two additional means of appropriation were developed by seed producers: the development of hybrid varieties (maize, sunflower, and rapeseed) and the deduction of a tax on on-farm produced seeds (soft wheat in France).

Is switching from inbred line seeds to hybrid seeds optimal from a social point of view?

The analysis

Our analysis relies on a dynamic microeconomic sales model for durable goods. In fact, unlike hybrid seeds, inbred-line seed genetic traits are durable. Farmers may use inbred-line seed genetic properties (yield potential, resistance to illness, grain quality) more than one season by producing their own seeds.

This research work is part of a vast economic literature on price fixing of durable goods. However, the seed case presents two main specificities. First of all, unlike a standard durable good (e.g. a book), farmers must support a self-production cost to make the good durable. This cost can be compared to a maintenance cost, which exists other durable goods (e.g. a car). In addition, PBR do not allow farmers to market self-produced seeds: there is no second-hand market for inbred line seeds, contrary to what often exists for durable goods.

In our model, a monopolist seed producer sells seeds (hybrid or inbred line seeds) to farmers over two periods. In the first period, farmers may self-produce inbred line seeds for the second period. The other main characteristics are presented in the frame below. We make two determining assumptions on production costs, which need to be justified.

Inbred-line self-production by farmers is a source of inefficiency. This inefficiency is taken into account in the model by assuming that farmers have higher inbred line self-production costs than monopolists. Several arguments justify this assumption: (i) monopolists produce higher quantities and thus benefit from production economies of scale in the operations of seed sorting and treatment. (ii) Generally, on-farm produced seed quality is lower than that of seed producers, which can lead to yield loss. (iii) Finally, farmers may have a tendency to underestimate the cost of time spent to produce seed, so may choose to self-produce even if this entails a real loss.

For different reasons, for monopolists, hybrid production costs are higher than inbred-line: (i) production yield is lower because it concerns parental line yield and rows are only partly cropped. (ii) The parental line, which acts as a mother, must not produce any pollen, which generally requires additional castration costs.

To sum up, there is a potential efficiency loss with each type of seed. With inbred-line seeds, farmers’ self-production costs are higher than that of monopolists. With hybrid seeds, monopolist seed production-costs are higher than that of inbred line production.

Key results

There are different potential pricing strategies when monopolists choose to sell inbred-line seeds.

The first strategy consists in selling seeds as non-durable goods. Everything happens as if monopolists maximized their profit independently each of the two periods without taking into account of the goods’ durable characteristics. In the second period, the monopolist’s profit is lower compared to the first period because farmers can decide whether they buy seeds or self-produce them. The lower the self-production costs, the lower the monopolist’s profit is in the second period.

The second strategy consists in selling seeds as durable goods. Monopolists decide prices to maximize overall profit over both periods. They anticipate that farmers who have
low self-production costs are willing to pay a high price to purchase seeds in the first period, because these seeds will allow them to make a profit over several years. Unlike in first strategy, in the second period, monopolists do not try to compete with farmers by selling them seeds. The lower the self-production cost, the higher the monopolist can sell seeds in the first period and, thus, make a big profit. Ultimately, the monopolist always prefers the second strategy to the first.

The third strategy is a variation on the second one and consists in selling seeds at a different price in the second period, depending on whether or not the farmer purchased seeds in the first period. This strategy allows them both to charge high prices during the first period (like in the second strategy), and make sales and profit in the second period (like in the first strategy). Indeed, farmers are ready to pay a high price for their seeds in the first period if they know that, in return, they will get a seed price discount in the second period. Monopolists always prefer this strategy to both previous ones. Nevertheless, it presupposes a reliable check that farmers did buy seeds in the first period.

When monopolists choose to sell hybrid seeds, they fix the same price in both periods. Indeed, since self-production is not possible, seed demand is the same in both periods, leading to identical prices and profits in each period. To simplify the analysis and without losing any general characteristics, model assumptions are such that the monopolist keeps the entire economic surplus.

Now we can analyse the farmer’s choice for seed type and the consequences of this choice on the total surplus. We shall rely on figure 1 to do so.

This figure shows the monopolist’s profit or total surplus according to hybrid production cost. With inbred-line seeds, these profits or surplus are horizontal lines because they do not depend on hybrid seed cost any more. Remember that self-production is a source of inefficiency because inbred-line self-production costs are higher than monopolists’ production costs. Since there is always a proportion of farmers who self-produce when monopolists choose their optimal strategy, the total surplus at equilibrium \((W_L)\) is always lower than the maximum surplus that would be generated if there were no self-production \((W_{LMAX})\). Moreover, the farmers’ net profit is always positive at equilibrium so the monopolist’s profit \((B_L)\) is always lower than the total surplus \((W_L)\). With hybrid seeds, the monopolist’s profit \((B_H)\) is equal to the total surplus. These two values decrease with hybrid seed production cost. The more we shift to the right side of figure 1, the greater the efficiency loss linked to hybrids.

We now analyse the consequences of the monopolist’s seed choice on total surplus. The seed producer chooses the seed providing the best profit: hybrid seed if \((B_H)\) is higher than \((B_L)\) (areas A and B) and otherwise, inbred line seed (area C). In area A, hybrid seed may bring about a loss of efficiency \((W_{H} - W_{LMAX}\) if hybrid seed cost is high enough), but this loss is always lower than the efficiency loss linked to inbred-line self-production. \((W_{LMAX} - W_L)\). Hybrid technology is the best, both from the monopolistic and collective points of view. The opposite phenomenon exists in area B: the efficiency loss linked to hybrid costs is greater than the one from inbred-line self-production. From the monopolists’ point of view, hybrid technology is the best because it allows them to limit the profit released to farmers but, from a collective point of view, it is the least favourable. Finally, in area C, hybrid seed cost is such that monopolists prefer inbred line seed which, from a collective point of view, is the best choice.

To sum up, whatever the strategy adopted by monopolists to sell inbred line seeds, they cannot obtain as large a share of the total surplus as that obtained from hybrid seeds. From an economic point of view, there is always a value-area of hybrid production costs where monopolists’ choice of seed type involves a loss.

What results from the introduction of a fee on on-farm self-produced seeds like PBR? Tax discourages self-production. It cuts farmers’ earnings. Since it is paid back to producers, this reduction benefits monopolies. It improves global efficiency because losses linked to self-production costs are lower. Referring to figure 1, curves \(B_L\) and \(W_L\) shift upwards. Compensating losses, due to the durable nature of inbred-line seeds, makes hybrid-seeds strategy less attractive. This reduces the inefficient introduction area (area B) of hybrid seeds.

Conclusion

In this paper, we have analysed the reasons why a seed producer may prefer hybrid seeds to inbred-line seeds, and the impact of this choice on collective surplus. We have shown that there are situations where seed producers prefer hybrid seeds although this technology is the least efficient in terms of seed production costs. We have also shown that tax can limit these situations, but with a transfer of profit from farmers to seed producers.

Other types of technological changes cause a similar phenomenon to the case studied here. Two recent examples relating to GMO may be mentioned. The first concerns GMO inbred line seeds (e.g. rapeseed or soybean tolerant to weed-killers). In North America, the GMO characteristic is patent-protected, allowing seed companies to restrict the farmer’s privilege. In concrete terms, in the case of Glyphosate, when farmers buy GMO seeds, they sign up with Monsanto (the patent holder) a license contract in which they commit not to reuse their seeds. GMO inbred line seeds have the same properties as hybrid seeds in the previous analysis. The other example concerns the restrictive use of genetic technologies (“Genetic Use Restriction Technology” or GURT) which allows play with the activation of certain genes, and in particular, those relating to fertility. Such technologies could be used to make farmers’ sterile self-produced seeds, which would prohibit all practice of the farmers’ privilege.

It is important to emphasize the limits of this analytical framework. Not taking into account the efficiency loss linked to the exercise of monopolies’ power is the first one. In fact, in our analysis price fluctuations in hybrid seeds have no effect on demand, so they only bring about a profit transfer from farmers to monopolists without modifying the total surplus. It would be more realistic to presuppose that the power of monopolies, which is greater with hybrid seeds, causes a surplus loss due to a more restricted
dissemination of the innovation. Not considering the R&D stage is the second major limit. Better profit appropriation with hybrid seeds is an incentive, which certainly leads to an increase in research investment and thus to an increase in performance gaps between both seed types. Removing these two restrictions is part of our research programme.

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For further information


Frame:

Two types of seeds may be sold by the monopolist: inbred-line seed \((L)\) and hybrid seed \((H)\). The farmers’ gross profit with each type of seed is \(\Pi_L\) and \(\Pi_H\) (identical value for all farmers, \(\Pi_H \geq \Pi_L\)). The production cost of the monopoly is nil for inbred-line seed and \(c\) for hybrid seed \((c > 0)\). Farmers may self-produce inbred-line seed with a marginal production cost equal to \(\theta\), \(\theta\) being between 0 and a maximum limit. Farmers’ gross profit with inbred-line seed is the same, whether seed was bought or self-produced. The potential loss in yield linked to self-production is implicitly incorporated into the self-production cost \(\theta\).

At the first period, all farmers must buy the seed. At the second period, each farmer may self-produce seed if he used an inbred line seed the first year. The model resolution consists in defining the monopolist’s optimal strategy, that is to say the best type of seed and, for a given seed, the best prices for both periods.

With the inbred line seed, as the monopolist’s production cost is lower than the farmers’ self-production cost, surplus is maximal if none of the farmers self-produces. To be more precise, the maximum surplus on both periods is \(W_{LMAX} = 2\Pi_L\). At the equilibrium, the monopolist’s price in the second period is always higher than the marginal cost, so that the farmers, for who \(\theta\) is close to 0 prefer to self-produce. At equilibrium, surplus is quoted \(W_{LMAX}\). Therefore, the \(W_{LMAX} - W_L\) differential corresponds to the total cost of farmers who prefer to self-produce. Some farmers have a net positive profit at equilibrium. Consequently, the monopolist’s profit (quoted \(B_L\)) is lower than surplus \((W_L)\), the differential between them being the net profit made by farmers.

If a monopoly sells a hybrid seed, the optimal price is \(\Pi_H\) in each period. The farmers’ net profit is nil. The monopolist’s profit over both periods \((B_H)\) is equal to the whole surplus \((W_H)\). More precisely, \(W_H = B_H = 2(\Pi_H - c)\). This level of surplus is the maximum level which can be reached with a hybrid seed.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area (Mha)</th>
<th>Part of purchased seeds</th>
<th>Part of hybrid seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>5.2</td>
<td>58%</td>
<td>2%</td>
</tr>
<tr>
<td>Maize</td>
<td>3.2</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Barley</td>
<td>1.6</td>
<td>80%</td>
<td>0%</td>
</tr>
<tr>
<td>Canola</td>
<td>1.2</td>
<td>75%</td>
<td>31%</td>
</tr>
<tr>
<td>Sunflower</td>
<td>0.6</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Semences et Progrès (n° 123, 124 and 125)
Figure 1. Monopoly benefit according to hybrid-seed production cost