Investigating the Causes of Returns in the Seed Supply Chain

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Abstract:

Hoarding is a common occurrence during shortages of "hot" products in industries ranging from oil to toys and from computers to pharmaceuticals. Often the induced shortage due to hoarding is much stronger than the original trigger. This paper investigates the impact of dealer hoarding on generating large amounts of seeds returned to a seed corn supplier in the agribusiness industry. To understand the mechanisms leading to seed corn hoarding and returns, we build a formal model of seed hoarding in the agribusiness supply chain. Our insights suggest that dealer hoarding and subsequent seed returns result from the interplay between supply chain characteristics (e.g. timing of information availability and quality of dealers' orders) and human decision making (e.g. salespeople's effort allocation decisions and managers' pressure). In addition, a number of supplier actions can intensify dealers hoarding behavior, worsening the problem. Our analysis suggests several policies capable of effectively reducing the volume of returns.

Key words:

Seed returns, supply chain management, dealer over-ordering, agribusiness industry, simulation, system dynamics.

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1. Introduction

Hoarding – storing up supplies – is a common occurrence during shortages of "hot" products, ranging from the basic (e.g. gasoline and food) to the sophisticated (e.g. pharmaceuticals and new technology products). For instance, hoarding and gasoline shortages took place during the OPEC oil embargo against the United States in 1973, the oil supply reduction after the Iranian revolution in 1979, and in Britain and Europe in 2001. Such periods were marked by service stations rationing the maximum amount of gasoline purchased per customer and by panic consumer buying, with anxious consumers queuing for hours in attempts to top off their tanks. Some analysts reported that the hoarding was worse than the oil embargo itself. One example of the effects of hoarding was the illegal storage of the fuel (Anonymous 1974). In December 1999, fearing that Y2K problems would interrupt food supplies, overcautious customers stocked up on water, food and batteries (Weiss 1999). More recently, following the anthrax attacks of 2001, customers in the U.S. rushed to drug stores to hoard supplies of Cipro, causing generalized shortages of the drug (Petersen 2002). In all such cases, customers hoarded products to hedge against the expectation of shortages, often causing impacts much larger than if real shortages took place. Indeed, even the initially false rumor of shortages can trigger hoarding – a classic example of a self-fulfilling prophecy (Merton 1948).

This paper investigates the causes of corn seed hoarding in the agribusiness supply chain, leading to excessive seed corn returns to a major U.S. seed supplier. Excessive returns impose substantial costs on seed suppliers due to transportation, retesting, reconditioning, repackaging, discards due to poor storage, and discards due to lifetime expiration. By law, returned seeds must be retested and repackaged even when storage conditions at dealers' warehouses are satisfactory. Not all returned seeds can be reconditioned, however. Often, returned seeds need to be discarded due to poor storage conditions. Furthermore, corn has a maximum three-year shelf-life, after which it has to be discarded. Excessive returns also drive indirect costs associated with excess production capacity required to accommodate a large volume of returns.

The agribusiness industry traditionally faces returns of 15% of the total seeds shipped to dealers. The seed supplier tolerates some level of returns, since demand is uncertain. In addition, the seed supplier perceives the losses due to returns as much lower than the gains due to potential sales and market share. Seed suppliers often encourage dealers to overstock to stimulate opportunistic sales or to prevent competitors from having shelf-space for their products. Dealers also benefit from returns. Seed production takes place months in advance of grower demand, often resulting in a limited supply of specific hybrids. To hedge against shortages of high performing hybrids, dealers often place their orders early in the selling season, and also inflate them. If, later on, grower demand materializes, dealers benefit from their inflationary ordering behavior. If it does not, they can return any excess inventory at no additional costs. Hence, both the seed supplier and dealers can benefit from over-ordering and subsequent returns.

While the benefits (opportunistic sales and limited competitor shelf-space) associated with overstocking seeds at dealers exist, the direct and indirect costs may far outweigh them. In particular, the seed supplier, I investigated had returns twice as high as the industry average, and direct costs associated with corn seed returns on the order of 10% of revenues (about $20 million per year). Our interviews revealed that the ratio of produced seeds to sales equaled 1.7, that is, the total volume of seeds produced would be sufficient to sustain almost twice as many sales, hinting at significant indirect costs (excess capacity) that may far outweigh the direct costs of returns.

To understand the mechanisms leading to seed hoarding and returns, we build a formal model of seed hoarding in the agribusiness supply chain. By capturing the dynamics of salespeople’s effort allocation between competing tasks during the selling season, the model yields a number of insights into the process that lead to seed hoarding and returns. Our model rests on quantitative and qualitative data gathered from a three-month in-depth study of sales, services, planning, operations, logistics, and order processes at the company site, a major U.S. supplier of corn and soybean seeds. During our field work, we conducted about thirty semi-structured interviews with company and dealer managers. Eighty percent of the interviewees were managers at the seed supplier in charge of operations, logistics, quarterly initiatives, production planning, demand forecasting, sales, order processing, and supply chain management. The other twenty percent of interviewees were managers working at either agribusiness or seed-only dealers. The former sells seeds, herbicides, and other agribusiness products directly to growers and smaller dealers. The latter sells only seeds, primarily to growers. The quantitative and qualitative data support the development of a system dynamics model of the problem, providing crucial information on managers’ and salespeople’s decision heuristics for performing daily activities, causal relationships among different areas of the business, and specific data on monthly returns and net sales, weekly requests and shipment rates, sales quotas, and fraction of such quotas met by salespeople.

Model results suggest that dealer hoarding and excess seed returns result from the interplay between supply chain characteristics (e.g. timing of information availability and quality of dealers’ orders) and human decision making (e.g. salespeople’s effort allocation decisions and managers’ pressure). Most important, seed hoarding and excess returns can generate a self-reinforcing process. Returns from last season influence dealers’ ordering decisions this season, leading to hoarding and further returns. After having trouble getting the desired seeds last season, dealers learn to inflate their orders in the coming season to improve their chances of meeting farmer’s needs. In addition, actions by the supplier's managers can intensify dealers' hoarding behavior, worsening the problem. While it is difficult for the seed supplier to distinguish actual grower orders from dealers' inflated orders, salespeople's effort in positioning the seeds can help. However, salespeople's must also spend effort pushing seeds to meet revenue targets. When pressure to meet these revenue targets increases, salespeople allocate more effort to pushing seeds to dealers to the detriment of positioning them adequately. Managerial pressure to meet end-of-year revenue targets shifts salespeople's effort allocation from positioning to pushing seeds, leading to seeds located at dealers without grower demand and, ultimately, higher seed returns.

The paper proceeds as follows. The next section describes the seed supply chain and relates to the relevant literature. Section 3 describes the model and the evidence for its main assumptions. Section 4 contains the base simulation run, results, and sensitivity analysis followed by policy analysis in section 5. We conclude with a discussion of insights and areas for further research.

2. Seed Supply Chain

The seed supplier markets hundreds of corn SKUs every year. Corn hybrids are genetically engineered to provide insect protection, herbicide resistance, and specific performance for local weather conditions. Every year the supplier withdraws many old products and introduces several new ones. Product life-cycles are short. The supplier must also manage high demand and supply uncertainty. Supply uncertainty is highly dependent on weather variability, uncertain yields, uncertain growing (e.g. insect) conditions, and long delays in seed production. Demand uncertainty depends heavily on farmers' experience in the previous growing season. In many ways, the challenges faced by the seed-corn industry resemble those of the electronics and computer industries.

In a typical agribusiness supply chain, the seed supplier sells seeds to dealers, who then resell them to growers (Figure 1). Seed production takes place months in advance of grower demand, often resulting in a limited supply of specific hybrids. To secure the hybrids believed to be in high demand, dealers' inflate their orders and place them early in the selling season, before grower demand materializes. In turn, growers base their ordering decision on hybrids that perform well in the current planting season. Hybrid performance, however, is highly uncertain due to its dependency on weather conditions. Seed return policies in the agribusiness industry encourage dealers to order seed hybrids despite the uncertainty in grower demand.

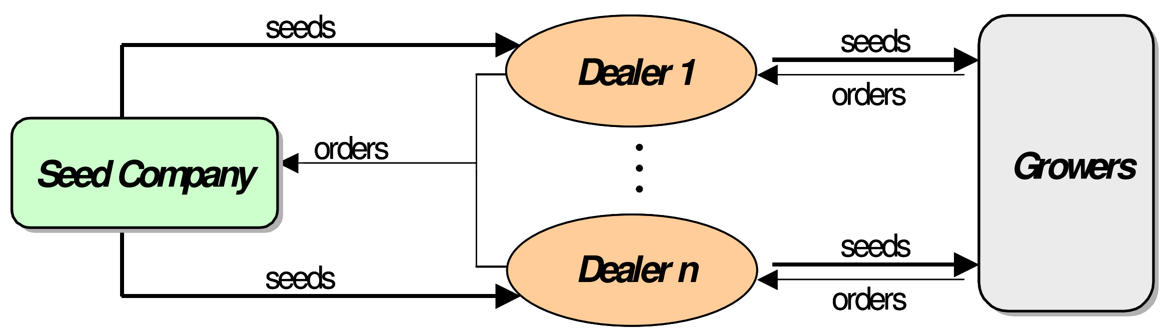

Figure 1. Distribution channel for the seed company

Research on the impact of shortages on supply chain instability dates back almost eighty years, when Thomas Mitchell (1924) described the mechanisms through which retailers caught short of supply increased their orders to suppliers. This "false demand" was passed back from stage to stage creating order amplification throughout the distribution channel. The first formal analytical study of supply chain instability appeared much later in the work of Jay Forrester (1958). Forrester represented the supply chain as a sequence of four levels, in which each of the upstream links pushed its contents downstream with an average residence time, representing the manufacturing and distribution delays. He also incorporated delays in managers' decisions and policies governing inventory adjustment and ordering. Forrester found that this system structure was capable of creating the oscillatory behavior observed in supply chains and suggested improved inventory adjustment policies to reduce the amplitude of oscillations. Forrester's model, however, did not represent the mechanisms that explicitly created Mitchell's "false demand." In 1958, Willard Fey converted the earliest formal system dynamics models dealing with supply chain instability into a game that subsequently evolved into the "Beer Game" (Sterman 1989a).

More recently, Donohue (1996) suggests that manufacturers using a returns policy (e.g. a rebate on unsold items) can often influence retailers to place larger orders. Webster and Weng (2000) corroborate this finding advising that while "returns policies can increase the 'upside potential' of manufacturer profit by encouraging retailers to order more, they also introduce 'downside exposure' through high rebate costs when demand is lower than expected." Jones et al. (2002, 2003) study the seed corn supply chain, but focus their attention on problems associated with the timing of production. Since production decisions take place several months before farmer decisions that determine demand, the product mix of available supply often does not match farmer's needs. The authors suggest a second production in a region in a different hemisphere, allowing for production decisions that incorporate information about grower demand.

Padmanabhan and Png (1995, 1997) propose that an unlimited returns policy can have an important role in increasing manufacturer's profit by increasing the intensity of retailer competition. In contrast, Gonçalves (2002) provides a theoretical model where an increase in retailer competition leads to inflationary ordering behavior, high order cancellation, and higher manufacturer costs, due to excess capacity and finished goods inventory. Expanding on that theoretical model, Shi's (2002) study of Cisco Systems showed how Cisco's actions – such as favorable credit terms to retailers with the intention of promoting demand growth – generated fierce retailer competition, a boom in retailer orders, further inflating the demand bubble, and intensifying the subsequent bust, contributing to a record $2.7 billion inventory write-off and massive layoffs.

Emmons and Gilbert (1996) investigate the role of returns to the maximization of manufacturer's profit while incorporating retailers' self-interested behavior into the manufacturer's policy decision. The authors first maximize retailer profits and incorporate those results in the supplier maximization problem. In sharp contrast to a model where fully rational agents make optimization decisions, our paper assumes that managers have cognitive, perception, information, psychological limitations on their rationality, presenting bounded rationality as suggested in theory (Simon 1982, Cyert and March 1963, and others) and observed empirically (Kahneman et al. 1982, Sterman 1989a, 1989b, Diehl and Sterman 1995, Croson and Donohue 2000).[1]

3. Model Structure and Assumptions

This section details the causal mechanisms that lead to the increase in returns and four main formulations, elicited during our fieldwork, describing agents' (dealers, supplier's managers, and salespeople) decisions and their intended rationality. While these decisions may not be optimal, they reflect the heuristics used by agents on their everyday decisions.

Consider the timing of seed corn production and shipments in the North American agribusiness industry (Figure 2). From January to March, the seed supplier chooses the mix and volume of hybrids to produce. Once those decisions are made the mix of corn-hybrids available in the following season is fixed. In April, growers plant the seeds produced and sold by the supplier the previous season. The supplier also plants in April and late October is harvesting time. After harvesting, the supplier must test, bag, and tag the corn-hybrids to get them ready for delivery to dealers. While shipments to dealers start only in mid November, dealers start placing their orders in mid September. Often dealers inflate their orders in an attempt to get the corn-hybrids they believe will be in high demand by growers. Estimating which hybrids will be in high demand, however, is not

[1] Also see Morecroft (1983, 1985) and Sterman (1987) for further discussion of bounded rationality in simulation models.

a trivial task due to the large number of corn-hybrids and uncertainty associated with weather conditions. One difficulty arises from the heuristics growers use to place their orders. Grower demand is highly influenced by the performance of corn-hybrids in the recently harvested crop. Another difficulty arises from the difficulty in determining grower demand. Dealers learn about grower demand only after harvesting (by late December), when growers place the bulk of their orders. Growers often delay receipt of seeds until they need them for planting at the end of March. At that time, the seed supplier stops shipping seeds to dealers. The majority of seed returns take place in July, long after the selling season is over. Even when returns occur earlier in the season, they often cannot be reconditioned in time to be sold in the current season, due to the time to re-test, recondition, re-bag, and re-tag them.

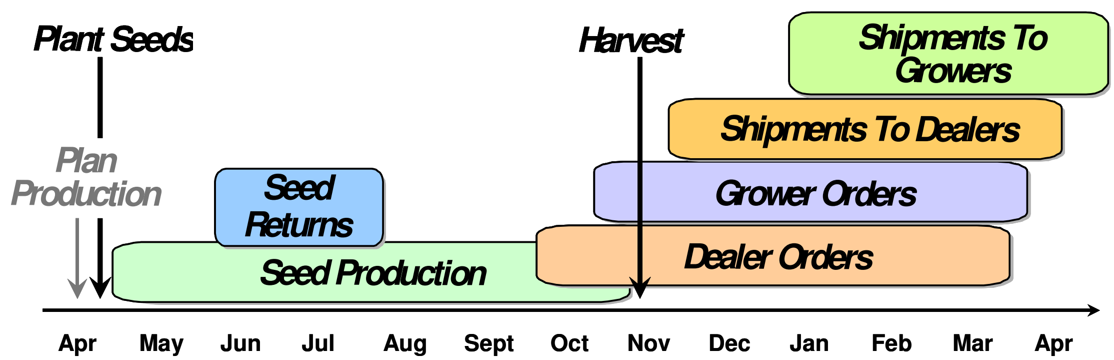

Figure 2. Timing of corn seed production, orders and shipments

While the seed supplier starts shipping seeds to dealers in mid November, its fiscal year ends in December. Therefore, any discrepancies between current and target revenues must be met within that six-week period. During this period, salespeople face increased pressure to meet the annual revenue target. As pressure increases, and given that dealers have placed large orders in the previous months to hedge against potential shortages, salespeople start to make phone calls requesting early delivery of existing orders. Dealers will tentatively delay receipt of orders – since most growers will still not have firmed their orders – but given that seeds can be returned later at no cost, dealers traditionally do not have a problem accepting seeds sent early. Naturally, since growers have not placed their orders, salespeople may be pushing corn-hybrids to dealers that lack the appropriate grower demand. As salespeople effectively "sell" more seeds, however, revenues increase, easing the pressure from corporate headquarters. The managerial response of focusing salespeople's effort on pushing seeds has the desired consequence of increasing revenues in the short run and meeting the revenue goals for the year. Figure 3 shows the balancing *Revenue* loop *(B1)*.

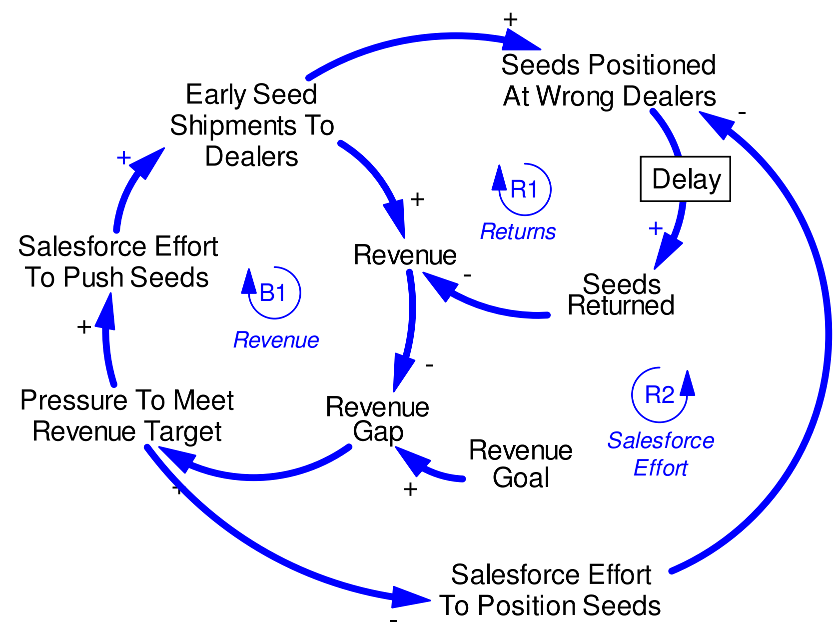

Figure 3. Causal loop diagram mapping salespeople's effort allocation

While shipping seeds early on the season reduces the stress on salespeople, it also leads to a poor positioning of seeds with dealers. Ultimately, seeds end up at dealer locations with inadequate grower demand. When seeds are shipped to "wrong" locations, they will be returned at the end of the season, reducing the following years' revenues, and further increasing the following year's pressure on salespeople. Managerial pressure is likely to increase salespeople's effort devoted to pushing seeds, leading to further returns. The reinforcing *Returns* loop *(R1)* captures the dynamics associated with returns from wrong dealers. The costs of pushing seeds are insidious. While the benefits of pushing seeds takes place instantly – salespeople immediately get rewarded (a cash bonus) for meeting the annual revenues' target – the associated costs occur only in the following year. Even then, the costs of returns to salespeople are not financial. When returns take place in July, the associated costs are added to the following season revenue target, raising the target and increasing future pressure.

Salespeople often gain a better understanding of grower demand, before it is realized, by interviewing farmers and dealers in their sales region. Starting in September, they make field trips to farmers and dealerships in their sales region to gather information about future demand. During these field trips, salespeople seek to understand from farmers which hybrids were used in the previous season and which ones were more effective. They also explore the farmer's intention to maintain/change planted areas and intention to rotate between crops. Similarly, field trips to dealers seek to review previous season's hot selling hybrids and any intentions to grow sales or gain market share. Some salespeople spend most of their time on these field trips, which often involve a phone call a week in advance (to schedule it) followed by a half-day (sometimes a whole-day) visit. While field trips require a considerable amount of salespeople's time and effort, it helps them build rapport with dealers and growers, and provides them with useful information to forecast future sales. Salespeople's effort in learning about seed demand allows them to better position the hybrids, avoiding later returns.

However, salespeople's time is spread thin between better positioning the seeds and pushing them to dealers to meet revenue targets. Salespeople can place little emphasis on reviewing dealer demand, especially when they are pressured to meet revenue targets. While salespeople that have gathered demand information can align supply availability with specific dealer's desires, salespeople more focused on pushing seeds for early delivery are left with orders that resemble a "wish-list" involving inflated quantities of hard-to-get "hot" hybrids. Pressure to meet revenue targets creates strong incentives for salespeople to push early seed delivery (prior to the end of the calendar year), increasing the probability of sending the seeds to "wrong" dealers, that is, those without corresponding grower demand. The reinforcing *Sales-force Effort* loop *(R2)* describes the dynamics that take place as the volume of early shipments increase and a greater fraction of them end up in "wrong" locations. The impact of pushing seeds instead of positioning them leads to an increase in returns and greater pressure to meet the revenue goals in the following year. This loop was captured by sales team leader:

> When it gets down to crunch time [we face] pressure that is coming from above… I understand that we need to make quarterly goals for the better of the company, but we kind of get ourselves in a vicious circle here. I want to make those quarterly goals. I'm a stock holder and I see it affecting my bonus too. But then all of a sudden, comes July when all of that corn starts coming back and we got a big [problem] on our hands.

The next two sections describe the main assumptions and model formulations for (a) managers' pressure on salespeople and (b) salespeople effort allocation generating the dynamics described in figure 3.

3.1.1. Managers' Pressure on Salespeople

Managers at the seed supplier face two periods of financial pressure during the year: one in December (at the end of the fiscal year) and one in April (at the end of the selling season). The former is motivated by financial pressure from "Wall Street" (the supplier is a publicly traded firm). Firm performance is closely monitored by capital markets, creating pressure to meet revenue and earnings targets. That pressure is very salient to managers. Managers are highly motivated to meet the gross revenue goals for the selling season. Target gross revenue (GR^*) is based on the previous year's gross accumulated revenue (GR) adjusted by a target growth rate (g), and changes associated with the costs of seed obsolescence *(OC)* and returns *(RC)* that adjust gross revenue from one year to the next. Gross revenue *(R)* is recognized at the time that the supplier ships the seeds to dealers. As gross revenues accumulate *(GR)* over the selling season, the supplier can compare it to the specified target *(GR^*)*[2]:

$$GR^*(s) = GR(s-1) \cdot (1+g) + \Delta OC(s) + \Delta RC(s) \tag{1}$$

Managers use the revenue gap as one source of information to set pressure on salespeople. The fractional gap in revenues *(FRG)* is given by the difference between the target revenue *(GR^*)* and the actual gross revenues accumulated so far *(GR)*, normalized by the target revenue *(GR^*)* for the period (calendar year for the pressure taking place at the end of Q4 and selling season for the pressure at the end of Q1).

$$FRG(t) = \frac{GR^* - GR(t)}{GR^*} \tag{2}$$

Managers compare the revenue remaining to the remaining time available in the calendar year, or selling season, to meet the target. The fractional time remaining *(FTR)* is given by the ratio of the time remaining *(TR)* and the total time available in the period *(TT)*, where the time remaining *(TR)* is given by the total time in the period *(TT)* minus the current time *(CT)*. The ratio of the fractional gap in revenues *(FRG)* and the fractional time remaining *(FTR)* in the corresponding period determines the pressure *(P)* faced by salespeople.

$$FTR(t) = \frac{TT - CT}{TT} \tag{3}$$

$$P(t) = \frac{FRG(t)}{FTR(t)} \tag{4}$$

[2] The variable *t* indexes the continuous dynamics within years. The variable *s* indexes discrete dynamics between years.

3.1.2. Salespeople's Effort Allocation

Salespeople allocate their effort between two activities: pushing seeds to or positioning seeds at dealers. The total effort *(TotEff)* exerted by a salesperson is assumed constant at 50 hours a week. The sum of effort to push *(EffPush)* and position *(EffPosit)* seeds result in the total effort, which assumes that salespeople do not shirk. Salespeople respond promptly and strongly to managerial pressure *(P),* such as the pressure to meet end-of-year (gross) revenues target, by pushing seeds to dealers instead of allocating effort to position seeds. We represent salespeople in aggregation, capturing their mean response over the distribution of possible response strengths. While individually salespeople differ in the intensity of their responses, our interviews support that on average they respond similarly to the same stimuli. For instance, all salespeople interviewed characterized that they faced a "crunch time" when trying to meet revenue targets. While all salespeople mentioned that they expedited dealer orders during crunch time, more experienced salespeople tended to manage their crunch time more effectively. As one sales team leader confided:

> We start out really trying to load toward true grower demand. Everybody makes an honest effort of doing that. But when it gets down to crunch time and teams are looking that they need – say another 10 thousand units to move up a notch on their bonuses – we have to load so much corn that you finally break down and you get to a point where you are just shipping what you can get, where you can get it, and when you can get it.

A nonlinear function *(f_1)* captures the impact of pressure on salespeople's fractional allocation of effort to position seeds.

$$TotEff(t) = PushEff(t) + PositEff(t) \tag{5}$$

$$PositEff(t) = TotEff(t) \cdot f_1(P(t)) \tag{6}$$

$$f_1 \geq 0, f_1' \leq 0, f_1(0) = 1, f_1(\infty) = 0 \tag{7}$$

By pushing *(EffPush)* more seeds to dealers during times of high pressure, salespeople reduce the time to schedule seed delivery (τ_{SCH}), thereby increasing the scheduling rate. The scheduling time (τ_{SCH}) is given by the product of the normal scheduling time (τ^N_{SCH}) and a function (f_2) of the ratio salespeople's pushing effort to the total effort.

$$\tau_{SCH}(t) = \tau^N_{SCH} \cdot f_2(PushEff(t) / TotEff(t)) \tag{8}$$

$$f_2 \geq 0, f_2' \geq 0, f_2(0) = f_{MAX} = 1.25, f_2(1) = f_{MIN} = 0.5 \tag{9}$$

Increased effort pushing seeds allows salespeople to make more deliveries and, thus, increase gross revenues. However, salespeople allocate less effort positioning seeds at dealers with actual grower demand, leading to a high volume of seeds at dealers with inadequate grower demand. The probability of shipping seeds to "right" dealer locations (PS_{Right}) increases with the salespeople's positioning effort, that is, effort spent understanding dealers' demand forecasts and past sales. A nonlinear function (f_3) captures the impact of salespeople's positioning effort on the probability of shipping right.

$$PS_{Right}(t) = f_3(PositEff(t)) \tag{10}$$

$$f_3 \geq 0, f_3' \geq 0, f_3(0) = f_{MIN} = 0, f_3(1) = f_{MAX} = 1 \tag{11}$$

The situation, however, is worse than that shown in figure 3. Early shipments also erode the supplier's seed stocks and its ability to fill later demand. Low ability to fill demand contributes to dealers' perceptions of the seed company's low supply reliability, which causes dealers to increase their safety stocks and hoarding seeds in the following season. Figure 4 shows the reinforcing *Reliability* loop *(R3)* that captures these dynamics. The supplier's ability to meet demand is also curtailed by the fact that there is no supply chain visibility. Hence, seeds positioned at dealers without the corresponding demand cannot be repositioned later. This creates the additional *Tied-up Stocks* reinforcing loop *(R4)*. In summary, early seed shipments allow salespeople and the seed supplier to meet the current year's revenue target, but may do so at the expense of the following year's performance, as measured in terms of increased returns, increased salespeople pressure, and low supplier reliability.

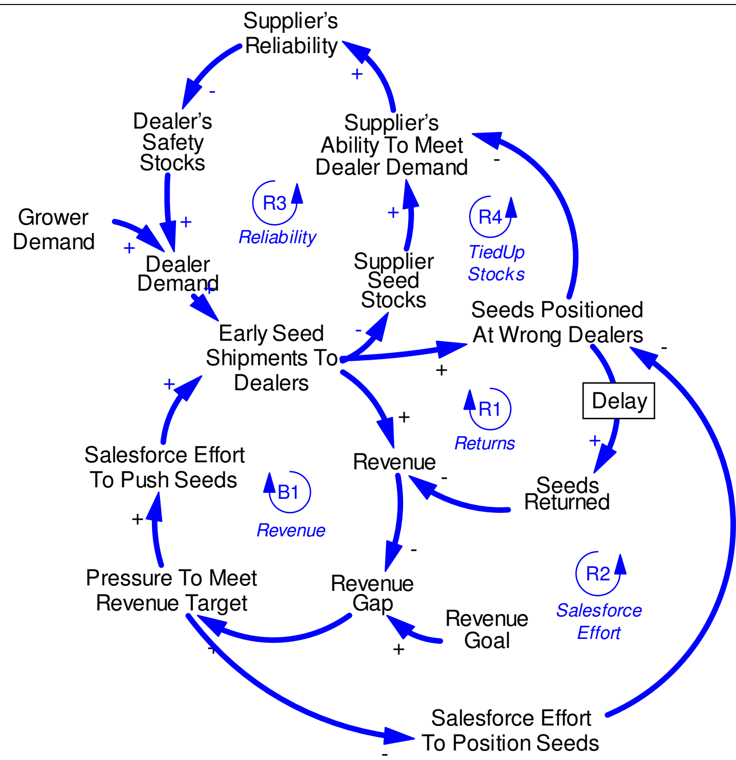

Figure 4. Causal loop diagram mapping supplier reliability and lost sales

The next two sections describe the main assumptions and model formulations for (a) dealers' desired orders and (b) supplier production rate generating the dynamics described in figure 4.

3.1.3. Dealers' Desired Orders

Dealers start placing orders with the seed supplier in mid September, two months prior to the end of the harvest of last years' crops. When dealers perceive the supplier's reliability as low, they place large stock orders to hedge against the possibility of shortages. To estimate the desired volume of stocked orders *(SO^*)*, dealers consider two sources of information: expected grower demand *(GO)* and expected return fraction *(ERF)*. When supplier reliability is high – the supplier can meet dealers' orders for each hybrid – dealers do not need to maintain large safety stocks and may order the expected grower demand. The orders will suffice to meet the demand and there will be few seed returns. When supplier reliability is low, however, dealers may order more than what they expect to sell to maintain large safety stocks and meet expected grower demand. As one seed dealer told us:

> Usually, we base our orders on last year's sales and typically we increase 10-20%/year. We also order early in the season. By September 15 we can place 50% of stock orders. If it would be in our benefit to order more than 50% of previous years sales we would do that. For example, we would order more than that, if we knew that supplies were short. We may learn this from conversations with our sales rep… Also, if the sales rep would tell me that a certain variety is on short supply, I would order as much as I could, or as much as my rep would allow.

Dealers' perception of the supplier's reliability is largely determined by the salient information provided by seed returns in the previous year. Dealers expect a large fraction of seed returns in one year if the previous one has also been large. To compensate for the expected returns, dealers inflate their orders by the amount necessary to adjust for all returns. The desired volume of stocked orders *(SO^*)* is determined by the ratio of grower demand *(GO)* and the complement of the expected returns fraction *(ERF)*. While dealers' do not have direct access to expected grower demand, they can get a good estimate of its value by the sum of total shipments to customers and the growers' unfilled orders. There may also be similar hoarding by growers, but for simplicity we assume that dealers know grower demand. In addition, we assume that grower demand is exogenous.

$$SO^*(t) = \frac{GO}{(1 - ERF(t))} \tag{12}$$

The supplier knows that dealers inflate their orders to hedge against shortages, so they may limit the amount that any dealer can order. The supplier's allowed stocked orders *(SO_A)* set a ceiling to stock orders as a maximum fraction *(SO_{MF})*, typically 10%, above last years cumulative sale to growers *(CS)*. The supplier has a good estimate of the volume of sales to growers by subtracting total shipments to dealers from the seeds returned. For simplicity, we use cumulative sales in our model.

$$SO_A(t) = CS(t) \cdot SO_{MF} \tag{13}$$

3.1.4. Supplier's Production Rate

To decide the volume of production the supplier considers two pieces of information: a term for dealers' desired stock orders (SO^*) and another for inventory adjustment *(IA)*. The supplier uses a bottoms-up approach for estimating the first term. In particular, the supplier takes into consideration future sales estimates from sales teams. As noted by a product manager:

> Earlier we used a top-down approach. We decided on a plan and then went out to sell if. Nowadays, we have a bottoms-up approach. We first get input from our sales teams. They give us a sales target for their region. That can be translated into a number of acres that need to be planted, and given the performance of hybrids, into the number of units.

Future sales estimates are based on desired dealer demand (desired stock orders). Production takes place during the fourth quarter, hence, the ratio of the volume of desired stock orders (SO^*) by the time available for production (τ_P) determines the first component of the production rate.

Second, the supplier adjust its production to maintain the inventory *(I)* at a desired inventory (I^*) level, over the inventory adjustment time (τ_I). The desired inventory (I^*) is given by a fraction (F_{SS}) of the dealers' desired stock orders (SO^*).

$$PR(t) = MAX\,(0, \frac{SO^*(t)}{\tau_P}, +(\frac{I^*(t) - I(t)}{\tau_I})) \tag{14}$$

$$I^*(t) = SO^*(t) \cdot F_{SS} \tag{15}$$

Finally, to evaluate production performance the industry adopts a heuristic relating the ratio for the volume of sales and the volume of production. While the industry ratio is typically of 70% the supplier maintains a lower ratio. According to the product manager:

> The industry standard for production is to shoot for sales that are around 70% of what we produce. Last years we have been around 55%. This year, we are going to move up to 62%.

The formulations for (a) managers' pressure, (b) salespeople's effort allocation, (c) dealers' desired orders, and (d) supplier's production rate cover the main formulations in the model.[3] To gain a deeper understanding of the processes leading to seed returns and to investigate policies capable of mitigating them, we simulate and analyze the system dynamics model.

4. Model analysis

This section presents the base case run of the model and investigates the incentives and pressures faced by salespeople as well as their rationale for shipping seeds early.

4.1. Base Case

The model runs for fifteen simulated years. We discard the first five years to get rid of the initial transient behavior in the model. Since the corn seed business is characterized by a first and fourth quarter business, we assume for simplicity that a simulated year is composed of 26 simulated weeks accounting for Q1 and Q4. In the beginning of Q4, dealers start placing their orders with the seed supplier. Several dealers will hoard (stock order) large quantities of seeds as soon as dealers start accepting orders, in response to the fraction of seeds returned in the previous year. The remaining orders are placed throughout the selling season, as dealers gather information on grower orders or as growers place their orders directly with dealers. In early November, salespeople start scheduling dealers' orders for delivery. Motivated by the pressure to meet the supplier's revenue targets, salespeople schedule delivery before the end of the calendar year. Figure 5a shows the ordering and scheduling rates. Shipments to dealers (Figure 5b) start in mid November (week 20), increasing sharply due to these financial pressures.

[3] Further details about formulations and assumptions in the model can be found in Appendix A. A running version of the model can be obtained upon request.

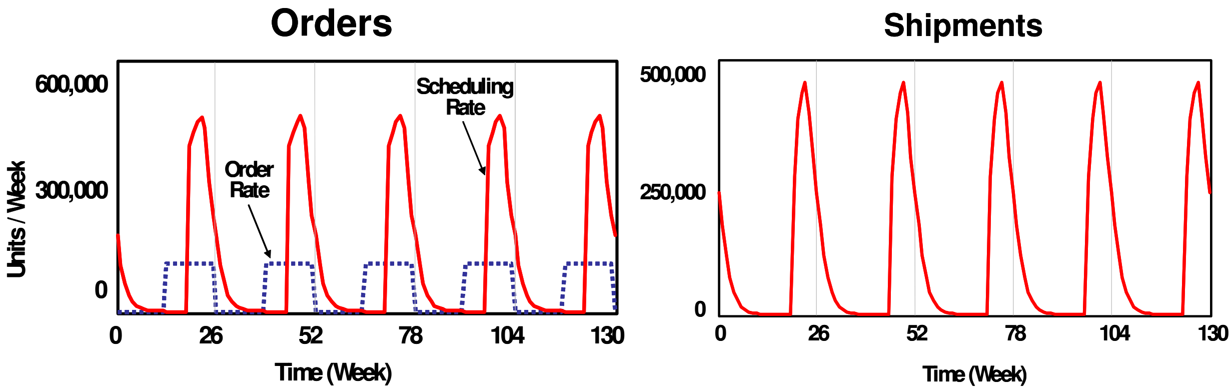

Figure 5. (a) Inflow and outflow of dealer orders and (b) stock of orders at seed supplier

The supplier sets a revenue goal based on last year's revenues adjusted for the additional costs of returns and obsolescence. The supplier recognizes sales revenue at the time the seeds are shipped to dealers. Corn seed prices ($100/bag), return costs ($20/bag), and obsolescence costs ($5/bag) are constant throughout the simulation. Initially in the quarter, pressure to meet the revenue target is low since salespeople have plenty of time to make sales. This pressure on salespeople (Figure 6a) increases, however, as time goes by and the end of the quarter approaches. The graph has a peak at the end of Q4, indicating an increase in pressure due to the little time availability to meet the revenue targets for the fiscal year ending in December. During high-pressure "crunch" periods, salespeople allocate most of their effort (time) pushing seeds to dealers and almost no effort positioning them adequately. Figure 6b shows salespeople's efforts in pushing and positioning seeds.

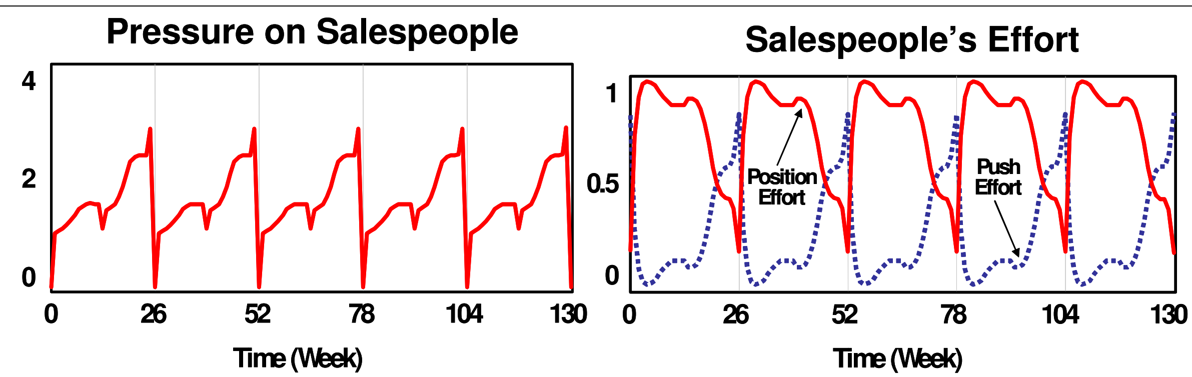

Figure 6. (a) Pressure to meet revenue targets and (b) salespeople's effort to position/push seeds

As pressured sales people push seeds, they incur a greater probability of sending it to dealers where no corresponding grower demand is available. Figure 7a shows that the probability of sending seeds to the "right" locations decreases as the pressure on salespeople increases with the end of the year. This leads to a stock of seeds in "wrong" locations – where no grower demand is available (figure 7b) – that will ultimately return to the seed supplier.

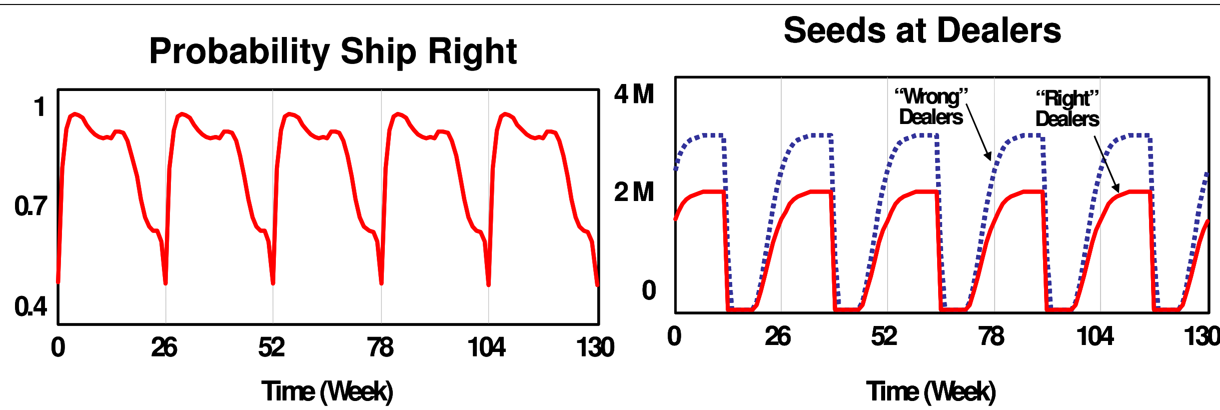

Figure 7. (a) Probability of shipping to right locations and (b) seed stocks at different locations

4.2. Sensitivity analysis

Model behavior is highly sensitive to the assumptions embedded in the non-linear functions for pressure on salespeople's effort allocation *(f_1)* and positioning effort on probability to ship "right" *(f_3)*. We follow a common procedure to obtain the results of the sensitivity analysis. We represent each nonlinear function as a linear combination of two polar cases capturing extreme assumptions. By varying the weight in the linear combination, we obtain a range of dynamic behavior in the model.

4.2.1 Sensitivity to Pressure on Salespeople's Effort Allocation

Consider the two polar cases of salesperson: experienced and inexperienced salespeople. An experienced sales force, characterized by function *(f_{1A})*, responds mildly to an increase in managerial pressure to meet revenue targets. Or at the extreme, an experienced salesperson may be completely insensitive to managerial pressure. In such case, the non-linear function *(f_{1A})* would be flat, describing that despite any amount of managerial pressure, an experienced salesperson would always allocate effort to positioning seeds and never would push them to dealers without appropriate grower demand. An inexperienced salesperson, characterized by function *(f_{1B})*, responds aggressively to an increase in managerial pressure. When managerial pressure increases, the inexperienced salesperson will adjust the allocation of effort significantly, dedicating a lot more effort to pushing seeds to dealers instead of adequately positioning them. Figure 8 shows the two polar specifications (f_{1A} and f_{1B}) for the effect of pressure on salespeople's effort allocation *(PSE)*. A general function for the effect of pressure on salespeople' effort allocation *(PSE)* is obtained from the linear combination of the two polar cases (f_{1A} and f_{1B}).

$$PSE = w_1 f_{1A} + (1 - w_1) f_{1B} \quad (16)$$

where w_1 corresponds to the weight of function (f_{1A}) and $w_1 \in [0,1]$. The base case simulation corresponds to $w_1 = 0.5$.

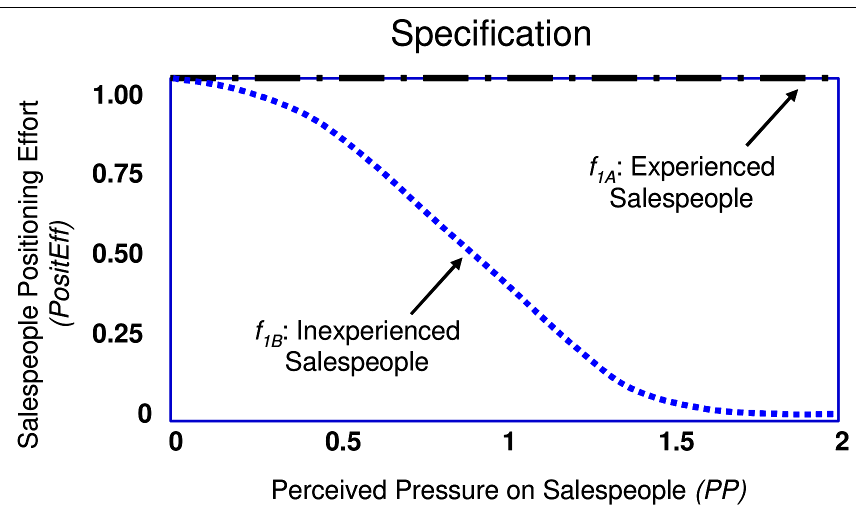

Figure 8 – Specification for Function (f_1): Positioning Effort.

Figure 9 (a) shows the sensitivity of seeds at "wrong" dealers and (b) the fraction of seeds returned for different specifications of the function *(f_1)*. The results suggest that the volume of seeds at wrong dealers decrease with salespeople's experience. When salespeople are very inexperienced, they react to managerial pressure by allocating more effort to push seeds and thereby send a greater fraction of shipments to dealers without the corresponding grower demand. When salespeople are experienced, they do not respond to managerial pressure. An experienced salesperson "breaks" the feedback response from actual revenues to effort to position seeds, avoiding the problem of shipping seeds to the wrong dealers.

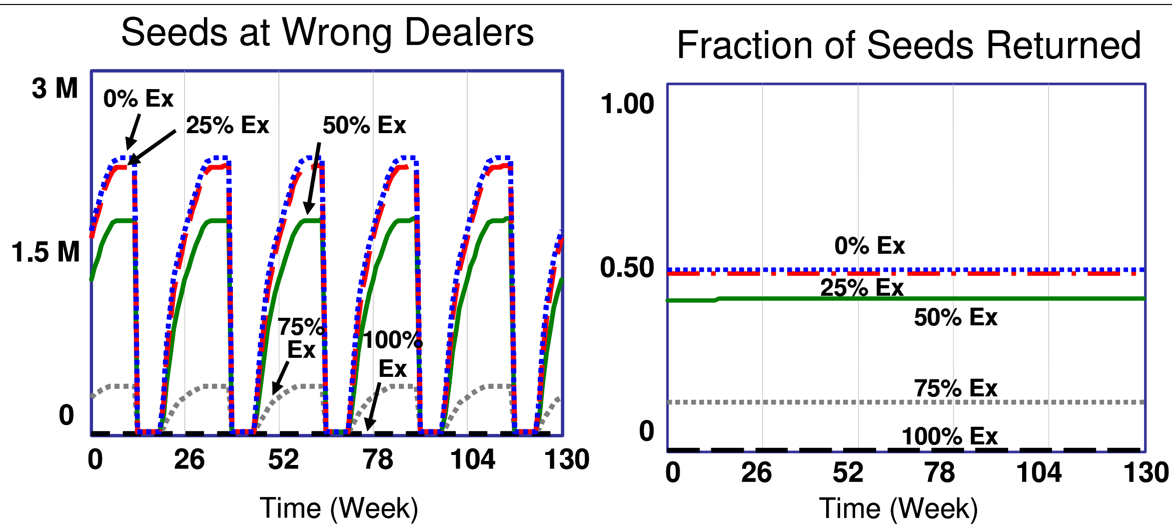

Figure 9 – Sensitivity of seeds at "wrong" dealers and returns to salespeople's responses.

4.2.1 Sensitivity to Position Effort on Probability

Consider the two extreme cases of the quality of dealers' orders. High quality orders, described by function *(f_{3A})*, are characterized by a perfect correlation between dealer and grower orders, reflecting the case of perfect orders. When dealer orders perfectly reflect actual grower demand, a lack of salespeople's effort causes no impact on the adequate positioning of seeds. Even if inexperienced salespeople pushed sales to dealers, by speeding delivery of previously placed orders, seeds would still be sent to the "right" dealers. On the other hand, low quality orders, described by function *(f_{3B})*, are characterized by a poor correlation between dealer and grower demand. Imperfect dealer orders suggest that a lack of salespeople's effort on positioning seeds can lead to a large fraction of seeds at “wrong” dealers. Figure 10 shows the two polar specifications (f_{3A} and f_{3B}) for the probability of shipping right *(PPR)*. A general function for the effect of positioning effort on the probability to send to “right” dealers *(PPR)* is obtained from the linear combination of the two polar cases (f_{3A} and f_{3B}).

$$PPR = w_2 f_{3A} + (1 - w_2) f_{3B} \qquad (17)$$

where w_2 corresponds to the weight of function (f_{3A}) and $w_2 \in [0,1]$. The base case simulation corresponds to $w_2 = 0.5$.

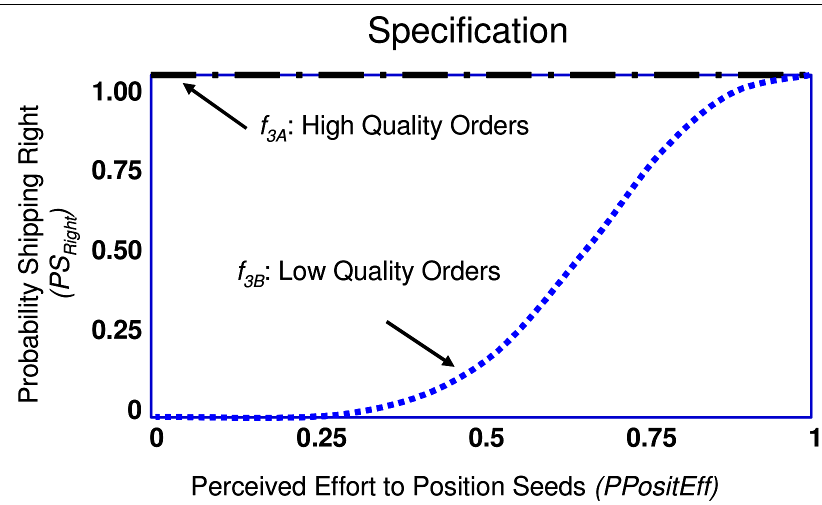

Figure 10 – Specification for Function (f_3): Probability of Shipping to Right Dealers.

Figure 11 (a) shows the sensitivity of seeds at “wrong” dealers and (b) the fraction of seeds returned for different specifications of the function *(f_3)*. The results suggest that the volume of seeds at wrong dealers decrease with the quality of dealers’ orders. When orders have a poor correlation with grower’s orders, there is a high probability that corn seeds will end up at dealers without the corresponding grower demand. When the quality of dealer’s orders is high, it can “break” the feedback influence of salespeople’s effort to position seeds to the probability of shipping to right dealers, which avoids the problem of shipping seeds to the wrong dealers.

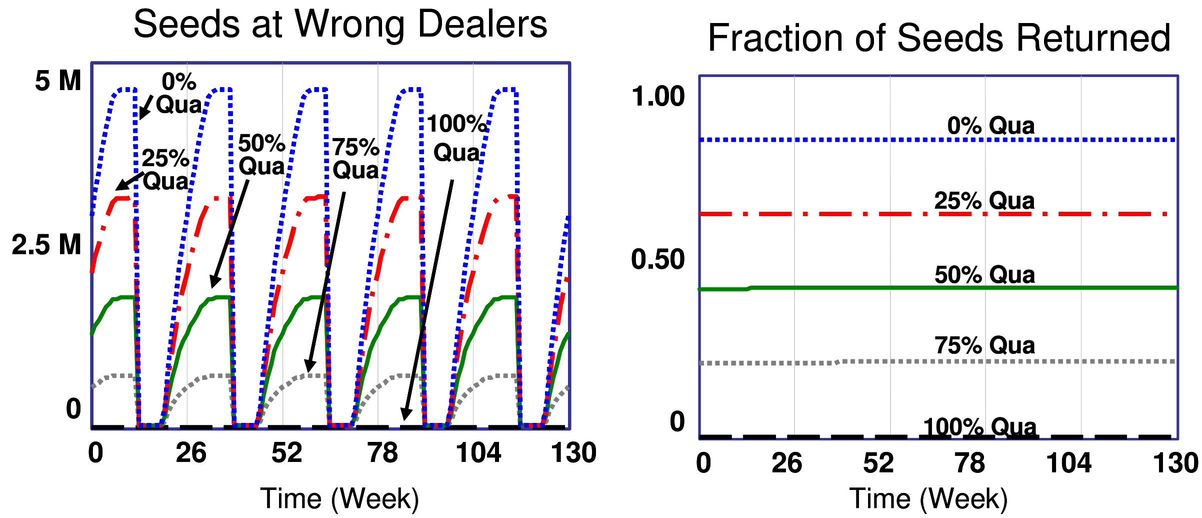

Figure 11 – Sensitivity of seeds at wrong dealers and returns to data quality.

The base case simulation shows how pressure to meet the revenue target can lead to poor allocation of effort by salespeople, resulting in an increase in seed returns. The next section explores the incentives faced by salespeople and the intended rationality of their actions.

4.3. The case for sending seeds early

While emphasis on pushing seeds may not seem rational in the long-term, sales people have huge incentives to do this. First, salespeople's financial rewards are directly proportional to meeting revenue targets. Bonuses, ranging from zero to 40% of base salary, depend on the fraction of the revenue quota the team achieves. Not meeting the quota has a clear negative impact: the team receives a low bonus. There is no ambiguity in the costs associated with such outcomes. This is in sharp contrast with the costs associated with returns. Sales teams are charged an "obsolescence rate" for returned seeds that spoil. All teams, regardless of individual contribution to total returns, share equally these costs. The salespeople we interviewed were unable to specify the policy used to charge them for obsolescence costs. More importantly, they could not quantify the dollar value that the charge represented. Furthermore, salespeople are charged for the direct costs associated with sales not made (returns). While salespeople do not experience a direct reduction in their bonuses as a result of returns, their revenue targets for the following year are adjusted upwards to account for any lost revenue. While there are clear and unambiguous monetary benefits to pushing seeds to dealers, the costs are ambiguous and translate into higher revenue targets instead of a monetary disincentive.

Second, the rewards accrued for pushing seeds occur closer in time to salespeople's actions. Salespeople receive their bonuses at the end of the calendar year (Q4), just as pushing seeds to dealers has peaked. Hence, salespeople have very salient information about the strength of their actions and the resulting outcome. In sharp contrast, seed returns take place at the end of the selling season (end of Q1) in the following calendar year, at which time the associated costs are taken into consideration. The costs associated with each sales team's returns lead to higher revenue targets in the following year. In summary, the costs associated with pushing seeds accrue one year after the benefits. Hence, the incentives to pushing seeds to dealers are not only unambiguous but they take place shortly after the actions are made.

Third, it takes much less effort to push seeds than to position them. Consider the amount of time and effort associated with positioning the seeds in dealers with adequate demand. The salesperson must first call the dealer to schedule a personal visit, where both can go over the current replenishment plan. Prior to the visit, dealers can explore potential grower demand and salespeople retrieve last year's sales information for their reference. At the scheduled date, the sales representative visits the dealer to discuss future ordering plans, which can take a whole day or at least one afternoon. Now consider the time and effort required to push seeds to dealers. In some cases, this boils down to a telephone call of a few minutes where the sales representative lets the dealer knows that he is sending some bags of seeds earlier than expected to meet the sales goals. Most dealers have already placed a large number of orders with the supplier, which they expect to receive some time during the season, so most of the salesperson negotiation focuses on early delivery. Laid-back salespeople are clearly better-off (in the short-term) by pushing seeds to dealers instead of trying to position them. Even industrious salespeople will be tempted to shift to pushing seeds when pressured to meet revenue targets. The uneven amount of effort to push and position seeds is likely to lead pressured salespeople to choose the former instead of the latter.

Finally, the early timing of benefits compared to costs generates an important reinforcing loop that intensifies the detrimental dynamics leading to high returns. When salespeople push sales to ease the short-term financial pressure, they generate returns in the following year. The supplier then adds the costs of returns to the following year revenue targets of the corresponding salespeople. Hence, in the following season, salespeople must meet an even higher revenue target and endure even more pressure than the previous year. Under additional stress, they are likely to rely even more on the pushing seeds strategy, which will lead to even higher returns in the following year. When salespeople enter into the mode of pushing seeds to meet revenue targets, the reinforcing loop makes it very difficult for them to change the situation.

5. Policy Analysis

Next, we explore policies that can mitigate the costs of high seed returns. We analyze four types of policies. The first policy – *Order pacing policy* – limits the initial pace of dealers' orders. The second policy – *Fiscal year policy* – shifts the fiscal year from the calendar year to the selling season year. The third policy – *Salespeople's playbook policy* – provides salespeople with a framework that helps them take action in the face of pressure. And the fourth policy – *Early ship policy* – provides salespeople additional time to meet their revenue target.

5.1. Order Pacing Policy

This policy establishes a pace for dealers' ordering rate. First, it limits dealer's initial volume of stock orders, establishing a maximum stock order of 50% of previous year's sales (net of returns) that can be placed when the supplier starts accepting orders. Then, it imposes a maximum pace for subsequent orders, i.e., dealers can place the remainder of their orders uniformly throughout Q4, reaching 75% in mid October, and 100% in mid November. Since the remaining stock orders are delayed, we allow them to have better quality. While dealers placed most of their orders before grower demand information becomes available – growers do not place most of their orders until late November or December (Figure 3) – dealers' fears of scarcity of desired seed hybrids motivated them to place large orders early in the season. For instance, if dealers sold 500 bags of a specific hot hybrid in the previous year, they would not hesitate in placing an order for more than 250 bags in mid September. This pattern of order pacing reflects a policy actually implemented by the seed supplier. Prior to this policy, dealers' placed large stock orders in the beginning of Q4, leaving many regions (and dealers) without any supply. Figure 12 shows the stock of seeds at wrong dealers for this policy compared to the base case. The order pacing policy reduces returns by 12%. This policy was successfully implemented by the seed supplier, allowing them to improve supply of high performing across all dealers.

5.2. Fiscal year policy

This policy shifts the fiscal year for the company allowing it to shift the pressure on salespeople from the end of the calendar year (end of Q4) to the end of the selling season (end of Q1). This policy has two direct benefits in reducing the volume of returns. First, it allows a much longer amount of time for salespeople to meet their revenue targets. Reducing the pressure experienced by salespeople will avoid the need to push seeds to dealers, and substantially reduce the volume of seeds returned. Second, by closing the books at the end of selling season, the supplier can postpone the starting date to receive dealer's orders. This allows dealers more time to gather grower demand information and place orders that more closely reflect them. We introduce this policy by shifting the end date of the annual period to meet the revenue target. Figure 12 (a) shows the inventory at wrong dealers for this policy; Figure 12 (b) shows the fraction of returns. The fiscal year policy reduces returns by 56%. This policy yields a large impact because it addresses the main cause of returns: the managerial pressure to meet financial targets. The supplier considered implementing this policy, but that has not yet taken place.

5.3. Salespeople's playbook policy

Salespeople have a dual role of pushing and positioning seeds. This policy emphasizes the important role played by sales teams in positioning seeds. Its intention focuses on minimizing the impacts of pressure on salespeople's behavior. Our interviews suggest that while salespeople respond to financial pressure in a similar way, inexperienced sales people were more prone to pushing seeds to the wrong dealers. Their lack of experience results in inadequate planning and postponed contacts with dealers. One sales team leader explained one way he managed his seed portfolio:

> I have my agronomist go through and analyze our entire portfolio and say what are the four or five key hybrids or varieties that we are going to hand our head on in [the following year]. I don't want fourteen million products that we are going to sell out here. We can't be all things to all people out there. We've got to focus on the four or five that we know that will perform well for our growers out there and make them more money than the competition. Yet, we are going to have other SKUs besides that, but we are going to focus on the four or five.

In addition, the interviews suggest that inexperienced salespeople respond more aggressively to financial pressure, resorting more frequently and more strongly to pushing seeds to dealers. This policy suggests the implementation of a protocol, or playbook, capable of supporting salespeople's desired behavior. We implement this policy in the model by introducing a function for sales people response that has a smaller slope to the pressure input. Figure 12 (a) shows the seed stocks at wrong dealers and Figure 12 (b) shows the fraction of returns for the salespeople's playbook policy. This policy reduces returns by 39%. The seed supplier has been emphasizing grower order accuracy, but we believe that there are still other opportunities to improve focus for sales teams. For example, one sales team leader shared the strategy used to get salespeople's focus:

> We had a little business card that had corn hybrids on one side and soybeans on the other, and it said what percent of the total mix we had of [a specific] product. So, [hybrid X], for example, was 18% of our total [team] supply. Everybody [in our team] knew what the top 10 hybrid varieties were. Everybody knew what we needed to be promoting. Everybody knew what we needed to be selling. Everybody knew what we needed to be positioning at a dealer. So, once you get that kind of knowledge and you go through that intensive process you are going to do a lot better job managing your supply in October, November, and December.

The playbook policy suggests that there are opportunities for making wide spread use of techniques developed by the existing salespeople, so that teams can learn from each others best practices.

5.4. Early ship policy

In this policy, the supplier anticipates the starting shipment date to dealers. This policy provides salespeople with additional time to meet their revenue targets, reducing the financial pressure they experience. Under lower stress levels, salespeople have an opportunity to position more seeds, correcting some of the discrepancies introduced during the early stock ordering process. This policy increases the probability that seeds are sent to the right dealers, which in turn reduces the amount of seeds returned. We implement this policy by allowing the seed company to start scheduling delivery of seeds two weeks in advance (early November). Since shipping early does not change the timing that dealers are placing their orders, it does not have any impact on the probability of shipping to adequate locations. Figure 12 (a) shows the stock of seeds at wrong dealers and Figure 12 (b) the fraction of returns for this policy compared to the base case and other policies. The early ship policy reduces returns by 4%.

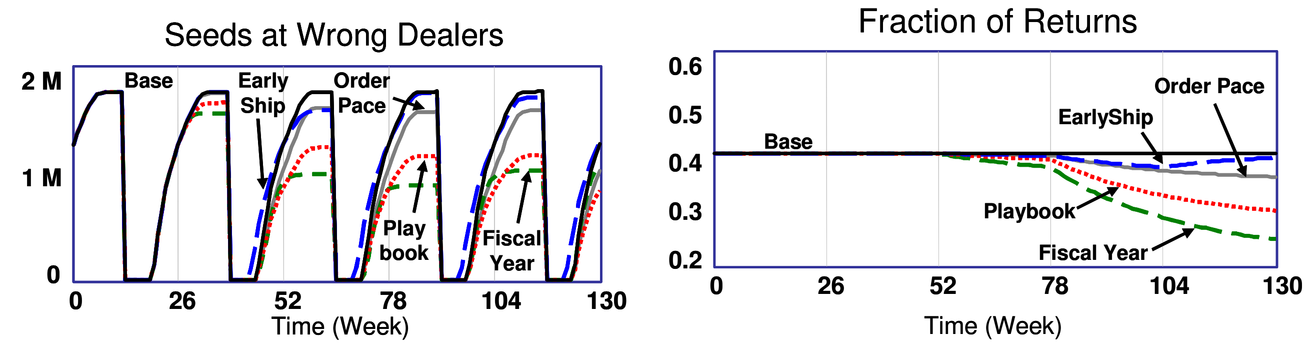

Figure 12. (a) Seeds at wrong dealers and (b) fraction of returns for different policies.

Table 1 presents a summary of the results for all policies investigated. The supplier can effectively reduce returns (by 39% or more) by emphasizing measures that reduce the pressure experienced by salespeople and promote a conservative response to financial pressure. Two policies (salespeople's playbook and fiscal year) reduce returns addressing the effect of financial pressure on salespeople. The first policy provides salespeople with a best practice protocol that helps then to meet dealer demand without heavily depending on pushing seeds. The second policy shifts the pressure to the end of the selling season, giving salespeople plenty of time to meet the financial pressure. The policies reduce returns by 39% and 56%, respectively.

Table 1. Summary results for policy analysis addressing reduction in seed returns.

Policy	Net Revenues (Million $ / year)	Revenue Improvement (%)	Returns (Million $ / year)	Return Improvement (%)
Base	254	–	38.7	–
Order Pace	273	7.5	33.9	12
Fiscal Year	288	13.4	17.1	56
Playbook	269	5.9	23.6	39
Early Ship	254	0	37.2	4

6. Discussion

Seed hoarding and returns result from the interplay between human behavior (e.g. salespeople's effort allocation decisions, dealers' ordering decisions, supplier's production heuristics, and managers' pressure) and supply chain characteristics (e.g. fixed product mix, timing of information availability, and quality of dealers' orders). While system dynamics has a long tradition of investigating the interplay of human decision making in different industries, this research provides an application to the agribusiness industry and provides insight into the mechanisms that lead to seed hoarding.

Although the intrinsic characteristics of corn-seed production, making available a fixed mix of products, influence dealers' hoarding behavior, a number of actions by the supplier can intensify dealers' inflationary behavior. For instance, a number of unintended consequences are triggered by the intendedly rational decision rules of managers and salespeople. To ease the managerial pressure to meet gross annual revenue targets, salespeople push seeds to dealers. Early shipments allows salespeople to meet the financial goals, however, the hybrids may end up at dealers lacking the appropriate grower demand. While managerial pressure has the desired consequence of increasing gross revenues and meeting financial goals, it also closes a number of positive loops that work in a detrimental way. Early seed shipments lead to poor positioning of hybrids with dealers. Ultimately, the hybrids end up in locations with inadequate grower demand, resulting in an increase in corn-seed returns, and further increase in financial pressure in the following year. Hence, the positive *Returns (R1)* loop leads to a higher fraction of seed returns this year and an even greater managerial pressure in the following year. In addition, the financial pressure to meet gross annual revenue targets creates strong disincentives for salespeople to position seeds. The limited effort devoted to positioning seeds increases the probability of sending them to dealers without corresponding grower demand. This positive *Sales-force Effort (R2)* loop will increment the volume of seed returns this year and the financial pressure in the following year.

The positive loops above, motivated by salespeople's responses to financial pressure, drive the system to a mode of operation characterized by high returns and financial pressure. These conditions further interact with the supplier's production heuristic creating an additional positive loop that intensifies the problem. As the volume of returns increase, the supplier increases the volume of production to maintain a desired level of inventory and sales. With larger inventories, the supplier can meet a greater fraction of dealers' orders, leading to more shipments and, everything else equal, more returns. The reinforcing "supplier production" loop also contributes to an increase in returns and financial pressure. The problem is intensified even more by dealers' ordering heuristics. Dealers' desired stock orders increase with the volume of returns. Higher orders lead to more shipments and, everything else equal, higher returns. The positive *Reliability (R3)* loop contributes even more to a high volume of returns and increased financial pressure. Hence, dealers' hoarding behavior is largely intensified by the suppliers' heuristics. While salespeople's effort to push seeds to dealers may be effective in reducing the short-term financial pressure, they can lead to a long-term increase in returns and financial pressure.

This research suggests a number of initiatives that can help the supplier reduce seed returns. First, the seed supplier can control the pace of dealers' orders. Currently, dealers can stock-up all of previous years' sales as soon as the supplier starts accepting orders. Dealers' over-ordering of specific seed hybrids can deprive entire regions of such hybrids, creating further incentives for all dealers to over-order in the following season. By controlling the pace of dealers' orders the supplier can ration the hybrids among all its dealers, allowing seeds to reach the dealers that are not over-ordering and also reducing dealers' need to over-order in the following season. While rationing does provide some dealers with an incentive to intensify over-ordering, it is less effective when the supplier controls the number of orders allowed. Second, the supplier can shift the fiscal year to coincide with the end of the selling season. This policy allows the supplier to meet their financial goals for the fiscal year in the end of the selling season (Q1) instead of the end of the calendar year (Q4). Changing the fiscal year shifts the pressure experienced by salespeople to the end of Q1, providing them with significantly more time to meet their targets. This policy further allows dealers to gather more reliable information about true grower demand, minimizing the need for dealer over-ordering. Third, the supplier can provide a "playbook" to guide salespeople's behavior. Since salespeople face tremendous pressure to meet financial goals, it is not surprising that they may focus their attention on pushing seeds instead of positioning them. While the supplier emphasizes the importance of salespeople's role in positioning seeds, we suggest a more practical approach. For example, the supplier could suggest the specific five hybrids that salespeople should focus on. In addition, the "playbook" could map challenges and contingent plans throughout the selling season to guide salespeople's actions and provide mechanisms to effectively prevent salespeople from giving into the pressure to meet the revenue targets. Fourth, the supplier can anticipate the initial date to start shipping seeds to dealers, to provide salespeople with more time to meet revenue targets. Easing part of the financial pressure faced by salespeople may allow them to emphasize on grower order accuracy. Our results suggest, however, that this policy may have a limited impact on behavior. Our analysis underscores the important role of salespeople's responses in the issue of seed returns. Overall, these policies stress the importance of grower order accuracy, particularly through the information gathered by salespeople as a proxy for actual grower demand. As one sales team leader told us: "[What we need are] real orders for real people." Relying on dealers' inflated stocked orders as a basis for shipments to dealers may simply not allow the supplier to reduce the amount of returns.

The results raise a number of issues regarding implementation. First, a salespeople "playbook" allows the rapid implementation of a policy that influences salespeople's responses. While hiring experienced people and diligent training would be a desirable alternative, it may take several years before the supplier can reap its benefits. An effective policy in the short-term may focus on developing a "best practice sales workshop" championed by experienced sales people. Such workshop would provide guidelines for actions and conduct to salespeople. The resulting framework could have a timeline for actions and achievements during the selling season. The guidelines could also provide a set of contingencies (questions to illuminate the potential causes of the problems and possible contingent actions) to guide salespeople's responses, when they face difficulty in keeping up with the timeline. A set of well established guidelines for salespeople's responses could allow them to behave more like experienced salespeople.

In addition, managers recognize that allowing returns in the first place is part of the problem. This practice, however, is industry standard. Managers hold the strong belief that more stringent return policies can lead to loss of market share. A potential solution that managers considered to tackle the excess returns was to rely directly on grower order demand. The ability to compare dealers' orders directly with grower's orders would allow the seed company to realize which dealers were hoarding which seed hybrids. Implementing such a policy, however, faced several constraints, such as getting the data on grower's orders and using it effectively. In terms of the former, many dealers are unwilling to share grower orders with the seed supplier. They fear that the company might use the data to bypass them and sell directly to growers. In terms of the latter, managers claimed that even if they could obtain the data on grower orders, they might not have use for it. Since grower orders become available only in late November, waiting for such data would not allow the company to meet its annual revenue quota. In addition, the supplier relies on the storage capacity of local dealers to stock the volume of seeds produced within the season.

While order pacing limited the volume of early orders and constrained dealers' hoarding behavior, some managers contended that the policy was a mixed blessing. On one hand, the supplier benefited from reduced hoarding of hot selling hybrids. On the other hand, it also reduced orders for other products. For instance, by waiting a couple of months before placing all its orders, dealers were able to avoid ordering products that were perceived to not perform so well, reducing the supplier's ability to sell products that were less appealing to dealers. Naturally, this argument fails to account for the fact that some of the seeds ordered by mistake would potentially be returned anyway, resulting in even higher costs (due to transportation, retesting and re-bagging.) Managers that were against the order pacing policy claimed that returns were an intrinsic part of the business and they were willing to accept some level of returns. As one manager put it:

> Unfortunately, in the seed business my perception is that it is almost a little bit of the nature of the beast. You are going to have returns. There is no 100% here. You can certainly work to minimize returns, and I think what we're trying to do as a company is to [ask] what is an acceptable amount of returns? Right now, we see that we are in excess of that and so we'd like to lower those returns from what they are today. But this is not a zero-sum game. You are not going to get them all of the way down to zero. It's the nature of the beast. When you are dealing with an industry influenced by the environment, orders change with time, they change by the day.

This work raises a number of possibilities for future research. A promising possibility is to study how hybrids of different performance can impact the results presented here. It was clear from our interviews that it is important for the supplier to emphasize the management of the whole product portfolio. Frequently, high performing seeds are quickly allocated to some dealers, when compared to low performing ones, often leaving other dealers with a perception that supply (for the products they want) is unreliable. In turn, perceived supplier unreliability potentially leads to seed hoarding in the following season. Furthermore, focus on high performing seeds leaves the supplier with unallocated low performing seeds, increasing the ratio of production to sales, augmenting costs, and decreasing supplier performance. Hence, the supplier must emphasize management of high performing hybrids, allocating them carefully across dealers, to avoid hoarding and to manage dealer's perceptions about supply availability and supplier reliability. For instance, the supplier can inform dealers about the adopted allocation policy for "hot" products and provide frequent updates on their availability. When high performing hybrids run out, the supplier may shift dealers' attention to other recommended hybrids. For instance, the supplier can suggest hybrids are good substitutes for specific "hot" products. In this context, it would be interesting to investigate the effectiveness of the previous policies when we model explicitly seed performance and account for dealers' preferences towards high performing seeds.

Finally, there is an opportunity to explore how other financial incentives can shape salespeople's and dealers' responses. In particular, the obsolescence charge used by the supplier is equally distributed among all salespeople. This creates an incentive for salespeople to push seeds, leading to potentially higher returns. By pushing additional seeds, salespeople get the full benefits of additional sales, but avoid some of the associated costs, since other salespeople pay for a fraction of the obsolescence costs. Subsequent to our intervention the policy was adjusted to proportionately impact sales teams based on their contribution to obsolescence. While this is a step in the right direction, other opportunities remain for creating the right incentives for dealers and salespeople. For instance, the lack of adequate incentives to dealers also contributes to the volume of seed returns. Dealers face significant penalties for under-stocking seeds, including sales and reputation losses. There are few or no penalties for over-stocking seeds, however. Prior to the 2000 season, dealers could send hybrids back to the seed manufacturer without any penalties. When seed returns rose in excess of 25% the supplier introduced an incentive plan charging dealers a restocking fee of 2% of the tag price, for seeds returned after February 28 – nearly at the end of the selling season – and in excess of the industry average. Even with this mild incentive – allowing dealers a significant amount of time to assess grower demand and no charges for returns within 15% – returns decreased the following season, perhaps because some dealers reduced their hoarding. This policy has suffered strong opposition and at one point was almost removed due to increased resistance from dealers and some managers at the seed supplier. Despite the resistance, the supplier adopted an additional incentive scheme in the last season. A product manager explains:

> We are keeping the old incentive policy that charges $2 per unit (bag) returned and adding a new incentive policy. The new policy adds a charge to the dealers' compensation package. Usually, we sell corn seeds for $100 and give back $11 to dealers as an incentive. When returns are over 20%, dealers loose 2% of total compensation. So for a bag of corn that may be sold for $100, the margin to the dealer is often around $10. A 2% charge of total compensation is $2, or 20% of their margins. So, this is a significant incentive.

In parallel with the implementation of punishment mechanisms for actions that lead to returns, the supplier can also implement policies that reward sales teams, dealers, and growers for low seed returns. Our interviews suggest that many dealers are successful in providing incentives for customers to place orders early. Finally, for both types of incentives it is crucial that the seed supplier provide complete visibility of the costs and rewards of different incentive systems, if it hopes them to be successful.

7. References

— (1974). *The New York Times*, February 15, Friday, Page 14, Column 5.

Donohue, K. 1996. "Supply Contracts for Fashion Goods: Optimizing Channel Profits." Working Paper, The Wharton School, Philadelphia, PA.

Emmons, H. and S. Gilbert. 1998. "Note. The Role of Returns Policies in Pricing and Inventory Decisions for Catalogue Goods." *Management Science*. **44**(2): p. 276-283.

Forrester, J.W. 1958. "Industrial Dynamics – A Major Breakthrough for Decision Makers." *Harvard Business Review*. **36**(4): 37-66.

Forrester, J.W. 1968. "Market Growth as Influenced by Capital Investment." *Industrial Management Review*. **9**(2): p. 83-105.

Gonçalves, P. 2002. "When do minor shortages inflate to great bubbles?" *Proceedings of the2002 International System Dynamics Conference*. System Dynamics Society: Albany, NY.

Shi, S. 2002. "Phantom Orders Roil Cisco's Supply Chain–A System Dynamics Study of Networking Equipment Industry's Supply Chain." Unpublished master's thesis, MIT, Cambridge, MA.

Jones, P.; T. Lowe; R. Traub; G. Kegler. 2002. "Matching Supply and Demand: The Value of a Second Chance in Producing Hybrid Seed Corn." *Manufacturing and Service Operations Management*. **3**(2): p.122-137.

Jones, P.; G. Kegler; T. Lowe; R. Traub. 2003. "Managing the Seed-Corn Supply Chain at Syngenta." *Interfaces*. **33**(1): p.80-90.

Merton, R. K. 1948. "The Self-fulfilling Prophecy." *Antioch Review*. **8**: p.193-210.

Mitchell, T.W. 1924. "Competitive Illusion as a Cause of Business Cycles." *Quarterly Journal of Economics*, **38**(4):p. 631-652.

Padmanabhan, V. and I.P.L. Png. 1995. "Returns Policies: Make Money by Making Good." *Sloan Management Review*. **Fall**. p. 65-72.

Padmanabhan, V. and I.P.L. Png. 1997. "Manufacturer's Returns Policies and Retail Competition." *Marketing Science*. **16** p. 81-94.

Petersen, M. (2002). "Anthrax and Anxiety." *The New York Times*, March 10, Sunday, Section 3, p. 4. Column 5.

Richardson, G. and A. Pugh. 1980. *Introduction to System Dynamics Modeling with Dynamo*. Productivity Press, Portland, Oregon.

Sterman, J.D. 1989a. Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment. *Management Science*. **35**(3): p. 321-339.

Sterman, J.D. 2000. "*Business Dynamics: Systems Thinking and Modeling for a Complex World.*" Chicago, IL, Irwin-McGraw Hill.

Webster, S. and Z. Weng. 2000. “A Risk-free Perishable Item Returns Policy.” *Manufacturing and Service Operations Management*. **2**(1): p. 100-106.

Weiss, J. (1999). *The Boston Globe*, December 31, Friday, p. B1.

Appendix A. Model description

The purpose of the modeling effort is to explore the causes of seed returns and derive policies capable of reducing them. The model captures dealers' ordering decisions, salespeople's effort allocation decisions, and managers' incentives at the seed supplier to meet sales targets. These actions contribute directly to seed hoarding, which results in returns. The paper explores the effect that financial pressure to meet the annual sales targets has on salespeople's effort allocation, resulting in pushing shipments of corn seeds to dealers and failing to position them adequately. The combination of early seed shipments and inadequate positioning at dealers influences the volume of seed returns.

In alignment with the model purpose, we adopt a level of aggregation that is sufficiently high to focus on the interaction of the seed supplier with its dealers through the company's sales force. Hence, we avoid detail complexity (e.g., multiple supplier warehouses, multiple dealer locations, and multiple products) that does not directly contribute to the dynamics of interest. Our model considers a supplier producing a single corn-hybrid and aggregates all corn-seed inventory in a single warehouse. While seed hybrids have different performance, both high and low performing products suffer from returns, due to dealers' attempts to hoard products early in the season and their inability to foresee which hybrids will become high or low performing products. Instead of investigating low and high performing products, we build a generic model and change parameters (e.g., the effect of positioning on shipping) when dealing with different types of hybrids. Here, we focus on high performing products.

A few months prior to harvesting last years' crops, dealers start placing orders to the seed company. The early stocked orders *(SO)* take place due to dealers' perception of unreliable supply in the previous year. The amount of orders stocked (the number of bags of corn) is given by the minimum of dealers' desired stocked orders *(DSO)* and the supplier's allowed stocked orders *(ASO)*.

The former is determined by the ratio of grower demand *(GO)* and the complement of the expected returns fraction *(ERF)*. While dealers' do not have direct access to grower demand, they can get a good estimate of its value by the sum of total shipments to customers and the growers' unsatisfied demand. Hence, we adopt grower demand in the model formulation and further assume it is constant. The latter, supplier's allowed stocked orders *(ASO),* sets a ceiling to stock orders as a maximum fraction (typically 10%) above last years cumulative sales *(CS)* to growers. The supplier has a good estimate of the volume of sales to growers by subtracting total shipments to dealers from the seeds returned.

$$SO(t) = MIN(SO^*(t), SO_A(t)) \tag{A1}$$

$$SO^*(t) = \frac{GO}{(1 - ERF(t))} \tag{A2}$$

$$SO_A(t) = CS(t) \cdot SO_{MF} \tag{A3}$$

Dealers place their stock orders *(SO)* over the course of a week *(* τ_{SO}*)* when the supplier starts accepting orders. When dealers' desired stocked orders *(* SO^**)* exceed the amount allowed by the supplier, the remaining orders *(OR)* are placed during the remainder of the selling season *(WS)*. All dealers' orders accumulate in an order bank *(OB)* until later in the year, when salespeople schedule them for later delivery. The scheduling rate *(SCH)*, which drains the order bank, is determined by the ratio of orders in the bank and the normal time to schedule them *(* τ_{SCH}*)*. The supplier maintains the scheduled orders in a stock of orders scheduled for delivery *(OSD)* which is drained when the supplier ships them to dealers. The seed supplier establishes a delivery delay target of one week *(* DD^**)* to deliver any scheduled orders. Order cancellations are not common, exactly because dealers can return any unwanted seeds.

$$O\dot{B}(t) = SO(t)/\tau_{SO} + OR(t)/WS - SCH(t) \tag{A4}$$

$$SCH(t) = {OB(t)} \big/ {\tau_{SCH}} \tag{A5}$$

$$O\dot{S}D(t) = OB(t) / \tau_{SCH} - SR(t) \tag{A6}$$

$$SR^*(t) = OSD(t) / DD^* \tag{A7}$$

The actual orders shipped to dealers depend on available inventory. Every year seed production *(PR)* increases supplier's available inventory *(I)*. Seed returns *(RR)* also contribute to available inventory. Dealers' ordering and salespeople' effort allocation decisions endogenously determine the volume of seed returns. Seed obsolescence *(O)*, however, depletes the supplier's inventory. We model seed obsolescence as a first-order exponential decay, given by the product of the supplier's available inventory and the fractional obsolescence rate (F_{OBS}). The choice of a first-order exponential decay assumes perfect mixing, that is, any item in inventory has an equally likely chance of spoilage.

$$\dot{I}(t) = PR(t) + RR(t) - O(t) - SR(t) \tag{A8}$$

$$O(t) = I(t) \cdot F_{OBS} \tag{A9}$$

The supplier's production *(PR)* decision has two main components. First, the supplier will produce as many seeds as dealers' are willing to stock-up (SO^*) early on the selling season. Production takes place all along the fourth quarter (τ_P). While dealers will try to hedge against the possibility of shortages, typically by ordering as much as total grower orders and adjusting the volume upwards depending on returns. The heuristic the supplier uses simply focuses on satisfying potential dealer demand. Second, the supplier will also adjust its production to maintain the inventory *(I)* at a desired inventory (I^*) level, over the inventory adjustment time (τ_I). The desired inventory (I^*) is given by a fraction (F_{SS}) of the dealers' desired stock orders (I^*).

$$PR(t) = MAX\,(0, \frac{SO^*(t)}{\tau_P}, +(\frac{I^*(t) - I(t)}{\tau_I})) \tag{A10}$$

$$I^*(t) = SO^*(t) \cdot F_{SS} \quad \text{(A11)}$$

The product of the desired shipment rate *(SR^*)* and the order fulfillment ratio *(OFR)* determines the supplier's shipment rate *(SR)*. While the desired shipment rate is determined by the ratio of the orders scheduled for delivery *(OSD)* and the target delivery delay *(DD^*)*, the order fulfillment ratio is a function (f_4) of desired shipment rate *(SR^*)* and the maximum shipment rate *(SR_{MAX})*. The latter is determined by the ratio of inventory and the minimum order processing time *(τ_{OP})*. Considering the shape of the function for order fulfillment, when the desired shipment rate is low relative to maximum, the supplier can send shipments at the desired shipment level. The supplier will never ship faster than the desired rate, because dealers try to postpone receiving the seeds as much as possible. When the desired volume of shipments equals the maximum, the supplier can still ship at the desired rate. But when the desired shipment rate is high relative to maximum, the supplier only sends a fraction of desired shipments. That fraction drops sharply when the desired shipment rate is much higher than the maximum. Given the assumption of a single corn-hybrid, the supplier can ship at the desired rate as long as there is availability of seeds. Once the inventory is depleted, the shipment rate will drop dramatically.

$$SR(t) = SR^*(t) \cdot OFR(t) \quad \text{(A12)}$$

$$OFR(t) = f_4\left(\frac{SR_{MAX}(t)}{SR^*(t)}\right) \quad \text{(A13)}$$

$$f_4 \geq 0, f_4' \geq 0, f_4'' < 0, f_4(0) = 0, f_4(.2) = 1, f_4(\infty) = 1 \quad \text{(A14)}$$

$$SR_{MAX}(t) = \frac{I(t)}{\tau_{OP}} \quad \text{(A15)}$$

Revenues *(R)* is recognized at the time that the supplier ships the seeds to dealers. Price *(p)* for corn is constant at US$100 per bag. As gross revenues accumulate *(AR)* over the selling season, the supplier can compare it to the specified target *(AR^*)*. The target revenue *(AR^*)* is based on the previous year's gross accumulated revenue *(AR)* adjusted by a target growth rate *(g)*, and changes from one year to the next associated with the expected costs of seed obsolescence and returns. The changes in the costs of obsolescence *(OC)* and returns *(RC)* compensate for additional costs that the supplier may incur from one year to the next. If returns and obsolescence costs are higher in a year than the previous year, salespeople must meet a higher revenue target to compensate for the difference.

$$R(t) = p \cdot SR(t) \tag{A16}$$

$$GR^{*}(s) = GR(s-1)\cdot(1+g) + \Delta OC(s) + \Delta RC(s) \tag{A17}$$

Managers consider the fractional revenue gap as one metric to set pressure on salespeople. The fractional gap in revenues *(FRG)* is given by the difference between the target revenue *(AR^*)* and the actual gross revenues accumulated so far *(AR)*, normalized by the target revenue *(AR^*)* for the period (calendar year/selling season). In addition, managers also consider the time remaining in the calendar year, or selling season, to pressure the work force. The fractional time remaining *(FTR)* is given by the ratio of the time remaining *(TR)* and the total time available in the period *(TT)*. The ratio of the fractional gap in revenues *(FRG)* and the fractional time remaining *(FTR)* in the corresponding period determines the pressure *(P)* faced by salespeople. Two important periods of financial pressure occur during the year: one at the end of the fiscal year (December) and the other at the end of the selling season (April). The former is motivated by financial pressure from "Wall Street," which is salient to managers. The latter is motivated to meet the gross revenue goals for the selling season.

$$P(t) = \frac{FRG(t)}{FTR(t)} \tag{A18}$$

$$FRG(t) = \frac{GR^{*} - GR(t)}{GR^{*}} \tag{A19}$$

$$FTR(t) = \frac{TR(t)}{TT} \tag{A20}$$

Salespeople allocate their effort between two activities: pushing seeds to or positioning seeds at dealers. The total effort *(TotEff)* exerted by a salesperson is constant at 50 hours a week. The sum of effort to push *(EffPush)* and position *(EffPosit)* seeds result in the total effort, which assumes that salespeople do not shirk. Salespeople respond promptly and strongly to managerial pressure *(P),* such as the pressure to meet end-of-year (gross) revenues target, by pushing seeds to dealers instead of allocating effort to position seeds. We represent salespeople in aggregation, capturing their mean response over the distribution of possible response strengths. While individually salespeople differ in the intensity of their responses, our interviews support that on average they respond similarly to the same stimuli. A nonlinear function *(f_1)* captures the impact of pressure on salespeople's fractional allocation of effort to position seeds.

$$TotEff(t) = PushEff(t) + PositEff(t) \tag{A21}$$

$$PositEff(t) = TotEff(t) \cdot f_1(P(t)) \tag{A22}$$

$$f_1 \geq 0, f_1' \leq 0, f_1(0) = 1, f_1(\infty) = 0 \tag{A23}$$

By pushing *(EffPush)* more seeds to dealers during times of high pressure, salespeople reduce the time to schedule seed delivery *(τ_{SCH})*, thereby increasing the scheduling rate. The scheduling time *(τ_{SCH})* is a function (f_2) of the ratio salespeople's pushing effort to the total effort.

$$\tau_{SCH}(t) = \tau_{SCH}^{N} \cdot f_2(PushEff(t) / TotEff(t)) \tag{A24}$$

$$f_2 \geq 0, f_2' \geq 0, f_2(0) = f_{MAX} = 1.25, f_2(1) = f_{MIN} = 0.5 \tag{A25}$$

A stronger pushing effort allows salespeople to make more deliveries and, thus, increase gross revenues. However, salespeople also allocate less effort to position the seeds at the dealers with actual grower demand, which leads to a greater volume of seeds sent to dealers without the corresponding grower demand. Hence, the probability of shipping seeds to "right" dealer locations *(PS_{Right})* increases with the salespeople's effort to position them. In practice, the more effort salespeople allocate to understanding dealers' demand forecasts and past sales the higher the likelihood that salespeople will adequately position the seeds. A nonlinear function *(f_3)* captures the impact of salespeople's positioning effort on the probability of shipping right.

$$PS_{Right}(t) = f_3(PositEff\ (t)) \tag{A26}$$

$$f_3 \geq 0, f_3^{'} \geq 0, f_3(0) = f_{MIN} = 0, f_3(1) = f_{MAX} = 1 \tag{A27}$$

We disaggregate dealers' inventories in two types: "right" and "wrong" locations. Inventory located at "right" locations have corresponding grower demand and can generate final sales. In contrast, seed inventory located at "wrong" locations will lead to returns to the seed supplier at the end of the selling season. For simplicity, we assume that once the seeds reach a specific dealer location they cannot be shipped to another one. In the real system, seed shipments across dealers are not common. The stock of seeds at "right" locations *(SE_{Right})* increases with the inflow of shipments to "right" dealers and decreases with sales to final customers. The former is given by the product of shipments *(SR)* and the probability of shipments to "right" locations *(PS_{Right})*. Sales to growers *(GS)* during each selling season accumulate through the selling season to determining the cumulative sales *(CS)*.

$$S\dot{E}_{Right}(t) = SR_{Right}(t) - GS(t) \tag{A28}$$

$$SR_{Right}(t) = SR(t) \cdot PS_{Right}(t) \tag{A29}$$

$$C\dot{S}(t) = SR_{Right}(t) \tag{A30}$$

The stock of seeds at "wrong" locations *(SE_{Wrong})* increases with the inflow of shipments to "wrong" dealers *(SR_{Wrong})* and decreases with returns *(RR)* to the seed supplier. The former is given by the product of shipments *(SR)* and the probability of shipments to "wrong" locations *(PS_{Wrong})*.

$$S\dot{E}_{Wrong}(t) = SR_{Wrong}(t) - RR(t) \tag{A31}$$

$$SR_{Wrong}(t) = SR(t) \cdot PS_{Wrong}(t) \tag{A32}$$