

A SYSTEM DYNAMICS ANALYSIS OF A CAPILENE SUPPLY LOOP

by

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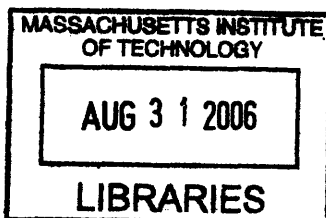
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ABSTRACT

In August 2005, Patagonia announced its Common Threads Garment Recycling Program. The company is reclaiming used Capilene long underwear from consumers and using them as an input for new Capilene garments. According to company assessments, making clothes from post-consumer fabrics is more energy efficient and emits fewer greenhouse gases than making garments from traditional, petroleum-based, materials. Patagonia has a long history of considering both the economic and environmental impacts of their business decisions and it is an integral part of their brand.

Changing business conditions and the rise of environmental consciousness among consumers have made supply loops an increasingly important topic in supply chain management. This is especially true in the electronics industry where the European Union has legislated mandatory recycling of all electronics products sold within its borders, as a response to environmental concerns. Electronics recycling is complex: the products are difficult and often hazardous to disassemble, recycling is often done overseas, and there are many players in the industry. Patagonia's Common Threads Garment Recycling Program, on the other hand, is a simple supply loop. There are two major players: Patagonia, a large outdoor apparel company based in California, and Teijin, a polyester manufacturer in Japan. There is one product being recycled: Capilene, a polyester fabric used in thermal underwear and technical outerwear. This simplicity makes it an excellent system to model.

This thesis assesses different rebate structures that Patagonia can use to induce customers to return their old clothes and the impact of these rebates on the overall success of the program as measured by profitability, volume and the recycled content of new garments. There are other factors, such as consumer education and word of mouth that also drive customer behavior. The framework developed here can be used in the future to analyze the effect of different levers, such as consumer education or technology changes, on the profitability and viability of this supply loop.

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I. Motivation

My interest in supply loops started when I read the book *Cradle to Cradle* by William McDonough and Michael Braungart. The book advocates keeping biodegradable materials separate from synthetics so that the former can biodegrade or be composted while the latter can be recycled and reused. I was intrigued by how companies could design supply loops to take back these synthetics and under what conditions these loops would thrive. I heard about Patagonia's program in the summer of 2005 just before it launched and thought it would make an excellent research topic. In November 2005, Randy Harward, Director of Quality and Raw Material Development at Patagonia, spoke about the Common Threads garment recycling program at the annual Net Impact Conference and approached him about writing a masters thesis about the program.

II. Company History and Corporate Strategy

Patagonia was started in 1973 when Chouinard Equipment, the leading US manufacturer and retailer of climbing equipment, decided to add a line of clothes to its product mix. Since then Patagonia has become a major player in the outdoor apparel market with 24 retail stores throughout the US and 22 stores abroad in Europe, South America and Asia (primarily Japan)¹. Patagonia is more vertically integrated than many of its competitors like ARC'TERYX, Columbia Sportswear and North Face. Though they design in-house and outsource production like everyone else, Patagonia sells its product through its own retail stores and avoids using discount retailers to dispose of end-of-season product. In FY 2002, Patagonia had \$220 million in revenue and just under 1000 employees.² Privately held by the Lost Arrow Corporation, Patagonia accounts for most of Lost Arrow's sales. Both Patagonia and its parent company are based out of Ventura, CA.

Patagonia's corporate culture goes back to its beginning. The founder and longtime CEO, Yves Chouinard, started the company in the 1950's to finance his climbing expeditions. He would forge pitons over the winter and climb all summer, selling the gear out of his car. Chouinard Equipment redesigned climbing tools making them stronger, lighter and more functional.³ Patagonia remains true to its origins. It is a company built around innovative design and superior quality. It remains a private company and proudly so. The Corporate headquarters is located a few blocks from the beach and employees are active users of Patagonia product.

Patagonia first made the business case for environmentally sound product and business practices in 1972 when they denounced pitons, then the mainstay of their

¹ Patagonia website: http://www.patagonia.com/za/PDC/Pgonia/find_a_store.jsp

² Hoovers. FY 2002, ending April 30, 2002, is the most recent year for which financial data is available.

³ Patagonia website: http://www.patagonia.com/culture/patagonia_history.shtml

business, as environmentally unsound⁴. They promoted an alternative, aluminum chocks. Piton sales evaporated while chocks grew quickly in popularity.⁵ Other environmental initiatives include switching to 100% organic cotton (1996), using recycled bottles in polyester (1993), and packaging Capilene underwear with a rubber band and a cardboard label instead of plastic wrap. The latter increased sales, to many people's surprise, since customers were able to feel the material before they bought it. Other initiatives include donating 1% of revenues to environmental organizations, allowing employees to work full-time for environmental organizations (for up to two months) while remaining on the company payroll, and building their new distribution center in Reno, NV according to green design principles.

Organic cotton is more expensive but Patagonia argues that it is possible to make apparel more cheaply because the organic fibers are of better quality and less cloth is wasted as scrap. When the company switched, designers had to relearn how to design with cotton fabric: their choices were more limited and the technical properties were slightly different. Eventually, costs came down.⁶ Other companies, such as The Gap, have not been as quick to adapt their designs and are still struggling with the costs. Patagonia's emphasis on design, quality, and innovation is the difference.

Patagonia's major competitors are ARC'TERYX, Columbia Sportswear and North Face. Other competitors include REI, Adidas, Marmot, L.L. Bean, and other outdoor clothing brands. There are no major barriers to entry in the industry. The fabrics are easy to purchase, apparel manufacturing is outsourced and the supplier base is very competitive. There are many small brands that have developed in recent years to fill small niches in the industry (women's gear, wool garments). Like many of its competitors, Patagonia focuses on high quality and technical innovation, especially innovative fabrics. This emphasis on quality and innovation is what differentiates the technical outdoor apparel market from general sportswear. Products between the different outdoor companies are mostly interchangeable and brand is the major differentiator.

Environmental activism is a major part of Patagonia's image and while competitors also stress their green credentials, Patagonia is acknowledged to lead the field. The company estimates that 5-10% of the customer's purchasing decision is environmental.⁷

⁴ A piton is a safety device that is hammered into the rock. It chips the rock both when it is placed and when it is removed destroying the natural face of the rock. Chouinard Equipment had developed a poor reputation among climbers as a result of its piton sales.

⁵ Patagonia website: http://www.patagonia.com/culture/patagonia_history.shtml

⁶ From Randy Harward's talk at the 2005 Net Impact Conference

⁷ Randy Harward, phone interview, February 2006

III. The Common Threads Garment Recycling Program

Capilene is the clothing company Patagonia's name for polyester with a hydrophilic surface finish. Capilene's core remains hydrophobic (water hating). Originally used in Patagonia-brand thermal underwear and in stretch versions where it has been blended with Lycra, it is now available from Patagonia in everything from base layers to outerwear, this is a super soft, very warm material most commonly used in long underwear.

- Wikipedia.org

Overview

In the fall of 2005, Patagonia launched their Common Threads garment recycling program. This initiative invites customers to send their used Capilene (polyester) underwear, t-shirts, jackets, back to Patagonia for recycling. Patagonia collects the items, removes the zippers and trim, and sends them back to the Capilene manufacturer in Japan where they are melted back into plastic pellets and spun back into new Capilene fabric that is indistinguishable from virgin material.

The program is motivated by environmental concerns. Patagonia, as a company, is committed to environmental practices⁸ and has a strong “green” image as part of their brand. They currently manufacture Capilene from recycled soda bottles. By recapturing the Capilene from consumers and turning into new material, Patagonia has moved from an open-loop to a closed-loop supply chain. The European Working Group on Reverse Logistics⁹ defines a closed-loop supply chain as “A sequence of logistics activities from a point of use to a point of reuse, which is either the original user (physical closed loop) or someone that uses the product with its original functionality (functional closed loop).” A closed-loop keeps the material out of landfill and reduces the need for virgin materials. Under the previous system, the soda bottle was reused once, recycled into Capilene, and then dumped in a landfill, perhaps making a detour through Goodwill or the Salvation Army. See the White Paper in Appendix 1 for an analysis of the ecological impacts of the program.

⁸ Patagonia’s distribution center in Reno, NV is an example of this commitment. It has innovative lighting and heating systems that make the warehouse unusually pleasant to work in and cheaper to maintain.

<http://www.fastcompany.com/online/37/benchmark.html>

⁹ <http://www.fbk.eur.nl/OZ/REVLOG/>

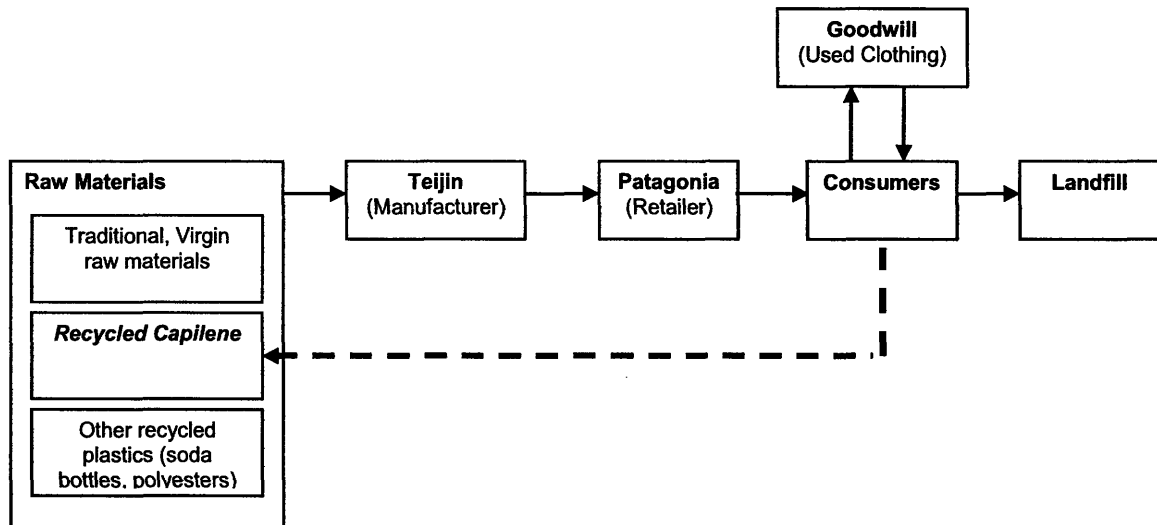


Figure 1: Capilene Lifecycle

The environmental reasons for this program are matched by economic reasons. Patagonia believes that this program can lower raw material costs and provides an alternative source. This second source is important since raw material prices have been rising since 1989. With energy prices high, and expected to continue to rise, petroleum derivatives like polyester can expect a continued increase in price. Coleman-Kammula (2005) provides an excellent overview of the polyester industry and the dynamics that are driving up prices.

Patagonia first started using Capilene in 1984, when they switched their entire line of polypropylene underwear to Capilene. Capilene has a higher melting temperature than polypro and doesn't melt in commercial dryers.¹⁰ Today Patagonia sells over 100 styles of Capilene apparel accounting for \$40 million in sales.¹¹ A third of Capilene sales are made in Japan. Of the \$40 million, \$30 million contain yarn from recycled soda bottles¹². A stated goal is to have at most 90% of sales from garments with recycled content: the PCR¹³ line. Patagonia estimates that it will take at least 3 years to achieve these levels. Recycled content means fibers from soda bottles, tents, or polyester clothes and uniforms.¹⁴ Annual Capilene sales growth is anticipated to be around 8 to 15%. Some clothing lines grow faster than others. For example, when the PCR fabrics were introduced there was a 20% jump in sales; the new fabric was re-engineered, higher quality, and better met customer needs.

Today, Patagonia sources its recycled Capilene from Teijin Fibers. Teijin Fibers is a division of Teijin Limited, a multinational company based in Osaka with sales of 900

¹⁰ Patagonia website: http://www.patagonia.com/culture/patagonia_history.shtml

¹¹ Randy Harward, phone interview, February 2006

¹² Randy Harward, phone interview, February 2006

¹³ PCR is derived from "post-consumer recycling"

¹⁴ <http://www.patagonia.com/enviro/pcr.shtml>

billion Yen per quarter (approximately \$8 billion/quarter¹⁵). Teijin started as a polyester manufacturer in 1918 and expanded into films, plastics, ethical drugs, and medical equipment.¹⁶ Teijin has developed a bottle to bottle recycling program that has won numerous awards¹⁷. Patagonia began sourcing Capilene from Teijin in 2005, drawn by its superior quality and recycled soda bottle content. Teijin developed the ECOCIRCLE technology that recycled polyester fibers back into virgin fibers. Teijin and Patagonia have entered into a partnership to develop a polyester recycling system with both parties taking short term hits to their margins in order to develop the program. Teijin entered into the partnership with a track record for technical innovation, especially around environmental issues, and more importantly it had excess capacity that it needed to fill. Appendix 2 illustrates the ECOCIRCLE process using documents from Teijin's website.

Patagonia's long-term goal is to develop a sustainable supply of post-consumer polyester. With enough volume and a well-developed supply chain, Patagonia and Teijin anticipate that the cost of recycled fibers will be the same as bottle based or virgin fibers. Patagonia does not disclose the exact terms of its supplier contracts. The purchase price is tied to the volume of returns on an undisclosed sliding scale and right now there is no discount because the volumes are so small. Patagonia has absorbed the higher costs and lowered its margins. So has Teijin. They anticipate that margins should recover in 3-5 years.

Teijin's ECOCIRCLE fiber to fiber process can recycle more than just Capilene. They also produce and recycle polyester uniforms, tents, curtains, and bags. Patagonia's Capilene returns are just one input that will be used in the new Capilene. With Teijin's sophisticated technique, Patagonia seeks to eventually recycle all polyester fabrics, bring other outdoor brands into the program and begin recycling other fabrics like nylons. Whether or not to accept clothing from other brands is an interesting decision. On the one hand, it diverts product from landfills and helps Patagonia achieve scale and decrease costs. On the other hand, it dilutes Patagonia's image as the only recyclable brand.

The program faces many hurdles. The most obvious is to convince consumers to recycle their old underwear. When the program was first introduced people were enthusiastic, but some were uncomfortable with the idea of recycling underwear. Another deterrent is that the consumer bears the cost of returning the item. Patagonia does not pay for shipping nor does it offer customers rebates or coupons for returning the items. Used clothing must be mailed to Patagonia's distribution center in Reno or returned to one of its retail locations. One hurdle that Patagonia has already overcome is regulation. By law you can't import trash into Japan. Patagonia and Teijin convinced the Japanese government to reclassify the used polyester as a raw material. It is unclear how much Capilene has been returned thus far. The program is

¹⁵ May 17, 2006 exchange rate: \$1 = 0.009 Yen

¹⁶ Teijin website: www.teijin-eco.com

¹⁷ Teijin CSR Report

still in its infancy but plans are already being developed to start a nylon recycling program.

Teijin is a unique partner for Patagonia. European polyester manufacturers are resistant to developing garment-to-garment recycling technologies. They like using the PET bottle stock. Polyester from bottles is very pure, more pure than fabrics so it is easy to recycle and of a very high grade (food grade). Teijin is willing to take a risk on this process. Other players need to be convinced of the viability and worth of the process before they are willing to participate. So growth is contingent on demonstrated success.

The program is only offered in Japan and the United States. Recycling polyester in Japan is easy and efficient: it is a large consumer of Capilene, Teijin is nearby, there is high population density, and a small geographic area in which to collect and ship the material. Recycling in the US is more difficult but still feasible. There is density in the cities and so within a small geographic area, a significant amount of material will be returned. But the distances between cities are large and shipping, especially “last mile” shipping from the customer to Patagonia, is expensive and environmentally wasteful. The US program only works if the volumes are large enough. Europe is the most difficult for recycling. Although there is high population density, Patagonia’s sales are spread throughout the continent and it is very far from Japan. To be efficient, Europe would need its own recycling infrastructure with its own regional Capilene manufacturing. For these reasons, geographic expansion beyond Japan and the United States will be very slow.

Program Details¹⁸

The supply loop is very simple. Teijin produces the fabric in Japan. It is then shipped to garment factories in the Caribbean and elsewhere, and then shipped again to retail outlets. Consumers buy the clothes and usually own them for 5 to 10 years. At the end of the garment’s useful life the consumer has three choices: throw it away, donate it to charity, or return the garment to Patagonia for recycling. Patagonia collects the garments at the distribution center, removes non-polyester trim from the garment and ships it back to Japan to be recycled¹⁹. Shipping to Japan is cheap because the containers that carry goods from Asia to the US return to Asia mostly empty. Patagonia was able to negotiate excellent rates with shipping companies who were eager for the business. In Japan, Teijin melts the polyester back into its molecular state, re-polymerizes it, and creates polyester identical to non-recycled polyester. There are no limits to the number of times that the fibers can be recycled.

¹⁸ Information from this section came from Teijin and Patagonia’s websites, and a phone interview with Randy Harward, February 2006

¹⁹ For now the cutting and bailing is done at the Reno Service Center. If the program achieves scale it will outgrow the site and Patagonia will have to assess whether to continue to cut and bail in-house or whether to outsource. Outsourcing this step to a third world country would save on labor costs but the environmental impact from the additional shipping might not be worth it.

However, the conversion rate is approximately 90%²⁰. So each time a garment is recycled about 10% of the material is landfilled.

Fiber and Fabric Production

About 100 styles in 8-12 colors can be recycled, basically anything made out of pure polyester. Capilene/Lycra blends are excluded. This means that virtually the entire Capilene line is recyclable. A garment is never too dirty to be recycled. Contaminants, such as dye stuffs, are removed when the fabric is melted into pure polyester resin.

The recycling process begins when Patagonia removes all buttons, metal snaps, and non-polyester features. They do try to use as much plastic as possible in design to make this step easier and to maximize the conversion rate. The garments are then chopped up and needle punched. For environmental reasons, Patagonia prefers to use the polyester fibers again in their current form instead of melting them down and recycling them in Japan. For example, the fibers can be reused in the US as office panels (cubicle walls). This avoids the energy intensive step of melting and respinning the fibers. If the garments are still in good shape they are donated to Goodwill.

Garments from the US market that are to be recycled are baled and shipped to Teijin in Japan. Japan itself is a third of the Capilene market and the fabric is being recycled there are well. The US and Japan are the only two markets with recycling programs and for now and because of the low volume and high cost of shipping from the US most of the garments being recycled are from Japan.

Post-consumer Capilene is currently a tiny part of Teijin's raw materials. They process thousands of tons, annually, of recycled resins and Teijin has its own source of recycled soda bottles. Another sources of raw materials include Teijin's own production waste (for example blemished CD's and DVD's), Capilene scrap, polyester uniforms, tents, bags, and other plastics.

According to plan, post-consumer polyester will eventually become a major raw materials source, though not all of it will be recycled through Patagonia. Patagonia plans to use 50% of Teijin's capacity when the program is fully operational. If the program succeeds and other companies get onboard, new plants will need to be built in about 5 years to increase capacity.

Teijin produces 100% of the recycled fibers that Patagonia uses to make the PCR line. PCR fabrics contain at most 74% recycled content. This is because each fabric uses multiple types of yarns. Currently only four types, out of hundreds, are available to be recycled. Eventually this ratio will increase. Each type of recycled yarn is at most 90% recycled content. Yarns have performance characteristics (tensile strengths

²⁰ Patagonia white paper, see Appendix 1

etc) that they must meet and virgin materials are added, as needed, to achieve these qualities.

Once the fibers are dyed, knit and finished into fabric, it is sent by container either to the US or to Europe²¹. Half of the fabric sent to the US remains in Los Angeles for production. The other half is sent to the Caribbean. Scrap from garment factories can be recycled. Shipping is cheap and it is feasible to ship them back to Teijin. However, the factory scrap has paper mixed in. Patagonia prefers to keep the scrap domestic and reuse it in coarser fabrics.

Consumer Behavior

Demand

Demand for Capilene garments is highly seasonal. Winter sales are twice as high as sales in the spring and summer. It is unclear what the demand elasticity is. There is some stickiness due to brand name and the level of quality, but there are many substitutes for Patagonia's products. When asked, Patagonia says that they are sensitive to the fact that their products are expensive and they would reduce prices if doing so would increase sales volume²². Nonetheless, when Patagonia introduced its new recycled line, they were able to charge 10% higher prices and still increase sales. The increased demand came from better design that gave customers more of the features that they've been asking for.

Why would a customer recycle?

To be a success, the Common Threads garment recycling program must achieve significant volume. Exactly what that volume is is unclear, but it certainly can not be achieved without consumer participation. There are many reasons why a customer would recycle. The one that Patagonia is relying on at the start of the program is the environmental ethics of its customers. Certainly the average Patagonia customer is more aware of environmental issues than the average citizen and a certain fraction of them will incur costs in order to do recycle. Another important factor is economic. Rebates and coupons are incentives for people to recycle instead of hoarding or throwing things away. Other factors that drive recycling include the ease with which products can be returned: geographic proximity, ease of participating, comfort with the idea of recycling clothes, and consumer education about the existence of the program and its benefits.

Patagonia has not made it easy for people to recycle. Current returns are driven almost entirely by the ethics of the customers and customer bear the entire cost, in

²¹ 80% is sent to Los Angeles for eventual sale in the Americas and Asia. 20% is sent to Europe.

²² The price point is part of the brand image. They are an exclusive, high-end product. So while the prices may drop slightly so that they are cheaper than the competition, the price point will remain high.

time and money, of returning the garment either to a Patagonia store or shipping it to Patagonia's distribution center in Reno, NV. There is no discount or refund. There is very little consumer education. There is a small link on the company's homepage (see Appendix 3) and there are recycling bins and pamphlets in the stores but they are not prominent. The employees in retail stores are knowledgeable and enthusiastic about the program and do some customer education, but like the displays they are discreet. When the program was launched there were stories in the press about it but since then the noise has calmed down. Most people I've talked to informally are not aware that this program exists. On the whole there isn't a big push to grow the program at this time.

How fast can the program expect to grow without an investment from Patagonia to educate their customers and induce them to recycle? Are the timelines that they have laid out realistic?

IV. Literature, Regulation and Industry Review

Why Study Supply Loops?

Supply loops have become a hot topic in supply chain management due to four main drivers. First, product life-cycles are shrinking and companies are increasingly willing to accept customer returns. Practically, this means that there are increased return volumes and a shorter window in which to resell the products back to the market. Companies, particularly electronics manufacturers, must pay close attention to the changing marketplace brought about by the Internet. Second, governments have begun to pass legislation to limit the disposal of electronics in landfills. There is a growing need to find alternative ways to dispose of products that are at the end of their design life. Third, as consumers are becoming more conscious of environmental issues, companies are burnishing their “green image” to improve their brands. Fourth, supply loops are very profitable if implemented correctly [Krikke (2004), Biehl (2005), Fleischman (2003), Geyer (2004)]²³. Much of the literature on supply loops and remanufacturing focuses on the electronics industry and OEMs since ‘e-waste’ is such a hot topic. Apparel retail is clearly a different industry but many of the underlying drivers are similar.

Guide (2003) focuses on the need to develop new business models to adapt to modern necessities such as lenient product return policies, increased global competition and environmental legislation. A company that can think strategically about their supply chain and that can integrate all aspects of the life-cycle including returns will have a competitive advantage over the competition. The correct business model is important. In electronics, product value erodes rapidly so quick turnover is important, and remanufactured sales volume must be increased for remanufactured items to be viable. Currently companies don’t forecast returns well and remanufactured items don’t have a clear place: do they cannibalize sales of new products or not? Academics must help business to answer these questions.

Government Regulation

Government regulation is also driving interest in supply loops. In 2002, the European Union passed its Waste Electrical and Electronic Equipment directive (WEEE)²⁴. The WEEE directive requires companies to take back used electronics from customers free of charge and to divert the product from landfills. The measure is an attempt to make companies internalize their products’ landfilling costs. As a result, companies doing business in Europe now have to manage a new reverse supply chain. The US has no federal legislation that mandates the recycling of e-waste. States have stepped into that void, each with their own rules and regulations. Currently two

²³ Krikke (2004) discusses programs at Océ, Honeywell and Auto Recycling Netherlands. Biehl (2005) studies reverse logistics in the carpets industry. Fleischman (2003) discusses reverse logistics at IBM and Geyer (2004) discusses the success of steel recycling and reuse.

²⁴ http://europa.eu.int/comm/environment/waste/weee_index.htm

states, Maine²⁵ and California²⁶, have passed legislation that mandate the collection and recycling of e-waste. Maine requires that manufacturers take responsibility for their own products and all electronics sold in the state must have the name of the manufacturer clearly visible. In California, consumers pay a recycling fee when they purchase the products. As of February 2006, New York City, Massachusetts, North Carolina and New Jersey are considering producer takeback legislation.²⁷

Profitability and Image

The third reason to implement a closed-loop supply chain is to promote a company's "green image. Kodak was particularly effective at this strategy. When their single-use cameras were first released there was a public backlash against the perceived waste of using the product just once and then sending it to the landfill. Kodak then implemented an innovative program that reused the camera bodies up to six times. Photo developers collected the camera bodies that picture takers left with them when they developed their photos. Kodak then bought the cameras back, refurbished them, and reintroduced them to the market as new cameras. The program generated significant cost-savings and completely changed the product and company image [Goldstein (1994)].

Kodak isn't the only company to find economic value in remanufacturing. Krikke (2004) presents three case studies that illustrate key aspects of reverse supply chain management. (Oce, Honeywell, Auto Recycling Netherlands) Oce and IBM [Fleischman (2003)] are other examples of OEMs profitably retrieving and refurbishing parts. The management of their reverse supply chain is a strategic advantage. Whole industries have also voluntarily implemented product recovery strategies. Auto recycling is well known and has thrived as an industry for decades [Zamudio-Ramirez (1996)]. Steel recycling is also a well-established and profitable industry [Geyer (2004)]. Very little steel is ever deposited into landfills. Among new initiatives, the US carpet industry has voluntarily set a target of 40% diversion from landfills by 2012. Biehl (2005) studies the performance of the carpet reverse logistics supply chain. Like Patagonia's program, carpet manufacturers reclaim and recycle the polyester fibers and re-spin it into new polyester.

Academic Literature

Patagonia's Capilene recycling is a perfectly closed, single-product, materials recycling supply loop with only two major actors. As such, it is unlike other programs that have been studied. Patagonia has described it as a "simple" supply chain. Its simplicity is its appeal as an object of study. Previous studies that are relevant to Patagonia fall into three groups: operations research on remanufacturing,

²⁵ <http://janus.state.me.us/legis/statutes/38/title38sec1610.html>

²⁶ <http://www.ciwmb.ca.gov/electronics/act2003/>

²⁷ http://www.computertakeback.com/legislation_and_policy/e_waste_legislation_in_the_us/index.cfm

including case studies in intra-company remanufacturing such as IBM, Océ and Kodak; large scale system dynamics modeling of a recycling or remanufacturing industry; and conceptual modeling of single-product supply loops.

Operations Research

Reverse Logistics

Reverse logistics is similar to forward logistics but differs in a few significant ways.²⁸ The partners in a reverse supply chain are not necessarily the same as the forward logistics partners. This means that the system design will be different. Forward supply chains distribute the product to many customers from a few suppliers (few → many). Reverse logistics reclaim product from many customers, consolidate the product and return it to a few producers (many → few). Reverse logistics also have an important sorting and testing step. Not all returned product is fit to be refurbished or recycled. Deciding where and when to test and sort is an important part of reverse logistics. Another key difference between forward and reverse logistics are the new sources uncertainty. Not only is demand unknown, so is supply. Volume and lead-times are both uncertain as well. Fleischman et al (1997) and Guide et al (2000) provide excellent reviews of the literature. Guide and Van Wassenhove (2001) review the business case for closed-loop supply chains and consider the question from marketing and accounting perspectives as well as the more traditional operations view. In general, research into closed-loop supply chains have focused on issues central to remanufacturing: distribution planning, inventory control, and production planning.

Remanufacturing

Remanufacturing refers to the disassembling product, followed by the cleaning and repairing the parts so that they are as-new. Remanufacturing involves inventory control and network configuration issues that are much more complex than those in materials recycling. In remanufacturing, the condition of a part lies in a range between new and irretrievable. The testing and sorting process is more complex and costly. Should a company test all parts as soon as they come in, discard obsolete parts and only store repairable ones? This would increase testing costs but decrease holding costs. Or should they store all returned parts and only test and repair once the part is needed? This increases holding costs but decreases testing and sorting. Should companies use a push or pull system? Should companies plan to use the remanufactured parts in the pipeline or should they wait until they are fixed and hit inventory?

Materials recycling programs are much simpler than remanufacturing and Patagonia's system is one of the simplest among them. A Capilene garment can either be recycled or it can't, so the sorting process is very simple and there is no need to test

²⁸ Fleischmann et al (1997)

the product before it is recycled. The dismantling process consists of removing trim and zippers, an inexpensive and low-skill process. Holding costs are relevant but used Capilene is a low-value item and it never becomes obsolete. Since the recycled material is indistinguishable from virgin, there are no issues of cannibalization of the original market by the recycled product. The last interesting differentiating feature of the Patagonia program from electronics recycling is that it is not government mandated; it is entirely motivated by economic and environmental reasons.

Large Scale System Dynamics Models

Since its beginning, system dynamics has been used to analyze and simulate supply chains [Forrester (1961)]. Like other disciplines, System Dynamics has studied forward supply chains. Among the first to study recycling systems using system dynamics was Meadows and Randers (1971). They study the market for copper, a nonrenewable but recycled material and question what drives the flows of materials through the system and how recycling fractions and recycling rates can be increased. Their model encompasses the entire copper production process from extraction to solid waste and pollution. The dynamics are definitely different from my Capilene model since I am only looking at “secondary” production. I do not consider “primary” production where the petroleum is extracted, refined, and manufactured into the raw materials for polyester.

More recent studies include two MIT theses. Zamudio-Ramirez (1996) looked at the auto-recycling industry as part of his LFM thesis. He developed a detailed Automobile Recycling Dynamic Model (ARDM) which captures the major interactions between car manufacturers, consumers, dismantlers and shredders. Using the model he determined the impact of various design changes (design for disassembly and increased plastics content) on the behavior and profitability of the various actors in the auto recycling industry. Taylor (1999) looked at the market mechanisms of paper recycling in the US. He considers recycling in the context of the larger materials management system in which it operates instead of simply as a tool to dispose of waste.

System Dynamics Models of Closed-Loop Supply Chains

Recently, there have been several publications that specifically model a closed-loop supply chain using system dynamics. The first, Spengler (2003) models the Agfa-Gevaert supply chain and focus on the type of information that a company needs to implement component-recovery strategies in closed-loop supply chains. Agfa outsources recycling to specialized firms. At the same time, their suppliers provide little information about their components which makes in turn makes it harder for recyclers. So, Agfa is in the position of coordinating upstream and downstream information while also deciding how to manage its inventory of remanufactured parts and the timing of manufacturing small batches of new parts to fill unmet demand.

Georgiadis and Vlachos (2004) consider capacity strategies and the long term effects of “green image” on demand, take-back legislation and state campaigns for the proper disposal of used products. They assume a single product with two stages in the forward supply chain: manufacturer and retailer. Their model is deliberately conceptual so that it can be applied to many situations. The follow up to this paper, Vlachos et al (2005), uses system dynamics to evaluate long-term capacity expansion strategies (leading, trailing, matching) for remanufacturing facilities: when, where, and how much. Given that the objective is to maximize the NPV of profits over “a few years”, how should a company best to respond to highly variable return flows? Like the preceding paper, Vlachos et al specifically consider green image and environmental policy effects. Collection capacity and Remanufacturing capacity are modeled more explicitly and they consider the number of reuse cycles before the item becomes obsolete.

V. Methodology

Randy Harward, Patagonia's Director of Quality and Raw Materials, was my primary Patagonia contact. I met him at the 2005 Net Impact Conference in Palo Alto, California. I spoke with him again in February 2006 where he answered my questions about the program's details. I also met with Huntley Dorman, Social Compliance Manager, and discussed the strategic objectives of the recycling program. I supplemented these two interviews with internet research and a literature review.

VI. The Model

Parameter Estimation and Calibration

There are no data on Capilene returns since the program has existed for less than a year. The lead times and safety stocks are assigned values based on conversations with Patagonia. Cost values are educated guesses as are the values that describe consumer behavior. The analysis is meant to illustrate a method and some basic dynamics of the program. Further investigation is definitely required but it is outside of the scope of this Masters thesis.

Model Description

The skeleton of the model is a supply loop with two components: Capilene Production and Garment Production and Use.

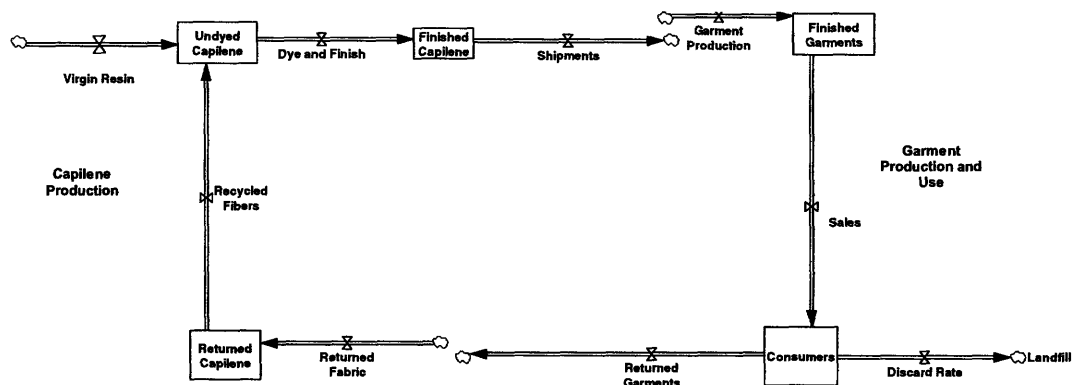


Figure 2: Basic Supply Loop

Fiber Starts

Capilene Production has two inputs: recycled fibers from polyester fabric that is returned from consumers through the supply loop and virgin fiber sources. All non-Patagonia fiber sources (soda bottles, non-Patagonia recycled polyester, and true

virgin fibers) are lumped under the rubric Virgin Fibers and its supply is assumed to be unbounded.

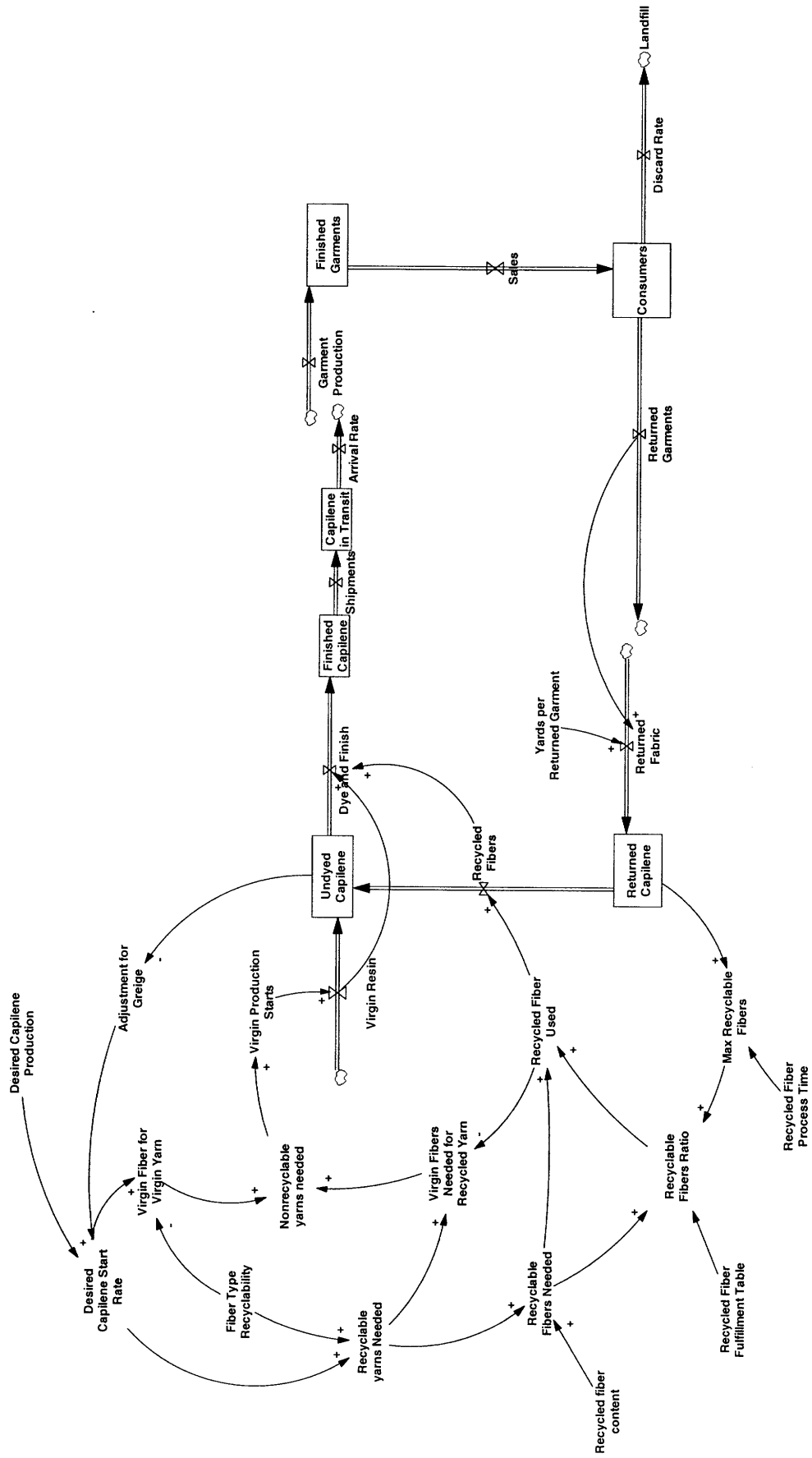


Figure 3: Fiber Starts

When recycled garments are received from the consumer, trims, zippers, and non-Capilene fabrics are removed. Then the Capilene is melted into its pure resin form, and impurities are skimmed off the top. The percentage of original Capilene that is recovered after the trim and impurities are removed is the *Yards per Returned Garment*. Its units are the yards of Capilene that can be produced from the recovered material. The recovered units are stored in the *Returned Capilene* stock.

Both sources of fibers are used to make the greige or *Undyed Capilene*. This is the stock of Capilene that has been knit using the various fibers. Each type of fabric uses multiple yarns to achieve the desired technical properties of the fabric. Most yarns can not be made from recycled sources, yet. Only a small percentage, around 2-4%, of fiber types (among other things, fibers are categorized by their length), can be recycled. When determining how much recycled fiber is needed for production, the first question is: what percentage of the yarns needed can be made from recycled material? Within each yarn, there is an upper limit to how much can come from recycled sources. Again, to achieve the technical and tensile properties that are required, about 10% of “recycled” yarns come from virgin sources. The *Recycled Fibers* rate is the amount of recycled fibers that are used each month. It is bounded by both the need for and availability of recycled material. If there is not enough recycled material to cover the need, the deficit will be filled with virgin material. The *Virgin Resin* rate is the sum of the resin used for the virgin yarns and the incremental virgin material that is used in recycled yarns.

Capilene Production

The model uses standard structures to represent the stocks of inventory and the inventory control decision processes that decide the flow of materials through the system [Sternan (2000, Ch. 17)]. The structure is used for both the Capilene and Garment flows. The desired rate of Capilene fabric starts, the sum of the *Virgin Resin* and *Recycled Fibers* rates, is driven by the expected demand for Capilene and the desired level of finished goods to be held in inventory. The desired finished goods inventory (*Desired Capilene Inventory*) is based on the expected demand for Capilene, desired levels of safety stock and coverage needed while the orders are being processed. The desired inventory levels are adjusted for the stock-on-hand in finished goods inventory and work-in-process (greige) inventory.

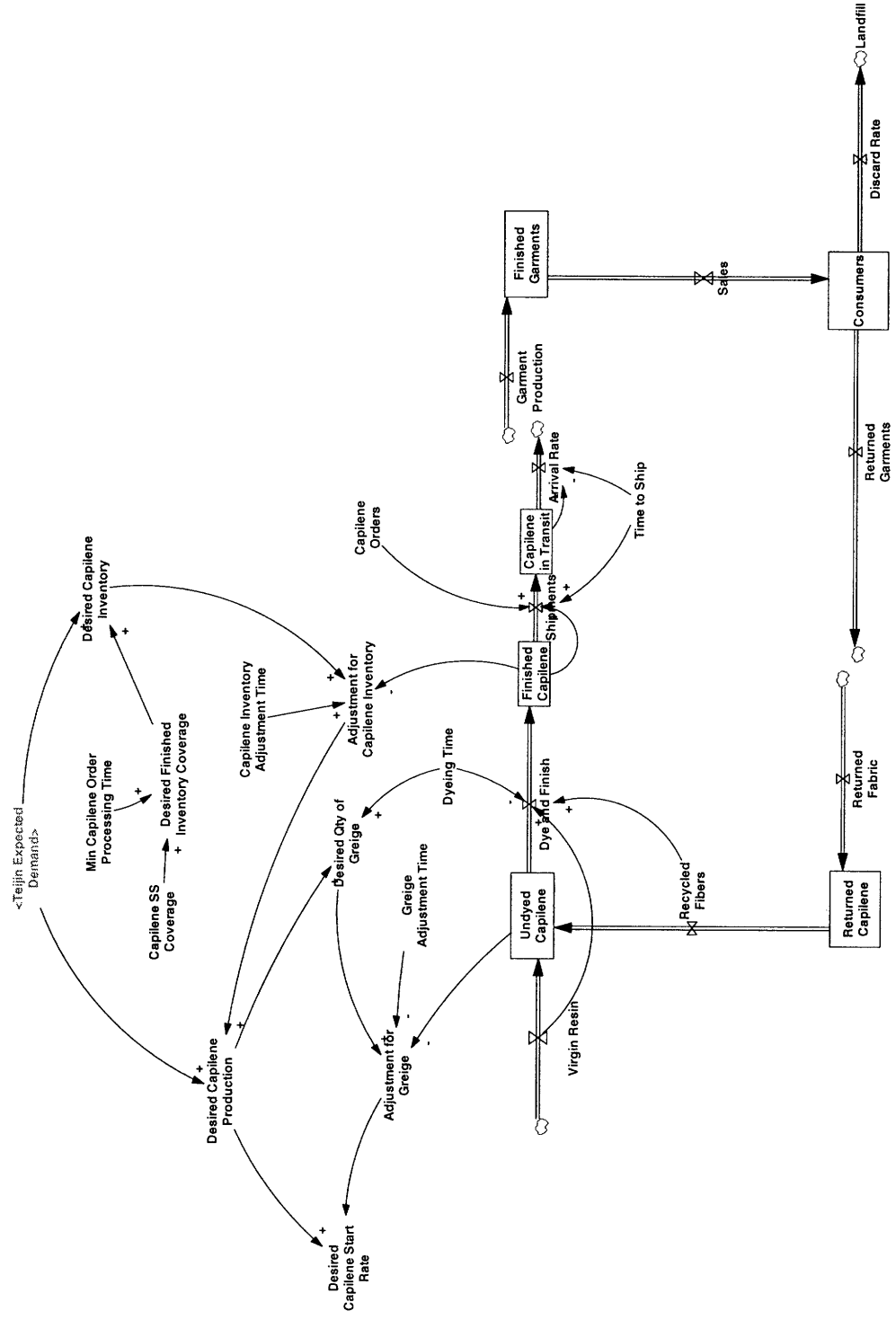


Figure 4: Capilene Production

Dye and Finish is a process that, through chemical reactions, changes the color of the fabric. When the fabric is finished it sits in the *Finished Capilene* inventory until it is shipped, by boat, to the cutting and sewing factories. Capilene is manufactured in Japan and the cut-sew factories are mostly in the Caribbean. The rate at which the fabric arrives in the factories is the link between the Capilene Production and Garment Production and Use systems.

Garment Production and Use

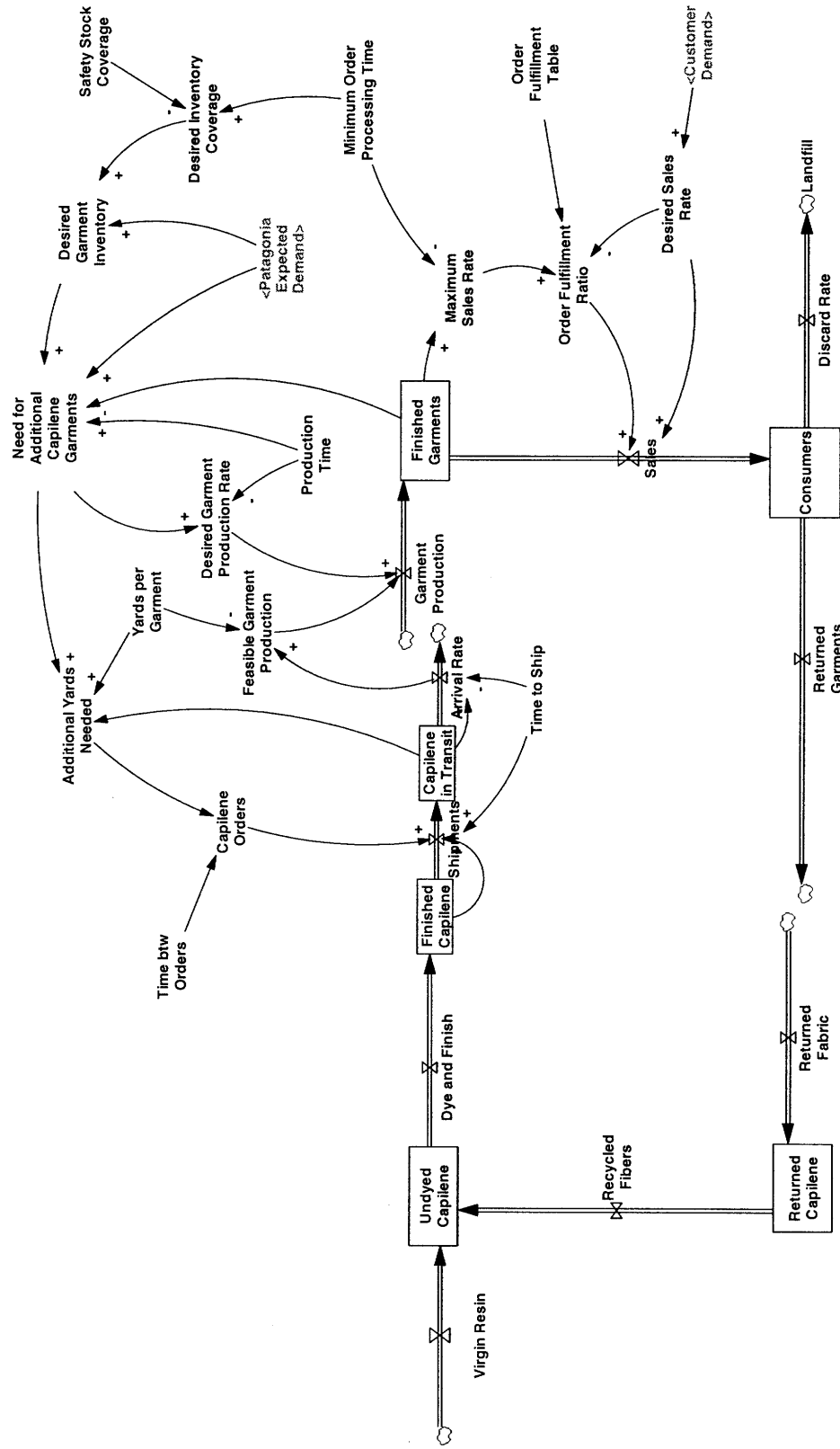


Figure 5: Garment Production and Sales

Garment production starts are modeled according to the same principles as Capilene Production starts. The need for additional finished inventory triggers a raw material order. Actual production is constrained by the amount of material that is on hand. This model assumes that the apparel factories don't carry an inventory of fabric and that all material is used up as soon as it arrives.

There is a desired inventory level based on expected customer demand, desired safety stock and processing time coverage. Units change in this structure from yards of Capilene to number of garments. The *Yards per Garment* variable converts one to the other. Once the garments are cut and sewn, they sit in the Retailer's inventory, *Finished Garments*. The model does not distinguish between inventory held in distribution centers or in store inventory.

Customer orders drive the rate of sales within the constraints of product availability. Because there are so many Capilene SKUs, a customer may find that the particular item they are looking is out of stock.

Garment Returns

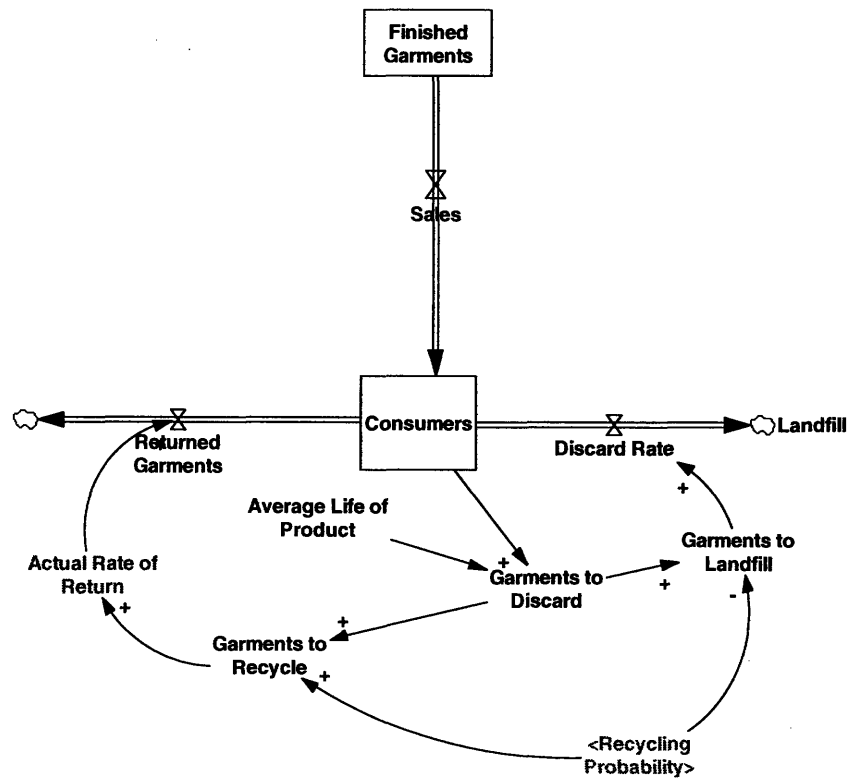


Figure 6: Consumer Returns

In the real world consumers have three options: they can throw away their old clothes, they can recycle them or they can donate them. If the clothes are donated, their lifetime is extended and the new owners must then decide whether to discard or recycle. The dynamics of the used clothing industry are complex and are not included here. A larger model that includes that industry would be an interesting topic for the future.

In this simpler model, consumers can discard or recycle their old clothes. *Garments to Discard* is a third order material delay variable to capture the fact that some clothes will be recycled before others. I use a third order delay because individuals have very different definition of “old clothes” and so there is a lot of dispersion around the mean.

Probability of Recycling

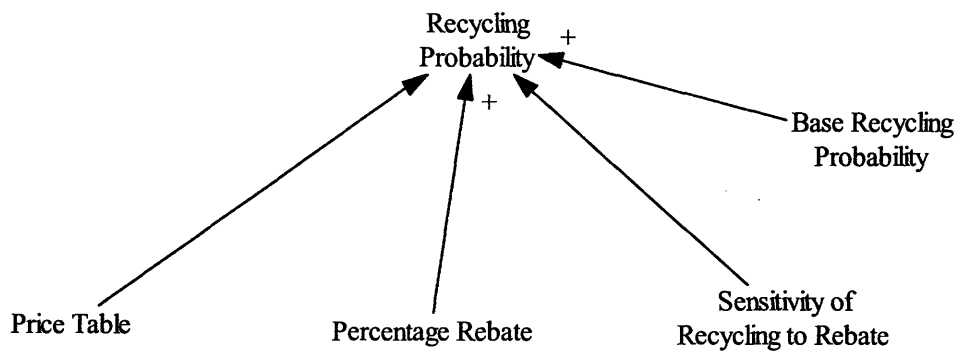


Figure 7: Recycling Probability

The probability of recycling is driven by many different factors among which are: consumer education, ease of recycling, environmental consciousness, rebates, and in the case of recycling underwear, comfort with the idea. This model considers the effects of offering a rebate coupon to customers who recycle.

$$\text{Recycling Probability} = \text{Base Recycling Probability} + \text{Sensitivity of Recycling to Rebate} * f(\text{rebate})$$

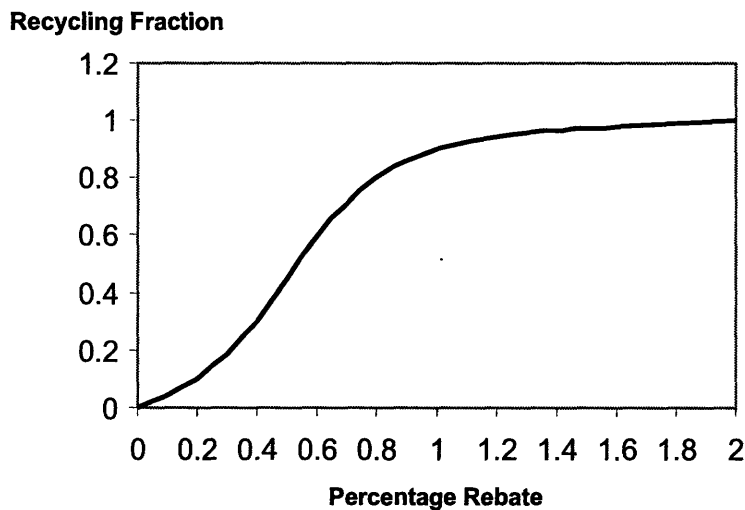


Figure 8: Price Table

The relationship between the size of the rebate and the likelihood of recycling is shown in Figure 8: Price Table. The horizontal axis is the size of the rebate as a percentage of the price of a new item. A value of 0.5 is a 50% rebate. At 1.0, consumers get the equivalent of a free garment for every garment they return. At 2.0, consumers receive a coupon worth twice the value of a new garment. The s-shaped curve estimates the fraction that starts recycling as a response to the rebate. The *Base Case Recycling* variable is the fraction of consumers who will recycle without an economic incentive. They are motivated by intrinsic forces such as a concern for the environment. This variable is set to 0.2 or 2% of the population.

In the base case, the *Sensitivity of Recycling to Rebate* variable is set to 0.4 so even with extremely large rebates no more than 0.42 or 42% of people will recycle. *Sensitivity of Recycling to Rebate* taken in conjunction with $f(\text{rebate})$, i.e. the Price Table, yields the true effect of the rebate on the probability of recycling. Separating this effect into two variables makes it easier to test its sensitivity.

Base Case Recycling and *Sensitivity of Recycling to Rebate* are subject to sensitivity tests as described in the Sensitivity section. The true value of these two variables is unknown but we can fairly confidently estimate a range of values. What is the range of values that the *Probability of Recycling* can have given the range of inputs and how does it affect the rest of the model?

I consider three scenarios for the size of the rebate: no rebate at all, a rebate that ramps up from 0% to 40% over 72 months, and a rebate that ramps down from 50% to 10% over 72 months.

Expected Demand

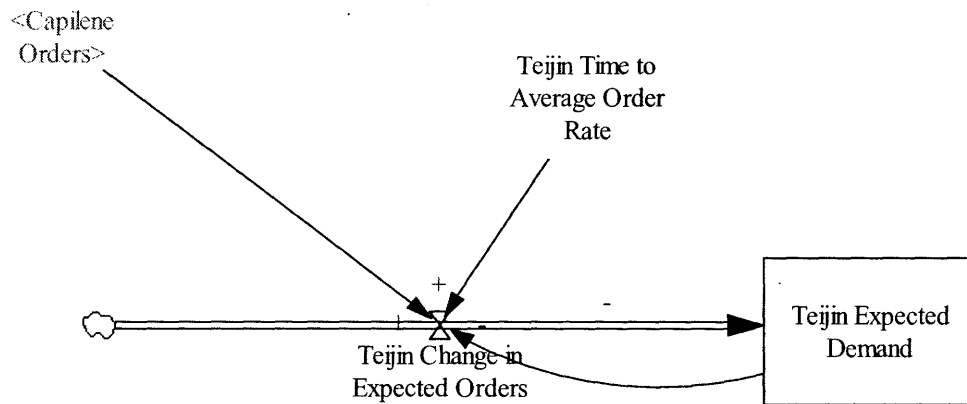


Figure 9: Teijin's Expected Demand

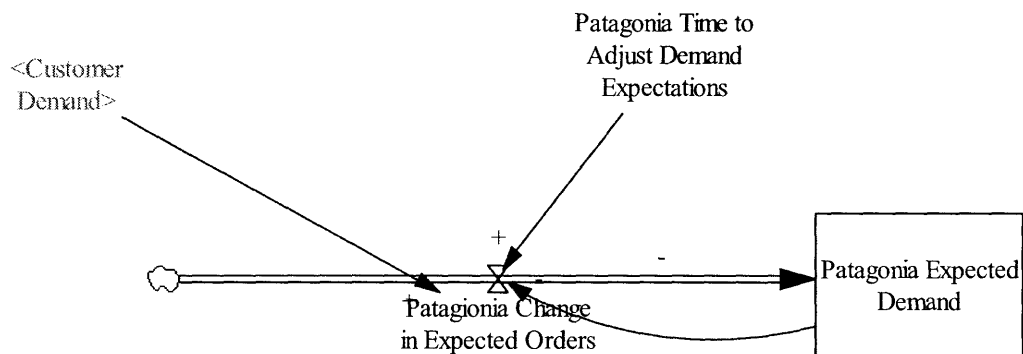


Figure 10: Patagonia's Expected Demand

Both Teijin and Patagonia set their desired inventory levels and production decisions based on their expectations of customer demand. I use a standard exponential smoothing model²⁹ to simulate managers' expectations. Capilene sales are strongly seasonal and it may take a full year to see and adjust to a true shift in demand.

Profitability

The program must be economically viable if it is to survive long term, let alone serve as a model for the industry. Neither Patagonia nor Teijin disclosed their cost structures so I have made educated guesses based on published profit margins.

Teijin Profitability

²⁹ Sterman 2000, Chapter 16

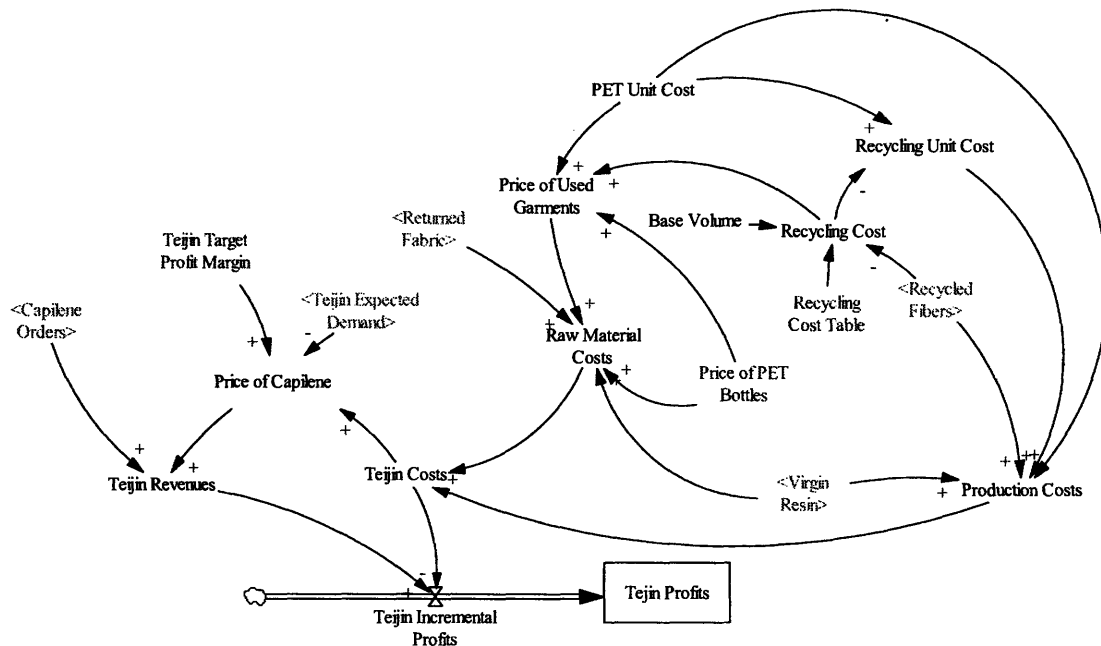


Figure 11: Teijin Cost and Revenue Structure

Polyester manufacturing is a capital intensive, high fixed costs industry. The startup costs are high and by now they are sunk. The model measures the operating profits that vary with volume. For simplification assume that Teijin has two major costs: raw material costs and production costs.

$$\text{Raw Material Costs} = \text{Price of Traditional Fibers} * \text{Traditional Volume} + \text{Price of Garments} * \text{Recycled Volume}$$

I assume that the price of traditional fibers is exogenous, constant³⁰, and equal to 1.

There is no external market for post-consumer Capilene so Teijin and Patagonia set the price through negotiations. The price is set according to an undisclosed sliding scale based on the volume of returns.³¹ To estimate this scale, assume that Teijin would like to be indifferent between making Capilene from PET bottles and making Capilene from used polyester.

$$\text{Price (Traditional)} + \text{Unit Production Cost (Traditional)} = \text{Price (Garment)} + \text{Unit Production Cost (Garment)} [1]$$

Teijin makes polyester products for many customers so another simplifying assumption that I make is that Patagonia's orders do not significantly affect total volume and so traditional unit production costs are constant and set to 1.

$$\text{Unit Production Cost (Garment)} = \text{Unit Production Cost (Traditional)} * (1 + M)$$

³⁰ In the real world, the prices of recycled materials are cyclical.

³¹ Randy Harward, phone interview, February 2006

M is the additional cost and is a function of recycled fiber production volume relative to the initial volume of traditional fiber manufacturing. A graph with M on the y-axis and Garment volume/PET volume on the x-axis is an s-shaped curve.

Recycling Cost

(Multiple of Virgin Costs)

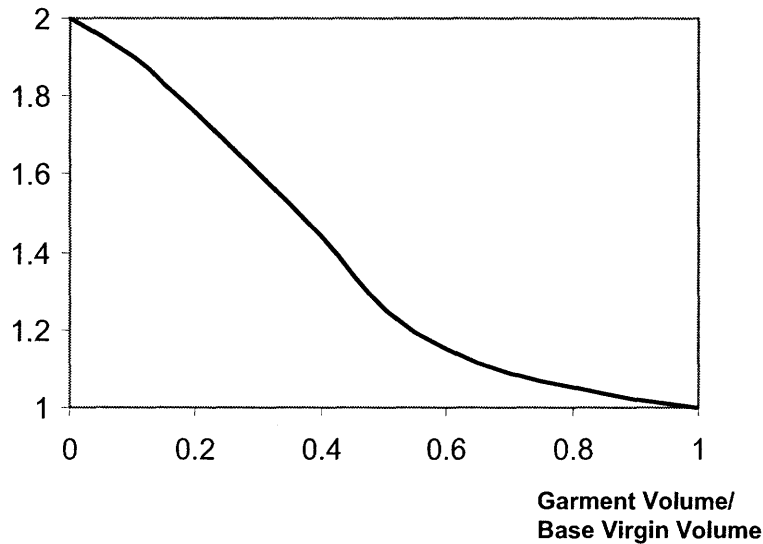


Figure 12: M – Fiber-to-Fiber Production Cost Multiple

Simplifying [1] we get

$$\text{Price (Garment)} = \text{Price (Traditional)} - M * \text{Unit Production Cost (Traditional)}$$

Price is non-negative so,

$$\text{Price (Garment)} = \max(0, \text{Price (Traditional)} - M * \text{Unit Production Cost (Traditional)})$$

In other words, Teijin won't pay much to Patagonia for its Capilene returns until the volume is large enough to drive economies of scale. There is also a learning story here since as Teijin manufactures more from reclaimed fibers, it will improve its processes and become more efficient. Not only is the rate of production important, so too is the cumulative amount of Capilene produced from recycled fibers. That is an interesting question and one that is not modeled in this thesis.

In this closed system, Teijin's revenues are all from the sale of Capilene to Patagonia: volume sold times price. Teijin's FY 2005 Operating Margin for its Synthetic Fibers division was 4%³².

Patagonia Profitability

³² Operating income was 14,548 million yen. Net sales were 327,764 million yen. Source: Teijin Consolidated Financial Statements, May 8, 2006

Patagonia has two prices that it can control: the price of its clothes and the rebate that it will pay to its customers.

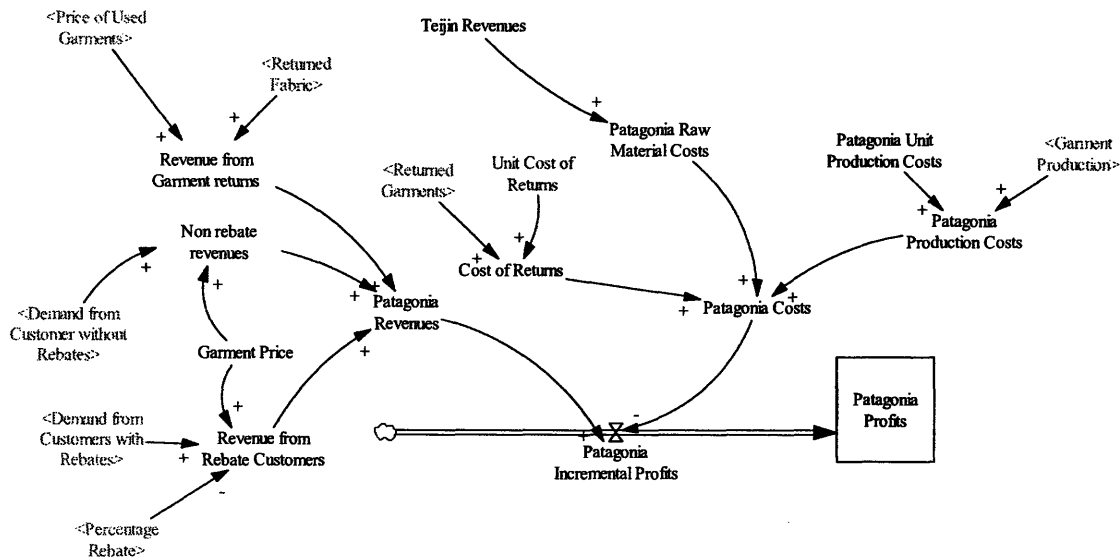


Figure 13: Patagonia Cost and Revenue Structure

Costs are separated into two groups: production costs and raw material costs. Raw Material Costs are the cost of purchasing the Capilene from Teijin. This is the same as Teijin’s revenues. Production Costs include transportation costs, manufacturing and retail costs. Production costs are constant for both types of Capilene (PET and recycled). Since I do not know the cost structure, I guessed that before the recycling program raw material costs were 30% of the total and production costs comprised the rest. The cost of the recycling program, i.e. collecting product form consumers, holding, bailing and shipping is estimated to be around a quarter of “forward” production costs.

As a private company, Patagonia does not release its financial statements. Columbia Sportswear, a comparable but publicly traded company had operating margins of 16% in FY 2005.³³ Patagonia has committed not to raise prices simply because they are incurring higher raw material costs from the recycled fiber Capilene. If pre-recycling operating margins were around 16% then given costs we can back out the price.

$$\text{Price} - (\text{PET Capilene unit cost} - \text{Unit production cost}) = 16\%$$

Effect of Rebates on Demand

³³ Columbia’s FY 2005 Operating income was \$14.548 million, and Net sales were \$327.764 million. Source: Columbia Sportswear Form 10-K, Fiscal Year 2005

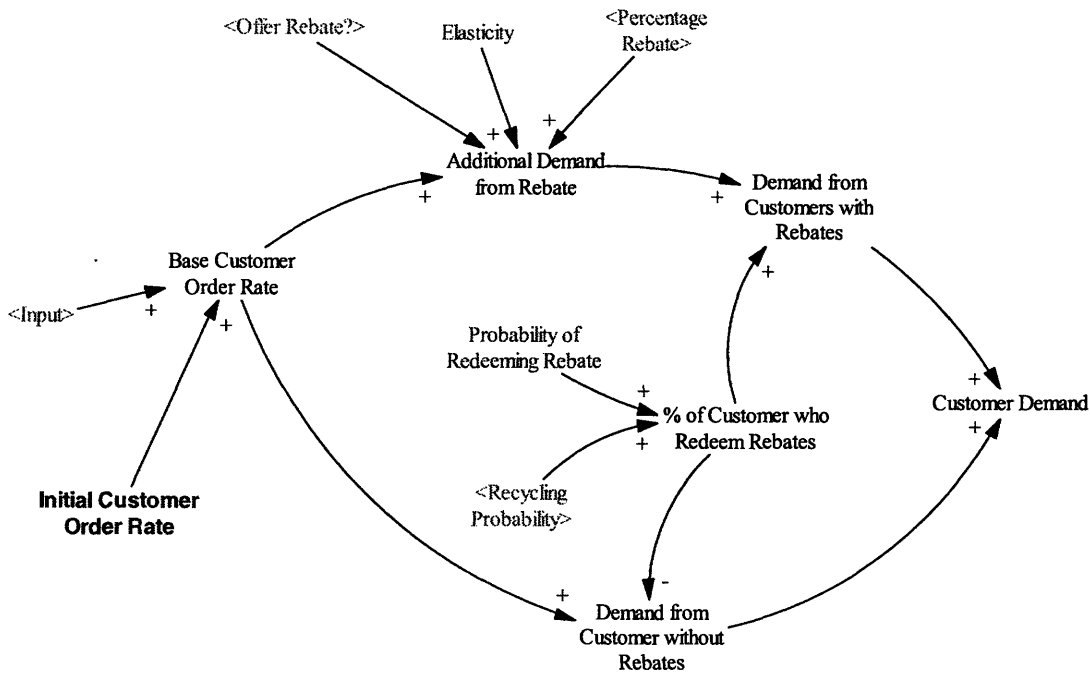


Figure 14: Rebate Effect on Consumer Demand

Rebates drive consumer behavior in two ways. As discussed above, they are a factor in people’s decision to recycle. Rebates lower the price of new Capilene product and so has an effect on demand.

The initial customer demand at the beginning of the simulation is 100 (garments/month). The initial demand can be subject to linear growth, step increases, and noise and seasonality.

Patagonia can influence demand through their use of rebate coupons. When customers return their Capilene, Patagonia can issue rebate coupons to them. The rebate could be good for just the next Capilene item purchased. Here I assume that the coupon is valid on the next Capilene order (unlimited number of items). Only a small fraction of rebate coupons are usually redeemed (*% of Customers who Redeem Rebates*). Those customers who do see lower prices and will purchase more. The additional quantity they purchase is the elasticity of demand times the size of the rebate. Those customers who do not have or who do not use the rebates continue to purchase at the old price. The total demand is the sum of the purchases of those two segments.

Model boundaries

The model makes a series of simplifying assumptions to define its boundaries. I assume that the only two companies in the system are Teijin and Patagonia. This is a

reasonable assumption in the early stages of the program. If the program grows to include other brands and other suppliers then the boundaries will need to be relaxed.

No learning is modeled, yet gaining experience in garment recycling is very important to both Teijin and Patagonia. Part of increasing volume is to gain economies of scale but also to learn about the processes and get better at them.

I don't model information flows. I could not find out about the information sharing between Teijin and Patagonia and the visibility of each into the pipeline of the other. They are partners in this venture and one would hope that they communicate often. Other studies, for example Spengler (2003), have shown that increased visibility into the supply chain leads to better inventory and production planning.

On the supply side, I lump many types of raw materials together as "Virgin", assume that the supply is unlimited and that the prices are constant. This category includes soda bottles, true virgin fibers, and non-Patagonia recycled polyester. Each of these inputs has its own price fluctuations and lead times. If the use of post-consumer polyester garments as a raw material increases, the dynamics between the supply of soda bottles, virgin polyester and recycled polyester will become more intertwined.

Other simplifying assumptions:

- No capacity constraints are modeled.
- No backlogs.
- No labor requirements.
- No changes in technology to increase productivity.

The model simulates ten years of real time.

VII. Analysis

There are multiple criteria for judging the success of the Capilene recycling program.

- 1) It must be profitable for both parties.
- 2) It must have sufficient scale.

For Teijin this is important for learning and for economies of scale. It will justify the investment in the technology and encourage them to develop it further. For Patagonia, achieving scale means lower costs and increases the chances that other companies may emulate the program.

- 3) It must be a viable second source of raw materials for Capilene.

Overview

Scenarios

How do different rebate structures affect the success of the program? I consider three different rebate schemes:

Base Case: There is no rebate and only the intrinsically motivated recycle their old underwear.

Scenario 1: The rebate starts at 0% then grows linearly over the first 6 years³⁴ and flattens out in month 72 at 40%.

Scenario 2: The rebate starts at 50% and decreases linearly over the next 6 years and flattens out in month 72 at 10%.

Sensitivity Analysis

Many important parameters in the model are guesstimates. What are reasonable assumptions for demand growth? How elastic is demand? How many customers would recycle without rebates? How sensitive are consumers to the rebate scheme and of those that do, how likely are they to redeem the rebate coupons?

How do these sensitivities affect economic factor like prices and company profits? How do they affect the volume of recycled garments and is that volume sufficient to meet production needs? If not, how will the percentage of recycled fibers change over time?

Within each scenario there are four sets of sensitivity tests that are run to answer these questions. I use Monte Carlo simulations to get a range of possible outcomes and the probabilities of these ranges.

Sensitivity to Growth:

³⁴ Why 6 years? Patagonia hopes the program will be self-sustaining in three years. Based on results from the model, six years is a more realistic timeline for establishing a self-sustaining supply loop.

The first sensitivity test considers the effects of a range of growth scenarios. Patagonia forecasts growth in the 8-15% range. The base case uses a growth rate of 10%. The sensitivity range test the entire range of plausible growth rates.

<u>Variable</u>	<u>Distribution</u>	<u>Min</u>	<u>Max</u>
Demand Growth	Uniform	0%	25%

Sensitivity of Recycling to Rebates:

The second sensitivity test tests the variables that drive the recycling probability.

<u>Variable</u>	<u>Distribution</u>	<u>Min</u>	<u>Max</u>
Base Recycling Probability	Uniform	0	5%
Sensitivity of Recycling to Rebate	Uniform	0.1	0.7

Sensitivity of Demand to Rebates:

The third sensitivity test tests the effects of the rebate on consumer demand.

<u>Variable</u>	<u>Distribution</u>	<u>Min</u>	<u>Max</u>
Demand Elasticity	Uniform	0.5	3.0
Probability of Redeeming the Rebate	Uniform	0%	60%

Sensitivity of Recycling to the Average Life of the Garment:

The fourth sensitivity test tests the effects of the rebate on consumer demand.

<u>Variable</u>	<u>Distribution</u>	<u>Min</u>	<u>Max</u>
Average life of Product	Uniform	12 Months	120 Months

Base Case: No Rebate

In this scenario there is no rebate given for returns so only the customers who are educated about the program and sufficiently motivated by non-monetary factors will recycle. The growth rate is constant at 10% growth each year. Since there are no rebates this scenario shows the basic dynamics of the model.

Results

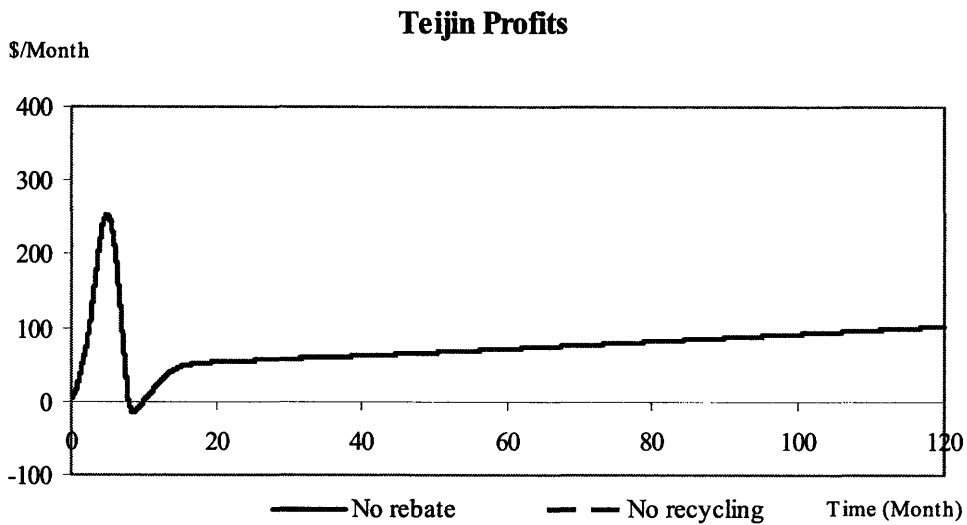


Figure 15: Teijin's Profits – No rebate v. No recycling

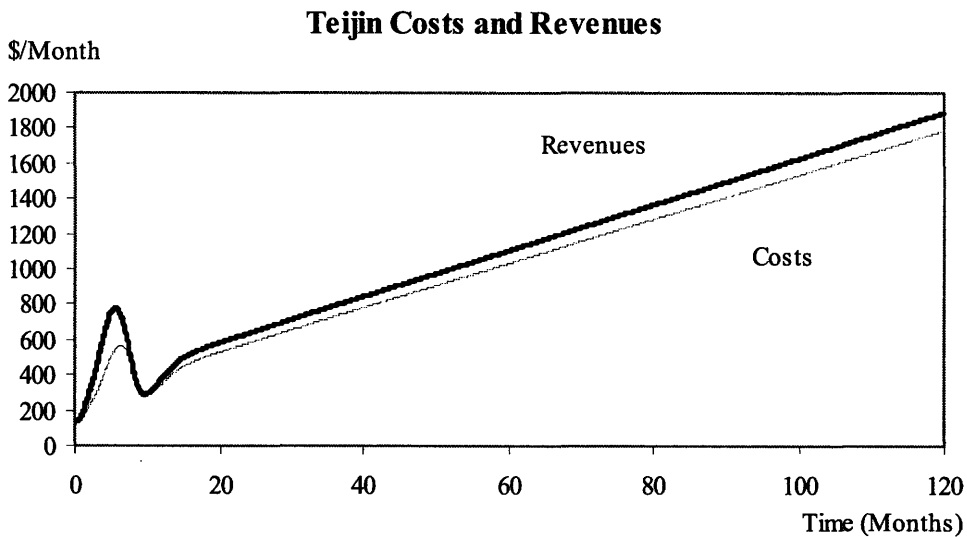


Figure 16: Teijin Costs and Revenues – No rebate

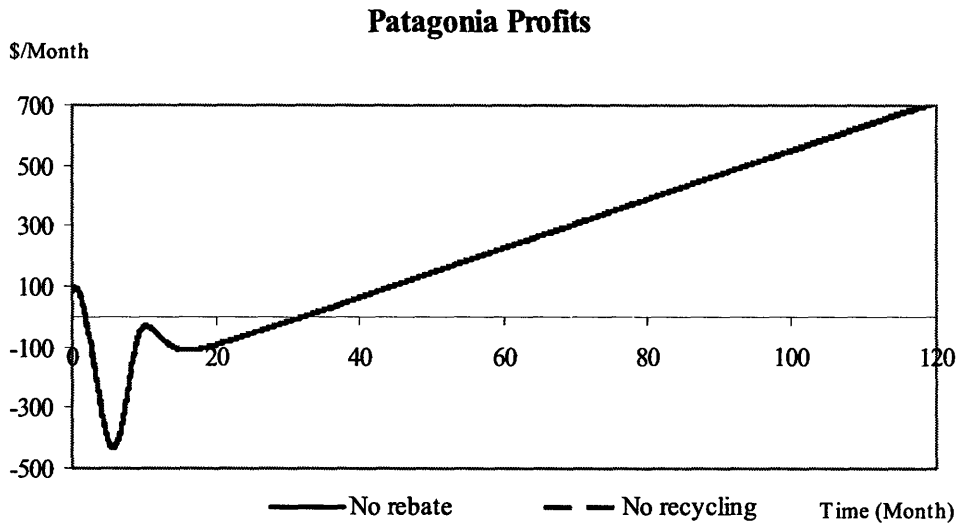


Figure 17: Patagonia's Profits – No rebate v. No recycling

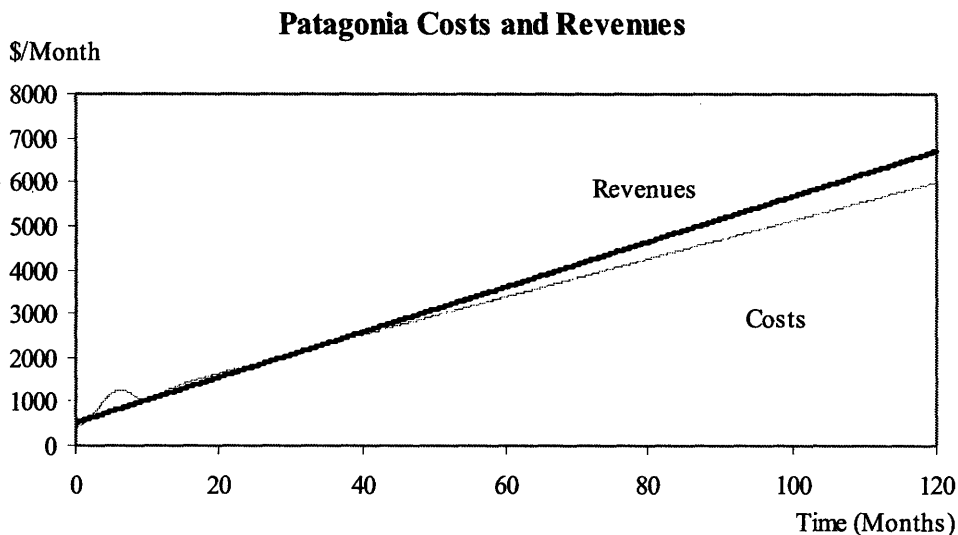


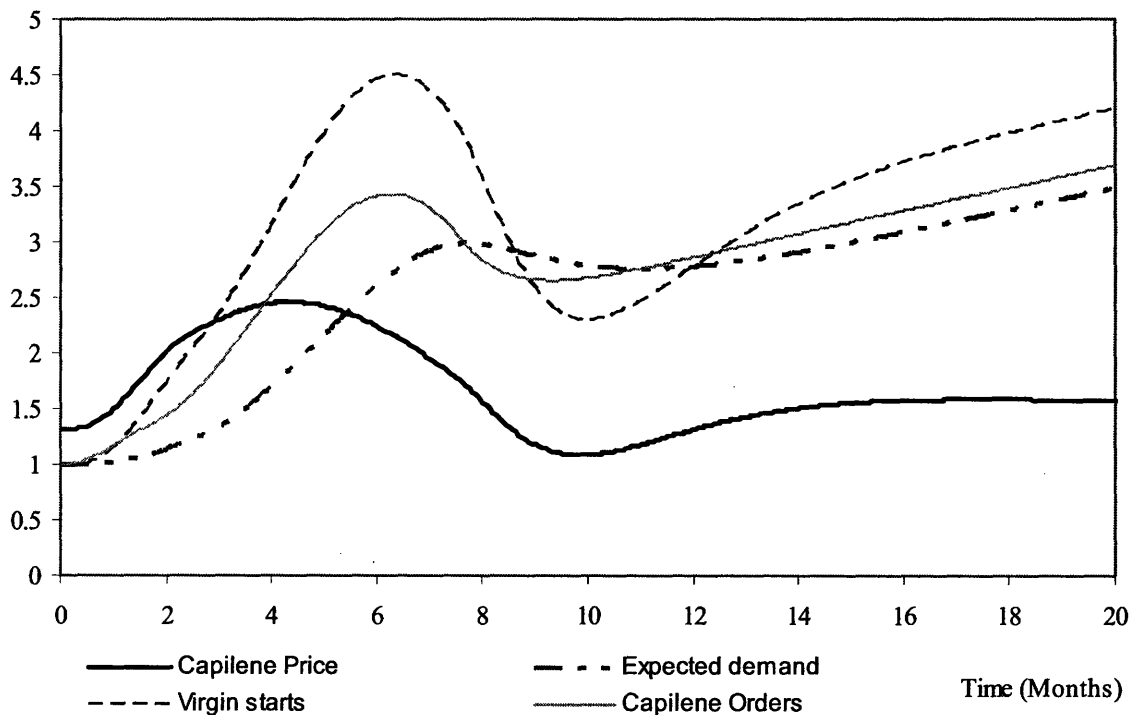
Figure 18: Patagonia Costs and Revenues – No rebate

Figures 15 and 17 compare expected profits for a world without a recycling program versus a recycling program without a rebate. The results are practically identical. Teijin's profits are insignificantly higher with a recycling program. Patagonia's are insignificantly lower. This is partially a construct of the model where Teijin is able to purchase recycled polyester from Patagonia for free while passing on part of the higher production costs through higher Capilene prices.

The oscillations in the first two years are due to the delays in adjusting for changes in expected demand. The instability is an artifact of the initialization of the model and does not necessarily reflect real world dynamics. The model is oscillating because it is moving from an equilibrium state with constant demand to a new state with linearly increasing demand. Any change in demand or in the rate of change of demand will

cause the model to overshoot and collapse as it recalibrates its equilibrium position. The model has a similar pattern to a step increase in demand though the overshoot is less dramatic. This oscillating behavior is consistent with what one expects when demand changes in the real world.

Early Price and Demand Fluctuations



Price is in \$/Yard; Orders, Expected demand and Starts are in Yards/(100*Month).

Figure 19: Capilene Price and Demand Fluctuations

As shown in Figure 11: Teijin Cost and Revenue Structure, the price of Capilene is set by dividing the costs of production and procurement in that period and dividing it by the expected demand for finished Capilene. The difference between the volume of production starts and the expected demand explains the oscillations. As the demand increases at time zero, the actual demand is greater than the expected demand so the WIP inventories are depleted. Teijin then increases production as it adjust its demand forecasts upwards and needs to fill its depleted pipeline. So the volume of production starts is greater than expected demand and Capilene prices increase. Prices are maximized when the ratio of starts to expected demand is at its highest. The production overshoot is a classic bullwhip effect. The model makes too many simplifying assumptions for it to be a good forecasting tool. In the real world, I would anticipate a bullwhip effect but not necessarily of this exact shape or magnitude.

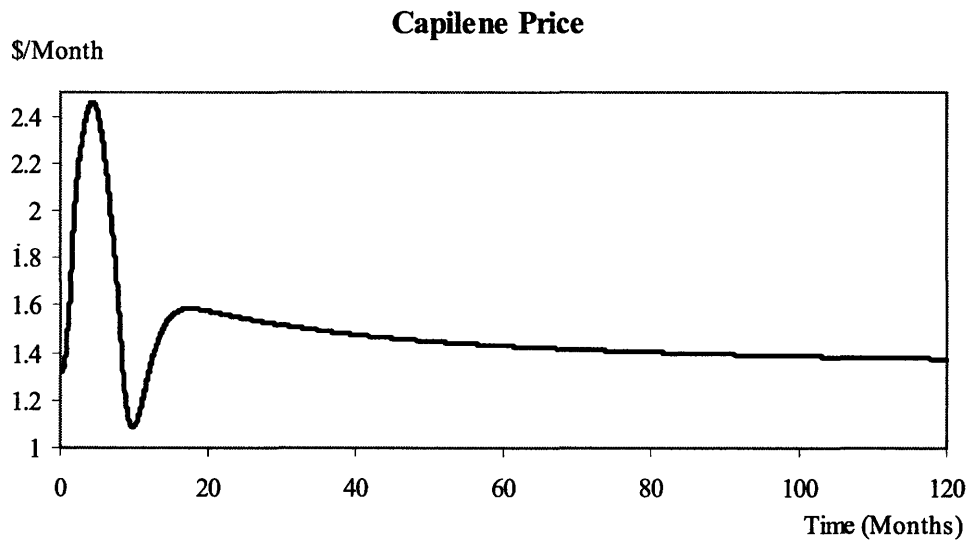


Figure 20: Capilene Prices – No rebate

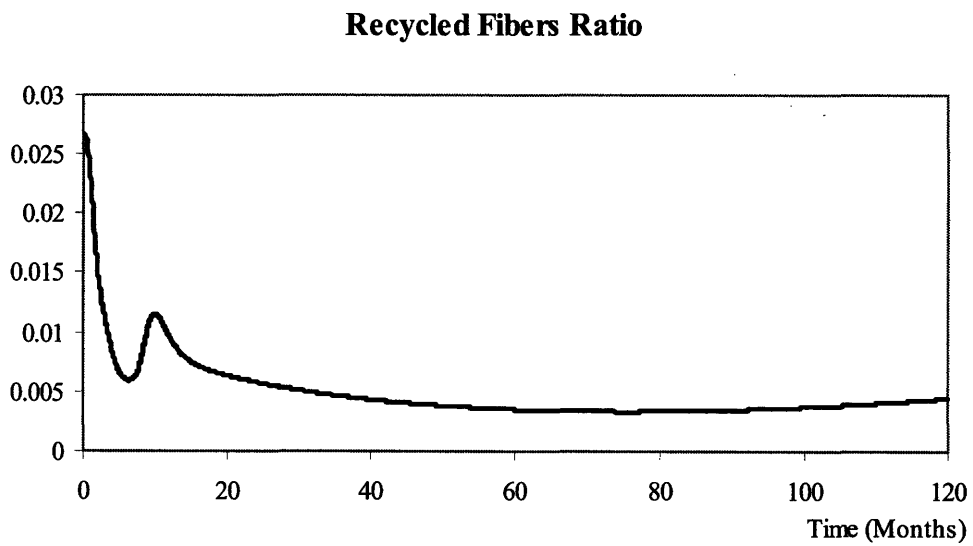


Figure 21: Ratio of recycled fibers to Total fibers – No rebate

Used and Returned Garments

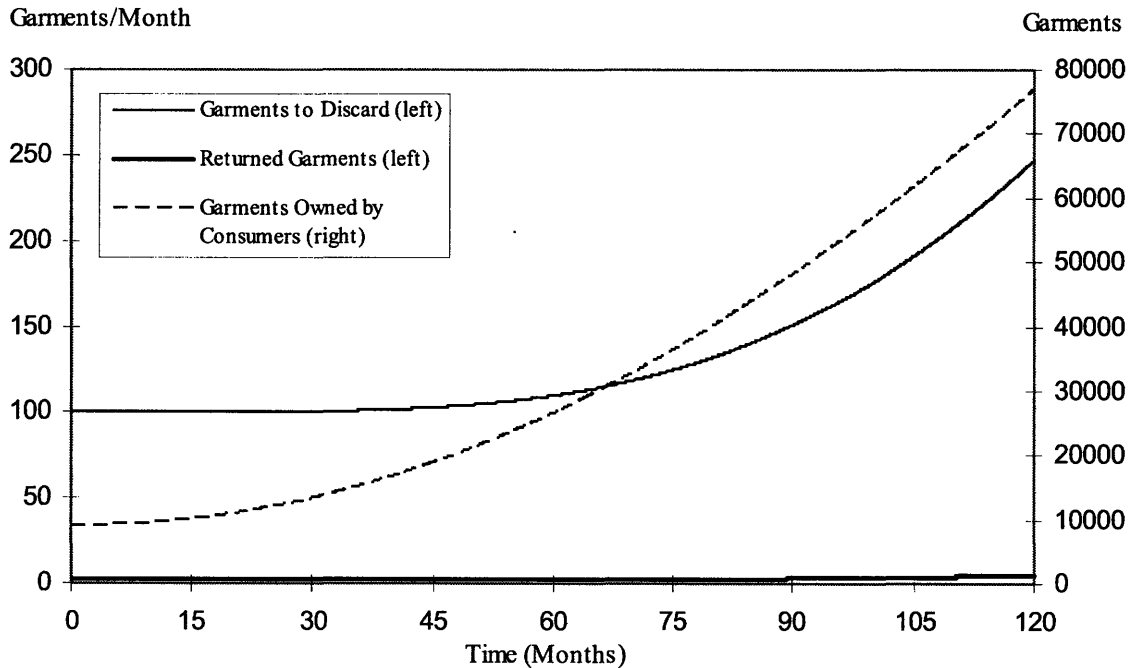


Figure 22: Used and Returned Garments – No rebate

There is a doubling of capacity in 110 months; however the base level of traditional fiber production is 98 yards/month. Why is garment recycling so slow to start up? A very important delay is the average life of the product. Though the stock of Capilene owned by consumers is growing exponentially, consumers wear their long underwear for a long time. The model uses third order, 7.5 year delay to model the time that Capilene is worn. In month 0, there are 9000 garments owned by consumers of which 100 are ready to be discarded. Of the 100, 2% are recycled. The rate of increase in the stock of used garments is delayed as the stock ages.

Under the base case, the program does not achieve significant scale and it is not a viable second source of raw materials. Only a small percentage of consumers return their used Capilene and the model doesn't include any feedback loops that increase the return rate. The long life of Capilene delays the growth of the used Capilene stock that can be returned.

Sensitivity to Growth Assumptions

The base case assumes a constant growth rate of 10%. Patagonia estimates an 8 to 15% growth rate depending on the line of clothing. This sensitivity test allows the growth rate to vary between 25% and -5%.

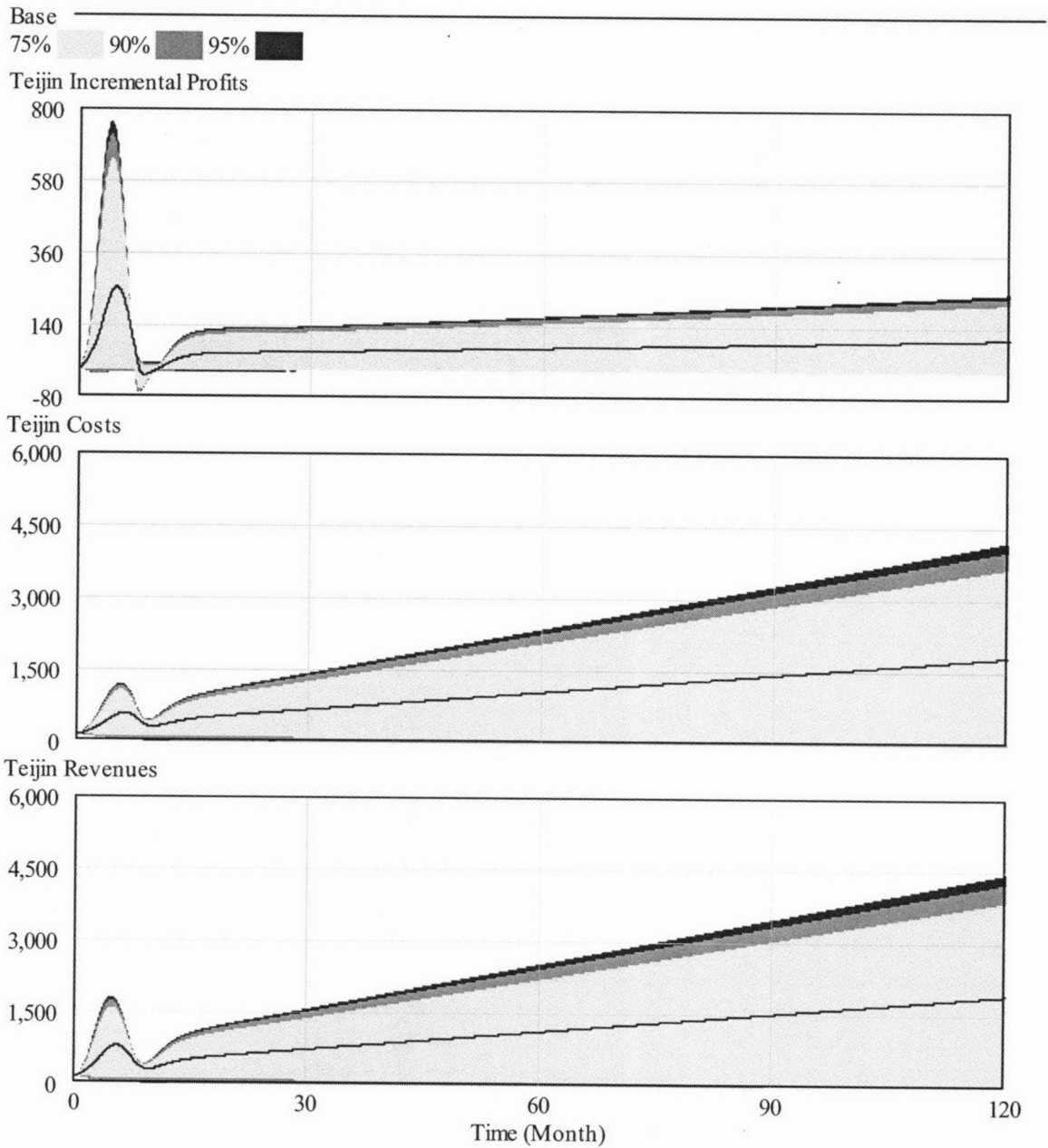


Figure 23: Sensitivity of Teijin Cash Flows to the growth of demand – No rebate

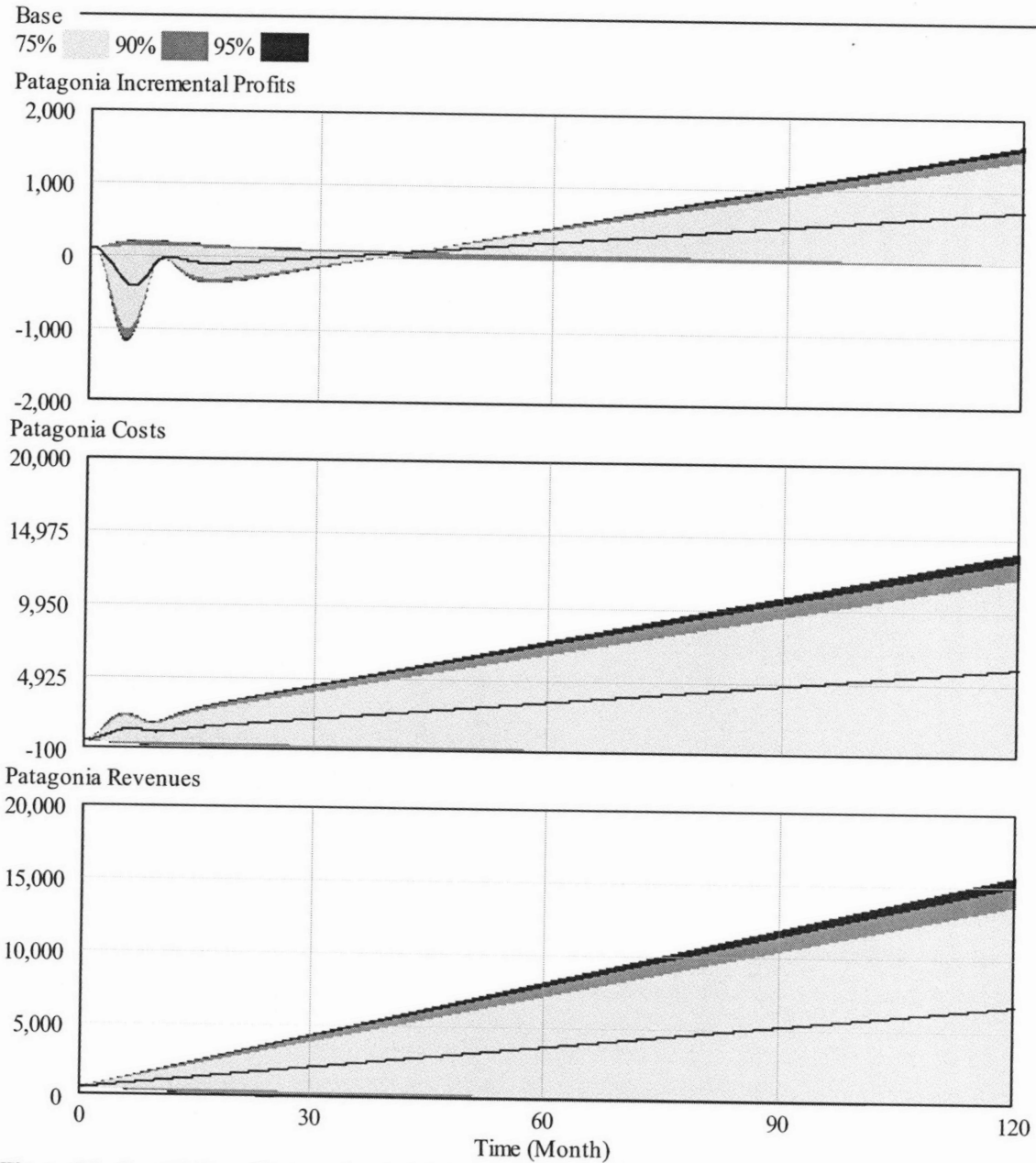


Figure 24: Sensitivity of Patagonia Cash Flows to the growth of demand – No rebate

The range of possible profits is evenly distributed when the system is in equilibrium. Teijin is able to capture the profit by raising Capilene prices when there is a positive change in demand. This is the dynamic that was discussed earlier. When there is negative demand growth, Teijin drops prices initially and Patagonia benefits. The benefit for Patagonia is not symmetrical because the negative demand slope is not as steep as the positive one.

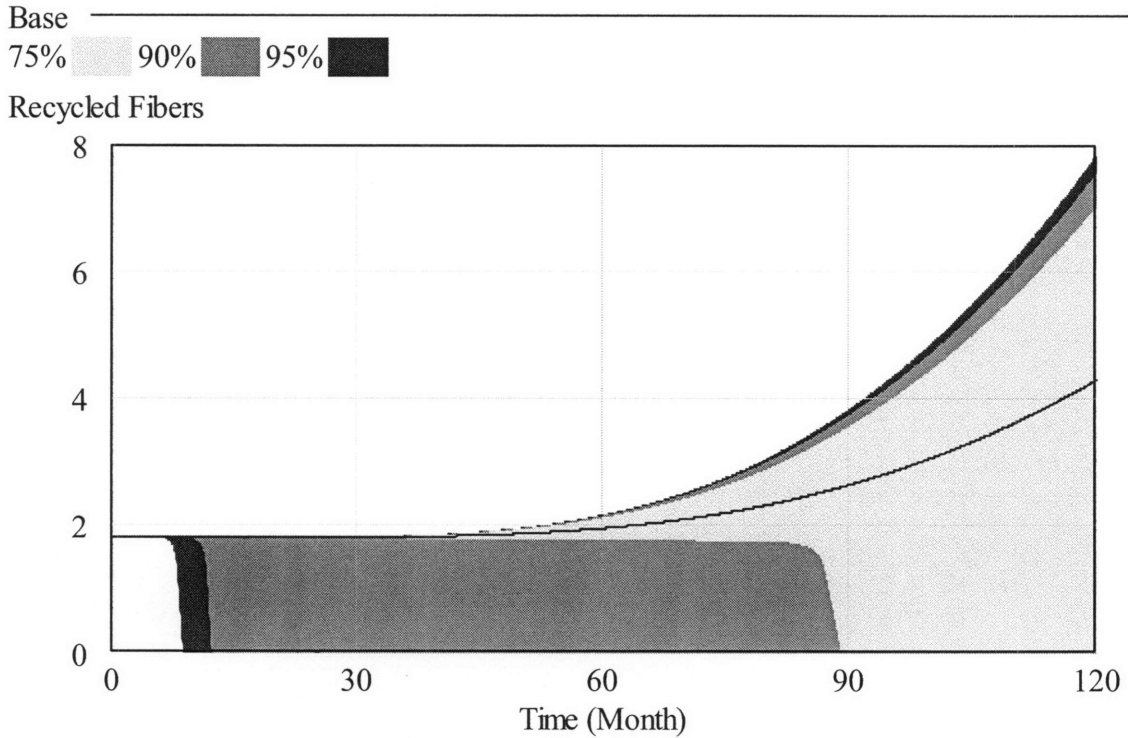


Figure 25: Sensitivity of the volume recycled to the growth of demand – No rebate

Though the rate of returns may be up to twice as high as the base case in the high growth scenarios, it remains too low to yield significant economies of scale. The recycled fiber ratio goes to zero in cases where demand shrinks and Capilene production is stopped.

Sensitivity of Recycling to Rebate

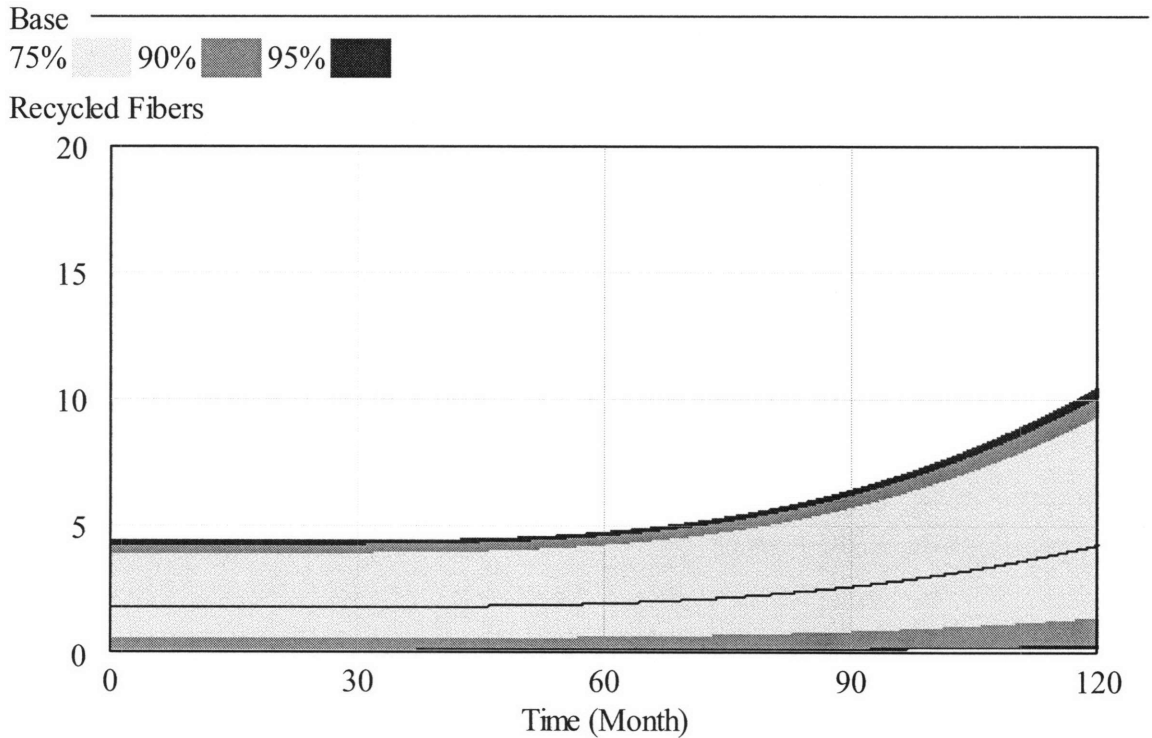


Figure 26: Sensitivity of recycled volume to changes in base recycling rate.

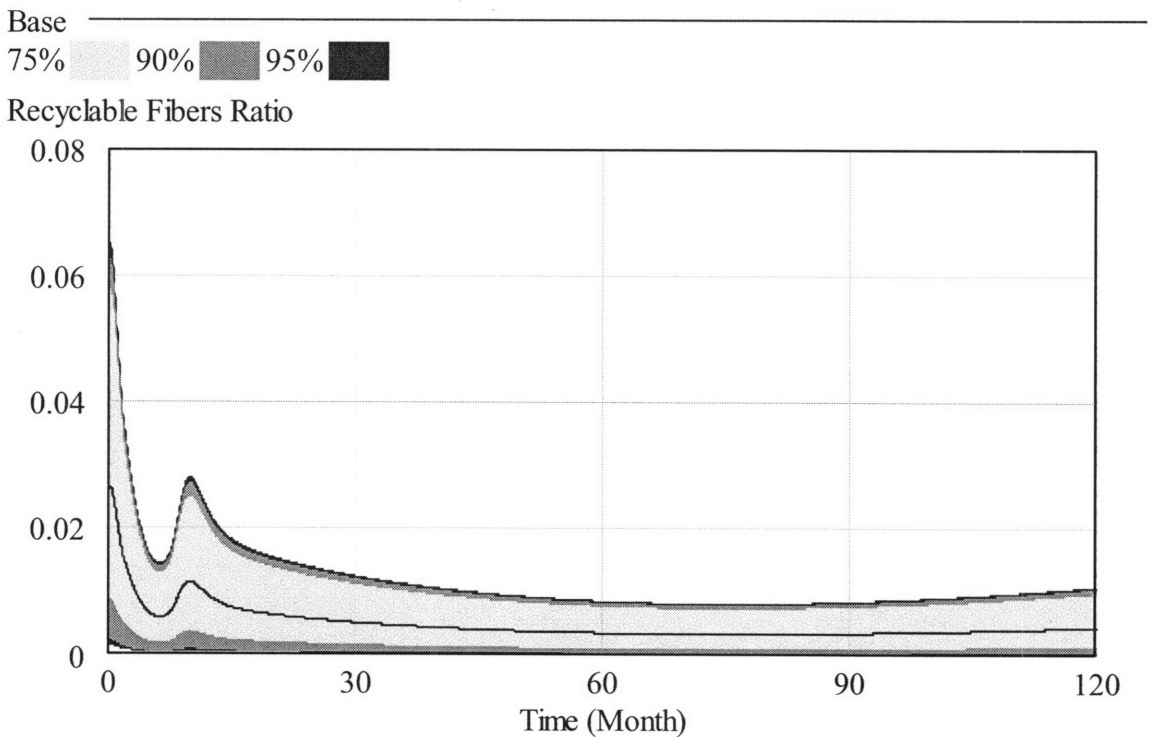


Figure 27: Sensitivity of recycled content to changes in base recycling rate

It is unlikely that the percentage of customers who recycle simply because the program exists is more than 5%. Within this bound, the base recycling rate does not

have a significant impact on the success of the program. Under an extremely scenario of a 5% recycling probability the use of recycled fabrics does not increase enough to yield noticeable economies of scale (Figure 26). Nor does it increase enough to keep pace with increased demand for Capilene and the percentage of recycled content in new garments falls (Figure 28).

Sensitivity of Recycling to the Average Life of the Garment

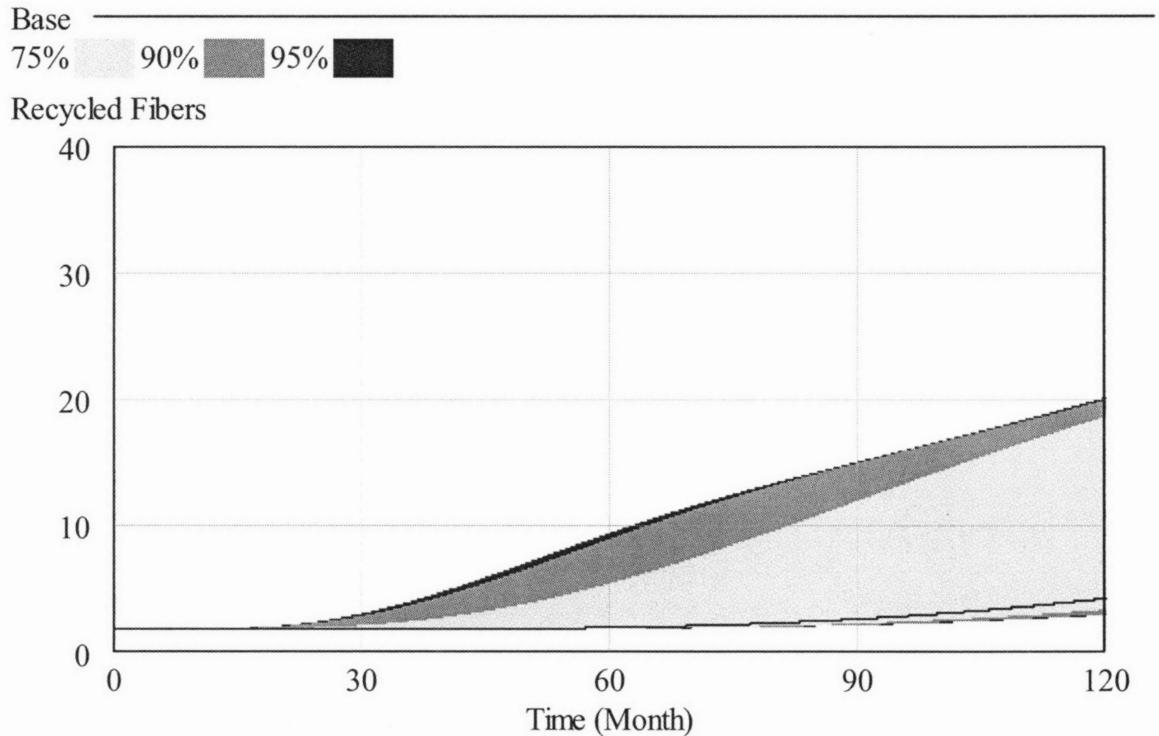


Figure 28: Sensitivity of recycled volume to the Average life of the Garment

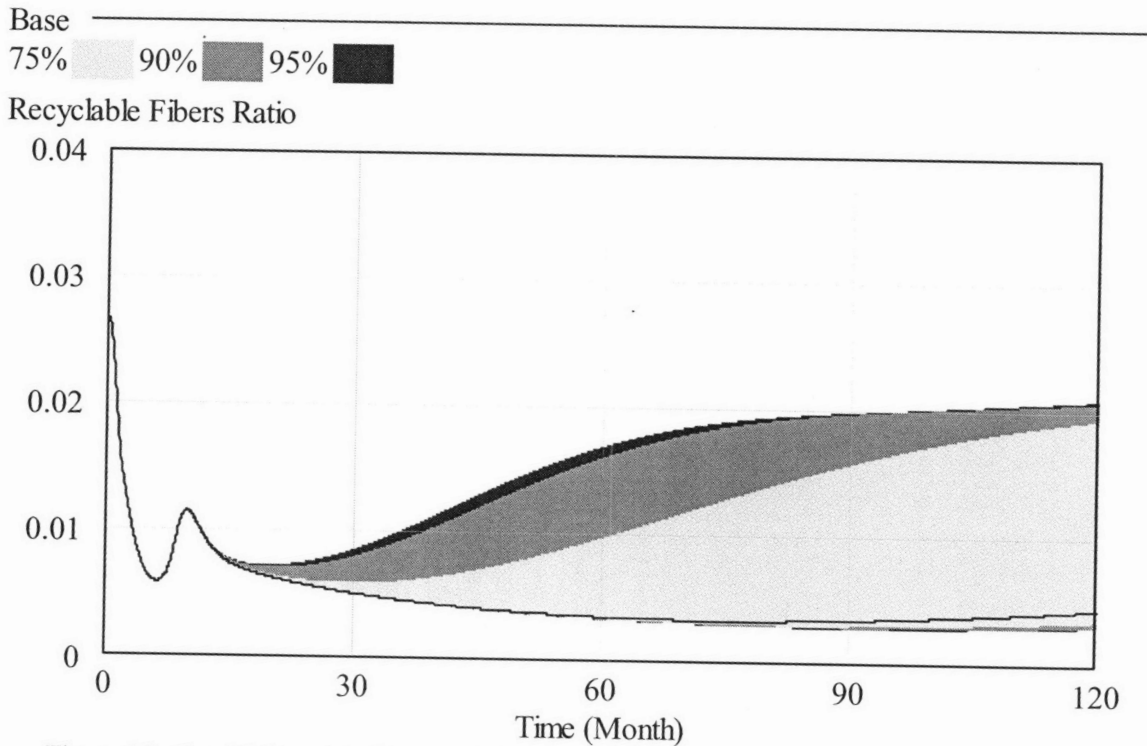


Figure 29: Sensitivity of the Recycled Content in new fabric to the Average life of the Garment

There is upside to recycling garments with shorter lifecycles. They become obsolete more quickly and so they impact recycling flows after a shorter delay. Though the volumes increase, the recycled flows remain low relative to what is needed for production. This is captured by the Recyclable Fibers Ratio which measures the difference between the total recycled fibers needed and those available. At most 2% of new fabrics will be from fibers recycled from Capilene.

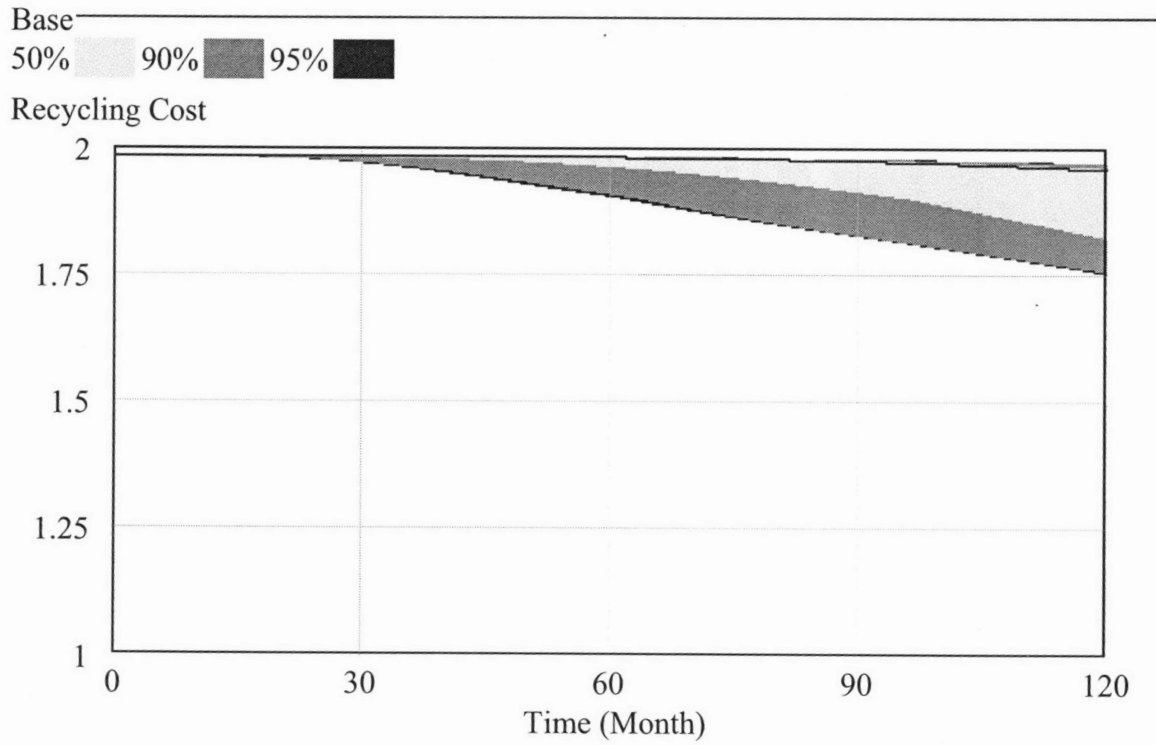


Figure 30: Sensitivity of recycled fiber production costs to the Average life of the Garment

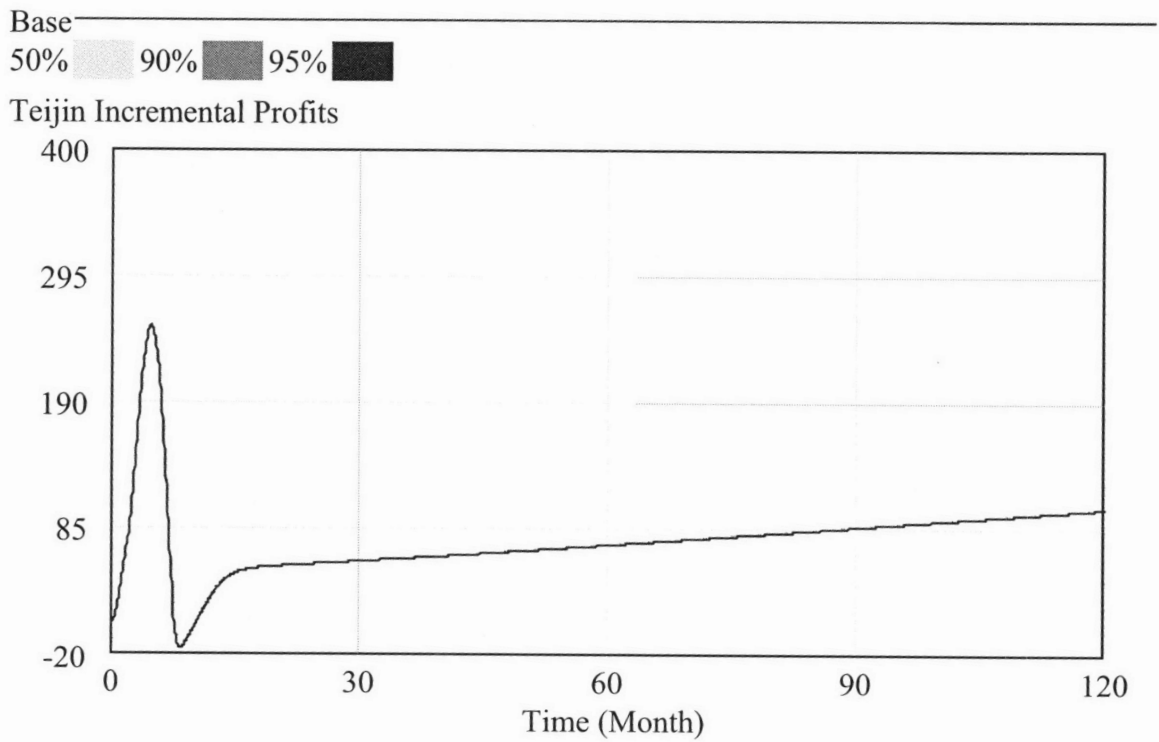


Figure 31: Sensitivity of Profits to the Average Life of the Garment

As recycling volumes increase, Teijin will begin to see economies of scale in production costs using recycled fibers. These savings will not have a noticeable impact on the bottom line because they are still small and because of the low volumes of recycled fibers. The graph of Patagonia's profits has just as little variation as Teijin's.

Scenario 1: Rebates that increase in size each year

This rebate scenario assumes a ramp in the size of the rebate coupon from 0% to 40% over 6 years. Although Patagonia would like to ramp up the program in the next three years, it will take longer than that for the recycling program to be a significant source of raw materials. Six years is a more realistic time frame.

Results

Neither Teijin nor Patagonia's profits change noticeably from the base case. This is discussed further in the policy implications section.

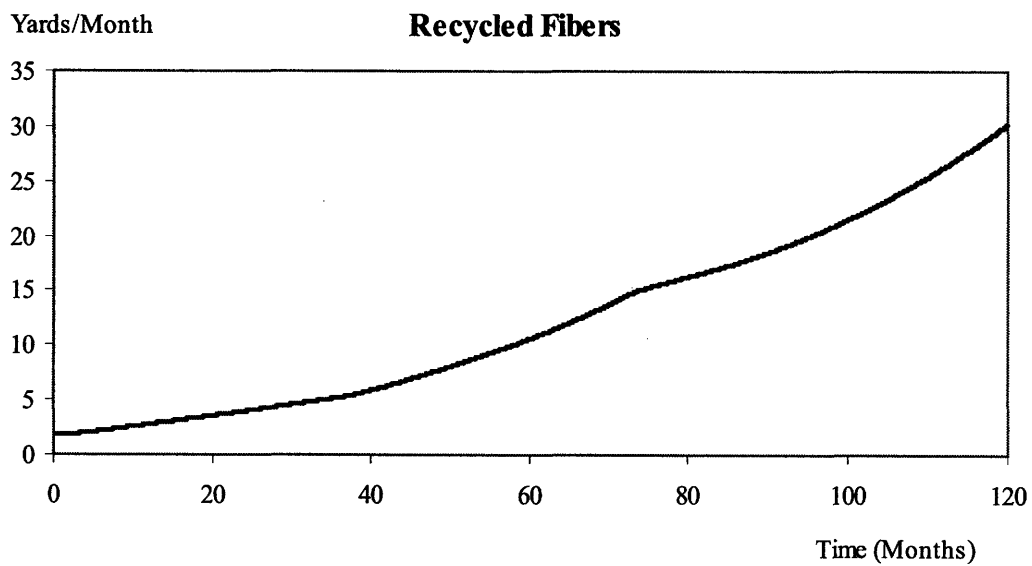


Figure 32: Volume of recycled fibers

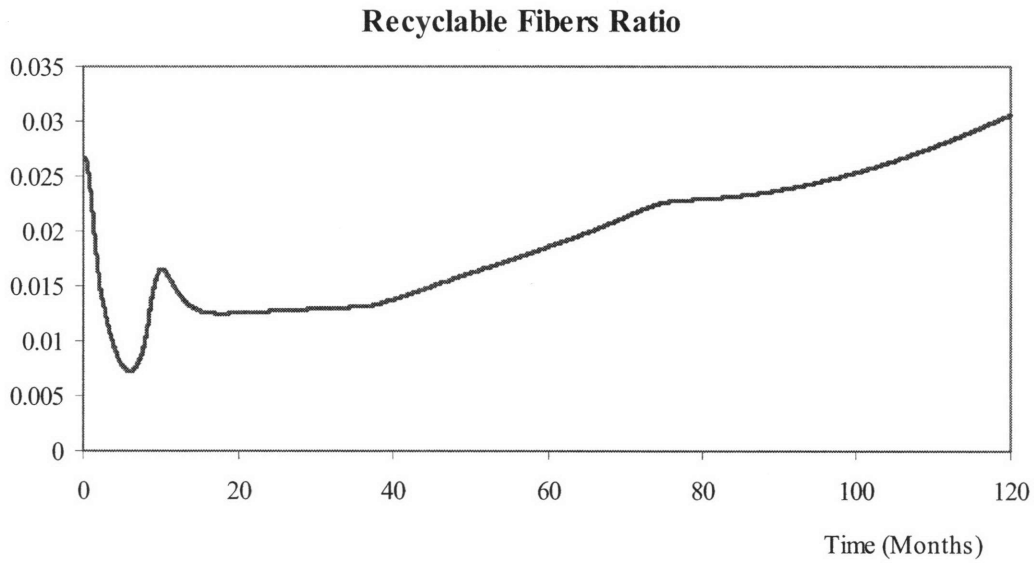


Figure 33: Percentage of new fabric that is from recycled fibers

The recycling volume is much higher than in the base case scenario. This translates into a larger percentage of recycled fibers in new fabrics. The expected percentage of recycled content is higher in this scenario than in the most optimistic sensitivity test in the base case, but it is still only around 2%.

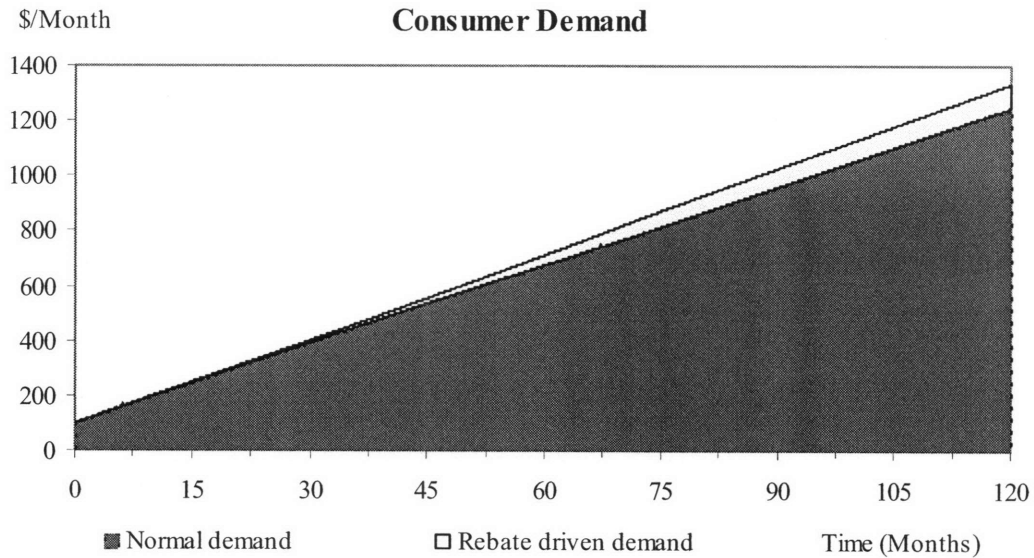


Figure 34: Consumer demand for Capilene garments

The rebates are creating additional demand especially in the long run as the rebates get larger and more and more people recycle.

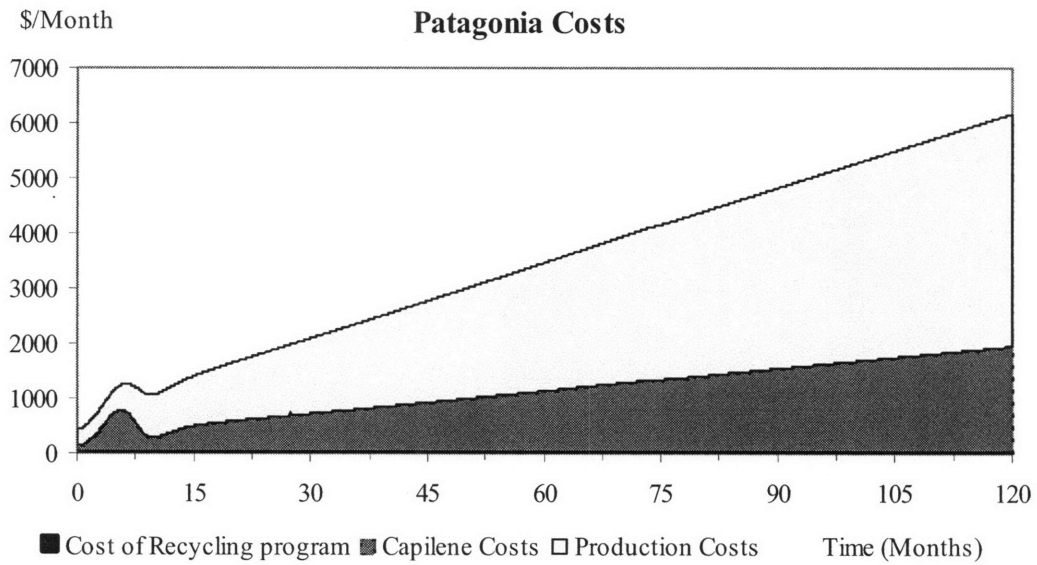


Figure 35: Patagonia's costs

The total volumes recycled are low and so the cost of the recycling program, i.e. sorting and shipping garments to Japan, is very small relative to Patagonia's other costs.

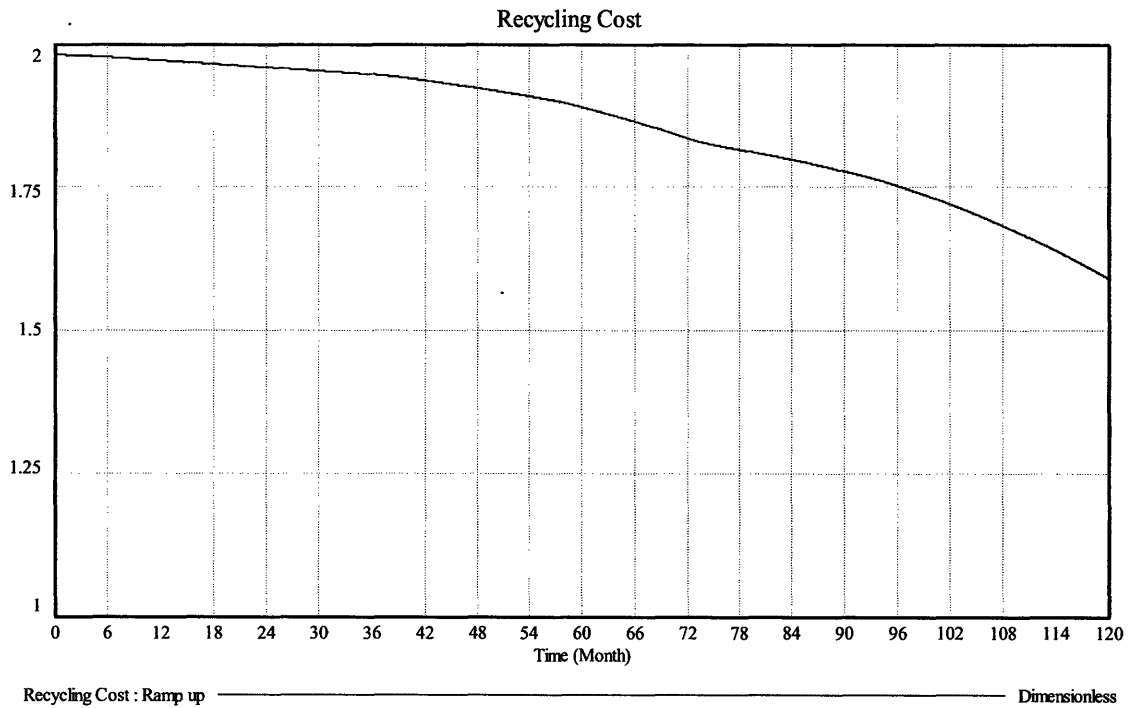


Figure 36: Production Costs using Recycled fibers

Compared to the base case, having a ramping rebate structure is less profitable for Patagonia because of the lower margins on purchases made by customers who redeemed coupons. The program is moderately more profitable for Teijin as the production costs are decreasing for the recycled fibers. More importantly for Patagonia, there is a slight increase in the recycled content of their clothes and the volume of returns is also increasing. Is this enough to convince competitors to join the program? I think the benefits are still too small for a company to join for purely economic reasons.

Sensitivity to Growth Assumptions

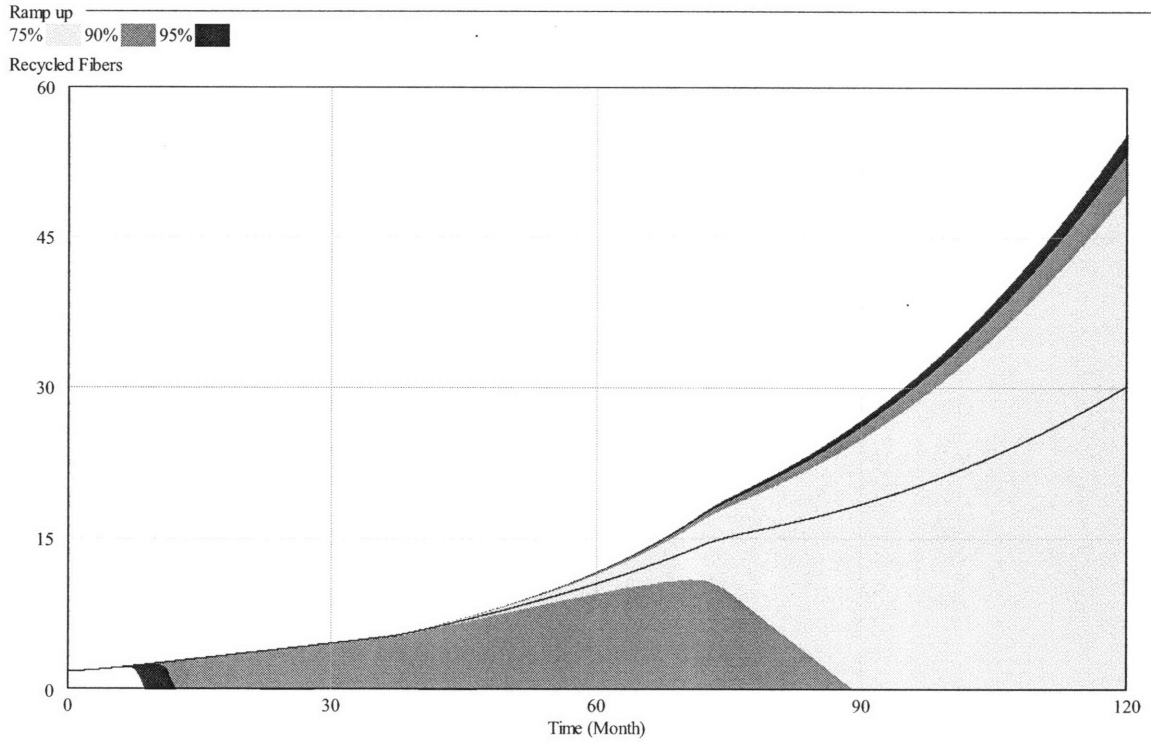


Figure 37: Sensitivity of the volume of recycled fibers to changes in demand growth

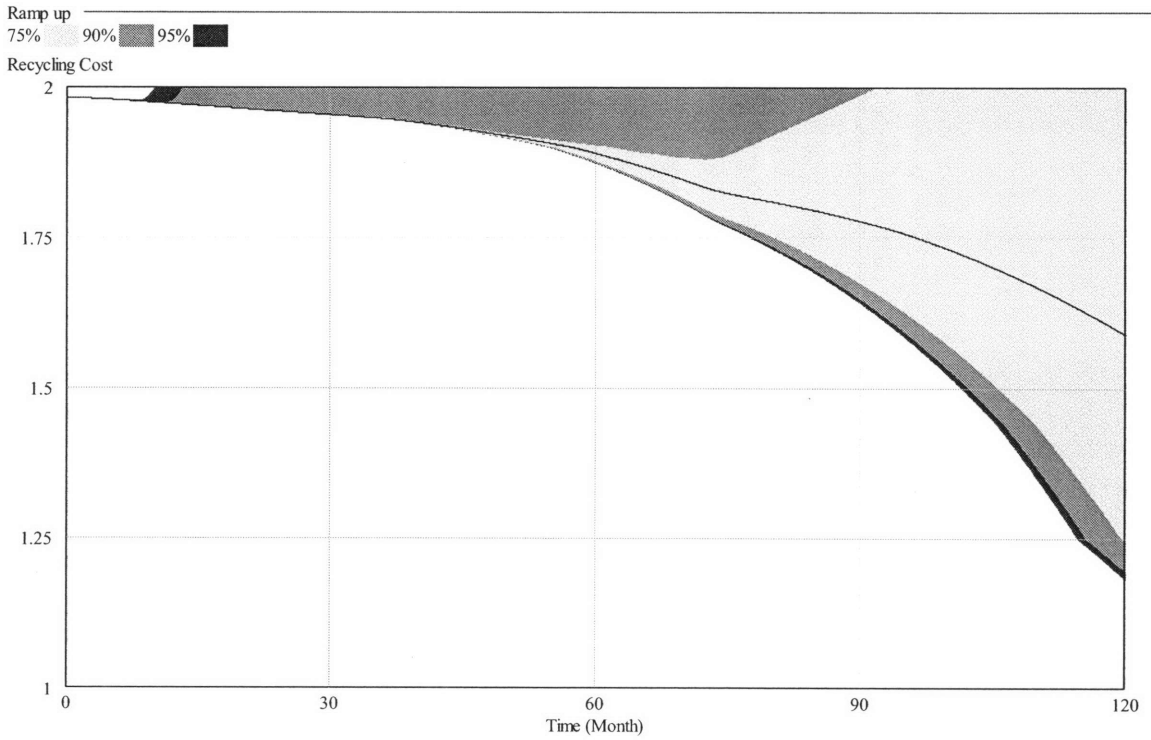


Figure 38: Sensitivity of the cost of using recycled fibers in production to changes in demand growth

There is the potential for significant gains in economies of scale if there are high growth rates. Producing fabric from recycled fibers would be almost as cheap as using virgin fibers. If there is negative demand growth for Capilene, or if demand falls to zero, the recycling program will disappear.

Sensitivity of Recycling to Rebate

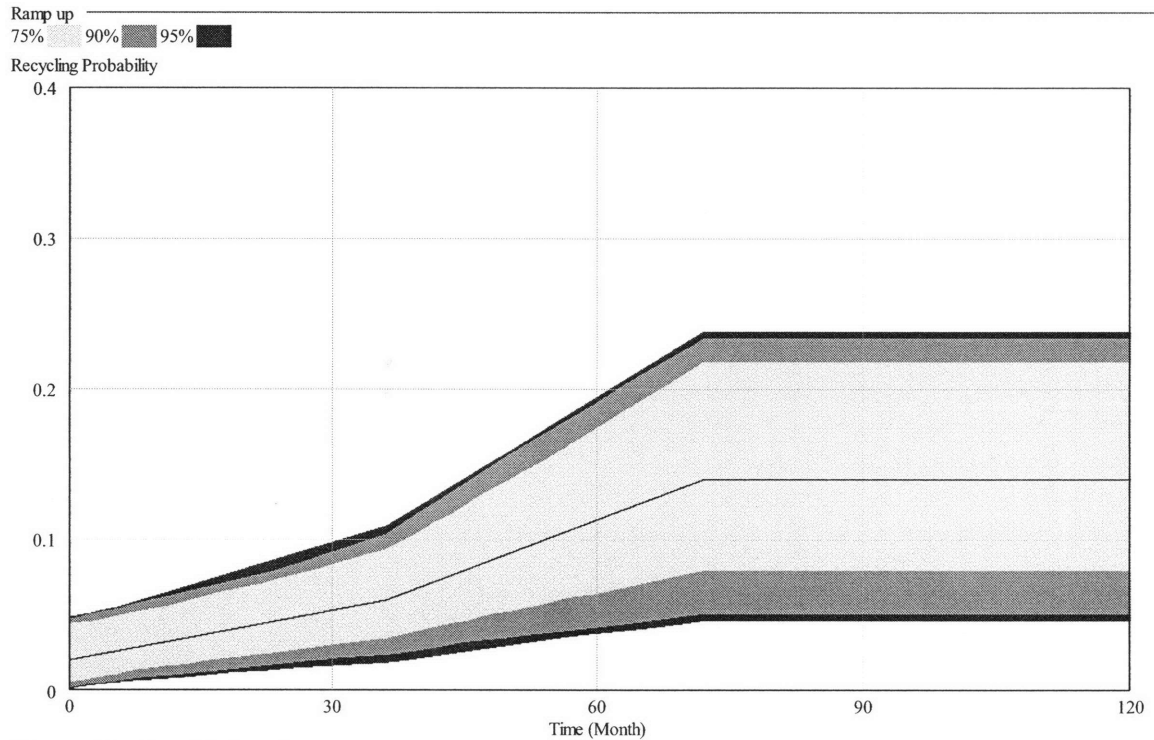


Figure 39: Sensitivity of the probability of recycling to changes in rebate sensitivity

This is the pattern that we expect to see. As the rebate increases through month 72, the probability of customers recycling also increases.

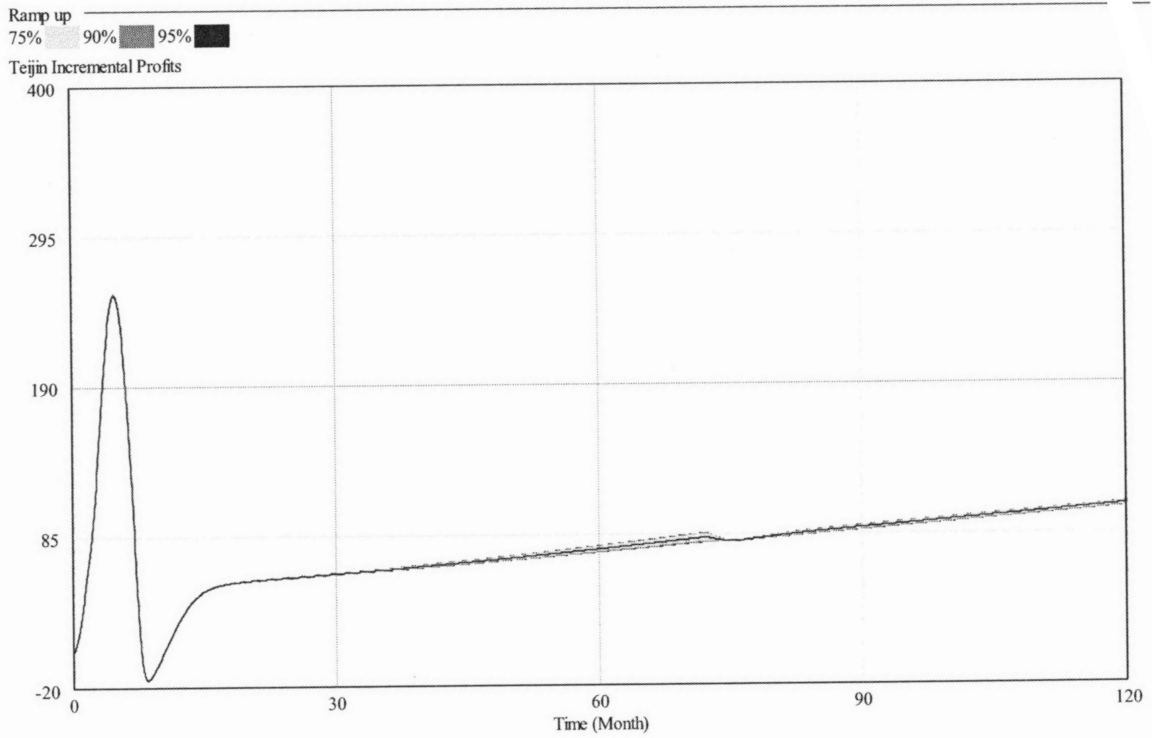


Figure 40: Sensitivity of Teijin Profits to customers' response to the rebates

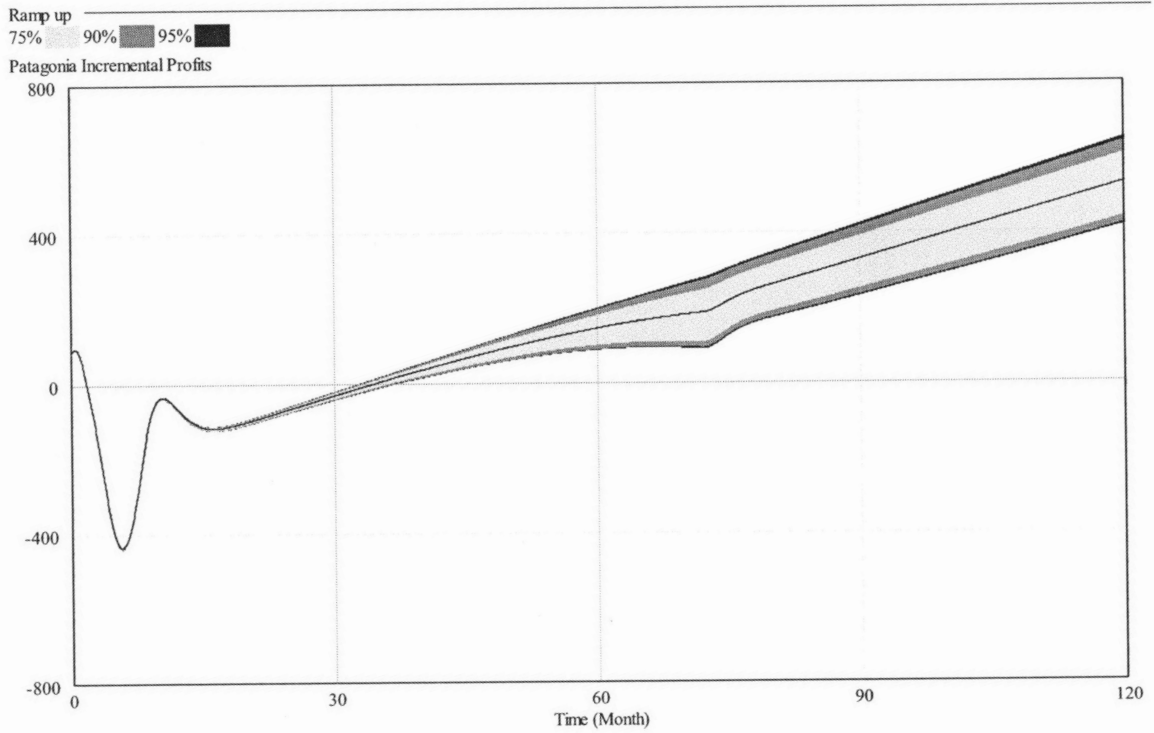


Figure 41: Sensitivity of Patagonia Profits to customers' response to the rebates.

The model is designed such that Teijin’s profits are sheltered from changes in recycling volume. According to the model Teijin sets the price at which it will buy used Capilene from Patagonia. They try to keep to virgin and recycled costs (raw material + production costs) as similar as possible. If they do not see sufficient economies of scale in recycled fabric production then they do not pay for the recycled raw materials. On the revenue end, Teijin sets the cost of Capilene fabric such that it keeps a steady profit margin of around 4%. Patagonia has committed to not raising prices on its garments so that price is constant. Patagonia must absorb the changing price of the Capilene fabric and the cost of collecting and shipping used clothes back to Japan.

This is not exactly how it works in the real world. In reality, Teijin and Patagonia have both lowered their profit margins (the split is unknown). Teijin does hold most of the market power so it is reasonable that they would lower their margins by less. Teijin owns the technology for garment-garment recycling and they have multiple sources of recycled fabric to use. Patagonia is a significant buyer of recycled polyester from Teijin but it is not the only one.

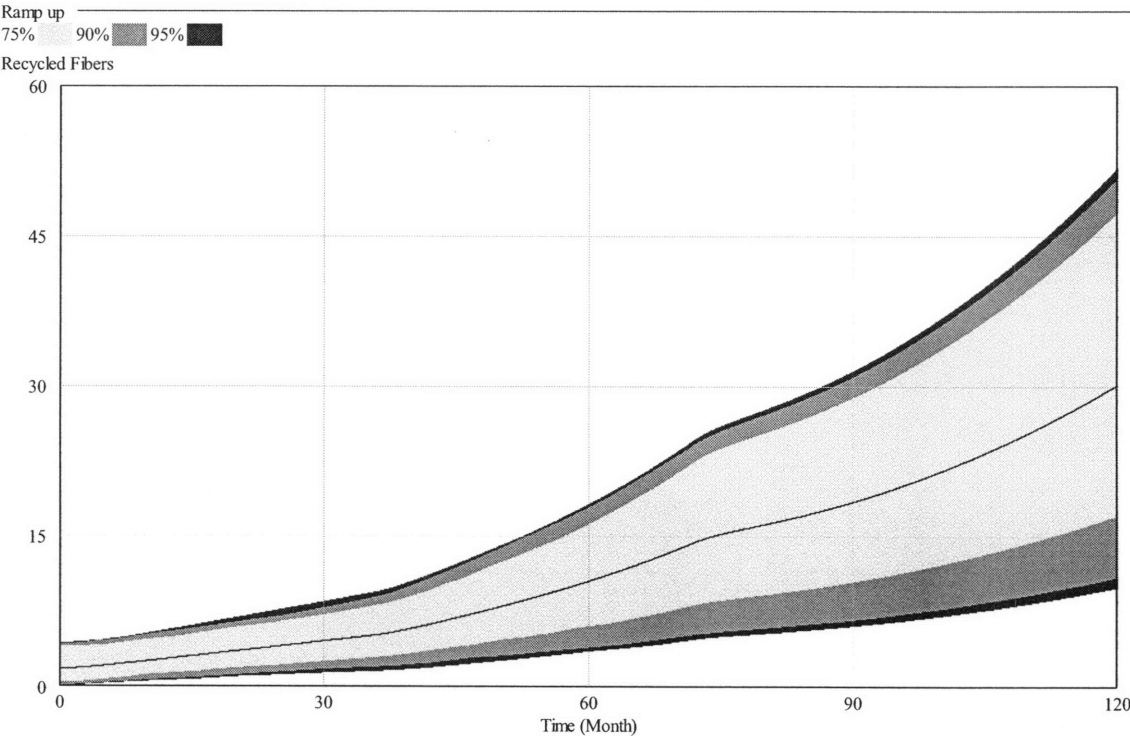


Figure 42: Sensitivity of recycled garment volume to changes in demand growth

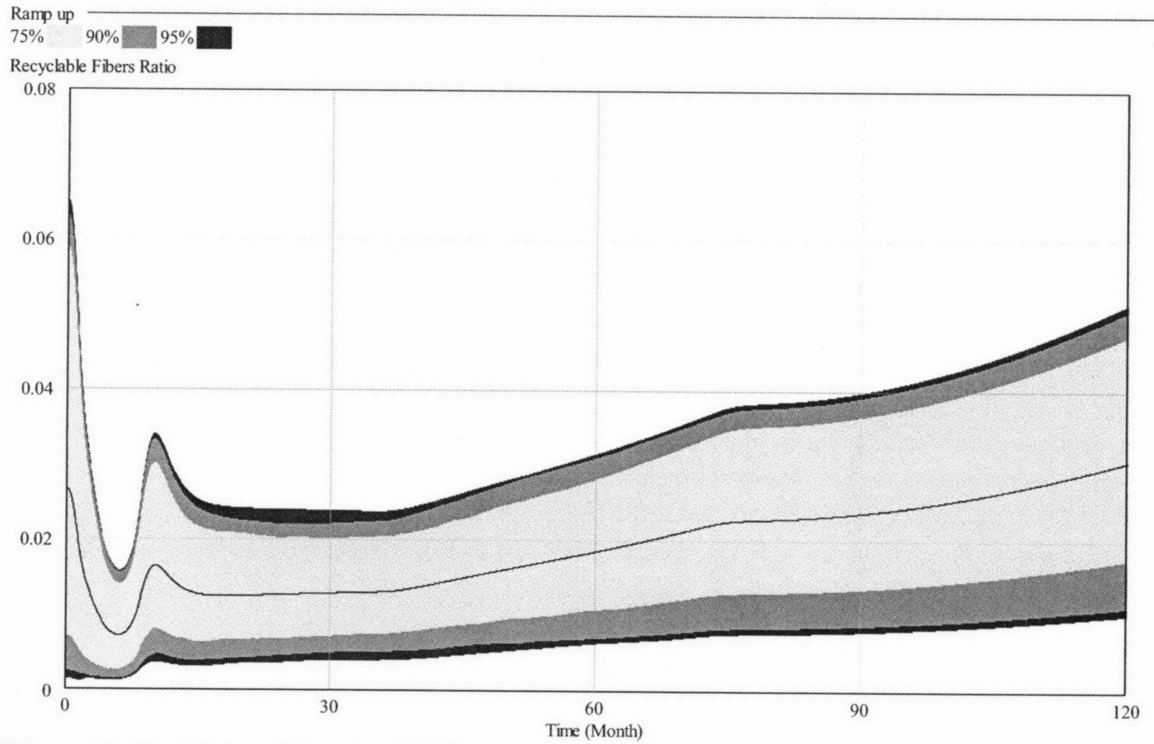


Figure 43: Sensitivity of the recycled fiber content of new fabric to changes in demand growth

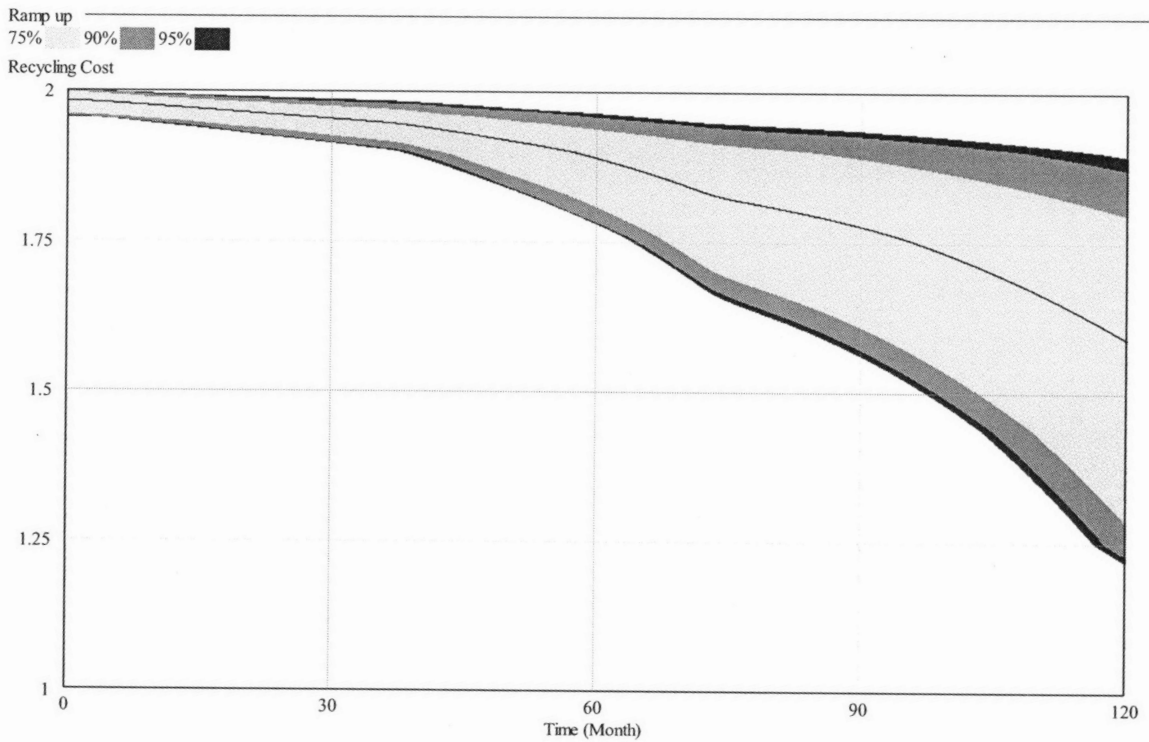


Figure 44: Sensitivity of recycled fiber production costs to changes in demand growth

The quantities of clothes that are returned in this scenario are very sensitive to the size of the rebate. The volume of returns drives the use of recycled fibers in new

fabrics and the economies of scale. The range of outcomes is enormous. In the best cases the cost of using recycled fibers is very close to the cost of using virgin fibers. In the worst case, if few people are interested in recycling, the rebates have little impact.

Sensitivity of the Rebate to Consumer Demand

As demand elasticities change, sales are more or less affected by the presence of the rebates. There is a positive feedback loop where when consumers recycle they receive a rebate, this increases the demand for Capilene and increases the installed base of the product. Over time the garments age and there is a larger stock from which to recycle. This closes the loop. How strong is this loop?

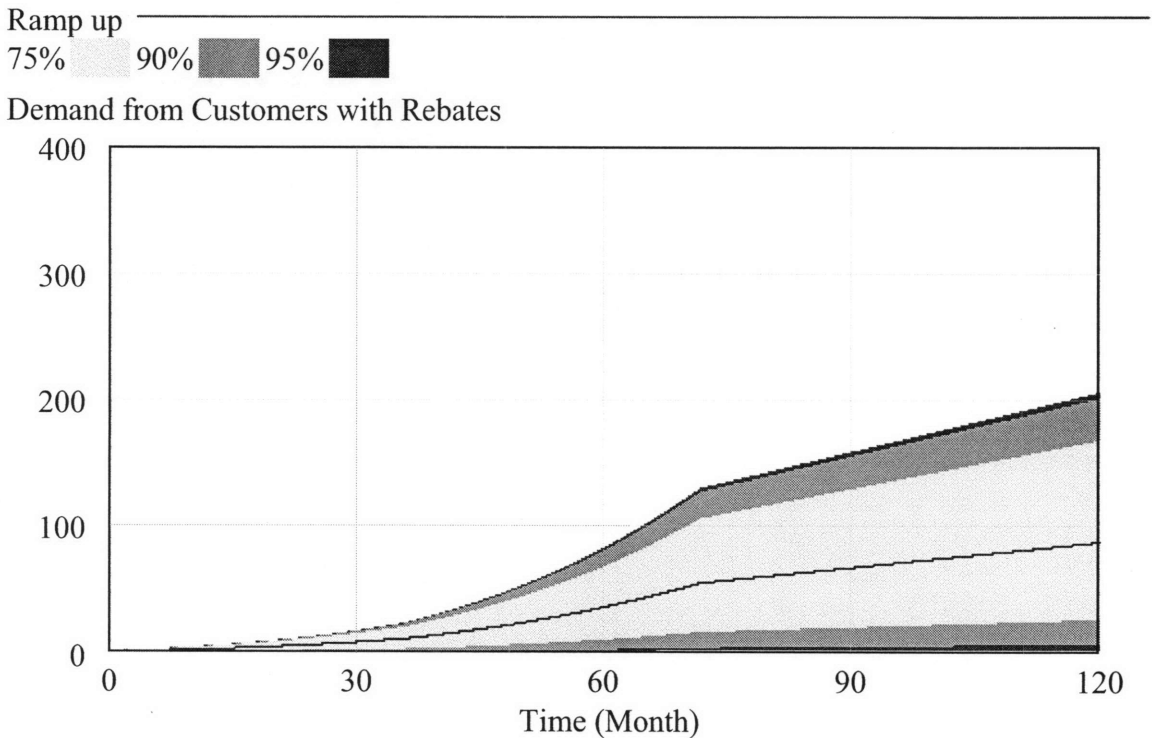


Figure 45: Sensitivity of customer demand to demand elasticity and rebate use

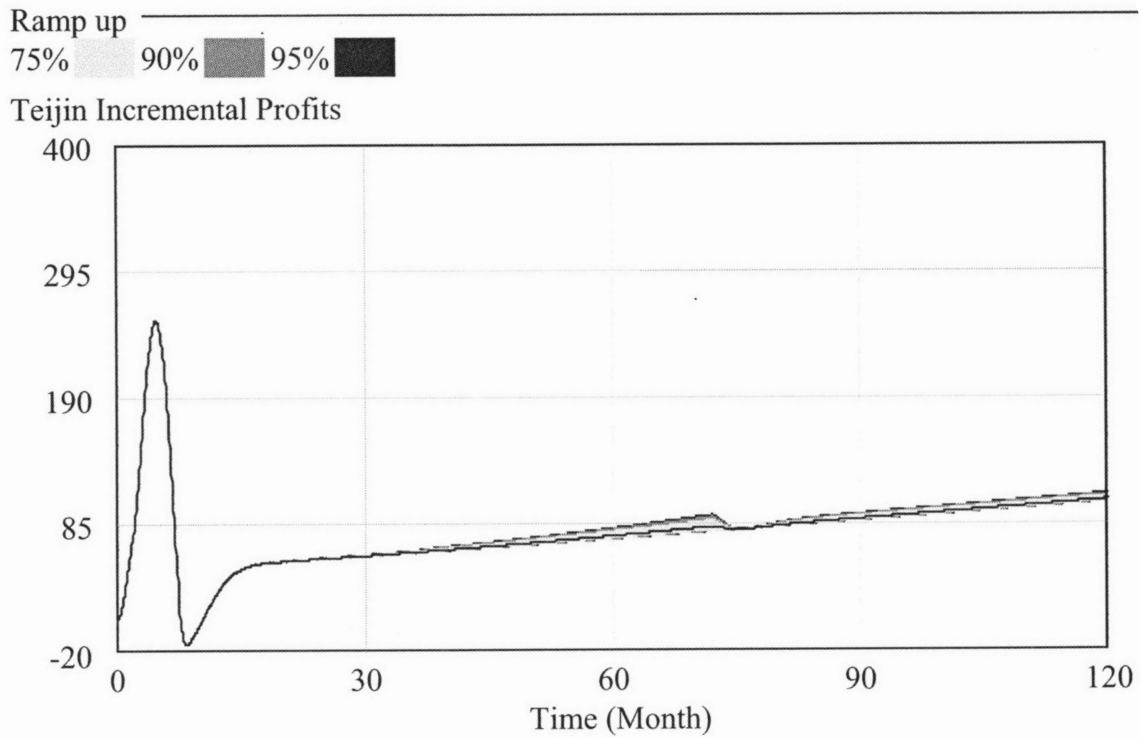


Figure 46: Sensitivity of Teijin profits to demand elasticity and rebate use

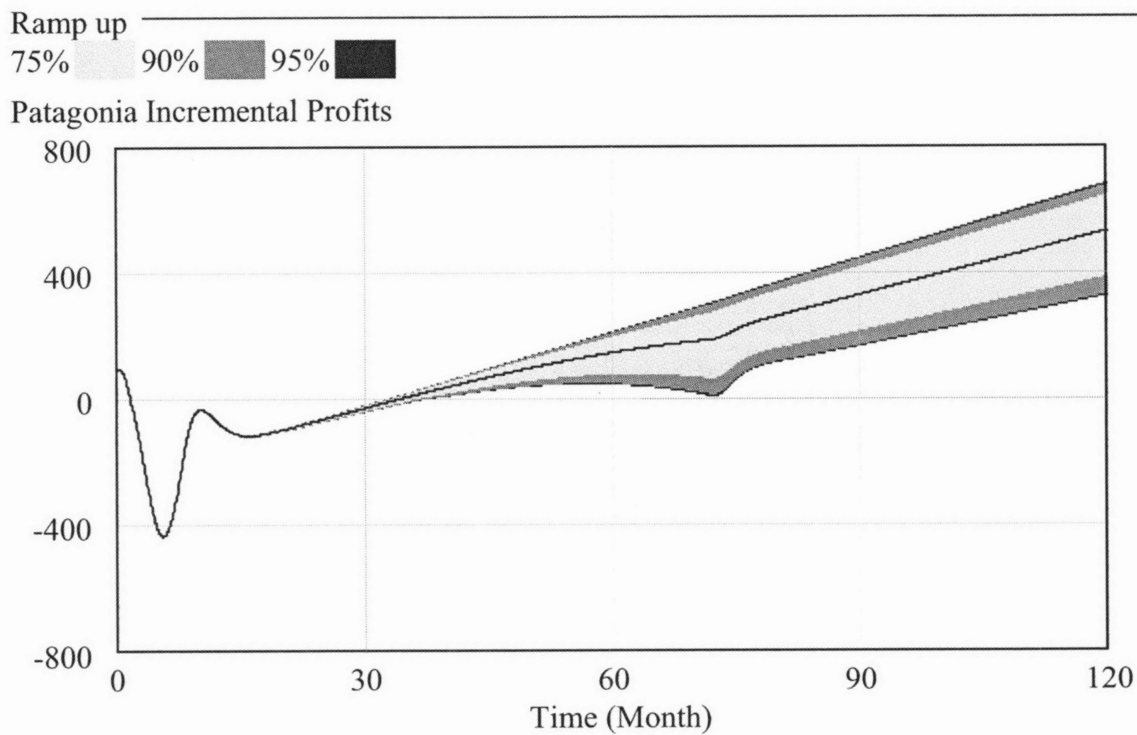


Figure 47: Sensitivity of Patagonia profits to demand elasticity and rebate use

Teijin is able to set prices for Capilene fabric and for recycled fibers which insulates it from fluctuations in demand and recycled volume. The range of Patagonia's profits is explained by the range of possible effects that rebates have on customer demand. If the demand elasticity is high ($\gg 1$) then there will be a big increase in quantities sold for every small change in price and Patagonia's profits will rise quickly. The opposite will happen if the elasticity is low. If the probability that the rebate will be redeemed is low then the changes in elasticity have little effect.

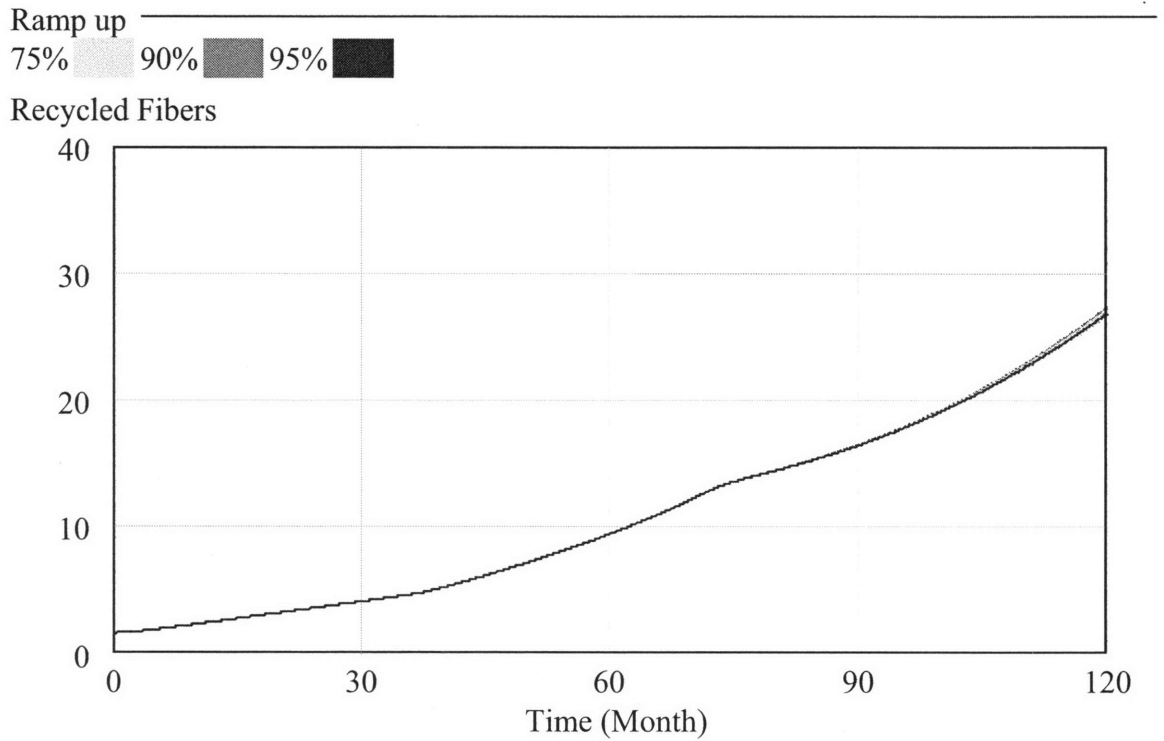


Figure 48: Sensitivity of recycling volume to demand elasticity and rebate use

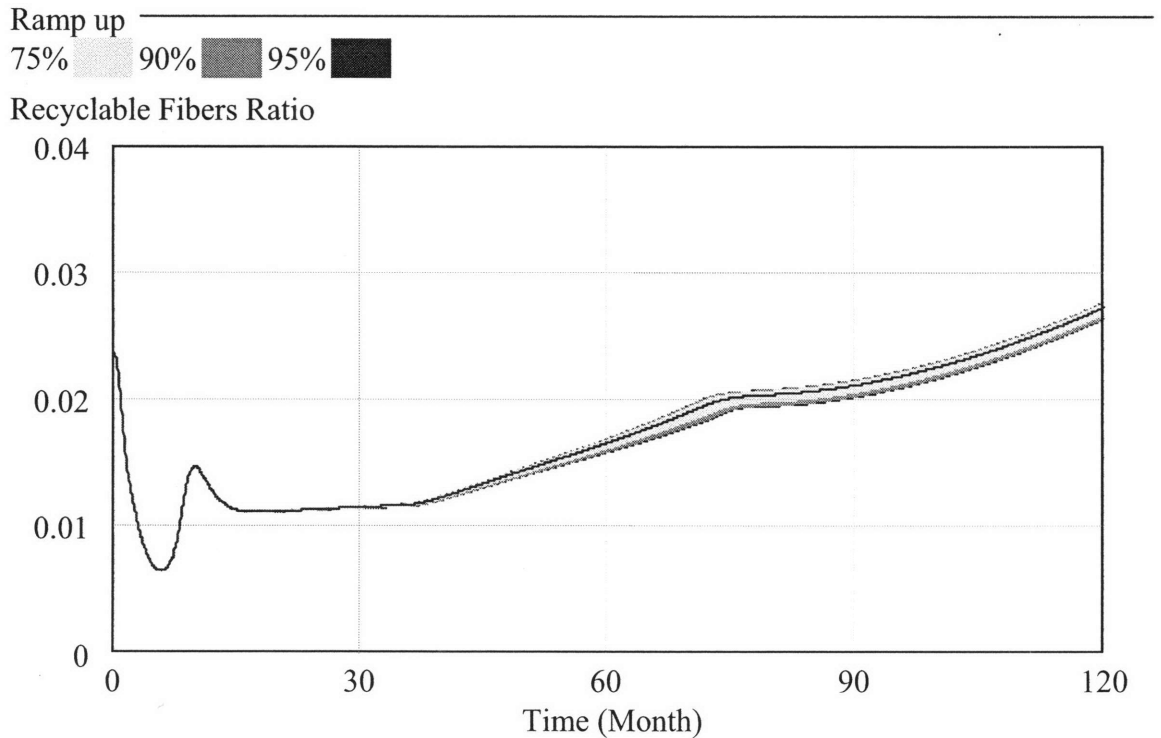


Figure 49: Sensitivity of recycled content in new fabric to demand elasticity and rebate use

In the long term there is more variability in the recycled content of new fabrics because there is more uncertainty of customer demand when the rebates are higher. The size of the installed base of Capilene is more variable and so the recycled volumes are more variable. On the whole, recycling ratios and volumes are robust to the assumptions of demand elasticity and rebate redemption. The only thing that varies is Patagonia's profitability.

Sensitivity of Recycling to the Average Life of the Garment

As in the base case, profits, costs and revenues are insensitive to changes in the lifecycle of the garments.

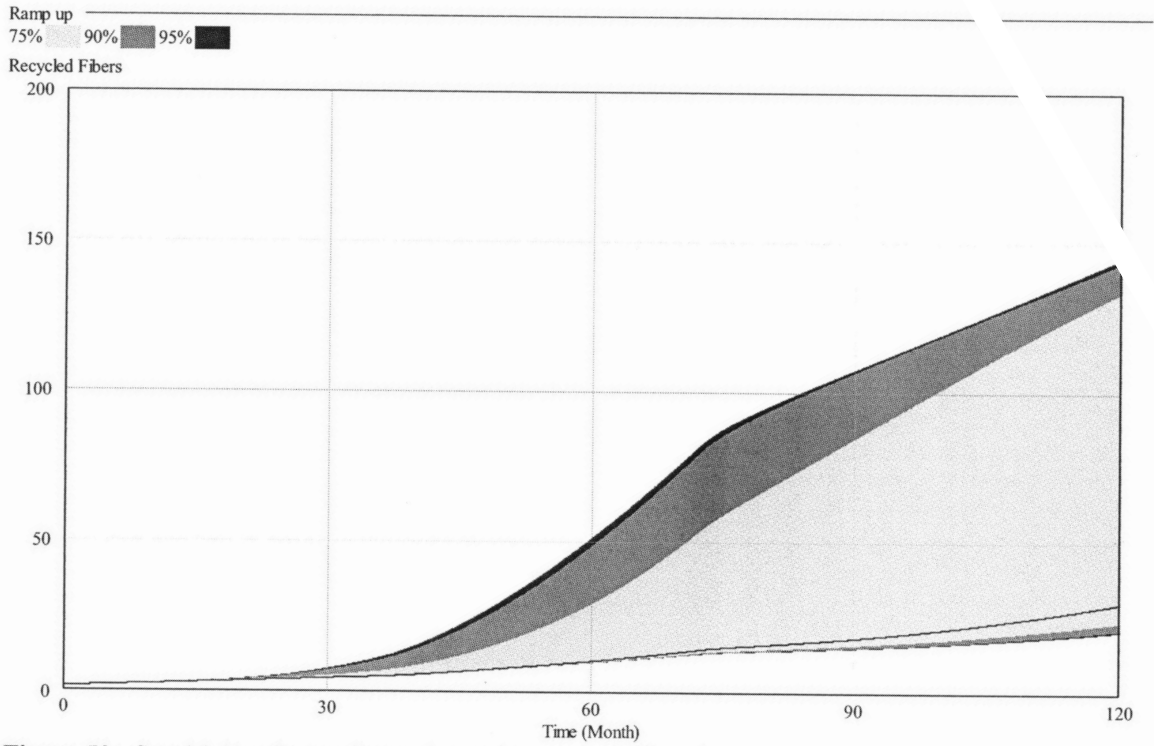


Figure 50: Sensitivity of recycling volumes to garment lifecycles

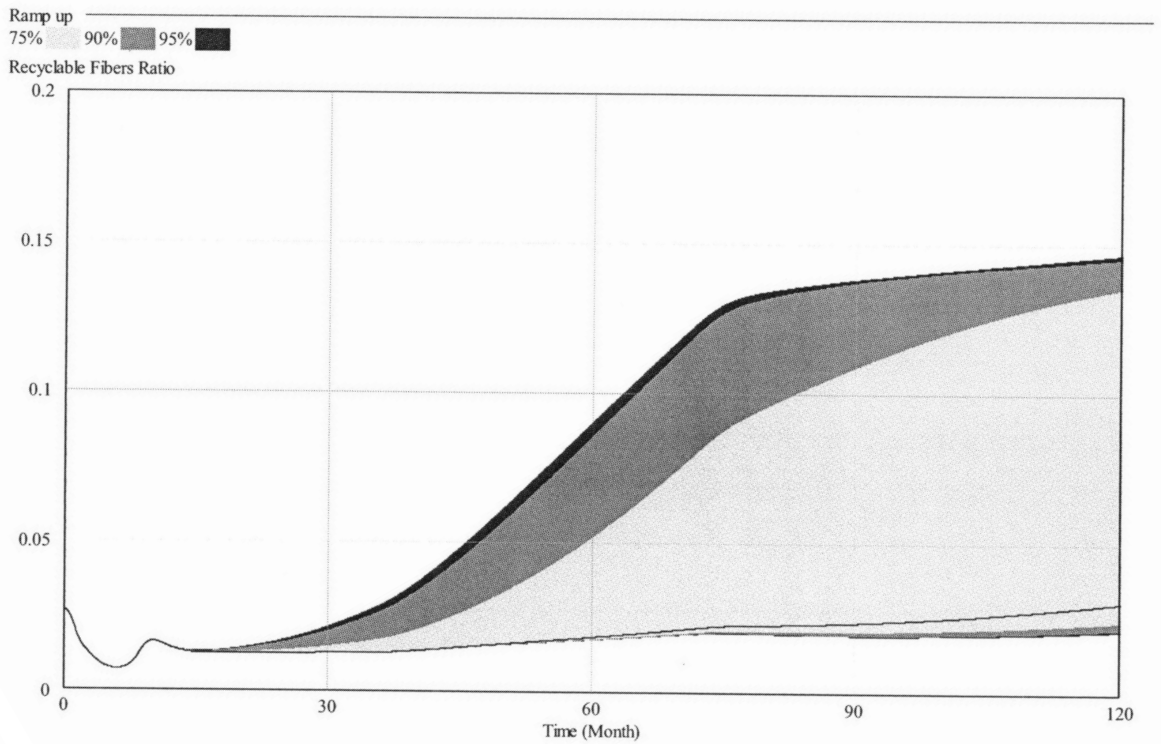


Figure 51: Sensitivity of recycled fiber in new fabrics to garment lifecycles

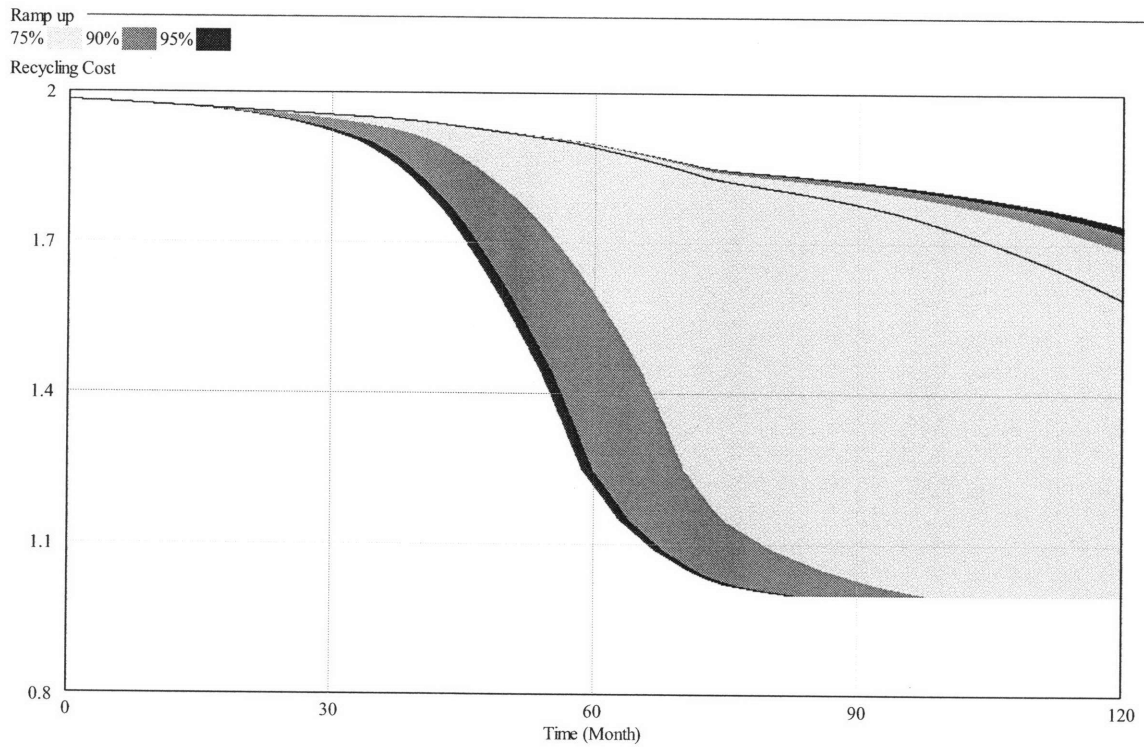


Figure 52: Sensitivity of recycled fiber production costs to garment lifecycles

The length of the garment lifecycle has a tremendous effect on the strength of the recycling program especially with rebate that ramp up over time. Shorter lifecycles mean that garments are used and recycled more quickly. Recycling rates do not lag sales as dramatically as they do in Figure 22: Used and Returned Garments – No rebate. As recycling volumes climb, costs decrease and savings are passed on to customers driving more demand, a larger installed base and more garments to recycle.

Scenario 2: Rebates that decrease in size each year

Patagonia could offer a series of rebates that decrease over time. Early in the program, it is logical to offer large discounts to induce consumers to recycle. Over time the discounts would decrease. This scenario considers a rebate structure that starts off at 50% and decreases linearly until it is 10% in month 72.

Results

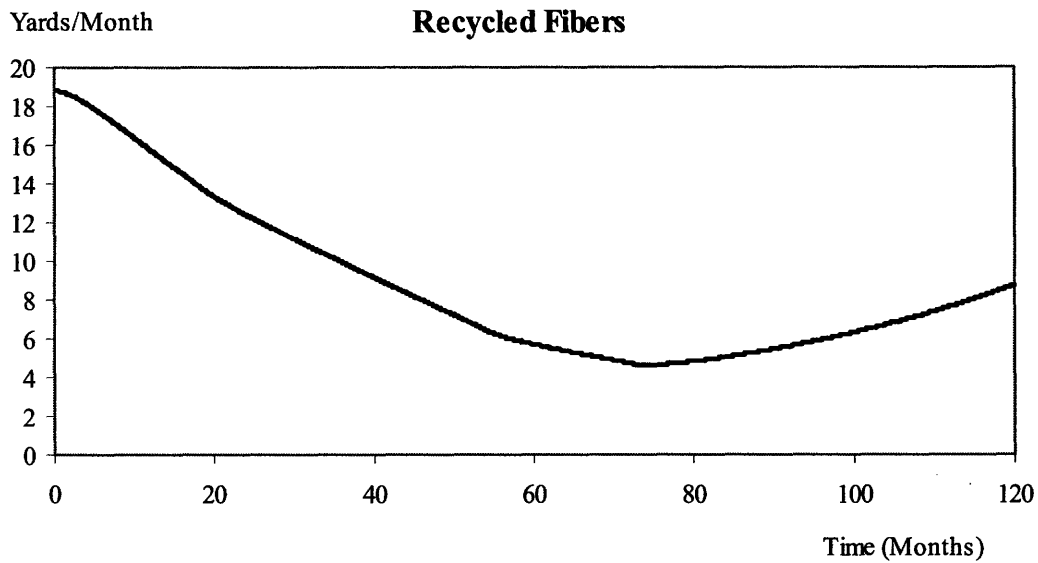


Figure 53: Volume of recycled fibers – Ramp down

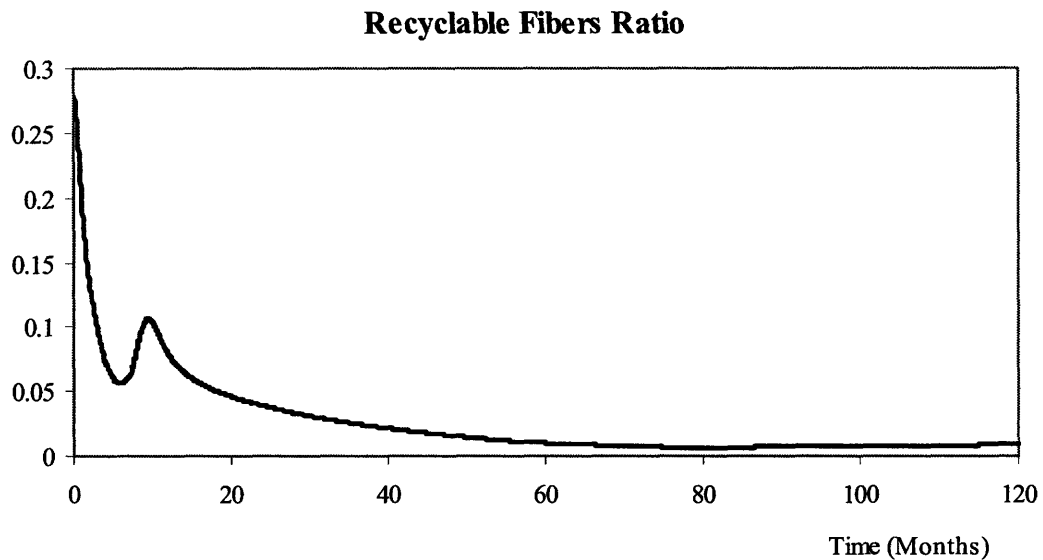


Figure 54: Recycled content in new fabrics – Ramp down

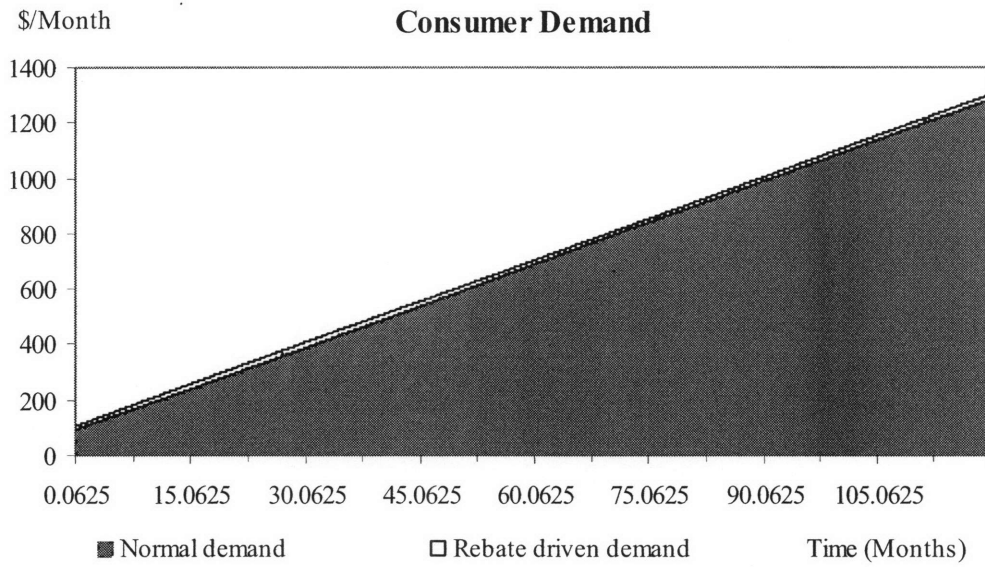


Figure 55: Consumer demand for Capilene garments – ramp down

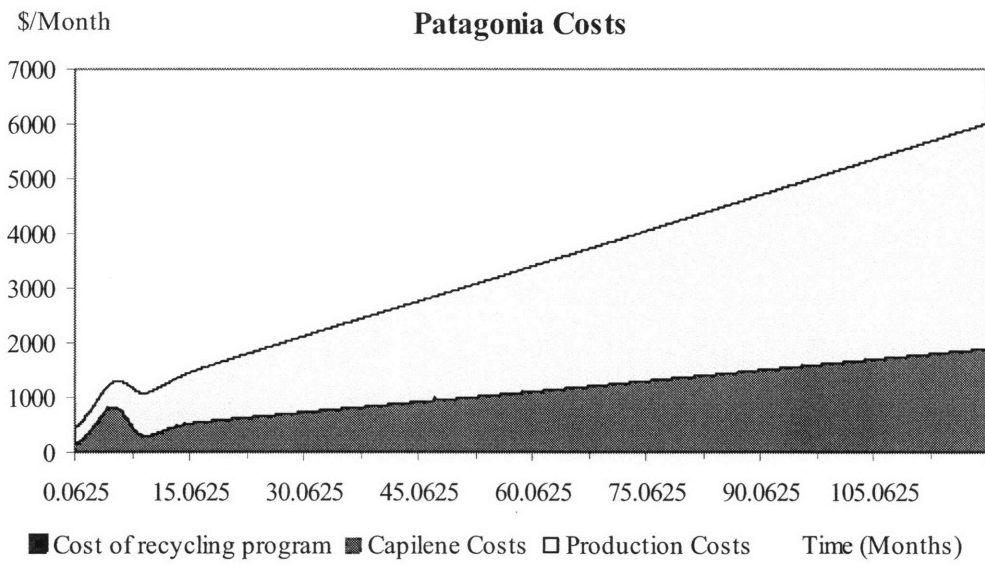


Figure 56: Patagonia's costs

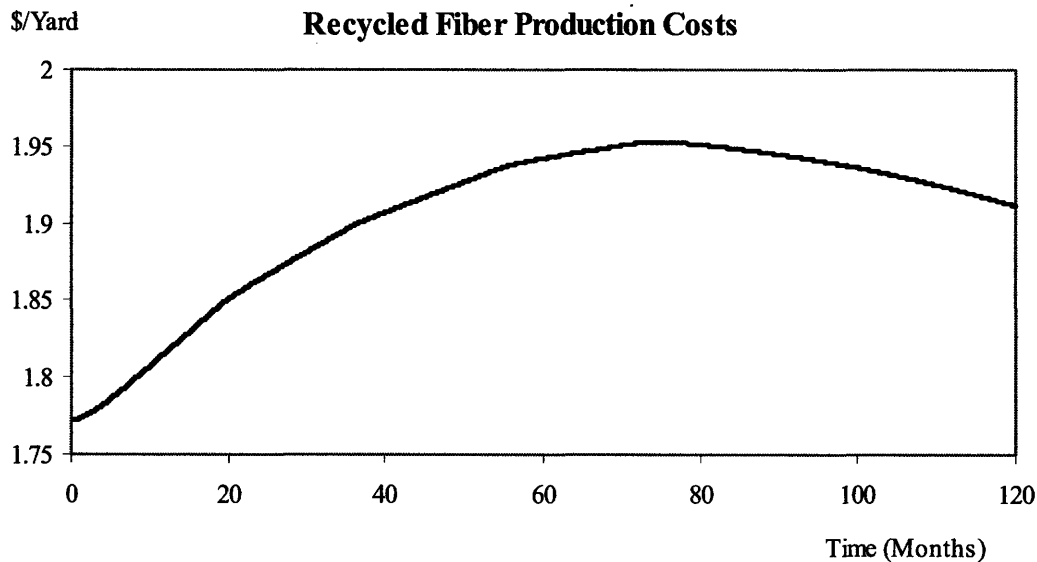


Figure 57: Recycled Fiber Production Costs – ramp down

Intuitively this rebate structure makes sense: offer large rebates at the beginning and scale them down over the life of the program. The model has several aspects that make this structure ineffective at increasing returns. The first problem is that the probability of a customer recycling garments is independent from period to period. In the real world, a customer's behavior in this period will affect his behavior in the next. If it was easy to recycle then he will be more likely to recycle tomorrow. If it was too difficult then he is less likely. There are no feedback loops like this in this model.

Without any positive reinforcing loops there is no justification for a rebate that ramps down over time. Patagonia should consider if it possible to teach consumers to recycle. If it is, then a rebate scheme like this one might work.

The volume of recycled garments does not increase over time because the rebate size is falling and consumers don't have an incentive to return their old clothes. Since the volume is dropping, the recycled content of new fibers also falls. The costs of producing fabric from recycled fibers increases as there is less and less used polyester flowing through the system.

This scenario has all of the downsides and none of the upside of Scenario 1. Patagonia's profits are lower than the base case and neither economies of scale or recycled content is achieved.

Sensitivity to Growth Assumptions

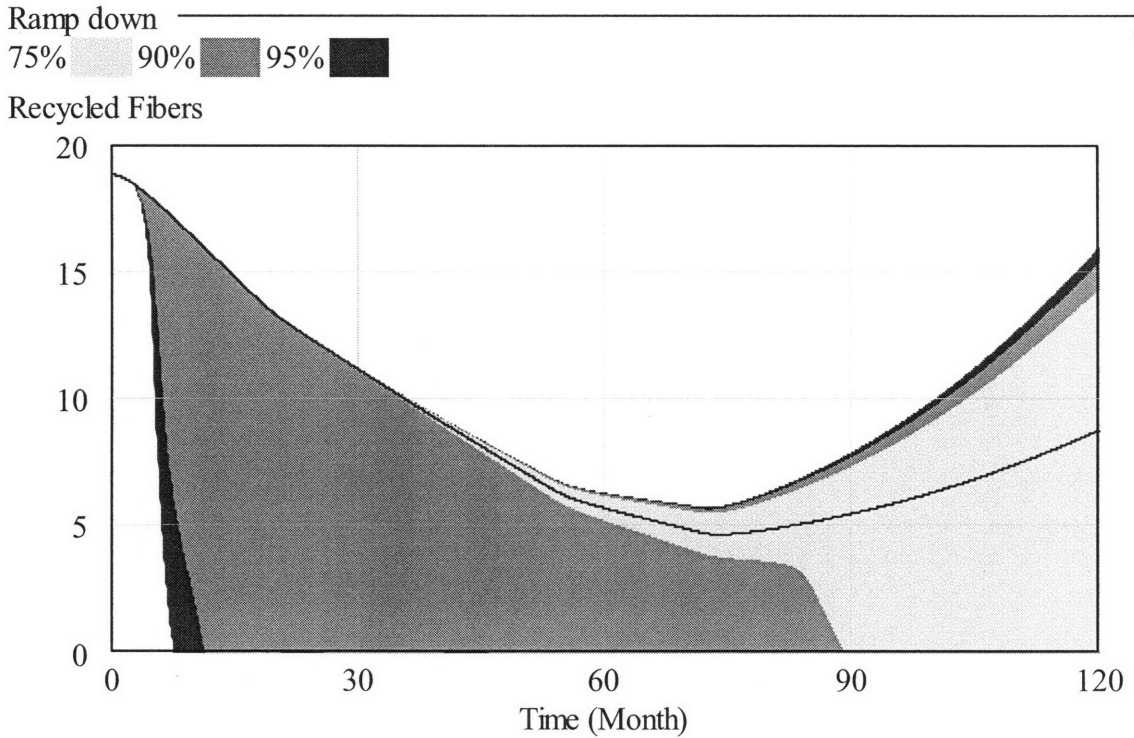


Figure 58: Sensitivity of recycling volume to changes in demand growth

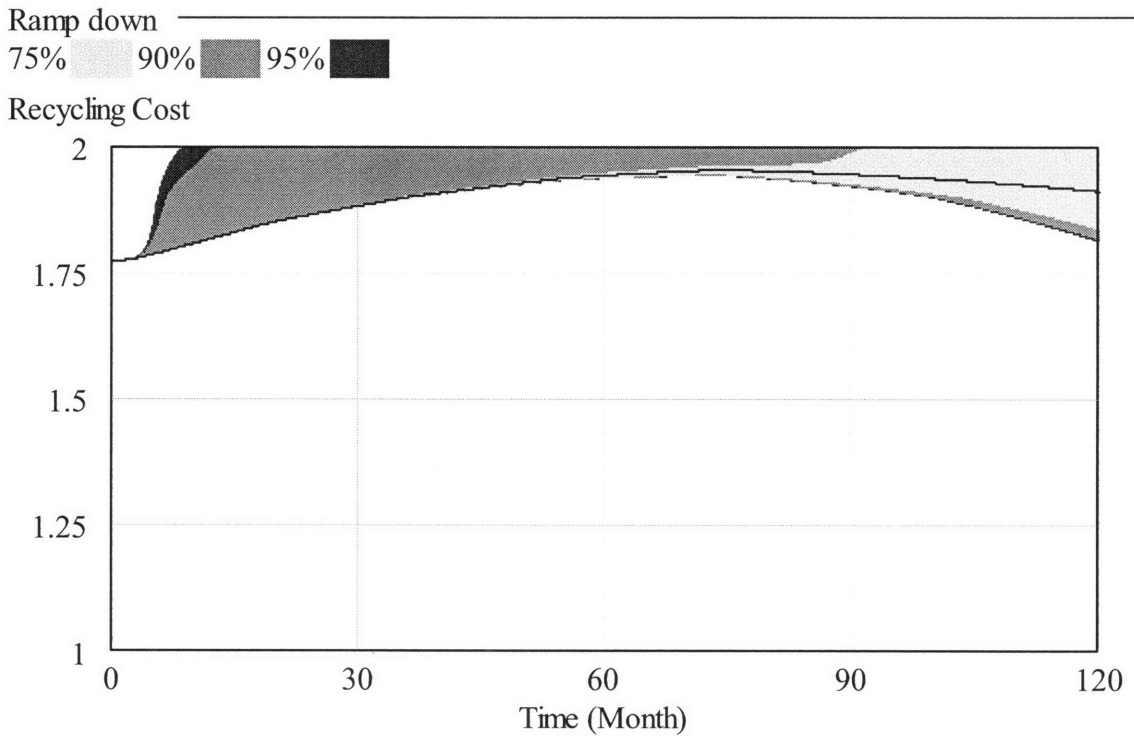


Figure 59: Sensitivity of recycled fiber production cost to changes in demand growth

In the short run there is only downside. An increase in demand growth increases the installed base of Capilene but not the used stock because of the time it takes before

the new clothes are used. There is no guarantee that there will be enough fabric recycled from consumers. The downside is from negative demand growth and the possibility that Capilene production might cease.

Sensitivity of Recycling to Rebate

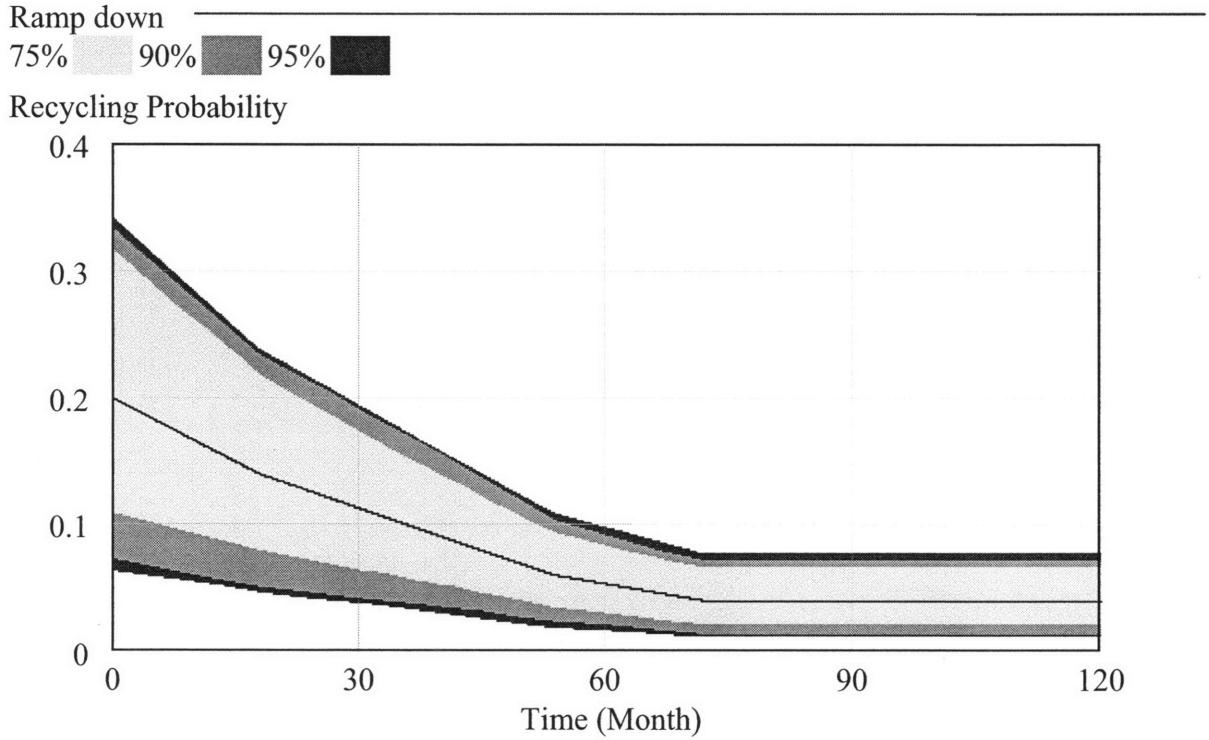


Figure 60: Sensitivity of the probability of customer recycling

This is the expected pattern: as the rebate decreases so does the probability that customers will recycle.

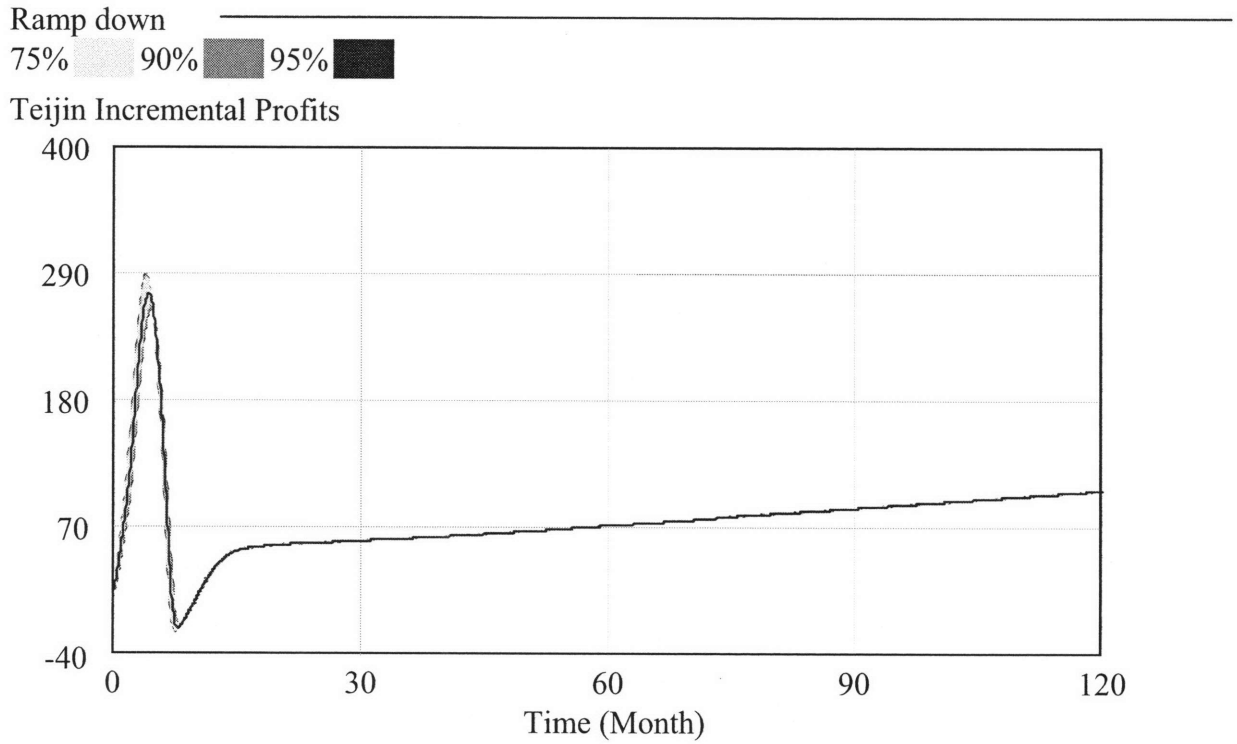


Figure 61: Sensitivity of Teijin profits to changes in rebate sensitivity

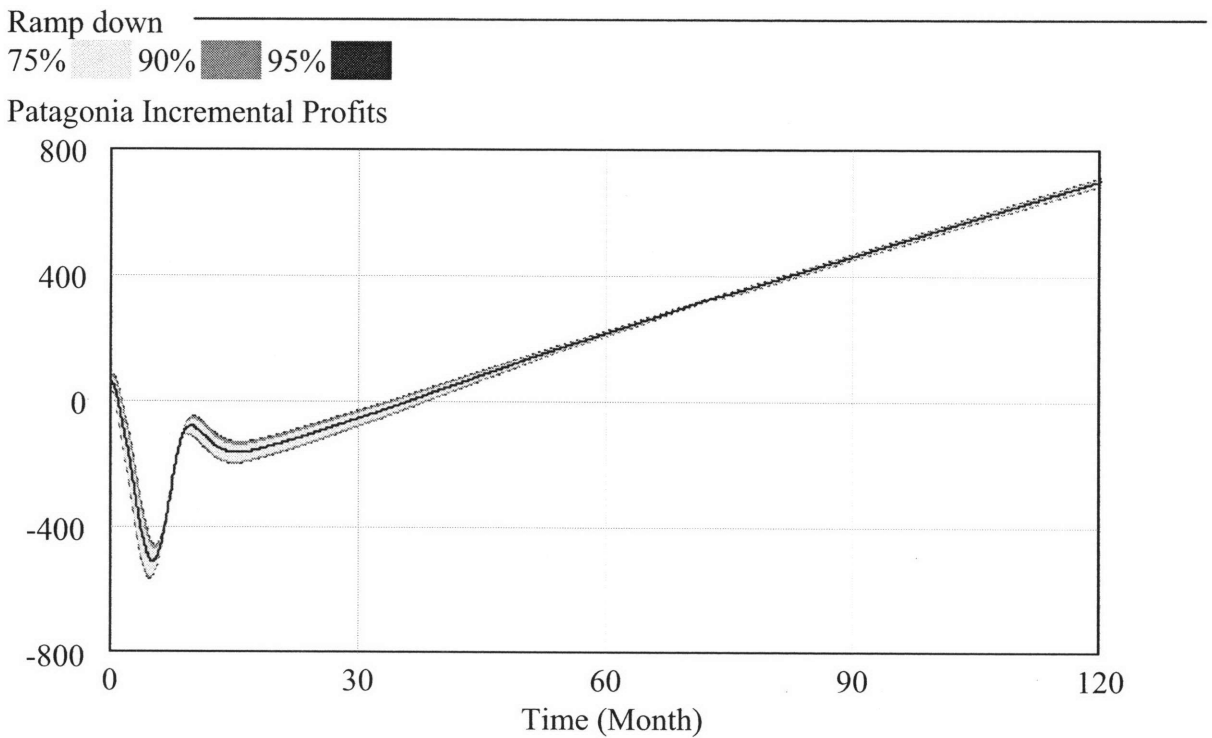


Figure 62: Sensitivity of Patagonia profits to changes in rebate sensitivity

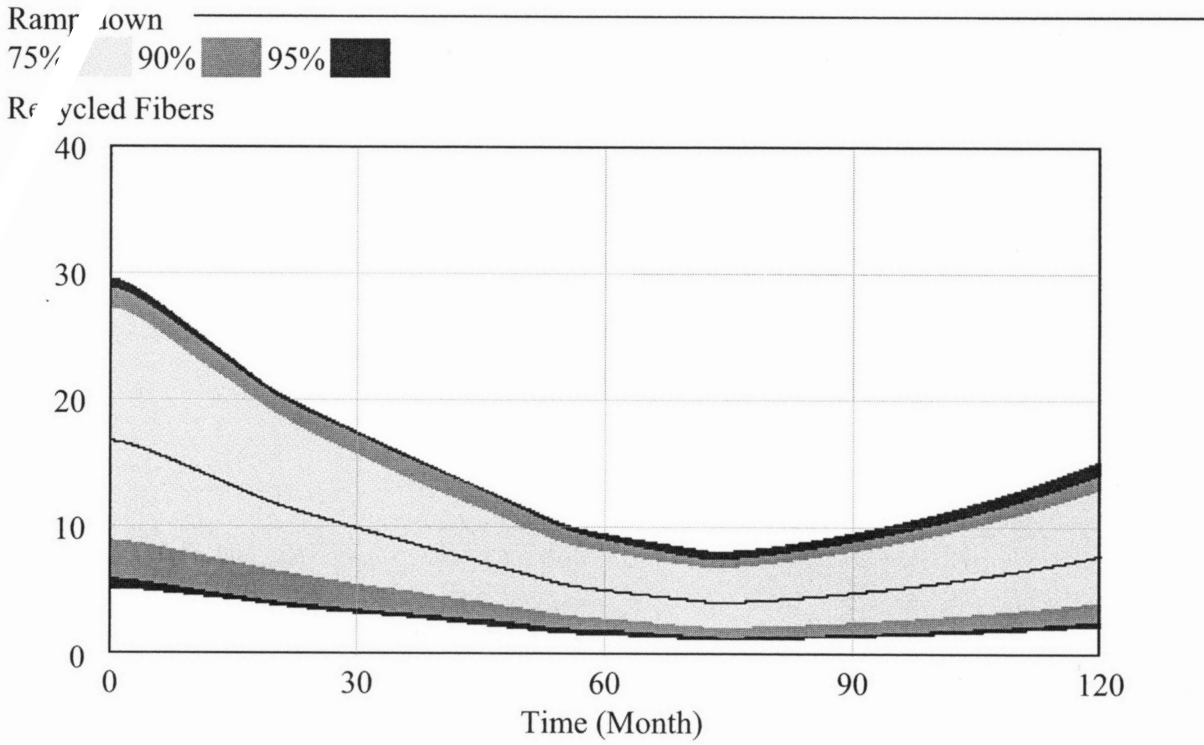


Figure 63: Sensitivity of recycled volume to rebate sensitivities

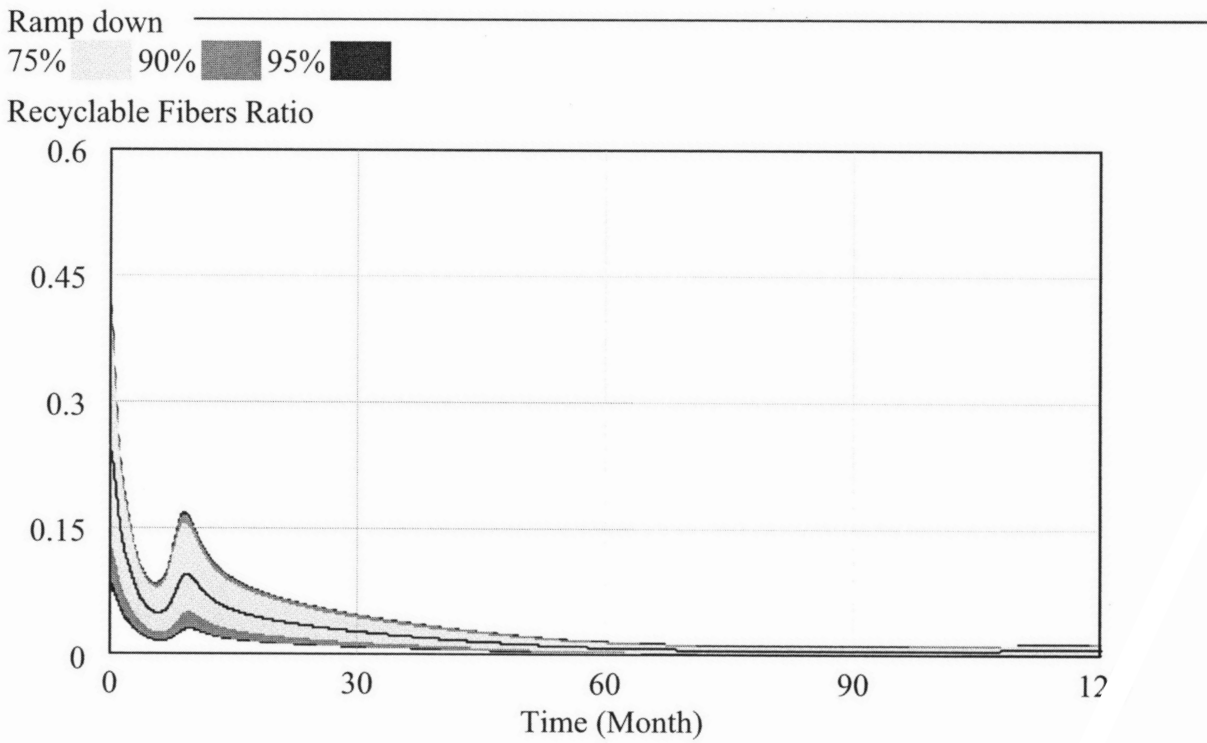


Figure 64: Sensitivity of recycled content in new fabric to rebate sensitivities

The quantities of clothes that are returned in this scenario are very sensitive to the size of the rebate. The volume of returns drives the use of recycled fibers in new fabrics and the economies of scale. The range of outcomes is neither large nor very promising. In the best cases, with lots of customer interest in recycling, it is still very expensive to use recycled fibers in new fabric. A positive aspect of the rebate is that even though it is not very effective, it doesn't have much of an effect on company profits either.

Sensitivity of the Rebate on Consumer Demand

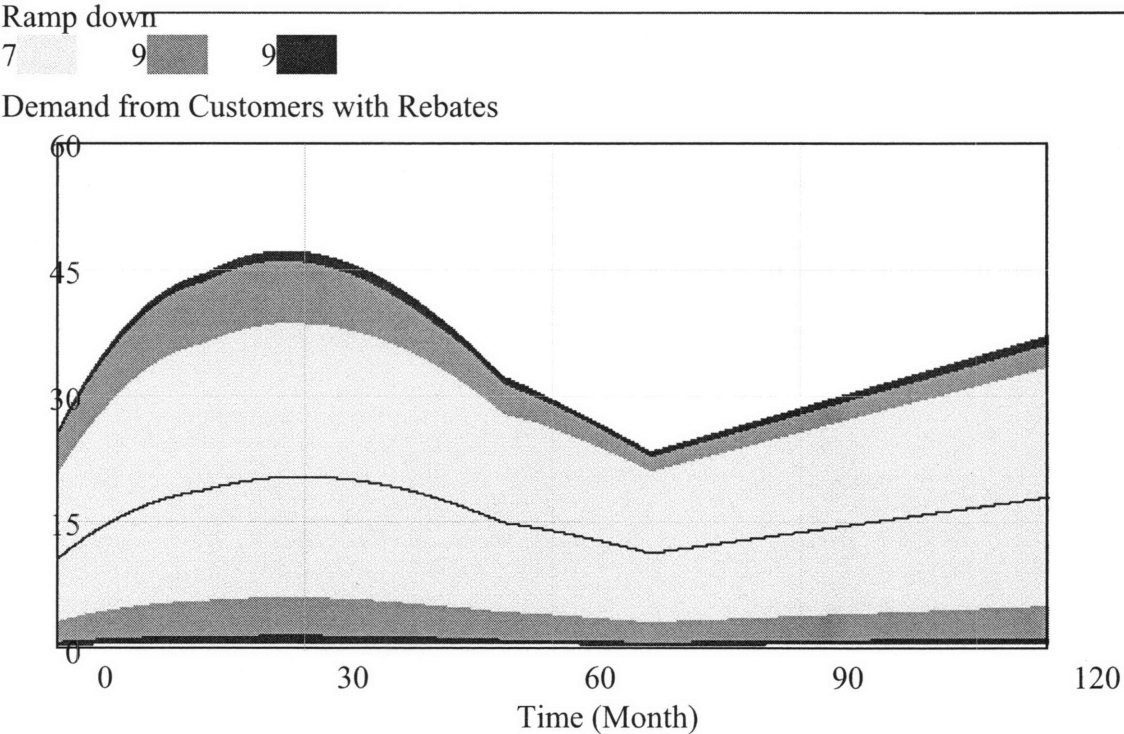


Figure 65: Sensitivity of customer demand to demand elasticity and rebate use

Ramp down



Teijin Incremental Profits

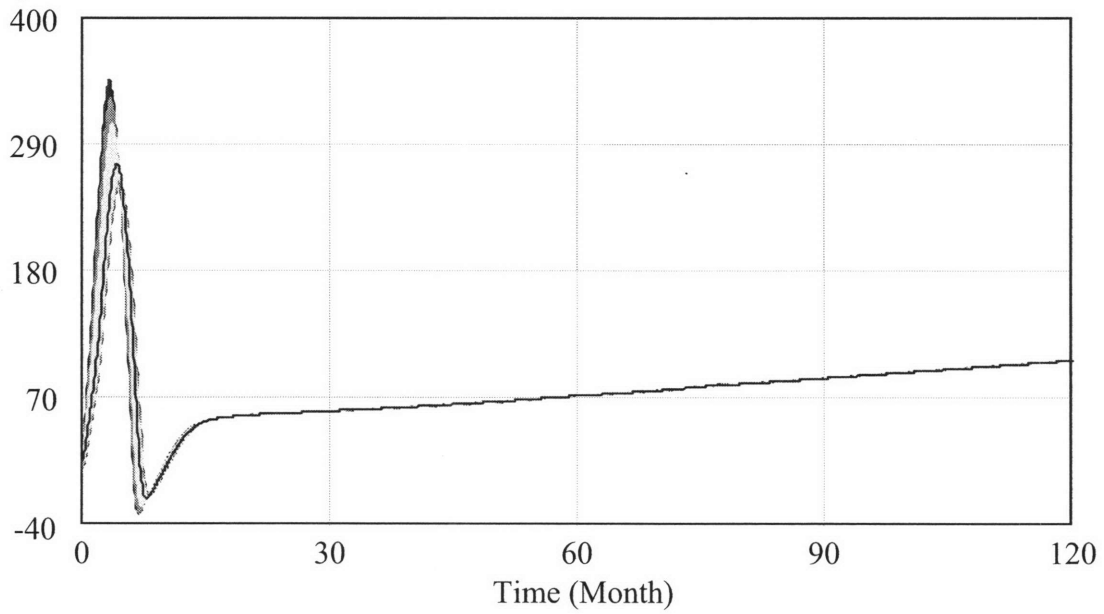


Figure 66: Sensitivity of Teijin profits to demand elasticity and rebate use

Ramp down



Patagonia Incremental Profits

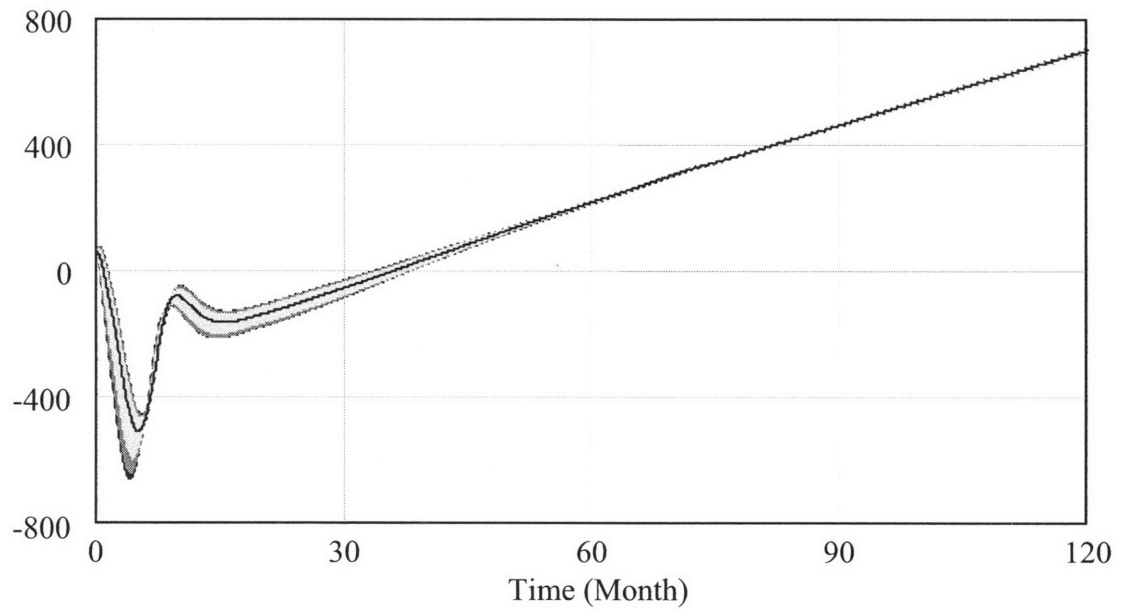


Figure 67: Sensitivity of Patagonia profits to demand elasticity and rebate use

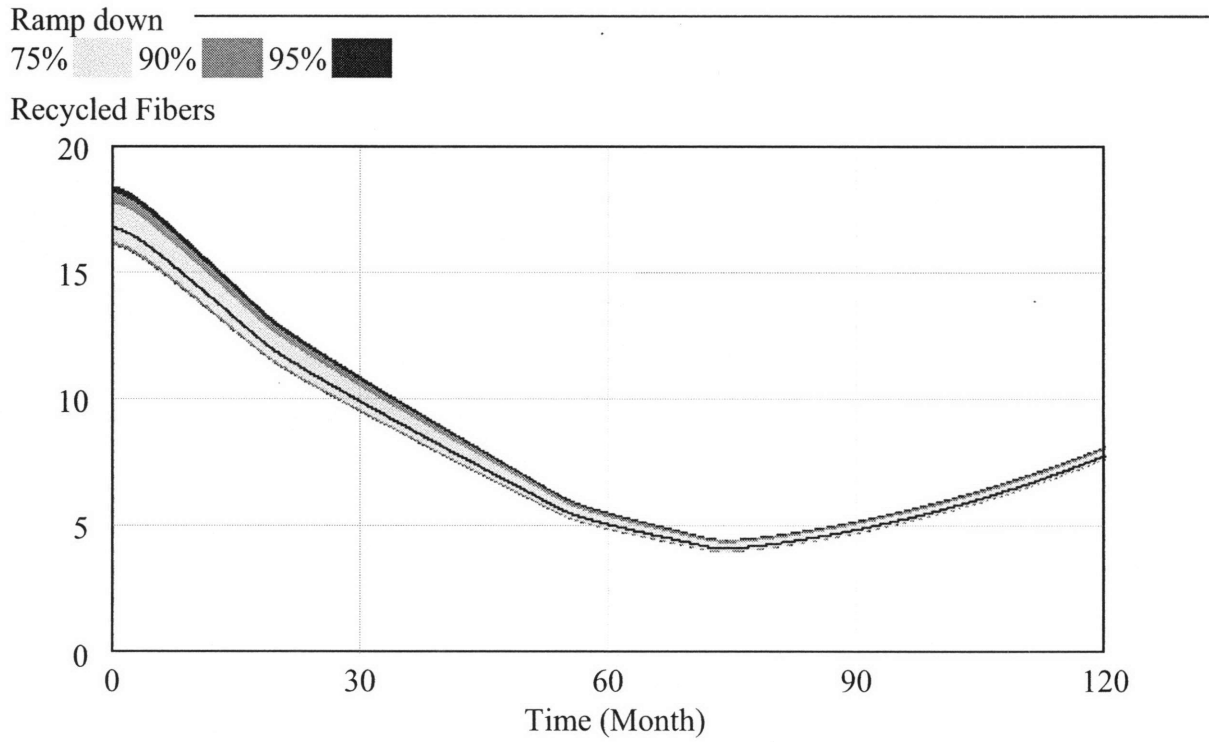


Figure 68: Sensitivity of recycling volume to demand elasticity and rebate use

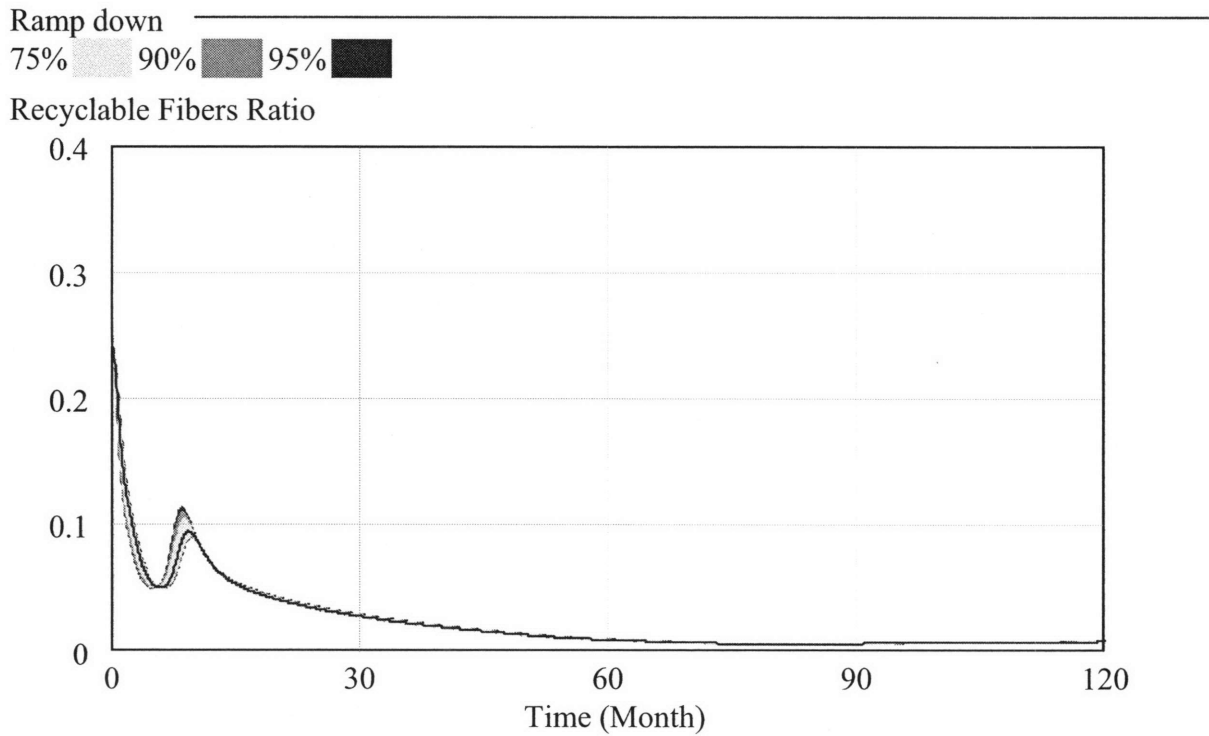


Figure 69: Sensitivity of recycled content in new fabric to demand elasticity and rebate use

In the long term there is less variability in the recycled content of new fabrics because there is less uncertainty of customer demand when the rebates are lower. The size of the installed base of Capilene is less variable and so the recycled volumes are less variable. On the whole, recycling ratios and volumes are robust to the assumptions of demand elasticity and rebate redemption.

The only things that vary are Patagonia and Teijin's profits. It is curious that profitability does not vary with volume. Because I do not have visibility into the cost structure I have omitted all fixed costs. I treat them as sunk and ignore them. The model understates the risk associated with changes in volume.

Sensitivity of Recycling to the Average Life of the Garment

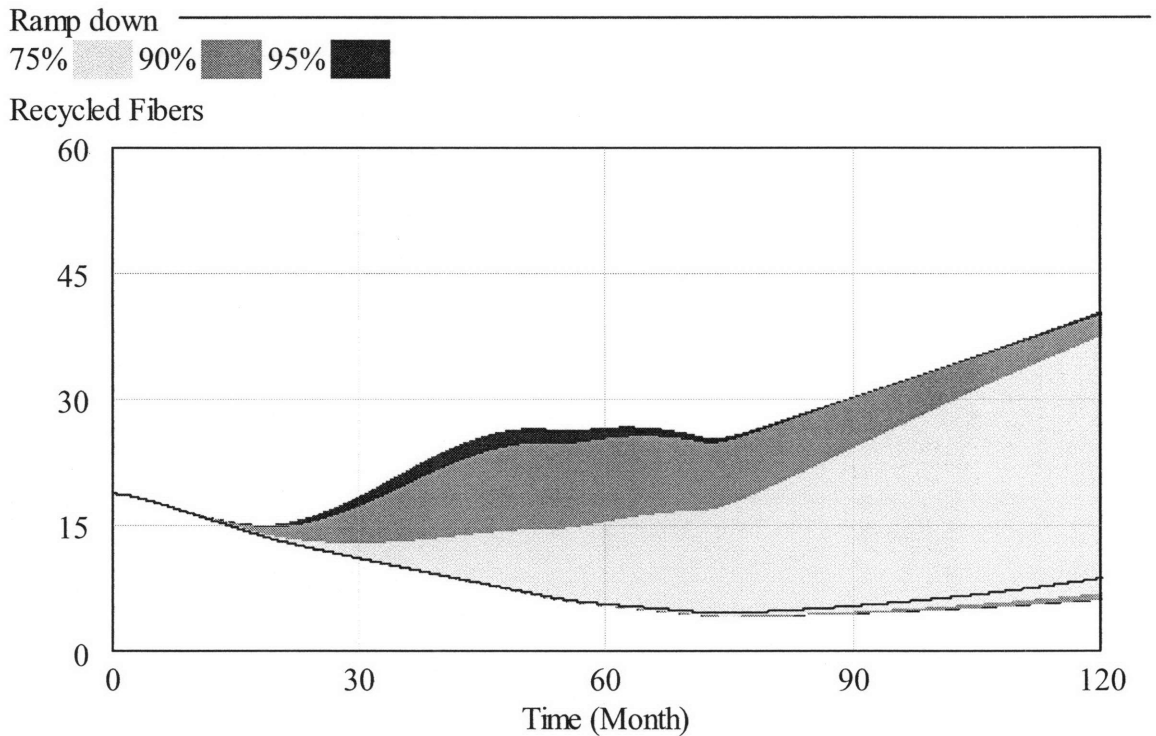


Figure 70: Sensitivity of recycling volume to garment lifecycle

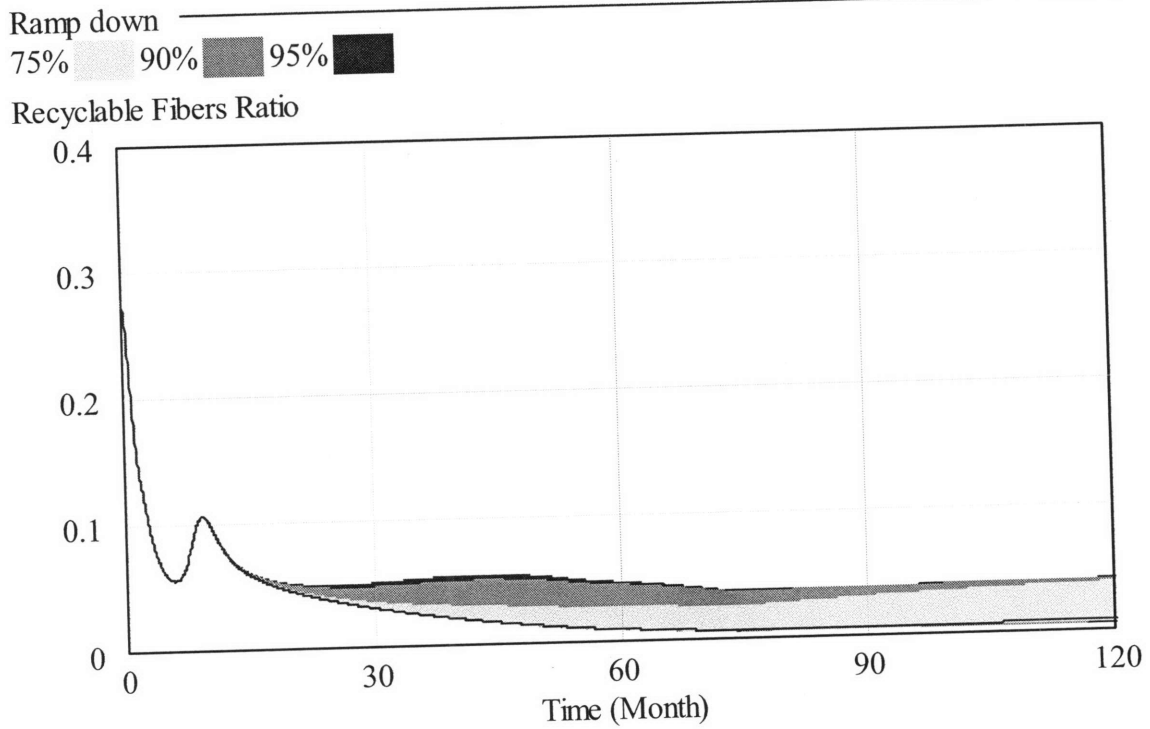


Figure 71: Sensitivity of recycled fiber content in new fabric to garment lifecycle

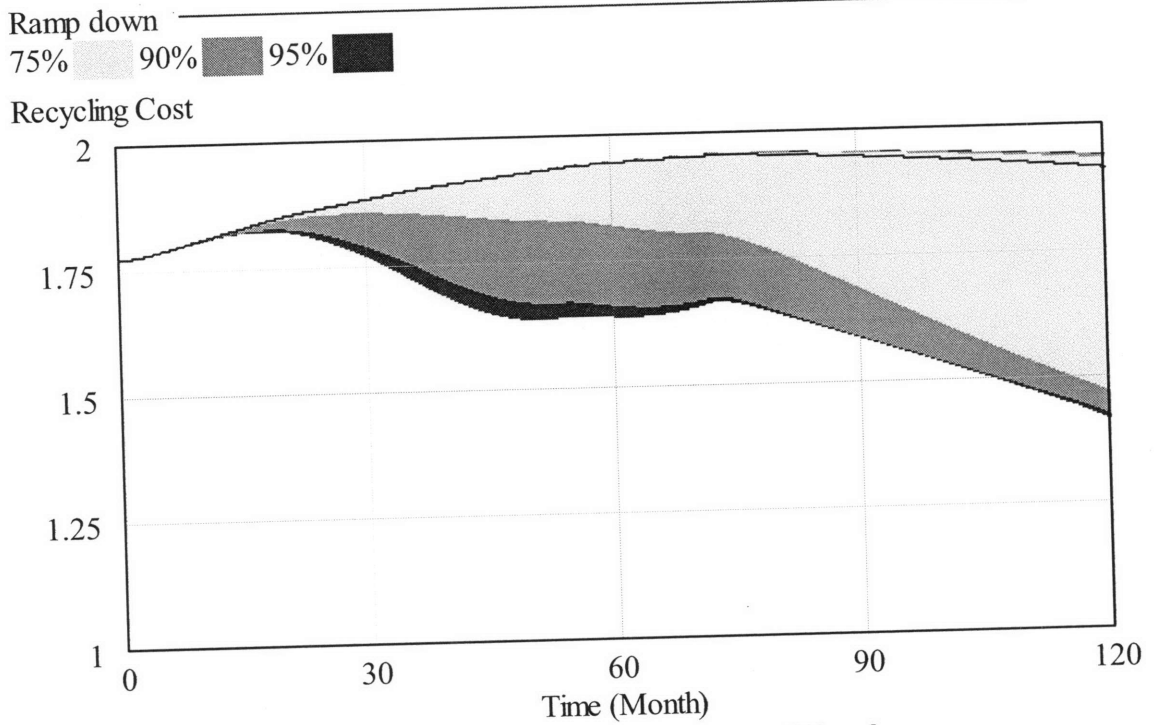


Figure 72: Sensitivity of recycled fiber production costs to garment lifecycle

Since the overall probabilities of recycling are lower in this scenario, shortening the useful life of garments does not have as large of an impact. That said, it is still the most important determinant of recycling volume.

VIII. Policy Implications

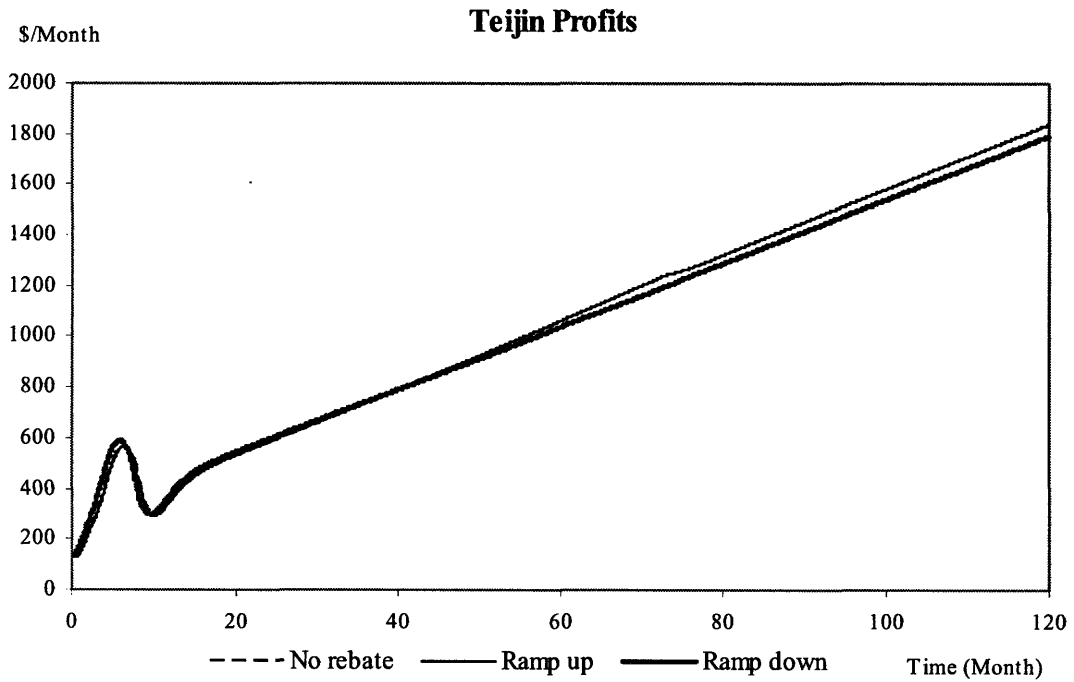


Figure 73: Comparison of Teijin profits

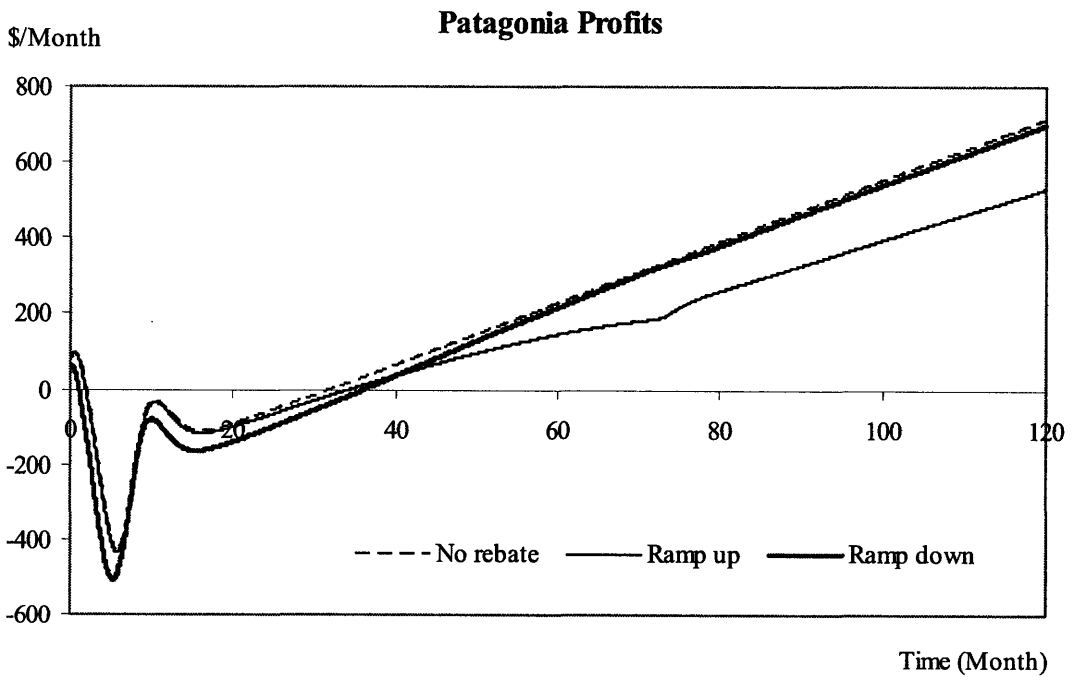


Figure 74: Comparison of Patagonia profits

Recycled Content in New Fabric

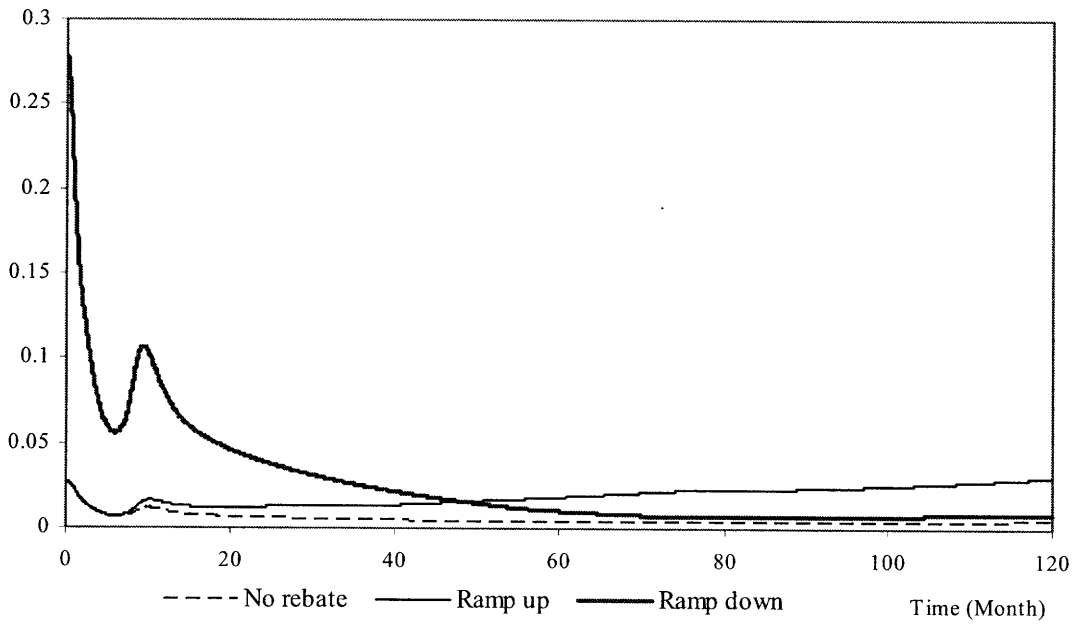


Figure 75: Comparison of recycled content in new fabric

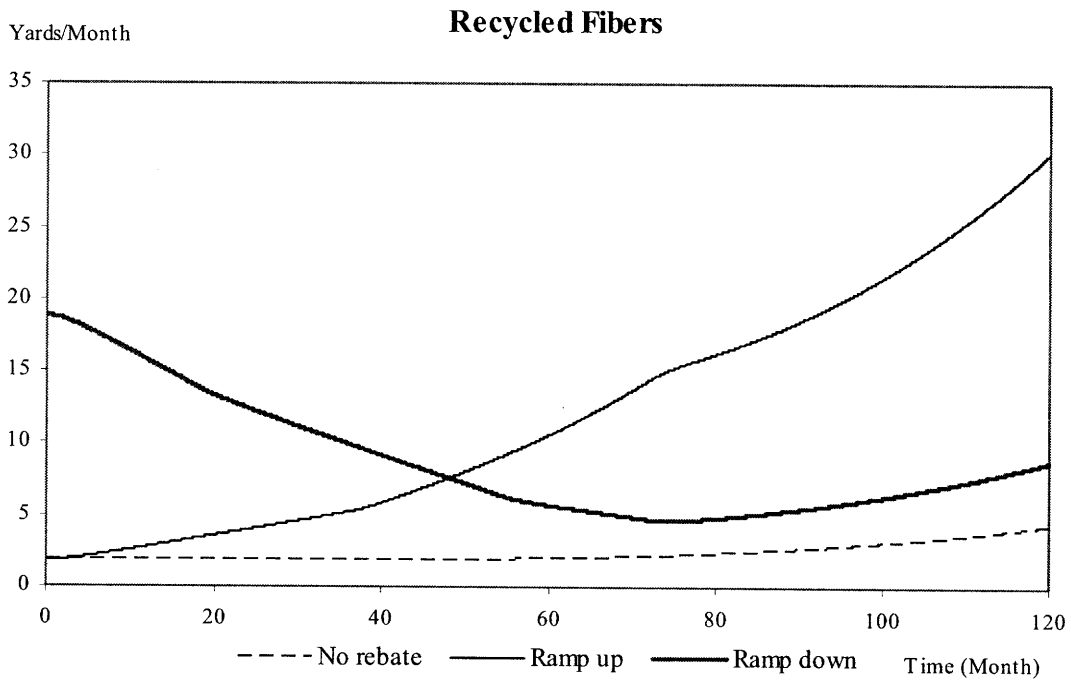


Figure 76: Comparison of recycling volume

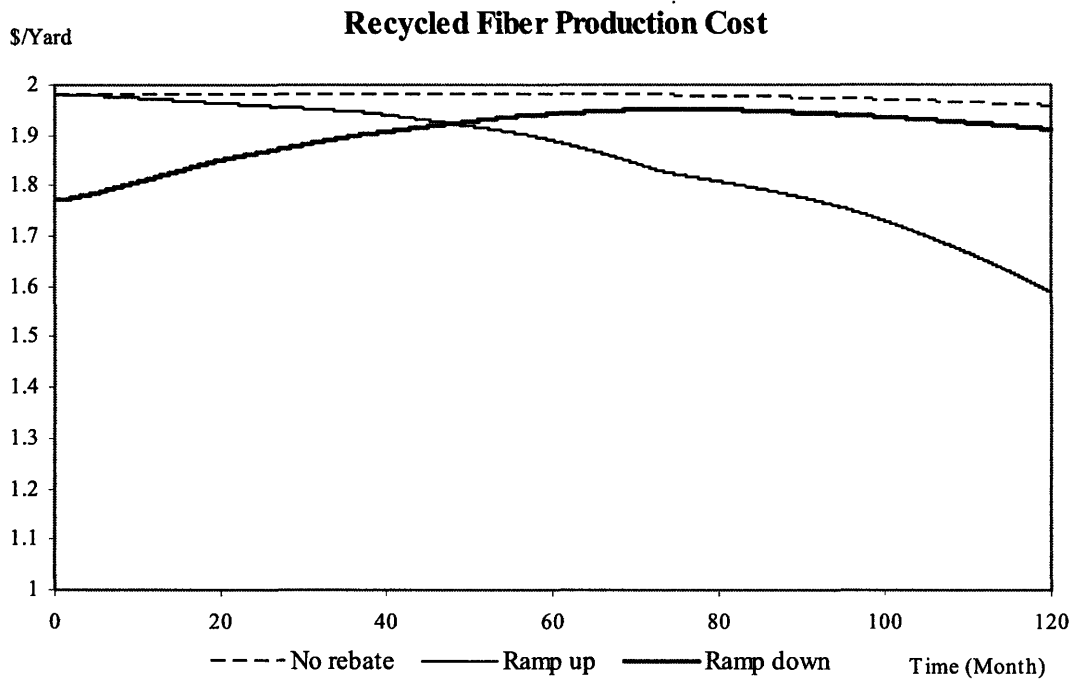


Figure 77: Comparison of recycled fiber production costs

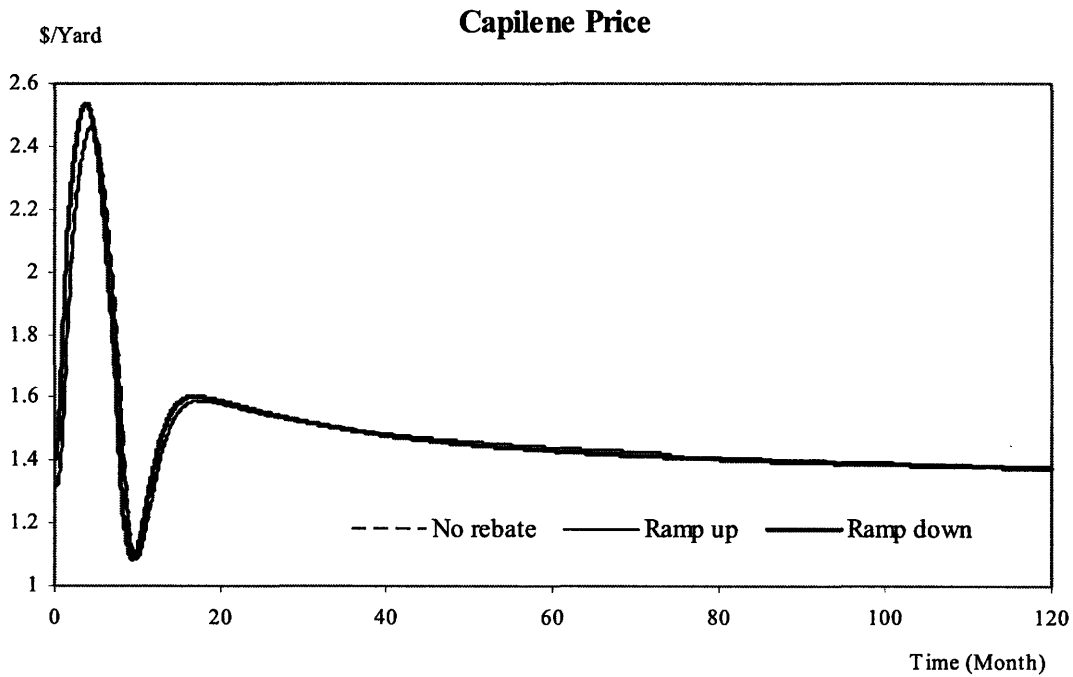


Figure 78: Comparison of Capilene prices

Implications for Teijin

This is a good program for Teijin. In all 3 scenarios there is very little change in profits, considering that Teijin's investments in R&D and capacity are sunk. It is a

problem for Teijin that the predicted volumes are so low. It will not fill excess their capacity.

Implications for Patagonia

Under my assumptions, Patagonia carries more of the risk in this program. The rebates do increase the likelihood of recycling but they also decrease margins. The program is expected to be profitable in all three scenarios but the profits are lower than if there were no recycling because the economies of scale are not achieved.

Capilene returns were a viable second source of raw materials in Scenario 1, but in the other scenarios they did not come close. Both Patagonia and Teijin must rely on recycled clothes from other sources. Recycled polyester uniforms are a good alternative source. They are easier to reclaim from customers and their lifecycle is shorter. It also allows Patagonia to keep its cachet as the only recyclable brand.

Of the three scenarios the upwards ramping rebate (Scenario 1) is clearly the best for achieving the objectives of the program. It is the only scenario where the recycled content of the fabric increased over time. But rebates alone don't induce consumers to recycle enough Capilene. It must be coupled with consumer education of the existence and benefits of the program.

Patagonia should also consider the lifecycle of the recyclable items. It is much easier for the program to ramp up the scale quickly if there is a large stock of used garments that consumers want to get rid of. It makes much more sense to recycle technical jackets, which is worn for only two to three years, instead of long underwear. The disadvantage of jackets is that there is more trim on the garment and so it is more tedious to recycle.

In this model Teijin is capturing the profits from the program in this model. In the real world they are also well placed to capture the value. They are the only polyester manufacturer with garment-to-garment recycling capabilities and other companies are not interested in developing the technology without proof that it turns a profit. It is unlikely that the margins from the program will be high enough, in the short-run, to induce other entrants. Whether or not customers will be able to capture value through lower prices is unclear. It depends on how much of the savings Teijin passes on the Patagonia and on the demand elasticity which determines whether lowering prices will increase profits through greater volume or lower profits because of decreased margins.

IX. Further research

This paper is a first pass at an interesting problem. As noted in the model boundary section, a lot of simplifying assumptions have been made. It would be very interesting to revisit this program in a few years once there is history to use to validate the model. The model itself should be expanded to include the used garment industry and raw material price and supply fluctuations.

Consumer behavior is much more complex than what is presented in this model. Past, present and future recycling habits are linked. So if consumers recycle a lot at the beginning (ramp down scenario) they should be more likely to recycle in the future. There are also links between word of mouth, rebate size, and consumer education. Future models should include multiple drivers of recycling behavior and should explore the links between them.

Appendices

- Appendix 1: Common Threads Recycling Program – White Paper
- Appendix 2: Teijin ECOCIRCLE
- Appendix 3: Common Threads Recycling Program on the Patagonia website
- Appendix 4: Full diagram of supply loop
- Appendix 5: Variable list
- Appendix 6: Capilene products
- Appendix 7: PCR product example

Appendix 1: Common Threads Recycling Program – White Paper

Patagonia's Common Threads Garment Recycling Program: A Detailed Analysis

Executive Summary:

Patagonia has a long history of innovating to reduce environmental impact, from using recycled soda bottles in our Synchilla jackets beginning in 1993 to switching to 100% organic cotton in 1996. The Common Threads Garment Recycling Program, launching in Fall 2005, marks the latest milestone in our history of innovation.

Through the Common Threads Garment Recycling Program, Patagonia will collect worn-out, old Capilene base layer garments from customers in order to recycle the garments into new filament yarns that will be used to make new polyester (PET). Using the ECOCIRCLE™ recycling system from Teijin, a progressive fabric manufacturer in Japan, Patagonia's old Capilene garments will be broken down to make new polyester fibers.

Using old Capilene garments to make recycled polyester has several environmental benefits. As traditional polyester is made from petroleum, using recycled fibers greatly reduces the fossil fuel-based inputs needed to manufacture polyester. In addition, the program will enable us to take responsibility for Patagonia's Capilene garments at the end of their useful life. This take-back program will give us the ability to limit the waste that we are responsible for by diverting old garments from landfills – in perpetuity!

While the use of recycled PET significantly reduces the direct use of petroleum and natural gas (the raw material source for the production of DMT (dimethyl terephthalate) the primary precursor chemical used in the production of PET for Capilene garments), recycling US based Capilene involves increased transportation related energy requirements due to transcontinental shipments of used garments between the U.S. and Japan. Thus, we wanted to compare the environmental impacts of Teijin's three PET manufacturing options. We evaluated the energy use and greenhouse gas emissions that result from the following three scenarios:

- A.) Virgin Process: Teijin's production of polyester from virgin materials
- B.) Locally Recycled Process: Teijin's production of polyester using recycled garments that were collected locally. Garments collected at Patagonia Japan locations fit into this scenario.
- C.) Recycled Capilene Process: Teijin's production of polyester using Patagonia's recycled Capilene garments that were collected in the US.

We completed a detailed environmental analysis on these three options, explained in the following paragraphs and were able to compare the environmental impacts of manufacturing virgin and recycled polyester as well as quantify the impact that result from transporting used Capilene from our US customers to Japan.

Source: http://www.patagonia.com/pdf/common_threads_whitepaper.pdf

Environmental Analysis:

Introduction

Patagonia’s Capilene garments are made from polyester (Polyethylene Terephthalate (PET))-based fabrics and designed for use primarily as base layer insulation layers. This polyester fabric can be recycled in Teijin’s ECOCIRCLE™ recycling system and used to make new PET. Teijin currently manufactures PET from both virgin materials and recycled polyester. At this point in time the polyester used in Teijin’s ECOCIRCLE recycling system is collected from local sources in Japan.

Teijin uses DMT (dimethyl terephthalate) as the intermediate chemical in the manufacture of PET. Teijin provided us with energy use and CO₂ emissions information for both production of DMT from virgin materials and recycled polyester. Because we assume that Teijin uses the same process of polymerization from DMT to PET for both the virgin and recycled DMT we have not included it in the comparison. The unit of comparison from which all calculations contained in this analysis are normalized is 1 ton of DMT fiber. This analysis focuses on the energy used and CO₂ emitted up to the production of DMT and does not include steps beyond this point in the life cycle of polyester.

What follows is an explanation of how we calculated the energy use and CO₂ emissions from the three different production scenarios. Please refer to the Addendum/Appendix at the end of this document for conversion details and explanations for transport calculations.

A.) Virgin Process: Production of DMT from virgin materials

Production Energy – DMT manufacturing

Teijin provided the DMT manufacturing energy use data for the Virgin Process. The energy use data includes the following steps:

- Extraction and transport of raw materials (oil and natural gas)
- Manufacturing of DMT from raw materials (oil and natural gas)

Teijin	Energy Use (MJ/metric ton DMT)
Production of 1 metric ton DMT by Teijin	72,422

Production CO₂ – DMT manufacturing

Teijin provided the DMT manufacturing CO₂ emissions data for the Virgin Process. The CO₂ emissions data includes the following steps:

- Extraction and transport of raw materials (oil and natural gas)
- Manufacturing of DMT from raw materials (oil and natural gas)

	CO ₂ (metric tons/1 metric ton of DMT)
CO ₂ equivalents	4.183

B.) Locally Recycled Process: Teijin’s production of DMT using recycled garments that were collected locally

Production Energy – DMT manufacturing

Teijin provided the DMT manufacturing energy use data for the Locally Recycled Process. The energy use data includes the following steps:

- Collection of polyester from local sources (Japan)
- Manufacturing of DMT from recycled polyester (Japan)

Teijin	Energy Use (MJ/metric ton DMT)
Production of 1 metric ton DMT by Teijin	11,962

Production CO₂ – DMT manufacturing

Teijin provided the DMT manufacturing CO₂ emissions data for the Locally Recycled Process. The CO₂ emissions data includes the following steps:

- Collection of polyester from local sources (Japan)
- Manufacturing of DMT from recycled polyester (Japan)

	CO ₂ (metric tons/1 metric ton of DMT)
CO ₂ equivalents	0.98

C.) Recycled Capilene Process: Teijin’s production of DMT using Patagonia’s recycled Capilene garments

Teijin provided energy data for the production of DMT from recycled polyester fiber. All other data was derived based on a combination of estimates and assumptions of critical factors.

The Recycled Capilene Process includes five steps:

- Step 1:** Used garment collection (customers mail garments via bulk shipments 1200¹ miles from their homes to Reno refer to Transport section)
- Step 2:** Collection and storage of garments (Reno, NV)
- Step 3:** Transport from Reno NV via truck 200 miles to Oakland Port
- Step 4:** Transport from Oakland Port to Matsuyama, Japan via container ship 5,600 miles
- Step 5:** Manufacturing of DMT from recycled polyester (Japan)

Garment Collection Explanation

Although Patagonia produces a number of Capilene styles, and all Capilene styles will be included in the take back program, this analysis is based on a single fabric/garment

¹ The distance of 1200 miles from customer to Reno, NV was selected because it is the average distance from all of our retail stores to Reno.

combination—Midweight Crew Neck Capilene (MW Capilene). We chose to focus on just one specific style of Capilene in order to maintain consistency in our analysis. Although our various Capilene styles appear similar, each is quite different; some styles include zippers, while others differ in sleeve length. These style differences along with the different fabric weights, causes differences in the overall weight of the garments. In order to calculate how many garments we need to produce one ton of DMT, we have to know the weight of the polyester contribution of each garment. We wanted to use a consistent weight so we chose to analyze only MW Capilene because it offers a good representation of the entire product line in regards to materials and weight. Our MW Capilene is one of 7 different Capilene categories and made up 22% of the total Capilene sold by Patagonia in FY 2004.

Garment Conversion

To estimate the number of used garments necessary for the production of 1 metric ton of PET fiber we used efficiency information provided by Teijin. Because Capilene garments are 100% polyester, the Japanese manufacturer estimated that the conversion during the recycling of the garments to DMT could be greater than 90%. Absent valid efficiency data, we have assumed that the conversion efficiency will be 90%. Therefore, to produce one metric ton of DMT will require 1.11 metric tons (4,900) of garments.

Recycled Garment to DMT Conversion

Unit	Conversion used
1 metric ton =	35,274 ounces
1 MW Capilene Crew Neck =	8 ounces
4,406 MW Capilene Crew Neck garments =	1 metric ton
Need 1.11 metric tons (factoring in 90% efficiency) to manufacture 1 ton of DMT =	4,900 garments
4900 garments =	1 metric ton DMT

Step 1: Transport from Customer to Patagonia’s service center in Reno, NV

Please refer to the Transportation Appendix at the end of this document for conversion details and explanations for transport calculations.

Because we are encouraging our customers to mail their recycled garments to Patagonia, for this analysis we are assuming that all 4,900 garments (1.11 metric tons) will be mailed from our customers directly to our Reno Service Center. We also assume that the average distance the garments are mailed will be the average distance from Patagonia retail stores to the Service Center in Reno, NV. These assumptions, should they be inaccurate, have the potential to have a large impact on the results of our analysis.

- Garments mailed: 4,900
- 1,200 miles by truck
- Gallons of fuel: 22
- Weight of transport: 1.11 tons of garments transported
- Energy used: 3,504 MJ
- CO₂ emissions: 0.124 metric tons CO₂

Step 2: Garment Collection and Storage/Reno Service Center Activity

Production Energy

Assumptions

The 1.11 metric tons of garments will be shipped 1,200 miles from a Patagonia retail store to the Reno Service Center. At the Reno Service Center each box will be unpacked, the used Capilene garments will be cut into pieces using a band saw, and the fabric scraps will be repacked into boxes. Once the scraps are packaged they will be transshipped to the Japanese manufacturer. We then assumed that it would take approximately 2 hrs total to unload, store, cut up garments, retrieve, and load each box for shipment to Japan. 45 boxes will be needed to transport all the garments (110 garments per box) We estimated that the 45 boxes will require 90 person hours (approx 2 hrs per box) at the Service Center and approximately 30 square feet of space.

Calculations

Energy use associated with Service Center activities is estimated to be negligible (0.261 MJ) as shown by the conversion and calculation details in the table below.

Reno Service Center - Energy Calculations

Calculation Components	Conversion Factor	Result
FY'04 Total Energy Use at Reno Service Center		3,985,294 MJ
Service Center size		211,000 sq. ft.
Estimated sq ft for garment recycling activities		30 sq. ft.
Sq. footage used as a percent of total sq. ft.	30 sq.ft./211,000 sq.ft.=	0.01%
Allocation of estimated annual energy use for 30 sq ft	3,985,294 MJ*0.010% of total sq.ft.=	566 MJ
Number of garments per garment box	110 (info provided per field trial)	110 garments per box
Number of boxes needed	45	45
Estimated handling and cutting time per garment box	2 hour	2 hour
Estimated staff hours for 1.11 tons (4,900) garments	(4,900 total garments/110 garments per box) * 2 hrs per box =	90 hrs
Staff time as a percentage of total annual staff hours	90 hrs /(10 hrs a day*5 days a week*52 weeks a year *75 employees) =	0.046%
Estimated Service Center energy use for garment recycling	566 MJ * 0.046% =	0.261 MJ

Production CO₂

Garment Collection and Recycling/Service Center Activity:

Based on a regional CO₂ emission factor of 0.22 lbs CO₂/MJ, we calculated a negligible amount of CO₂ emissions (0 metric tons) for the estimated 0.277 MJ energy use.

Step 3: Transport from Service Center in Reno, NV to Port in Oakland, CA

200 miles by truck
 Gallons of fuel (diesel): 4
 Weight of transport: 1.11 metric tons of garments
 Energy used: 544 MJ
 CO₂ emissions: 0.021 metric tons CO₂

Step 4: Transport from Oakland, CA to Matsuyama, Japan

This transport will likely include an initial stop at the port in Kobe, Japan and then be shipped via boat to Matsuyama. The initial distance from SF to Kobe is approximately 5374 miles via boat. It is then approximately 210 miles from Kobe to the Japanese manufacturer in Matsuyama.
 5600 miles by boat
 Gallons of fuel (residual fuel oil): 12
 Weight of transport: 1.11 metric tons of garments
 Energy Used: 1,723 MJ
 CO₂ Emissions: 0.081 metric tons CO₂

Step 5: DMT manufacturing

Production Energy

Teijin provided the DMT manufacturing energy use data for the Recycled Capilene Process. The energy use data includes the following steps:

- Collection of polyester from local sources
- Manufacturing of DMT from recycled polyester

Teijin	Energy Use (MJ/metric ton DMT)
Production of 1 metric ton DMT by Teijin	11,962

Production CO₂

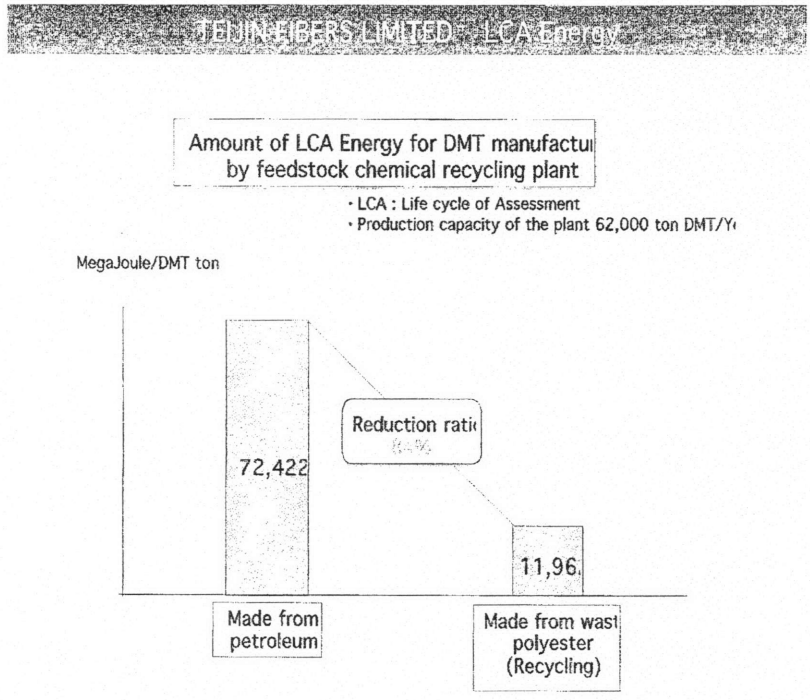
Teijin provided the DMT manufacturing CO₂ emissions data for the Recycled Capilene Process. The CO₂ emissions data includes the following steps:

- Collection of polyester from local sources
- Manufacturing of DMT from recycled polyester

	CO ₂ (metric tons/1 metric ton of DMT)
CO ₂ equivalents	0.98

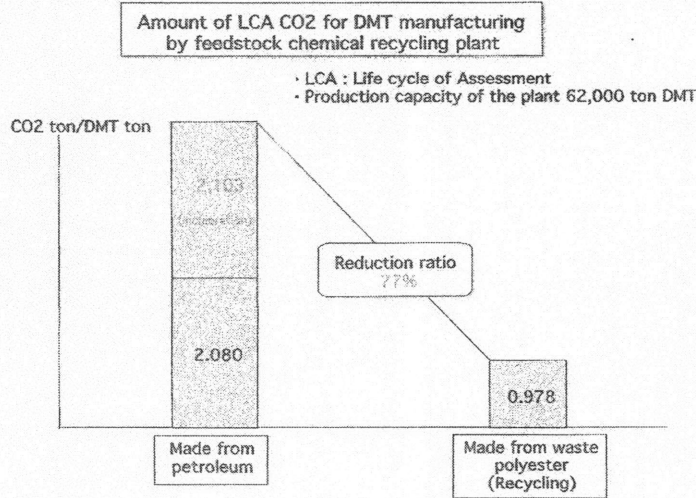
Results:

After researching and collecting data from Teijin we were able to complete our analysis. We found that the process required to manufacturing DMT from raw materials (extraction and transport of oil and manufacturing DMT) uses 84% more energy than the process of manufacturing DMT from recycle polyester (local collection of polyester and manufacturing DMT). The chart below illustrates this information.



There are 77% fewer CO₂ emissions when DMT is manufactured using recycled polyester instead of using raw materials. As you can see in the illustration below, that more than half of the CO₂ produced during the Virgin Process is the result of incinerating old, used garments instead of recycling them.

TEIJIN FIBERS LIMITED LCA CO₂



The two charts above compare the energy use and CO₂ emissions from options A and B explained above. These charts reveal that using recycled polyester to manufacture DMT uses significantly less energy and produces significantly fewer CO₂ emissions.

When the transportation from Patagonia Customer in the US to Japan is factored into the ECOCIRCLE recycling system, manufacturing polyester fiber from recycled materials results in 76% less energy usage and 71% less CO₂ emissions than producing polyester from virgin materials. These statistics are encouraging, and they give us great hope that this program can help us reduce our environmental footprint.

The following chart provides a quantitative comparison of the three possible DMT manufacturing scenarios that were evaluated in this analysis.

Category	Option A Teijin w/ out Recycling	Option B Teijin w/ Local Recycling	Option C Teijin with Capilene Recycling	Units
Distance	0	0	7,000	Miles
Fuel for transport	0	0	38	Gallons
Energy (production)	72,422	11,962	11,962	MJ
Energy (transport)	0	0	5,771	MJ
Total Energy	72,422	11,962	17,733	MJ
CO ₂ emissions (production)	4.18	0.98	0.98	Metric tons
CO ₂ emissions (transport)	0.000	0.000	0.226	Metric tons
Total CO₂ Emissions	4.18	0.98	1.20	Metric tons

Conclusion:

We provide this information for the benefit of our customers, the public at large, the media, and students conducting research on these topics. We hope that this information will help our customers understand why we have embarked upon such a program and how they can help reduce our collective ecological footprint. We wanted this analysis to reveal realistic environmental impacts that could result from transporting garments to Japan. We had to make assumptions, as we don't know how our customers will participate. We tried to think of our own habits and what would be best for the planet. We chose one scenario that would be best from an environmental perspective with the hope that this will encourage people to participate in the lowest impact way. For example, mailing in old Capilene garments rather than making a special trip to drive them to a Patagonia store results in significant energy and emissions savings.

We realize our analysis indicates that in terms of energy use and CO₂ emissions, the process of recycling old Capilene garments and shipping them from the US to Japan, is not the option with the least impacts. It also revealed that surprisingly, the international shipping from the US to Japan is not the area that produces the greatest impact. The transportation required to move old Capilene garments from customers' closets to collection centers domestically (either Retail stores or the Reno Distribution Center) has the greatest potential to produce environmental impacts. This is an encouraging finding because it's an area over which we have some control. By making wise choices, we have the opportunity to significantly reduce the impact of the overall process!

Fortunately recycling is the right thing to do with garments that have worn out. There are other factors that come into play that increase the environmental benefits of this program. The benefits of reducing oil extraction for polyester manufacturing and reducing the amount waste that enters our solid waste stream are important and are not factored into our analysis.

It's critical that we recognize that recycling clothing is not a cure-all for our environmental challenges. Room for improvement abounds. We plan to continue to hold ourselves to a rigorous standard for reducing our environmental footprint, with the support and cooperation of our suppliers and our customers alike. On the transportation front, greater use of alternative energy and high-volume shipping methods (such as railway and ship) will help to reduce the impact. Greater use of alternative energy in domestic and international transportation will also be a boon. This program can serve to inspire more companies to develop recycling technologies and participate in such programs. It is our hope that as demand grows for clothing made using recycled garments, facilities such as Teijin's ECOCIRCLE™ recycling plant will open in more locations, reducing the mileage collected garments need to travel on their journey. We feel that all of these factors work together to make Common Threads a very worthwhile program.

Transportation Appendix:

Units/Conversions

All energy values are reported in mega joules (MJ) and all CO₂ emissions are measured in metric tons-CO₂e. All additional weight measurements are also measured in metric tons. All weight and energy unit conversions (for example converting kWh to MJ) were made using conversion factors and calculators at www.onlineconversion.com.

Geographic Distances

The distances between geographic locations as materials flow through the Capilene life cycle stages were found using www.indo.com/distance/index.html. The website calculates distances in miles between two specific locations. In cases where a specific geographic location was not available in the online distance tool, the closest location was used and an estimate was made for the distance to the target city. For example, in calculating the distance between San Francisco and Kobe, Japan, because Kobe is not in the distance calculator, we used the distance between San Francisco and Osaka, plus an estimate of the distance from Osaka and Kobe.

Transportation Energy

Transportation energy was calculated through a combination of identifying transport distances and modes (truck, train or ship). Originating and destination locations were identified with any intervening waypoints (e.g., trucking from origin to a port, shipping to another port, trucking to destination). The method of transport was identified through research on the supply chain or provided by Patagonia staff and consultants or the Japanese manufacturer.

Fuel use was determined using miles per gallon estimates available at: www.gicaonline.com/media/tools/gica040312.pdf and <http://www.irpt.net/irpt.nsf/LinksView/EnvironmentalAdvantages?Opendocument>. These websites estimated that one metric ton of freight using one gallon of fuel can be shipped the following distances for each mode:

Mode	Distance in ton-miles per gallon of fuel
Automobile*	19
Truck	59
Train	386
Boat	522

* The mpg values for the automobile are not in ton-miles per gallon they are miles per gallon for an average sized sedan.

The ton-miles per gallon values for truck, train and boat in the chart above are high because they are based on shipping one ton one mile. These numbers reveal that shipping a lot of weight in one shipment can be very efficient. Using these estimates, we calculated the gallons of fuel needed for each mode segment by multiplying the segment

distance by the tonnage of material and then dividing by the appropriate mpg estimate. Fuel usage in gallons was then converted to MJ using the following factors:

Mode of Transport	Fuel	Energy Content per Gallon in MJ
19 mpg Car	Gasoline	132
Truck, Train, Boat*	Diesel	146

*Note that boats use both Diesel Fuel Oil and Residual Fuel Oil. For the purposes of this report we have assumed that the all shipments via boat will use Diesel Fuel Oil
 Source: Diesel Fuel: <http://www.vigyanprasar.com/comcom/definition.htm>
 Residual Fuel Oil: http://www.digal.pt/Digal_1/s13.htm
 Distillate Fuel Oil: <http://www.vigyanprasar.com/comcom/definition.htm>

Energy values were multiplied by gallons of fuel needed for each mode segment, which were then summed to find the total energy needed for transport between the origin location and destination.

Transport CO₂ Calculations

All CO₂ emissions were calculated using the “Emissions Based on Distance” worksheet in the GHG calculation tool, “Calculating CO₂ Emissions from Mobile Combustion” found at <http://www.ghgprotocol.org/standard/tools.htm>. Emission factors used at that site by transport mode are:

Transport CO₂ Conversions

Mode	Kg CO ₂ /Metric Ton-Mile
19 mpg Automobile	0.4305
Truck	0.0937
Train	0.0260
Boat	0.0132

Appendix 2: Teijin ECOCIRCLE

TEIJIN WEB SITE

TEIJIN Human Chemistry, Human Solutions

http://www.teijin-eco.com/english/ecoproducts/rec_01...

For Your Inquiries about the Environment

TEIJIN WEB SITE

The TEIJIN GROUP'S
**Environment, Safety
and Health Activities**

Eco-Partners
If you are thinking of
starting an
environmental business...

**Eco-Products
Eco-Technologies**
If you are interested in
the Teijin Group's products
and technologies...

The Teijin Group
CSR Report
FY 2005
→ PDF download
Archives
→ PDF download

Green Purchasing

Philanthropic Activities

Links

Key Word Glossary

Eco-Quizzes

Message from the President Basic Policy for Environmental Conservation	Toward the Creation of Recycle Oriented Technologies and Products Teijin Group's goals and midterm targets	CSR Report Group ESH Management Organizations	Press Releases Environmental Activity Performance and Awards
--	---	---	--

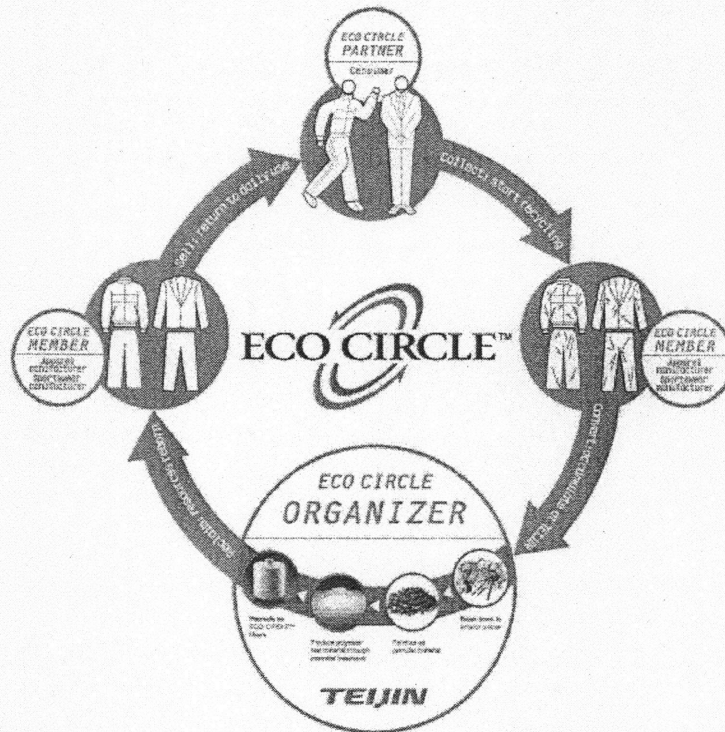
TOP PAGE

BACK TO PREVIOUS PAGE

ECO CIRCLE™

ECO CIRCLE is a closed-loop recycling system. Collected used polyester products are recycled to polyester raw materials and reborn into new products.

From fiber to fiber, bottle to bottle, film to film, polyester products can be recycled, for example, fiber products can be recycled as follows:

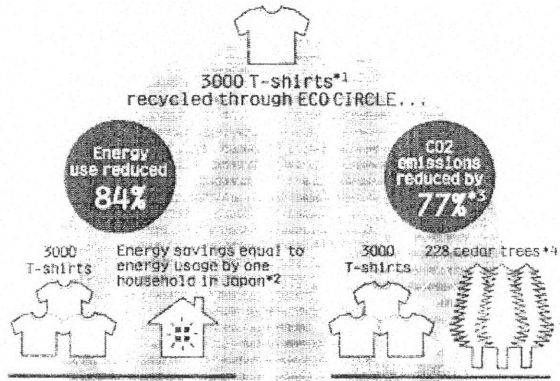
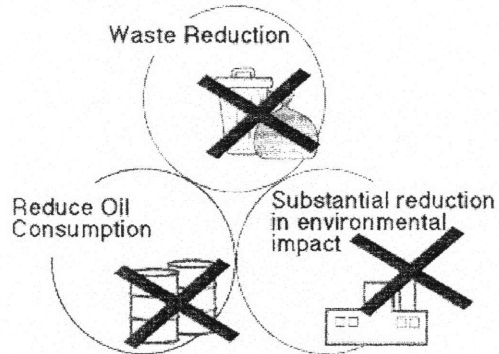


Fiber to Fiber

Bottle to Bottle

Film to Film

ECO CIRCLE™ is an environmentally friendly system. This closed-loop recycling system can realize many environmental benefits.



ECO CIRCLE reduces energy consumption by 84% compared with production of new polyester raw material from petroleum - equal to the energy consumed by one Japanese family for one year. That's a significant step towards a brighter future.

Compared with making new polyester raw material from petroleum, ECO CIRCLE cuts CO2 emissions by 77% - equal to a stand of 228 cedar trees. That's a valuable contribution to prevention of global warming.

- 1) Calculated as 1(one) Ton
- 2) Calculated as approx. 60,000 MJ
- 3) When added emitted Carbon Dioxides from burnt waste instead of being recycled
- 4) Calculated as 32 Tons

✉ For More Information about This Product

🏠 TO TOP OF THIS PAGE

The TEIJIN GROUP'S
**Environment, Safety
and Health Activities**

Message from the President	Toward the Creation of Recycle-Oriented Technologies and Products	CSR Report	Press Releases
Basic Policy for Environmental Conservation	Teijin Group's goals and midterm targets	Group ESH Management Organizations	Environmental Activity Performance and Awards

TOP PAGE

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If you are thinking of starting an environmental business...

Eco-Products Eco-Technologies
If you are interested in the Teijin Group's products and technologies...

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- Green Purchasing
- Philanthropic Activities
- Links
- Key Word Glossary
- Eco-Quizzes

ECO CIRCLE™

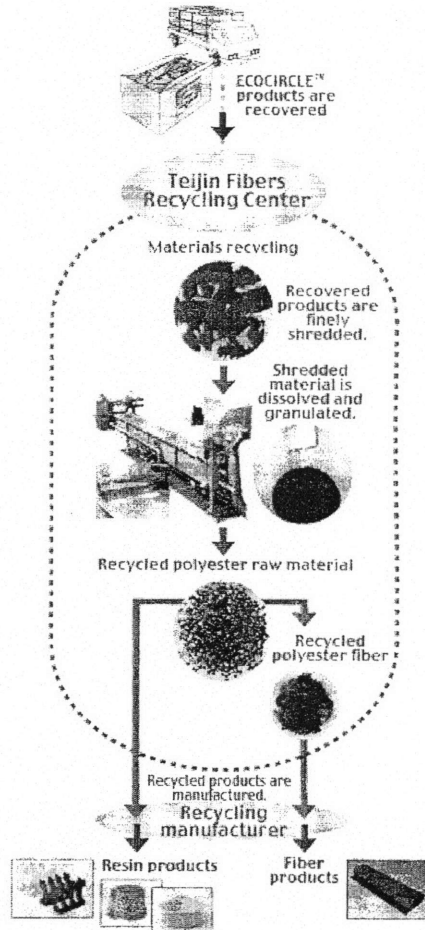
Materials recycling

The ECOCIRCLE® products recovered by the ECOCIRCLE® members are disassembled and processed into new products.

Example applications:

1. Work uniforms
2. School uniforms (students' uniforms)
3. School jerseys (athletic wear)
4. Interiors (curtains, brackets)
5. Sporting goods (tents)
6. Others (bags)

BACK TO PREVIOUS PAGE



PREVIOUS PAGE

NEXT PAGE

For More Information about This Product

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Message from the President	Toward the Creation of Recycle-Oriented Technologies and Products	CSR Report	Press Releases
Basic Policy for Environmental Conservation	Teijin Group's goals and midterm targets	Group ESH Management Organizations	Environmental Activity Performance and Awards

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Philanthropic Activities

Links

Key Word Glossary

Eco-Quizzes

ECO CIRCLE™

ECOCIRCLE® members

The ECOCIRCLE® network aims for cooperation in the development, marketing, recovery and reuse of environmentally friendly products among member companies in favor of its goals of environmental conservation and efficient use of resources.

- * Proportional allocation of recycling expenses
- (1) Recycling costs
- (2) Freight for transportation to recycling plants

Example applications:

1. Work uniforms
2. School uniforms (students uniforms)
3. School jerseys (athletic wear)
4. Interiors (curtains, brackets)
5. Sporting goods (tents)
6. Others (bags)

Member registration (registry form)

ECOCIRCLE® organizer
TEIJIN

ECOCIRCLE®
Secretariat in the Marketing Department,
Teijin Fibers Limited
TEL: +81-6-6268-2710
e-mail: ekoha@teijin.co.jp

After examination and approval by the Secretariat, the applicant is registered as a member.

Application for certification of an ECOCIRCLE® product is filed.

ECOCIRCLE® organizer
TEIJIN

Certification of the ECOCIRCLE® product is obtained from the Secretariat.

The ECOCIRCLE® product is launched in the market with the ECOCIRCLE® Product Mark (woven label).



Sale of the ECOCIRCLE® product

Recovery, integration and sorting of used ECOCIRCLE® products

Request for acceptance of the recovered ECOCIRCLE® product and sending of recovery labels



ECOCIRCLE® organizer
TEIJIN

The recovered ECOCIRCLE® product is transported to the Teijin Fibers recycling center.



PREVIOUS PAGE

For More Information about This Product

TO TOP OF THIS PAGE

Appendix 3: Common Threads Recycling Program on the Patagonia website

The screenshot shows the Patagonia website interface. At the top is a large banner image of a person in a dark, misty environment. Below the banner is the Patagonia logo with the tagline "committed to the core". A navigation bar contains links for "shop patagonia", "about patagonia", "customer service", and a search bar. Below the navigation bar are several promotional banners: "you have a choice" (surf collection), "READ AN ENVIRO REPORT" (Crossing a Line in Marine Conservation), "BEND TO BAJA" (Let the Trip Begin...), and "OCEANS AS WILDERNESS" (Action Alert!).

Below the banners is a section titled "Catalog Quick Shop: The quickest way to get your gear." with a circled link: [2005 Piolet d'Or Award](#). Below this is another circled link: [Change Your Underwear for Good: Patagonia's Garment Recycling Program](#).

At the bottom of the main content area is a navigation bar with links: "free catalog", "find a store", "email sign-up", "shopping cart", and "call us anytime 1.800.638.6464".

Below the navigation bar are four regional sections:

- 日本サイト (Japan Site):** Inspired by the dreamy powder and epic surf of Hokkaido, Patagonia Japan has been cranking turns since 1987.
- Patagonia Europe:** We started our European adventure in 1987 by opening a store in Chamonix, the birthplace of modern mountaineering.
- water GIRL:** Spirited clothing for athletes who love water – they embody the ageless soul of the water girl.
- LOTUS DESIGNS:** Our years of passion and practice have bred exceptional clothes and devices for enjoying life in the water.

Below these sections is a photo of Belinda Baggs in a kayak with the caption: "Belinda Baggs in trim and at speed, south of Sydney, Australia. Photo: Jeff Johnson".

At the bottom of the page is a footer with five columns of links:

- SHOPPING OPTIONS:** Shop Patagonia, Gift Cards, Catalog Quick Shop, Request a Catalog
- MORE IN STORE:** Our Retail Stores, Patagonia Dealers, Pro Sales, Affiliate Info, Corporate Sales/Group Sales
- CONTACT US:** Send us an Email (800-638-6464), Email Sign-Up, Jobs
- ACCOUNT INFO:** Shopping Cart, Your Account, Shipping Info, Order Status/Tracking
- CUSTOMER SERVICE:** Our Guarantee, Repairs and Returns, Size Chart, Product Care, Privacy/Security, Site Map

Source: <http://www.patagonia.com>

- Shop Patagonia
- About Patagonia
- Sports We Do
- Enviro Action
- Enviro Essays
- Grants Program
- Organic Cotton
- PCR Clothing
- Our Buildings
- Enviro Internship
- Conservation Alliance
- 1% For The Planet
- Beneficial T's
- Our Culture
- Design Philosophy
- Customer Service



Our Guarantee



View Your Cart



Gift Cards

Change Your Underwear for Good

Patagonia's Common Threads Recycling Program

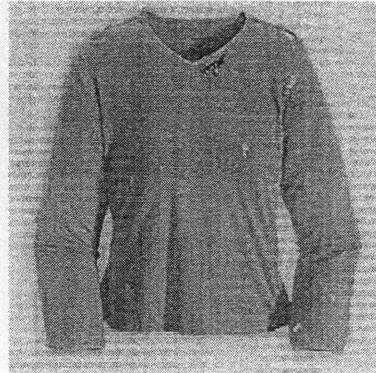
wear it out

Please make sure your Capilene® baselayer is thorough: worn out, buried, and dunked about recycling it.

We Want Your Underwear!

For the past 20 years, Patagonia Capilene® baselayers have accompanied hundreds of thousands of outdoor enthusiasts on countless adventures.

From climbing trips in the Cordillera to raft trips on the San Juan, they've kept us warm, dry and comfortable, blocked the sun's rays and even been used to strain pasta. But with enough use, even the highest quality clothing eventually wears out. And that's when we want your Capilene baselayer.



watch how it works

faq's

pdf's / add'l info

wear it out drop it off we recycle it it lives on

Water Girl® | Lotus Designs® | 日本サイト | Europe

Free Catalog | Shopping Cart | Gift Cards | Email Sign-Up | Our Guarantee
 Contact Us | Jobs | Affiliate Info | Corporate Sales/Group Sales
 Privacy & Terms of Use | Site Map | Home
 Customer Service | Your Account

Call us anytime 1.800.638.6464



Top Photo: Jeff Johnson | © 2006 Patagonia, Inc.

05/21/06 18:0

Source: http://www.patagonia.com/recycle/wearit_out.shtml

- Shop Patagonia
- About Patagonia
- Projects We Do
- Activist Action
- Activist Essays
- Grants Program
- Organic Cotton
- CR Clothing
- Our Buildings
- Activist Internship
- Conservation Alliance
- For The Planet
- Beneficial T's
- Work Culture
- Design Philosophy
- Customer Service



Our Guarantee



View Your Cart



Gift Cards

Change Your Underwear for Good

Patagonia's Common Threads Recycling Program

drop it off

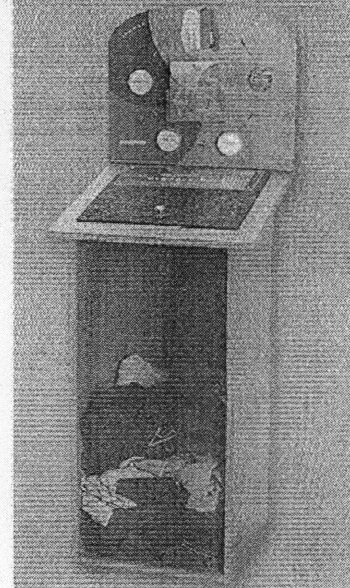
Our Patagonia stores and Patagonia Service Center are ready to accept it.

It's Easy

Just drop off your old Capilene baselayer (washed please) at a Patagonia store or send it to the Patagonia Service Center.

Mail It To:
 Patagonia Service Center,
 ATTN: Common Threads Recycling Program
 8550 White Fir Street,
 Reno, NV 89523-8939

Drop It:
At your local Patagonia store.



- watch how it works
- faq's
- pdf's / add'l info



wear it out drop it off we recycle it it lives on

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Call us anytime 1.800.638.6464



Top Photo: Jeff Johnson | © 2006 Patagonia, Inc.

05/21/06 18:00

- Patagonia
- Patagonia
- We Do
- Action
- Essays
- Program
- nic Cotton
- Clothing
- Buildings
- Internship
- ervation Alliance
- or The Planet
- icial T's
- Culture
- in Philosophy
- omer Service

-  Our Guarantee
-  View Your Cart
-  Gift Cards

Change Your Underwear for Good




Patagonia's Common Threads Recycling Program

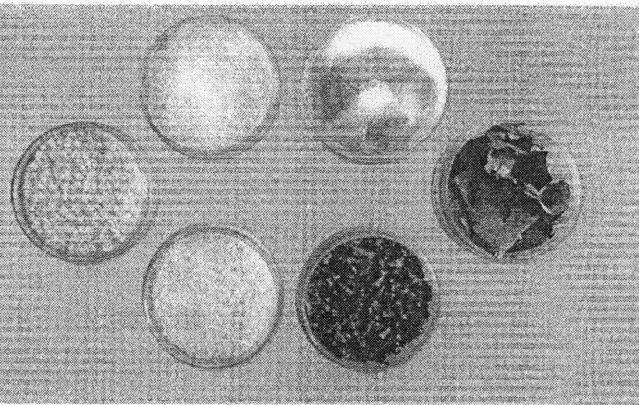
we recycle it

We turn old into new using ECOCIRCLE™ fiber-to-fiber recycling system.

We'll Recycle It

Our Common Threads Recycling Program uses the ECOCIRCLE™ fiber-to-fiber recycling system to make new Capilene garments from old. Our research shows the environmental benefits of recycling Capilene fabric into new clothing are significant.

-  watch how it works
-  faq
-  pdf's / add'l info



wear it out drop it off we recycle it it lives on

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05/21/06 18: 3

- o Patagonia
- ut Patagonia
- rts We Do
- iro Action
- iro Essays
- nts Program
- anic Cotton
- l Clothing
- Buildings
- iro Internship
- ervation Alliance
- For The Planet
- edical T's
- Culture
- ign Philosophy
- omer Service

-  Our Guarantee
-  View Your Cart
-  Gift Cards

Change Your Underwear for Good

Patagonia's Common Threads Recycling Program

it lives on

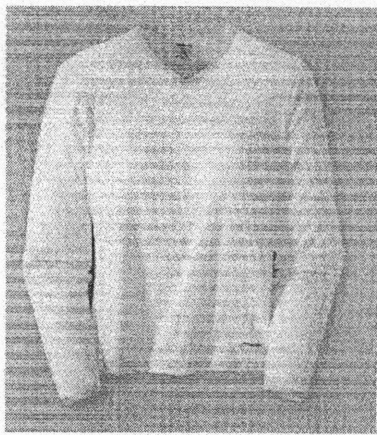
Recycled - and recyclable - the garment's life cycle continues in perpetuity.

We'll Recycle It

Our Common Threads Recycling Program uses the ECOCIRCLE™ fiber-to-fiber recycling system to make new Capilene garments from old. Our research shows the environmental benefits of recycling Capilene fabric into new clothing are significant.

One Last Thing

We don't want your Capilene baselayer if it can still be worn. But if it's so worked no one would ever wear it again, give it to us. We know what to do with it.



watch how it works

faq's

pdf's / add'l info



wear it out drop it off we recycle it it lives on

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Call us anytime 1.800.638.6464



Top Photo: Jeff Johnson | © 2006 Patagonia, Inc.

05/21/06 18:)

Source: http://www.patagonia.com/recycle/itlives_on.shtml

Appendix 5: Variable list

- 1) "% of Customer who Redeem Rebates"=
 $\text{Recycling Probability} * \text{Probability of Redeeming Rebate}$
Units: Dimensionless
- 2) Actual Rate of Return=
 $\text{Garments to Recycle}$
Units: Garment/Month
- 3) Additional Demand from Rebate=
 $\text{Base Customer Order Rate} * (1 + \text{Elasticity} * \text{Percentage Rebate} * \text{"Offer Rebate?"})$
Units: Garment/Month
- 4) Additional Yards Needed=
 $\max(0, \text{Need for Additional Capilene Garments} * \text{Yards per Garment} - \text{Capilene in Transit})$
Units: Yard
- 5) Adjustment for Capilene Inventory=
 $(\text{Desired Capilene Inventory} - \text{Finished Capilene}) / \text{Capilene Inventory Adjustment Time}$
Units: Yards/Month
- 6) Adjustment for Greige=
 $(\text{Desired Qty of Greige} - \text{Undyed Capilene}) / \text{Greige Adjustment Time}$
Units: Yards/Month
- 7) Arrival Rate=
 $\text{Capilene in Transit} / \text{Time to Ship}$
Units: Yard/Month
- 8) Average Life of Product=
90
Units: Months
- 9) Base Customer Order Rate=
 $\text{Initial Customer Order Rate} * \text{Input}$
Units: Garment/Month
- 10) Base Recycling Probability=
0.02
Units: Dimensionless
- 11) Base Volume=
98.4
Units: Yards/Month
- 12) Capilene in Transit= INTEG (
 $+\text{Shipments} - \text{Arrival Rate},$
 $\text{Patagonia Expected Demand} * \text{Time to Ship} * \text{Yards per Garment}$)
Units: Yards
- 14) Capilene Inventory Adjustment Time=
3
Units: Months

- 15) Capilene Orders=
 Additional Yards Needed/Time btw Orders
 Units: Yard/Month
- 16) Capilene SS Coverage=
 0.2
 Units: Months
- 17) Change in Pink Noise = (White Noise - Pink Noise)/Noise Correlation Time
 Units: 1/Month
- 18) Change in Pink Noise 0 = (White Noise 0 - Pink Noise 0)/Noise Correlation Time 0
 Units: 1/Month
- 19) Consumers= INTEG (
 +Sales-Discard Rate-Returned Garments,
 Customer Demand*Average Life of Product)
 Units: Garment
- 20) Cost of Returns=
 Returned Garments*Unit Cost of Returns
 Units: Dollars/Month
- 21) Customer Demand=
 Demand from Customer without Rebates+Demand from Customers with Rebates
 Units: Garment/Month
- 22) Demand from Customer without Rebates=
 Base Customer Order Rate*(1-"% of Customer who Redeem Rebates")
 Units: Garment/Month
- 23) Demand from Customers with Rebates=
 "% of Customer who Redeem Rebates"*Additional Demand from Rebate
 Units: Garment/Month
- 24) Desired Capilene Inventory=
 Desired Finished Inventory Coverage*Teijin Expected Demand
 Units: Yards
- 25) Desired Capilene Production=
 max(0, Teijin Expected Demand+Adjustment for Capilene Inventory)
 Units: Yards/Month
- 26) Desired Capilene Start Rate=
 max(0,Desired Capilene Production+Adjustment for Greige)
 Units: Yards/Month
- 27) Desired Finished Inventory Coverage=
 Capilene SS Coverage+Min Capilene Order Processing Time
 Units: Months
- 28) Desired Garment Inventory=
 Desired Inventory Coverage*Patagonia Expected Demand*1.8
 Units: Garment

- 29) Desired Garment Production Rate=
 $\frac{\text{Need for Additional Capilene Garments}}{\text{Production Time}}$
 Units: Garment/Month
- 30) Desired Qty of Greige=
 $\text{Dyeing Time} * \text{Desired Capilene Production}$
 Units: Yards
- 31) Desired Sales Rate=
 $\frac{\text{Customer Demand}}{\text{Production Time}}$
 Units: Garment/Month
- 32) Discard Rate=
 $\frac{\text{Garments to Landfill}}{\text{Production Time}}$
 Units: Garment/Month
- 33) Dye and Finish=
 $\text{delay} * (\text{Virgin Resin} + \text{Recycled Fibers}) / \text{Dyeing Time}$
 Units: Yards/Month
- 34) Dyeing Time=
 $\frac{1}{2}$
 Units: Months
- 35) Elasticity=
 1.5
 Units: Dimensionless
- 36) Feasible Garment Production=
 $\frac{\text{Arrival Rate}}{\text{Yards per Garment}}$
 Units: Garment/Month
- 37) Fiber Type Recyclability=
 0.75
 Units: Dimensionless
- 38) FINAL TIME = 120
 Units: Month
- 39) Finished Capilene= INTEG (
 $\text{Dye and Finish} - \text{Shipments},$
 $\text{Desired Capilene Inventory}$)
 Units: Yard
- 40) Finished Garments= INTEG (
 $\text{Garment Production} - \text{Sales},$
 $\text{Desired Garment Inventory}$)
 Units: Garment
- 41) Garment Price=
 $\frac{(1.3 + 0.7 * 1.3 / 0.3)}{(1 - 0.16)}$
 Units: Dollars/Garment
- 42) Garment Production=
 $\min(\text{Feasible Garment Production}, \text{Desired Garment Production Rate})$

- Units: Garment/Month
- 43) Garments to Discard=
 $\text{delay}3(\text{Consumers}, \text{Average Life of Product}) / \text{Average Life of Product}$
 Units: Garment/Month
- 44) Garments to Landfill=
 $(1 - \text{Recycling Probability}) * \text{Garments to Discard}$
 Units: Garment/Month
- 45) Garments to Recycle=
 $\text{Recycling Probability} * \text{Garments to Discard}$
 Units: Garment/Month
- 46) Greige Adjustment Time=
 1
 Units: Months
- 47) Initial Customer Order Rate=
 100
 Units: Garment/Month
- 48) INITIAL TIME = 0
 Units: Month
- 49) Input=
 $1 + (\text{STEP}(\text{Step Height}, \text{Step Time}) +$
 $(\text{Pulse Quantity} / \text{TIME STEP}) * \text{PULSE}(\text{Pulse Time}, \text{TIME STEP}) +$
 $\text{RAMP}(\text{Ramp Slope}, \text{Ramp Start Time}, \text{Ramp End Time}) +$
 $\text{Sine Amplitude} * \text{SIN}(2 * 3.14159 * \text{Time} / \text{Sine Period}) +$
 $\text{STEP}(1, \text{Noise Start Time}) * \text{Pink Noise } 0)$
 Units: Dimensionless
- 50) Max Recyclable Fibers=
 $\text{Returned Capilene} / \text{Recycled Fiber Process Time}$
 Units: Yards/Month
- 51) Maximum Sales Rate=
 $\text{max}(0, \text{Finished Garments} / \text{Minimum Order Processing Time})$
 Units: Garment/Month
- 52) Min Capilene Order Processing Time=
 3
 Units: Months
- 53) Minimum Order Processing Time=
 3
 Units: Months
- 54) Need for Additional Capilene Garments=
 $\text{Desired Garment Inventory} - \text{Finished Garments} + \text{Production Time} * \text{Patagonia Expected Demand}$
 Units: Garment
- 55) Non rebate revenues=
 $\text{Demand from Customer without Rebates} * \text{Garment Price}$

Units: Dollars/Month

56) Nonrecyclable yarns needed=

Virgin Fiber for Virgin Yarn+Virgin Fibers Needed for Recycled Yarn

Units: Yards/Month

57) "Offer Rebate?"=

0

Units: Dimensionless

58) Order Fulfillment Ratio=

Order Fulfillment Table(zidz(Maximum Sales Rate,Desired Sales Rate))

Units: Dimensionless

59) Order Fulfillment Table(

[(0,0)-(10,10)],(0,0),(0.2,0.2),(0.4,0.4),(0.6,0.58),(0.8,0.73),(1,0.85),(
1.2,0.93),(1.4,0.97),(1.6,0.99),(1.8,1),(2,1))

Units: Dimensionless

60) Patagonia Change in Expected Orders=

(Customer Demand-Patagonia Expected Demand)/Patagonia Time to Adjust Demand
Expectations

Units: Garments/(Months*Months)

61) Patagonia Costs=

Cost of Returns+Patagonia Production Costs+Patagonia Raw Material Costs

Units: Dollars/Month

62) Patagonia Expected Demand= INTEG (

Patagonia Change in Expected Orders,
Base Customer Order Rate)

Units: Garment/Month

63) Patagonia Incremental Profits=

Patagonia Revenues-Patagonia Costs

Units: Dollars/Month

64) Patagonia Production Costs=

Garment Production*Patagonia Unit Production Costs

Units: Dollars/Month

65) Patagonia Profits= INTEG (

Patagonia Incremental Profits,
0)

Units: Dollars

66) Patagonia Raw Material Costs=

Teijin Revenues

Units: Dollars/Month

67) Patagonia Revenues=

Non rebate revenues+Revenue from Rebate Customers+Revenue from Garment returns

Units: Dollars/Month

68) Patagonia Time to Adjust Demand Expectations=

2

Units: Months

69) Patagonia Unit Production Costs=

$1.04 * 1.25 * 0.7 / 0.3$

Units: Dollars/Garment

70) Percentage Rebate=

0

Units: Dimensionless

71) PET Unit Cost=

1

Units: Dollar/Yard

72) Pink Noise = INTEG(Change in Pink Noise,0)

Units: Dimensionless

73) Pink Noise 0 = INTEG(Change in Pink Noise 0,0)

Units: Dimensionless

74) Price of Capilene=

$zidz(\text{Teijin Costs}, \text{Teijin Expected Demand} * (1 - \text{Teijin Target Profit Margin}))$

Units: Dollars/Yard

75) Price of PET Bottles=

0.25

Units: Dollars/Yard

76) Price of Used Garments=

$\max(0, \text{Price of PET Bottles} + \text{PET Unit Cost} - \text{PET Unit Cost} * \text{Recycling Cost})$

Units: Dollars/Yard

77) Price Table(

$[(0,0)-(2,1)], (0,0), (0.2,0.1), (0.4,0.3), (0.6,0.6), (0.8,0.8), (1,0.9), (1.25, 0.95), (1.5,0.97), (2,1)$

Units: Dimensionless

78) Probability of Redeeming Rebate=

0.3

Units: Dimensionless

79) Production Costs=

$\text{Recycling Unit Cost} * \text{Recycled Fibers} + \text{Virgin Resin} * \text{PET Unit Cost}$

Units: Dollars/Month

80) Production Time=

3

Units: Month

81) Ramp End Time=

120

Units: Month

82) Ramp Slope=

0.1

- Units: 1/Month
- 83) Ramp Start Time=
0
Units: Month
- 84) Raw Material Costs=
Virgin Resin*Price of PET Bottles+Price of Used Garments*Returned Fabric
Units: Dollars/Month
- 85) Raw Starts Check=
Virgin Resin+Recycled Fibers
Units: Yards/Month
- 86) Recyclable Fibers Needed=
 $\max(0, \text{Recyclable yarns Needed} * \text{Recycled fiber content})$
Units: Yards/Month
- 87) Recyclable Fibers Ratio=
Recycled Fiber Fulfillment Table(zidz(Max Recyclable Fibers, Recyclable Fibers Needed))
Units: Dimensionless
- 88) Recyclable yarns Needed=
Desired Capilene Start Rate*Fiber Type Recyclability
Units: Yards/Month
- 89) Recycled fiber content=
0.9
Units: Dimensionless
- 90) Recycled Fiber Fulfillment Table(
[(0,0)-(2,1)],
(0,0),(0.2,0.2),(0.4,0.4),(0.6,0.58),(0.8,0.73),(1,0.85),(1.2,0.93),(1.4,0.97),(1.6,0.99),(1.8,1),(2,1))
Units: Dimensionless
- 91) Recycled Fiber Process Time=
2.25
Units: Months
- 92) Recycled Fiber Used=
Recyclable Fibers Ratio*Recyclable Fibers Needed
Units: Yards/Month
- 93) Recycled Fibers=
 $\max(0, \text{Recycled Fiber Used})$
Units: Yards/Month
- 94) Recycling Cost=
Recycling Cost Table(Recycled Fibers/Base Volume)
Units: Dimensionless
- 95) Recycling Cost Table(
[(0,0)-(1,2)],
(0,2),(0.1,1.9),(0.2,1.76),(0.3,1.6),(0.4,1.44),(0.5,1.25),(0.6,1.15),(0.7,1.09),(0.8,1.05),(0.9,1.02),(1,1))
Units: Dimensionless

- 96) Recycling Probability=
 $\min(1, \text{Base Recycling Probability} + \text{Sensitivity of Recycling to Rebate} * \text{Price Table} (\text{Percentage Rebate} * \text{Offer Rebate?}))$
 Units: Dimensionless
- 97) Recycling Unit Cost=
 $\text{PET Unit Cost} * (\text{Recycling Cost})$
 Units: Dollar/Yard
- 98) Returned Capilene= INTEG (
 $+\text{Returned Fabric} - \text{Recycled Fibers},$
 $\text{Actual Rate of Return} * \text{Yard per Returned Garment} * \text{Recycled Fiber Process Time})$
 Units: Yards
- 99) Returned Fabric=
 $\text{Returned Garments} * \text{Yard per Returned Garment}$
 Units: Yards/Month
- 100) Returned Garments=
 $\text{Actual Rate of Return}$
 Units: Garment/Month
- 101) Revenue from Garment returns=
 $\text{Price of Used Garments} * \text{Returned Fabric}$
 Units: Dollars/Month
- 102) Revenue from Rebate Customers=
 $\text{Demand from Customers with Rebates} * \text{Garment Price} * (1 - \text{Percentage Rebate})$
 Units: Dollars/Month
- 103) Safety Stock Coverage=
 0.1
 Units: Months [0,6]
- 104) Sales=
 $\text{Desired Sales Rate} * \text{Order Fulfillment Ratio}$
 Units: Garment/Month
- 105) Sensitivity of Recycling to Rebate=
 0.4
 Units: Dimensionless
- 106) Shipments=
 $\min(\text{Finished Capilene} / \text{Time to Ship}, \text{Capilene Orders})$
 Units: Yard/Month
- 107) Step Height=
 0
 Units: Dimensionless
- 108) Step Time=
 0
 Units: Month

- 109) Teijin Change in Expected Orders=
 (Capilene Orders-Teijin Expected Demand)/Teijin Time to Average Order Rate
 Units: Yards/(Months*Months)
- 110) Teijin Costs=
 Production Costs+Raw Material Costs
 Units: Dollars/Month
- 111) Teijin Expected Demand= INTEG (
 +Teijin Change in Expected Orders,
 Capilene Orders)
 Units: Yards/Month
- 112) Teijin Incremental Profits=
 Teijin Revenues-Teijin Costs
 Units: Dollars/Month
- 113) Teijin Revenues=
 Capilene Orders*Price of Capilene
 Units: Dollars/Month
- 114) Teijin Target Profit Margin=
 0.04
 Units: Dimensionless
- 115) Teijin Time to Average Order Rate=
 2
 Units: Months
- 116) Tejin Profits= INTEG (
 Teijin Incremental Profits,
 0)
 Units: Dollars
- 117) Time btw Orders=
 1
 Units: Month
- 118) TIME STEP = 0.0625
 Units: Month
- 119) Time to Ship=
 2
 Units: Months
- 120) Undyed Capilene= INTEG (
 +Virgin Resin+Recycled Fibers-Dye and Finish,Desired Qty of Greige)
 Units: Yards
- 121) Unit Cost of Returns=
 0.4
 Units: Dollars/Garment
- 122) Virgin Fiber for Virgin Yarn=
 Desired Capilene Start Rate*(1-Fiber Type Recyclability)

Units: Yards/Month

123) Virgin Fibers Needed for Recycled Yarn=
Recyclable yarns Needed-Recycled Fiber Used
Units: Yards/Month

124) Virgin Production Starts=
max(0, Nonrecyclable yarns needed)
Units: Yards/Month

125) Virgin Resin=
max(0, Virgin Production Starts)
Units: Yards/Month

126) White Noise = Noise Standard Deviation*((24*Noise Correlation Time/TIME STEP)
)^0.5*(RANDOM 0 1() - 0.5))
Units: Dimensionless

127) White Noise 0 = Noise Standard Deviation 0*((24*Noise Correlation Time 0/TIME STEP)
)^0.5*(RANDOM 0 1() - 0.5))
Units: Dimensionless

128) Yard per Returned Garment=
0.9
Units: Yards/Garment

129) Yards per Garment=
1
Units: Yards/Garment

29) Desired Inventory Coverage=
Minimum Order Processing Time+Safety Stock Coverage
Units: Months

Appendix 6: Capilene products



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 1.800.638.6464

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enter keyword or style #
SEARCH

your search results

Your search for **capilene** returned 113 results.

Narrow your results below:

Men's (45)

Women's (61)

Kids' (7)

Related site information
0 items found

Begin a new search

men's [View all results \(45\)](#)

		
M's Capilene® SW Boxers \$29.00	M's Capilene® SW T-Shirt \$32.00	M's Synchronia® Marsupial \$78.00

women's [View all results \(61\)](#)

		
W's Capilene® Briefs \$18.00	W's El Cap Jacket \$90.00	W's Lightweight R4® Jacket \$190.00

kids' [View all results \(7\)](#)

		
Kids' Capilene® MW Bottoms \$22.00	Kids' Capilene® MW Crew \$22.00	Baby Capilene® SW Set RETAIL \$38.00 NOW \$27.00

[Patagonia Gift Card](#)

Rhythm



W's Deopler Top
\$75.00

Best Sellers



M's Synchronia® Marsupial
\$78.00




SHOPPING OPTIONS
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1 of 2
05/21/06 18:43

Source: <http://www.patagonia.com>

Appendix 7: PCR product example



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Shop Patagonia


- Men's
- Women's
- Kids'
- Packs/Travel Gear
- Shop by Sport
- Web Specials

About Patagonia


Customer Service




Our Guarantee



View Your Cart



Gift Cards



M's Eco Torrentshell

\$185.00 Style No. 27067

Zoom

Description

Ideal Uses

Details

NEW **PCR**

This highly compressible two-layer rain shell, made entirely from recycled polyester, is wind-resistant, fully seam-sealed and treated with a Deluge® DWR (durable water repellent) finish to shed water. The mesh interior wicks moisture, keeping inner layers dry. Weather-deflecting features include a removable zip hood, detachable cuffs and storm flap over the top armholes.

How it fits:

Regular fit

Bog Green (535)

Qty: 1

Choose a size:


ADD TO MY CART

Size Chart & Fit Info

Bog Green (535)

Click swatch to view color


You may also like:



M's Breezeway Jacket

\$110.00

An eco-friendly, windproof, water-resistant PCR® (post-consumer recycled) shelled and mesh lined jacket.




M's Classic EI Cap Jacket

\$90.00

This indispensable base layer can be worn as a cold-weather midlayer or as a warm-up in mild conditions.

<p>SHOPPING OPTIONS</p> <ul style="list-style-type: none"> Shop Patagonia Gift Cards Catalog Quick Shop Request a Catalog 	<p>MORE IN STORE</p> <ul style="list-style-type: none"> Our Retail Stores Patagonia Dealers Pro Sales Affiliate Info Corporate Sales/ Group Sales 	<p>CONTACT US</p> <ul style="list-style-type: none"> Send us an Email 800-638-6464 Email Sign-Up Jobs 	<p>ACCOUNT INFO</p> <ul style="list-style-type: none"> Shopping Cart Your Account Shipping Info Order Status/ Tracking 	<p>CUSTOMER SERVICE</p> <ul style="list-style-type: none"> Our Guarantee Repairs and Returns Size Chart Product Care Privacy/Security Site Map
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Water Girl® | Lotus Designs® | 日本サイト | Europe



Source: <http://www.patagonia.com>

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