Multimarket goods and product line competition in the pesticide industry

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Introduction

In numerous industries, firms are competing on several markets with a certain range of products. Each firm can choose to diversify its product line by developing targeted products for each market or, conversely, it can restraint its product line by choosing designing a good that can be sold on several markets. Take the pesticide industry as an example. As for the pharmaceutical drugs, products are based on active ingredients that are efficient on a certain range of pests on different crops. After creating a new active ingredient, a firm can choose to embed it in one commercial product that can possibly be used on several crops or to embed it in different products, with different composition, each of them being more efficient to control the pests on some given crop.

This article analyses the product line competition between several firms in a theoretical model that allows firms to combine specialized and multimarket products. The former type of good is assumed to be more efficient that the second but it is limited to be sold on only one market. We consider both a static and a dynamic product line competition. In the dynamic setting, one firm chooses its product line before the other because it owns a property right that delays the entry of competing products, and makes monopoly profits during one period, before entry occurs. The properties from the theoretical model are confronted to data from the French pesticide industry.

Two main tradeoffs are central in our economic analysis. First, there is a fixed cost for the introduction of each new product. However, a larger range of products can be beneficial because targeted products are technically more efficient than the multimarket product, and also because selling several products enables to price discriminate among consumers. Hence the product line strategy is a tradeoff between

these benefits and the fixed cost of adding a new good to the product line. The second tradeoff is specific to the dynamic setting. As mentioned before, one firm is in a monopoly position during one period because it owns a property right that prevents competition. This firm may choose a larger product line at the first period to deter excessive product entry at the second period. These two tradeoffs are very important to understand the competition in the pesticide industry. Firms in the industry sell multiple products, some of them being based on the same active ingredient. Also, patents on active ingredients play a major role in the competition and enable the owner to have a temporary monopoly position before the introduction of generic competing products in a second period.

The results of our theoretical model show that, in order to prevent competition in certain markets, a firm that is in monopoly position expands its product line by offering a mix of targeted and multimarket products. If, however, firms decide to accommodate entry, such a mix of product types is never offered. Then, while both target and multimarket products might still coexist in a market, they are produced by different firms. A very preliminary statistical analysis done on a cross-section of our panel database seems to confirm these results. We used data from the French pesticide market. Further work will be carried out using more advanced empirical methods on a panel data that covers a period of eleven years, from 1999 to 2009.

The paper proceeds in the following way. Section 1 reviews the theoretical research that studies the strategies of multiproduct firms. Section 2 describes the model we use. The next two sections present, first, the results from a benchmark case in which only targeted goods are supplied, and, the second, the main results with both targeted and multimarket products. The theoretical results are then tested using descriptive statistics in Section 5.

1 Related literature

The theoretical model we develop in the following section builds on the literature that studies the strategies and the interaction of multiproduct firms (for a survey see Manez and Waterson 2001). Brander and Eaton (1984) were first to address these issues both in monopoly and in duopoly. They considered a setup in which firms were constrained to produce exactly two goods out of a total of four that could be potentially produced. The four products comprised two disjoint pairs of closed substitutes; products in different pairs were considered being distant substitutes. They showed that in oligopoly when firms decide simultaneously which products to produce, firms either segment the market and produce each a pair of close substitutes, or they interlace the market by producing each distant substitutes. If, however, one firm chooses its products before the other one, only the former situation appear in the market. Thus, in Brander and Eaton's (1984) setup there exist no general purpose product and firms are constrained to produce an arbitrary number of goods.

Brander and Eaton's (1984) model has been further generalized by Chisholm and Norman (2007) who endogenized the product line decision. In a model of Cournot competition where two firms choose the goods to produce among four (equally) differentiated varieties they show that the extent to which the resulting product lines overlap is driven by the market size and by the degree of product substability. Product lines comprise more products and overlap more when the market is large or when product substitutability is low. This steam from the tradeoff firm face between the benefits firms accrue from having wider product lines to "be where the demand is" and costs associated with higher competition and intra-firm product canibalization.

Closer to our study, Doraszelski and Draganska (2006) investigate the strategic considerations that determine a multiproduct oligopoly to produce general purpose products versus products that are tailored to specific consumer needs. To our knowledge this is the only model of multiproduct companies in which firms choose among these types of goods. Doraszelski and Draganska (2006) build a model of spatial competition in which firms offer either targeted or general purpose products, and in which consumers have idiosyncratic preferences for firms. The stronger are consumers' preferences towards a certain firm, the weaker is the competition between duopolists. Their results show that firms offer general purpose products if the fixed costs of offering an additional product are sufficiently high, if competition is weak, and if the utility that consumers get from a product tailored to their needs is small and, moreover, is smaller than their disutility from consuming a product tailored to a different segment. With respect to market segmentation, they show that high fixed costs or weak competition encourage the emergence of niche firms that serve only one market segment but inhibit the appearance of full-line firms that offer products for each segment. In addition full-line firms emerge if both the utility and the disutility consumers get from consuming products that are, respectively, tailored to them or to the other market segment, are small.

The setup we develop in this article aims to capture facts present in industries similar with the pesticide industry and departs in many respects from Doraszelski and Draganska's (2006) model. First, in the pesticide industry there are firms that have in their product line both targeted and more general purpose products, and therefore we have allowed firms to produce a mix of the two product types. Second, since pesticides used for more crops are deemed to be less efficient than pesticides targeted to a specific crop we considered that general and tailored products differ in quality, so we developed a model of vertical differentiation. However, other aspects of our model could be reinterpreted in the spirit of the exogenous variables used by Doraszelski and Draganska's (2006) in order to make our and their results more comparable. For example, we have fixed the fixed costs but we allowed the market size to vary. However, a higher market size could be interpreted as a case where firm face relatively lower fixed cost. Our results show that apart from the situations discusses by Doraszelski and Draganska (2006), there are equilibria in which both

tailored and general products are sold in the market, sometimes by the same firm. Yet, consistent with Doraszelski and Draganska (2006), a general product is sold to consumers only when market size is not too large.

Some aspects regarding the behavior of multiproduct firms and their incentives to segment their market have been already addressed in models of vertical differentiation (Champsaur and Rochet 1989, and Gilbert and Matutes 1993). Champsaur and Rochet (1989) use a generalized version of product differentiation that it is compatible with both vertical and horizontal differentiation. They show that under certain conditions duopolists lessen competition by segmenting the market: one firm offers only high quality products and the other one only low quality products. Firms' quality ranges do not overlap and thus there is always a gap between their product lines. Although Champsaur and Rochet (1989) do not analyze the case of Cournot competition, they mention that their result is not likely to hold in a less competitive environment. Indeed, in our setup where firms compete in quantities and firms offer targeted products, unless the market size is small, the product lines of oligopolists overlap. /* probably we have to delete the last two sentences */ Gilbert and Matutes (1993) combine vertical and horizontal differentiation models by allowing consumers to differ not only in their valuation of quality but also in their preferences for existing firms. In their setup there are two firms that could offer a premium and/or a basic good. They show that in a static Nash game where product line choice and competition occur at the same stage, duopolists introduce the maximum number of product varieties. Yet, if firms commit to their product lines before competing in the market, specialization occurs if the qualities of the basic and the premium goods are similar. If further, entry in the market becomes a possibility and the products are sufficiently differentiated, the incumbent deter the entry in the market by producing both products. Otherwise entry occurs and firms specialize, each producing one of the two goods. None of the above models of vertical differentiation allows firms to produce general products. In addition, since in our setup we have two completely different markets for the tailored products our results are not directly comparable with the results discussed above.

2 The model

Assume there are two markets that correspond to two different crops in the pesticide case. Consumers in both markets have the same indirect utility function, $U = \theta u_i - p_i$, where p_i and u_i are, respectively, the price and the quality of the good i, and θ is the consumer taste for the quality. The taste parameter, θ, is uniformly distributed between 0 and $S \geq 0$. Consumer density differs between markets, being 1 in the first market and λ ($\in [0, 1]$) in the second market. Hence the mass of consumer is S in the first market and λS in the second one.

We suppose that there are at most two firms, $F1$ and $F2$, which detain the same

technology (active ingredient and production process). The technology could be used to produce three goods for the two markets described before. Two of the products are targeted, each for a different market, thus being completely differentiated. Good i is produced and sold in the market i, $i = 1, 2$. They have, each on its market, a quality u_i that is normalized to 1 for simplicity. The third product, good 3, can be consumed in both markets and is considered to have, in each market, a lower quality with respect to the targeted goods sold in that market ($u_3 = \alpha \in [0, 1]$). Qualities are exogenously given. p_i and q_i are the price and (total) quantity of the good i.

The firms $F1$ and $F2$ have identical technologies that permit them to produce any of the three goods at an identical and constant marginal cost equal to 0. In order to introduce a product in a market, the companies have to pass through an authorization process that represents a fixed cost normalized to 1.

The interactions take place in one period in the static setting and two periods in the dynamic setting. Basically, each firm makes two successive decision in each period: it first chooses a product line and, then, it decides the quantity for each product (Cournot competition). The dynamic setting is a bit particular in the sense that only $F1$ is present in the market at the first period and, for simplicity, we suppose that this product line chosen by $F1$ at the first period is not revised at the second period.

We finish this section by presenting the demand system when a given set of products is sold on the market, either by one or two firms. In order to do so, we search for the taste parameter of the marginal consumer who is indifferent between consuming the product i and not consuming at all : Marginal consumer who is indifferent between consuming the product i or not consuming.

$$\theta_1 = p_1; \quad \theta_2 = p_2; \quad \theta_3 = p_3/\alpha$$

The consumer indifferent between consuming the product i ($(i = 1, 2)$ or consuming the product 3 is defined by the following taste parameter :

$$\theta_{13} = (p_1 - p_3)/(1 - \alpha); \quad \theta_{23} = (p_2 - p_3)/(1 - \alpha)$$

Seven products sets may be available on the market : one that contains all three goods three that contains two goods, and three that have one good. The table 1 synthesizes the demand with any of these sets.

3 Benchmark case with only targeted goods

We start by analyzing a situation in which the multimarket products are not technological feasible. This will be the benchmark case against which we will compare firms' product lines and the set of goods supplied in the market when firms have the choice of producing multimarket products.

Table 1: Demand system with any set of product

Product set	D_1	D_2	D_3
1	$S-\theta_1$	0	0
2	0	$\lambda(S-\theta_2)$	0
3	0	0	$(1+\lambda)(S-\theta_3)$
1, 2	$S-\theta_1$	$\lambda(S-\theta_2)$	0
1, 3	$S-\theta_{13}$	0	$(\theta_{13}-\theta_3)+\lambda(1-\theta_3)$
2, 3	0	$\lambda(S-\theta_{23})$	$(S-\theta_3)+\lambda(\theta_{23}-\theta_3)$
1, 2, 3	$S-\theta_{13}$	$\lambda(S-\theta_{23})$	$(\theta_{13}-\theta_3)+\lambda(\theta_{23}-\theta_3)$

Four product sets are possible in the benchmark case : no product, only the product 1, only the product 2, and both products 1 and 2. We first analyze the variety of products supplied either by a monopoly or a duopoly. Then we analyze in more details the product lines of each firm in the case of duopoly. At the end we discuss the product supply in a dynamic setting.

Lemma 1. *The monopoly supply the two goods if the markets are large ($S > 2/\sqrt{\lambda}$), only the good that is targeted for the larger market if the size is intermediate ($S \in [2, 2/\sqrt{\lambda}]$), and no good at all if the size is too small ($S < 2$).*

A duopoly always supplies (collectively) the same mix of goods that a monopoly would supply.

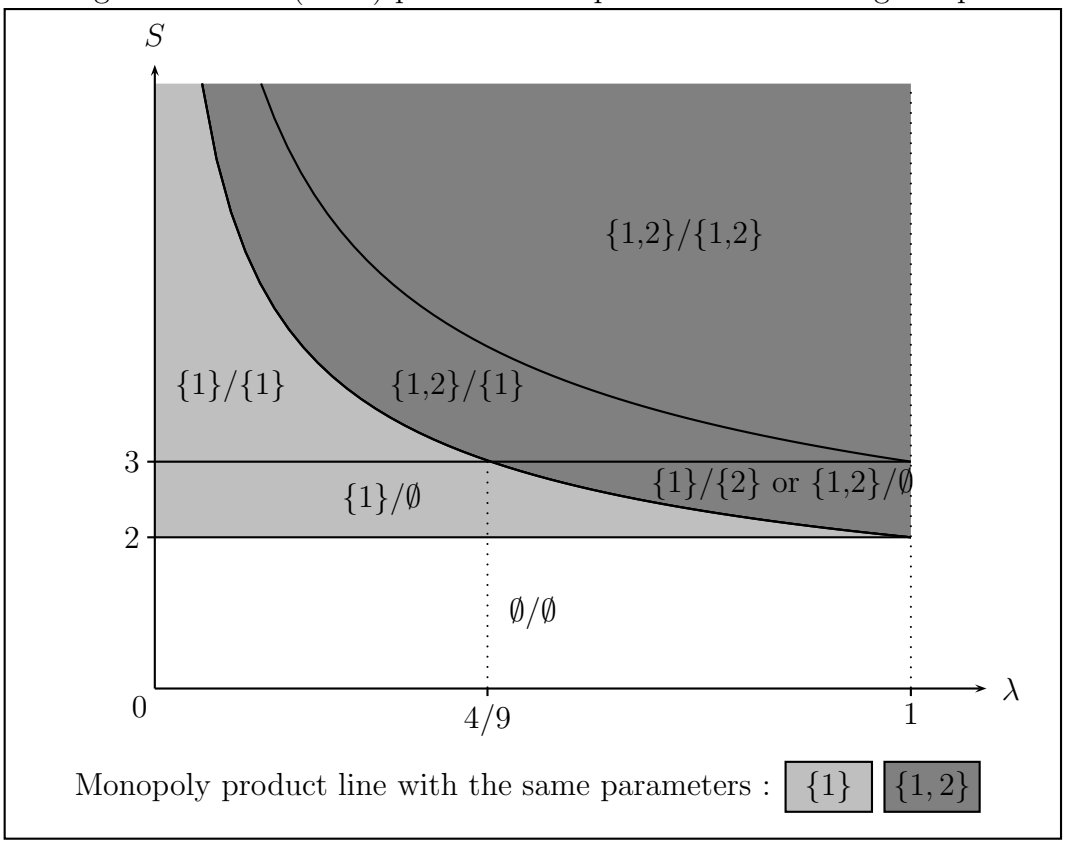
The appendixes B and C derive the product lines that a monopoly or duopolists produce in equilibrium. Figure 1 illustrates these equilibria.

The first result of the lemma is straightforward. The fixed cost of introducing a product is the same for the two goods. When the market size is too small ($S < 2$), the profits the monopoly would get in each market from introducing a good are not high enough to cover the corresponding fixed costs. As S increases, the two markets increase proportionally, and the monopoly introduces first the product 1 that is targeted for the largest market, and then the product 2 that has the smallest market. Thus, the monopoly never supplies the product 2 alone.

Let us now consider the product variety supplied by the duopoly. Since products are market specific, the supply on each market can be analyzed separately. As long as the monopolist does not make positive profits from introducing a good in the market, nor makes an oligopolist. Hence, the minimum market size for having one product supplied is the same with either a monopoly or a duopoly. The product variety is then always identical with both market structures.

Lemma 2. *When the product line of the two firms are aggregated, as the market size (S) increases from zero, the number of goods supplied (collectively) by duopolists raises from 0 to 4. When two goods are supplied, a good is sold in each market if*

Figure 1: Static (Nash) product line equilibrium with 2 targeted products



the two markets have close enough sizes (high enough λ), while only the good 1 is sold if market sizes are very different (low enough λ).

Let us still consider the two products independently. As the market size increases, there is a first threshold where there is enough space for only one firm in the market and a second threshold where there is enough space for two firms, thus for two varieties of the same product. As the market for the product 1 is larger than the market for the product 2, if there is enough space for one, respectively two, varieties of the product 2, there is necessarily enough space for at least one, respectively two, varieties of the product 1. If we increase the size of the two markets simultaneously from 0, then we progressively go from a situation where there is not enough space for any product to a situation where there is enough space at least for one variety of one or possibly both products and finally enough space for the two varieties of both products. The sequence in which the goods enter in the market is, however, different depending on the relative size of the second market (λ). If the market 2 is small, once a variety of good 1 is introduced in the market, as S increases, the second variety of good 1 will be introduced. In such a case, having only one variety of each product is not possible. Conversely, if the two markets have similar size, it is more interesting to introduce the first variety of the product 2 before the second variety of the product 1. Having both firm supplying only the product 1 is then impossible.

The equilibrium in the dynamic setting is derived in the appendix C and illustrated in the figure 2. With relatively little adjustments, lemmas 1 and 2 also hold in the dynamic setting. First, it is necessary to adjust the critical values of S for which the first variety of a good is launched into a market. In the dynamic setting a first variety is always introduced by the incumbent firm (firm $F1$) and, for the incumbent, the fixed costs are compared against two period profits. Second, when exactly one variety of each good is sold in each market, while in a static setting they might be supplied either by the same firm or by the two firms, in the dynamic setting the Stackelberg leader will appropriate all the profits by producing itself the two products.

4 Results with both targeted and multimarket products

As discussed in Section 2, when firms have the possibility of producing both targeted and multimarket products, they can choose between the seven product lines given in table 1. In what follows we describe the market equilibria for three different situations with respect to market structure and the timing of firms' choices: monopoly, duopoly in a static model, and duopoly in a dynamic model.

Figure 2: Dynamic (Stackelberg) product line equilibrium with 2 targeted products

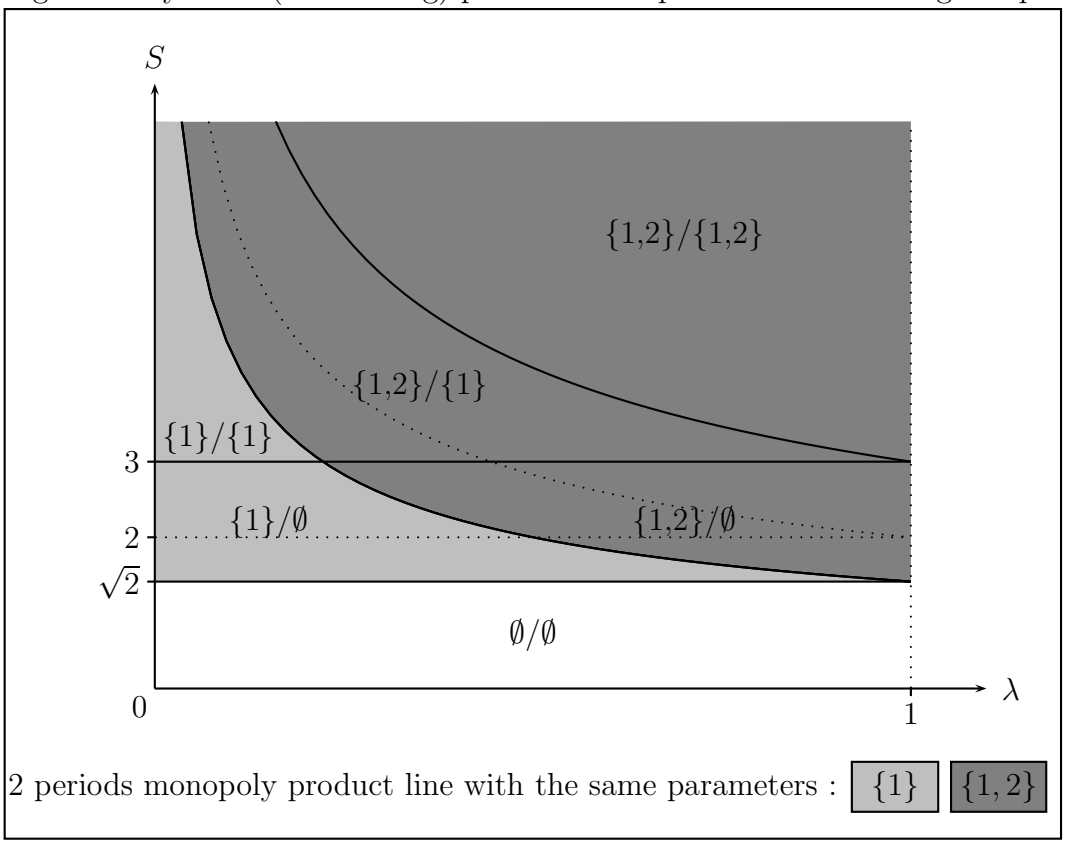
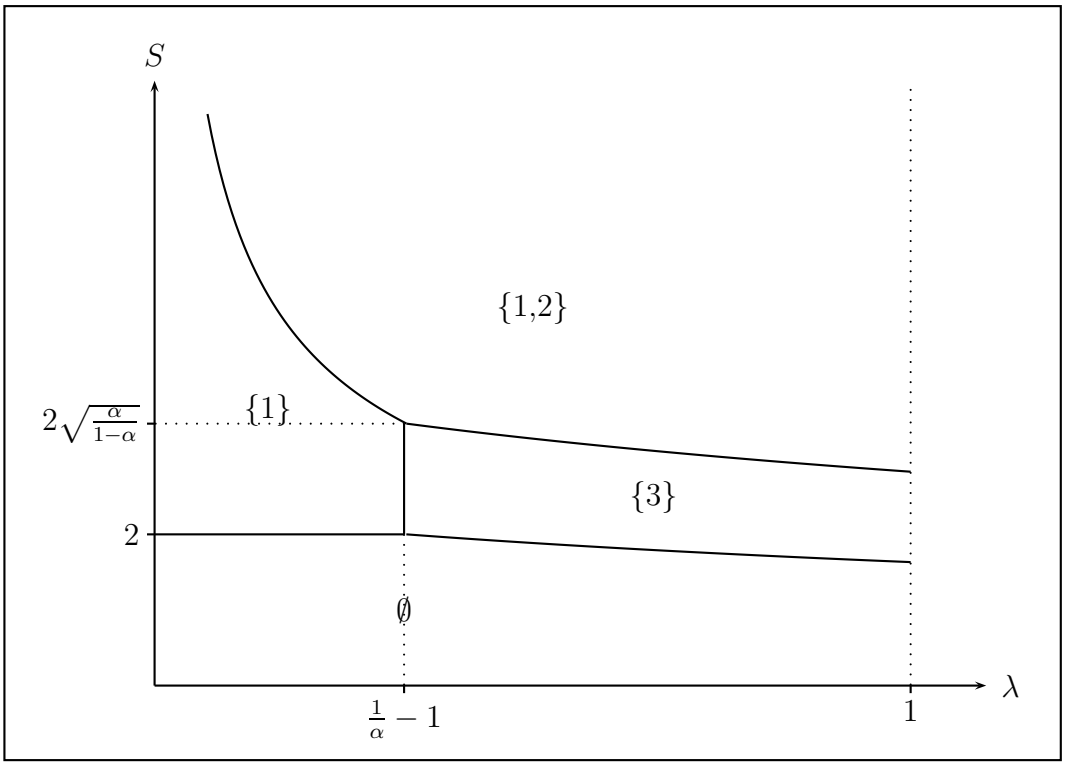


Figure 3: Product line strategy of a monopoly ($\alpha = 3/4$)



Monopoly.

Lemma 3. *If the monopoly can sell both targeted and multimarket products, his product line never contains both these two types of products. The multimarket product is sold if it is sufficiently efficient ($\alpha > 1/2$), if the market has an intermediate size($S \in [2/\sqrt{\alpha(1+\lambda)}, 2/\sqrt{(1-\alpha)(1+\lambda)}]$) and, in addition, if the relative size of the two markets is not very different ($\lambda > 4/9$).*

The proof of this lemma is given in the appendix D and figure 3 illustrates the results.

Stated differently, lemma 3 indicates that there is no room, in our model, for intra-market price discrimination. With no fixed cost, since the multimarket product is less efficient and its variable costs are the same as for a targeted product, the monopoly has no interest to sell it. The sole advantage of a multimarket product is that it enables a monopoly that covers both markets to halve its fixed cost, aspect which is particularly important when the gross profits from targeted products are small (small value of S). Any case in which the monopoly would sell both the targeted and the multimarket product is dominated either by a situation where the

Table 2: Static duopoly profit matrix ($\alpha = 0.85$, $\lambda = 0.5$ and $S = 3$)

Prod. line of $F1$	Product line of $F2$		
	$\emptyset$	$\{1\}$	$\{3\}$
$\emptyset$	(0,0)	(0,1.40)	(0,2.06)
$\{1\}$	(1.40,0)	(0.06,0.06)	(0.72,0.36)
$\{3\}$	(2.06,0)	(0.36,0.72)	(0.36,0.36)

monopoly sells only the more efficient targeted product or by a situation where the monopoly sells the multimarket product in order to save on the fixed cost.

Duopoly.

Proposition 1. *With both targeted and multimarket products, a duopoly does not necessarily sell the same mix of products as a monopoly. Thus, both types of products may be sold (collectively) by a static or a dynamic duopoly, but never by a monopoly.*

We illustrate the proposition by presenting a case where a static duopoly does not sell the same product set that a monopoly sells. Let $\alpha = 0.85$, $\lambda = 0.5$ and $S = 3$. The corresponding profit matrix[1] is given in table 2. It is immediate that in this case there are two Nash equilibria in pure strategies in which one of the duopolists produces the product targeted for the larger market, namely product 1, and the other duopolist produces the multimarket good. It can be analytically shown that this type of equilibria appears whenever the market size, S, is relatively small and the relative dimension of market 2 with respect to market 1 spans an intermediate range of values.[2] When the second market is negligible with respect to market 1, each duopolist wants to sell only good 1. As the size of the second market increases (λ increases), firms become interested to produce product 3 to penetrate in a market where there is no competition while being also present in the main market, market 1.

Even if both, the targeted and the multimarket products may be sold collectively, each firm sells only one type of product in the static setting. This property does not necessarily hold in the dynamic setting as stated in the following lemma.

Proposition 2. *In a dynamic setting the incumbent (firm $F1$) may sell both a targeted and a multimarket product in order to deter the entry of a competitor.*

[1]For simplicity this profit matrix is limited to the most interesting product line strategies. The product line strategies $\{2\}$, $\{1,2\}$, $\{1,3\}$, $\{2,3\}$, and $\{1,2,3\}$ are dominated when $\alpha = 0.85$, $\lambda = 0.5$ and $S = 3$.

[2]The proof of this statement and a figure that illustrates the market equilibria for various values of λ and S remain to be introduced in the paper.

Table 3: Dynamic duopoly profit matrix ($\alpha = 0.85$, $\lambda = 0.75$ and $S = 5$)

Prod. line of $F1$	Product line of $F2$		
	$\{2\}$	$\{3\}$	$\{1,2\}$
$\{1,2\}$	(17.27,1.08)	(14.77,2.75)	(13.8,2.86)
$\{1,3\}$	(13.84,3.45)	(13.3,3.13)	(12.73,3.27)

To illustrate this result we take $\alpha = 0.85$, $\lambda = 0.75$ and $S = 5$. The corresponding payoffs of the two firms are given in table 3.[3] These payoffs take into account that firm F1, which is the incumbent, makes monopoly profits during the first period and Cournot duopoly profits in the second period. Firm F2 has only Courno duopoly profits during the last period. The only equilibrium in pure strategies in which the incumbent is the Stackelberg leader with respect to the product line choice, is the case in which F1 produces the multimarket good and good 1 while F2 produces good 2. The incumbent's choice is driven by its attempt to deter entry in the largest market, namely market 1, while being able to make profits on market 2 that is already large enough. To do this, it forgoes the higher profits it would get as a monopolist, should have he chosen a product line that contains the two targeted goods.

In general, this type of equilibria appears for moderate values of the market size, S, for a relatively high second market, and for high levels of efficiency of the multimarket product (high αs).[4] In our model this is the only setup where a firm sells both targeted and multimarket products.

In addition, in the dynamic duopoly model, there exist a wide range of parameters for which one of the firms produces the multimarket product while the other one produces between 0 and 2 targeted products. Thus, this is the case for low to intermediate levels of market size, S, and for intermediate to high relative size of market 2.

5 Empirical analysis

This section is dedicated to the test of the predictions of our theoretical model on data drawn from the French pesticide market. This empirical part is still preliminary and limited to very basic statistics and a limited part of our dataset. We expect to be able to establish more robust conclusion in the future by using more robust econometric test on the basis of all our dataset.

[3] As in the case of static duopoly we have considered here only the most relevant product line strategies.

[4] A proof and a graphical illustration will be introduced in the paper.

It is important to make a clear distinction between active ingredients and pesticide products. Active ingredients are molecules that are generally patent protected. Pesticide products have a particular composition that incorporates one or several active ingredients at certain doses, a certain physical form (e.g. liquid, powder), and some adjuvants that improve the technical efficiency of the active ingredient. In the European Union, the market approval for the active ingredients is given at the EU level, while the market approval for pesticide products is given at the national level[5]. Our analysis is based on pesticide products and compares the product lines based on the same active ingredient. As active ingredients are subject to patent protection, pesticides based on an active ingredient that has been recently introduced in the market are likely to be produced by a sole firm while pesticides that contain an older active ingredient that is no longer patent protected are likely to be produced by several competing firms. In France, the market approval for pesticide products defines very specifically the condition under which the product can be used. In particular, a pesticide product can only be used to control some particular pest on some particular crops. This enables us to define the market on which the product can be sold.

Our dataset is based on two sources : the *'index phytosanitaire'* for the year 2005 and the *e-phy* database. The 'index phytosanitaire' is a general catalog, edited each year by the ACTA[6], that lists all the pesticide products that are sold in France each year. To build this catalog, the ACTA surveys all the pesticide companies about the pesticide products they will sell during the coming year. The interest of this catalog is thus to provide a list of products that are indeed sold[7]. The data from this source cover three variables: the product name, the firm that sells this product, and the type of pest that is controlled by this product (for example: fungicide, herbicide, etc.). The e-phy database is an online database[8] produced by the French market approval authority. e-phy covers all the products that are (or have been) approved in France during the last decades. For all the products of the 2005 'index phytosanitaire', the two additional variables are extracted from the e-phy database : the active ingredient contained in the product, and the set of usages for which the product is approved. The set of usages of each active ingredient enable to define the market on which the product is sold. In this paper, the usages are aggregated in four markets numbered from one to 4: fruit trees (1), vegetable (2), cash crops (3) and miscellaneous (4). The following results are based on a restricted dataset that covers only the fungicide products based on active ingredients that have been

[5]For pesticide products the regulation has been based for a long time on the directive 91/414, and is based now on the directive REACH.

[6]ACTA is a network of agricultural technical institute (réseaux des Instituts des Filières Animales et Végétales). Its web site is http://www.acta.asso.fr

[7]A company may have the approval for selling one product but prefers not to sell it because, for example, she recently got a market approval for a more efficient product.

[8]http://e-phy.agriculture.gouv.fr

authorized to be used in France since 1986.

The data are summarized in table 4. We characterized each product as either targeted or multimarket on the basis of the market for which it is authorized. For example, a product coded 'T2' corresponds to a targeted product sold only on the market 2 ; a product coded 'M34' corresponds to a multimarket product sold on markets 3 and 4. Our analysis focuses only on the competition between products that are based on the same active ingredient. Hence, we define a product line as the set of products based on the same active ingredient and that are sold by the same firm. 23 different product lines were built, among which 7 contain only targeted products, 6 contain only multimarket products and 10 contain both targeted and multimarket products. This simple counting validate our result that both targeted and multimarket products can co-exist in the same product line.

The 23 different product lines cover 16 different active ingredients. Eleven of these active ingredients correspond to a monopoly situation in the sense that all the products derived from this active ingredient are sold by the same firm. These cases where there is only one product line per active ingredient correspond generally to more recent active ingredients [9]. The five other active ingredients correspond either to a duopoly (4 cases) or to an oligopoly with three firms (one case). In four of these five cases with competition we observe a product line with both targeted and multimarket products.

At last, we intend to test the proposition 1 which indicates that, in given market conditions, the product sets are different in a monopoly compared to a duopoly. In order to compare cases that correspond to the same market conditions, we build different groups of active ingredient on the basis of the range of market they cover. Our theoretical finding tend to be validated in the three combinations of markets that contain at least four active ingredient. For example, when considering the four active ingredients that cover the markets 1 and 3, the three monopoly cases (Fluquinconazole, Spiroxamine, and Tetraconazole) leads to product lines containing only targeted product, while the oligopoly case (Copper oxychloride) leads to a product line containing both targeted and multimarket products.

[9] In average, active ingredient for which there is only one product line are introduced in 1996 while those for which there are several product lines are introduced in 1991.

Table 4: Product line based on recent fungicide active ingredient

Markets*	Active ingredient	Firm	Product lines**
1,3	Copper oxychloride	Sipcam-Phyteurop	{T1,M13}
	(1990)	Bayer	{M13}
		Calliope	{M13}
		Phylagro France	{M13}
	Fluquinconazole (1992)	BASF Agro	{T1,T3}
	Spiroxamine (1992)	Bayer	{T1,T3}
	Tetraconazole (1998)	Sipcam-Phyteurop	{T1,T3}
3,4	Epoxiconazole (1993)	BASF Agro	{T3,M34}
		Sipcam-Phyteurop	{T3}
1,2	Fenbuconazole (1988)	Philagro France	{T1}
		Dow Agrosciences	{M12}
	Mepanipyrim (2003)	Sipcam-Phyteurop	{M12}
1,2,3	Hexaconazole (1986)	Syngenta Agro	{T3,M12}
	Diethofencarbe (1986)	Phylagro France	{M123}
	Famoxadone (1996)	Cerexagri	{T1}
		Dupont	{T1,M12,M123}
	Fenamidone (2001)	Bayer	{T1,M23}
	Zoxamide (2003)	Dow Agrosciences	{T1,M23}
1,3,4	Kresoxim-methyl (1992)	BASF Agro	{T1,T3,M34}
		Sipcam-Phyteurop	{T3}
	Pyraclostrobine (2003)	BASF Agro	{T1,T3,M34}
	Quinoxyfene (1996)	Dow Agrosciences	{T1,T3,M34}
	Trifloxystrobine (1998)	Bayer	{T3,M14}

* 1=Fruits, 2=Vegetables; 3=Cash crops; 4=Miscellaneous.

** 'Tn' corresponds to a targeted product sold on the market n, and 'Mnk' corresponds to a multimarket product sold on the market n and k.

Appendix

A. Product line of a monopoly with two targeted products

- *One period.* Using the demand system defined in the table 1 we compile the optimum profit for each product set (i.e. each product line decided by the monopoly):

$$\pi^M_{\{1\}} = \frac{S^2}{4} - 1 \quad ; \quad \pi^M_{\{2\}} = \frac{\lambda S^2}{4} - 1 \quad ; \quad \pi^M_{\{1,2\}} = \frac{(1+\lambda)S^2}{4} - 2 \tag{1}$$

We move now to the stage 1 and analyse the choice of the product line by the monopoly. We can first observe that the product line, $\{2\}$ is dominated by $\{1\}$ because of the smaller market size ($\lambda < 1$). When comparing the profit with the two remaining product lines, we have:

$$\pi^M_{\{1\}} > \pi^M_{\{1,2\}} \quad \Leftrightarrow \quad S > 2/\sqrt{\lambda} \tag{2}$$

It is important also to establish the condition for having a positive profit[10]:

$$\pi^M_{\{1\}} > 0 \Leftrightarrow S > 2 \qquad \text{and} \qquad \pi^M_{\{1,2\}} > 0 \Leftrightarrow S > 2\sqrt{2/(1+\lambda)} \tag{3}$$

As $1/\sqrt{\lambda} > \sqrt{2/(1+\lambda)}$, the profit with the product line $\{1,2\}$ is always positive when this product line is prefered to $\{1\}$. The figure 1 synthetise the equilibrium strategy of the monopoly in this case with only two targeted goods.

- *Two periods.* The analysis of the monopoly strategy over two periods is necessary for the comparison with the dynamic duopoly. To compile the profit, the revenue part in the equation 1 is doubled and the fixed part is identical (the fixed cost is expended once for the two periods). Finally, the monopoly introduces no product is $S < \sqrt{2}$, the product line $\{1\}$ if $S \in [\sqrt{2}, \sqrt{2/\lambda}]$ and the product line $\{1,2\}$ if $S > \sqrt{2/\lambda}$ (cf. figure 2).

B. Static duopoly equilbrium with two targeted products

Stage 1. The table below summarizes the profit of each firm in the duopoly for any combination of product lines.

Product lines	Profit of $F1$	Profit of $F2$
$\{1\}/\{1\}$	$\frac{S^2}{9} - 1$	$\frac{S^2}{9} - 1$
$\{2\}/\{2\}$	$\frac{\lambda S^2}{9} - 1$	$\frac{\lambda S^2}{9} - 1$
$\{1,2\}/\{1,2\}$	$\frac{(1+\lambda)S^2}{9} - 2$	$\frac{(1+\lambda)S^2}{9} - 2$
$\{1\}/\{2\}$	$\frac{S^2}{4} - 1$	$\frac{\lambda S^2}{4} - 1$
$\{1,2\}/\{1\}$	$\frac{(4+9\lambda)S^2}{36} - 1$	$\frac{S^2}{9} - 1$
$\{1,2\}/\{2\}$	$\frac{(9+4\lambda)S^2}{36} - 1$	$\frac{\lambda S^2}{9} - 1$

Stage 2. The comparison of the duopoly profit at the stage 2 enables to establish the nest response to any product line (see table below). Not that the best response to $\emptyset$ (first column) corresponds to the product line of a monopoly (cf. previous appendix). Finally, six different cases need to be distinguished depending on the market size (parameters λ and S). In each case, the stage 1 equilibrium is defined on the basis of these best responses.

[10]Note that $\pi^M_{\{1,2\}}$ is always positive when the product line $\{1,2\}$ is prefered to either $\{1\}$ or $\{2\}$

Conditions on S and λ	Best response to $\emptyset$	$\{1\}$	$\{2\}$	$\{1,2\}$	Equilibrium
$S<2$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset/\emptyset$
$S>2$ and $S<\min[3,2/\sqrt{\lambda}]$	$\{1\}$	$\emptyset$	$\emptyset$	$\emptyset$	$\{1\}/\emptyset$
$S\in[2/\sqrt{\lambda},3]$ ($\Rightarrow\lambda\in[4/9,1]$)	$\{1,2\}$	$\{2\}$	$\{1\}$	$\emptyset$	$\{1\}/\{2\}$ or $\{1,2\}/\emptyset$
$S\in[3,2/\sqrt{\lambda}]$ ($\Rightarrow\lambda\in[0,4/9]$)	$\{1\}$	$\{1\}$	$\{1\}$	$\{1\}$	$\{1\}/\{1\}$
$S>\min[3,2/\sqrt{\lambda}]$ and $S<3/\sqrt{\lambda}$	$\{1,2\}$	$\{1,2\}$	$\{1\}$	$\{1\}$	$\{1,2\}/\{1\}$
$S>3/\sqrt{\lambda}$	$\{1,2\}$	$\{1,2\}$	$\{1,2\}$	$\{1,2\}$	$\{1,2\}/\{1,2\}$

C. Dynamic duopoly equilbrium with two targeted products The firm $F1$ is considered as the Stackelberg leader and $F2$ is the follower. The best response of $F2$ at the second period is defined identical to the static case. The profit of $F1$ is defined in the table below

	$\{1\}$	$\{2\}$	$\{1,2\}$
First period profit	$S^2/4-1$	$\lambda S^2/4-1$	$(1+\lambda)S^2/4-1$
Second period profit			
$S<2$	$S^2/4$	$\lambda S^2/4$	$(1+\lambda)S^2/4$
$S<2$ and $S<\min[3,2/\sqrt{\lambda}]$	$S^2/4$	$\lambda S^2/4$	$(1+\lambda)S^2/4$
$S\in[2/\sqrt{\lambda},3]$	$S^2/4$	$\lambda S^2/4$	$(4+9\lambda)S^2/36$
$S<\in[3,2/\sqrt{\lambda}]$	$S^2/9$	$\lambda S^2/4$	$(4+9\lambda)S^2/36$
$S>\max[3,2/\sqrt{\lambda}]$ and $S>3/\sqrt{\lambda}$	$S^2/9$	$\lambda S^2/4$	$(4+9\lambda)S^2/36$
$S>3/\sqrt{\lambda}$	$S^2/9$	$\lambda S^2/9$	$(1+\lambda)S^2/9$

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D. Product line of a monopoly with two targeted and one multimarket products

- *One period.* The monopoly profit with the product lines that contains the multimarket product is (see appendix A for the over product lines):

$$\begin{aligned}\pi^M_{\{3\}}&=\frac{\alpha(1+\lambda)S^2}{4}-1; \qquad \pi^M_{\{1,2,3\}}=\frac{(1+\lambda)S^2}{4}-3\\ \pi^M_{\{1,3\}}&=\frac{(1+\alpha\lambda)S^2}{4}-2; \qquad \pi^M_{\{2,3\}}=\frac{(\alpha+\lambda)S^2}{4}-2\end{aligned} \tag{4}$$

It can be observed that the product line $\{1,2\}$ dominates the product lines $\{1,3\}$, $\{2,3\}$, and $\{1,2,3\}$. The product line $\{3\}$ is prefered to the two over ones in the following conditions:

$$\pi^M_{\{3\}}>\pi^M_{\{1\}} \quad\Leftrightarrow\quad \lambda>\frac{1}{\alpha-1} \quad;\quad \pi^M_{\{3\}}>\pi^M_{\{1,2\}} \quad\Leftrightarrow\quad S<\frac{2}{\sqrt{(1-\alpha)(1+\lambda)}} \tag{5}$$

At last, the condition for the profit to be positive with the product line $\{3\}$ is:

$$\pi^M_{\{3\}}>0 \quad\Leftrightarrow\quad S>\frac{2}{\sqrt{\alpha(1+\lambda)}} \tag{6}$$

- *Two periods.*