Economic and Environmental Implications of Online Retailing in the United States

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Abstract

The advent of the Internet and e-commerce has brought a new way of marketing and selling many products, including books. The system-wide impacts of this shift in retail methods on cost and the environment are still unclear. While reductions in inventories and returns provide significant environmental savings, some of the major concerns of the new e-commerce business models are the energy and packaging materials used by the logistics networks for product fulfillment and delivery. In this paper, we analyze the different logistics networks and assess the environmental and cost impacts of different delivery systems. With a return (remainder) rate of 35% for best-selling books, e-commerce logistics are less costly and create lower environmental impacts, especially if private auto travel for shopping is included. Without book returns, costs and environmental effects are comparable for the two delivery methods.

1. Introduction

It is tempting to assume that the sale of products on the Internet is beneficial to the environment. For example, emissions from vehicles driven to shopping malls can be avoided, retail space can be reduced, and inventories and waste can be reduced. However, a product ordered online may be shipped partially by airfreight across the country and require local truck delivery. Also, the product is likely to be packaged individually, and the packaging may not be reused. The adverse impacts on the environment of such transportation can be significant, and the net effect of different logistics systems is not obvious (Matthews 2000).

Books are regularly purchased online as well as in retail stores. The high number of remainders (unsold books) also leads to an interesting case study. After sales have peaked, these remainders are either discarded, recycled or sold to a discount bookstore. E-commerce allows for lower inventories (since there is only one inventory point) and less remainders, thus reaping environmental benefits due to avoided warehousing and paper production.

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Two models of logistics networks will be considered in this case study. First, traditional retailing involves a retail outlet. In this model, books are shipped from the publisher through distributors and warehouses to the retail outlet. The customer then purchases the book at a retail store and brings it home. Second, the e-commerce model ships the book from the publisher to one warehouse by truck and then by air freight to a regional hub where it is sent by delivery truck to the customer.

Cost calculations are based on the comparative costs involved in selling a million dollars worth (at production) of 'best seller' books, or roughly 286,000 books at an assumed production cost of $3.50 each. We assume each book is 23 x 6 x 16 cm in size (9 x 2.25 x 6.25 inches) and weighs 1.1 kg (2.4 pounds).

2. Traditional Retailing Method

The traditional method of retail, where books are sold at retail stores, can be modeled as a series of transport links among facilities. The books are transported from the printer to a national warehouse and then shipped again to a regional warehouse. From the regional warehouse, the books are transported to a retail store, where a customer buys a book and takes it home. In addition there is a return link for unsold copies as roughly 35% of best sellers are unsold (Publishers Weekly 1997). We assume all transportation is carried out by truck in traditional distribution, and the distance between all destinations (e.g. warehouses and stores) is separated into segments of 805 km (500 miles). This allows the model to be easily adjusted for differing distances. The average consumer lives 16 km (10 miles) away from a bookstore (Brynjolfsson 2000) but consumers tend to buy more than one item at a bookstore (or as part of a shopping trip); thus, only a round-trip distance of 5 mi. was used for the round-trip to the bookstore.

We assume that the 35% remainder rate for books in traditional retail inherently causes the production of 35% more books than sold (or a total of 386,000 books). All of these books are transported in boxes of 10 to bookstores. Assuming that each box is 51 x 41 x 41 cm (20 x 16 x 16 inches) and weighs 910 grams (2 pounds), the cost of each box is $1.33 (ULINE 2001).

The environmental effects of automotive trips made by consumers to bookstores to purchase books must also be taken into account. Taking the fuel economy of a passenger car to be 9.6 km/l (22.5 mpg), and the fuel economy of a light truck to be 6.5 km/liter (15.3 mpg) (US EPA 1997), we can calculate that the energy required per mile for a passenger car is 3.6 MJ/km (5.8MJ/mi) and for a light truck is 5.3 MJ/km (8.6 MJ/mi). The environmental impacts of an average trip made to the bookstore are shown in Table 1.

Returns of unsold books from retailers in the traditional model are an important issue. Shipping of returns involves an additional truck leg, which we again assume to be 805 km (500 miles). We ignore returns from customers after purchases; we

Effect	Impact/km		Impact for 5 mile round trip		Total
	Car	Light truck	Car	Light truck	
Energy Use	3.6 MJ/km	5.3 MJ/km	29 MJ	43 MJ	9.7 TJ
Hydrocarbons	1.8 g/km	2.3 g/km	14.5 g	18.5 g	4,550 kg
CO	13.7 g/km	18 g/km	110 g	145 g	35,000 kg
NOx	0.9 g/km	1.2 g/km	7.5 g	9.5 g	2,350 kg
CO2	225 g/km	338 g/km	1818 g	2728 g	611,000 kg

Source: (US EPA 1997, NHTSA 1998), Total based on 286,000 trips, 65% cars, 35% trucks

Table 1
Environmental Impacts of Round trips to Bookstores in Passenger Vehicles

assume they would involve similar personal trips for both traditional and e-commerce retailing.

3. E-Commerce Retailing Logistics

We assume that the e-commerce method of selling a book (where a book is marketed and sold online) has fewer links but involves airfreight from the e-commerce warehouse to a Regional Logistics Center. We also assume that this warehouse is located near or at an air hub of a major logistics carrier (e.g. UPS or FedEx) so transfer from warehouse to the carrier is not included. Not all orders are shipped by air– this assumption is intended to represent a 'worst case' scenario for analysis.

The books are shipped 805 km (500 miles) from the printer to the company's major distribution warehouse via truck. The books are then air freighted to a regional center (again assuming a distance of 805 km) from which the books are delivered by local courier truck to the customer's residence.

The packaging used in e-commerce tends to be corrugated cardboard boxes. Assuming a box size of 30 x 23 x 11 cm (12 x 9 x 4.5 inches), a weight of 317 g (0.7 pounds), the cost of each box to be $0.41 (ULINE 2001) and that the books are packaged individually, we can calculate the cost in individually packaging the total shipment of $1 million worth of books as $117,000. We assume no remainders or returns in this model. However, the cost of the bulk packaging of 286,000 books also needs to be included, $38,000, for a total of $155,000.

4. Comparative Costs of Traditional and E-commerce Logistics

Selling $1 million of books in the traditional model with remainders requires 386,000 to be produced and shipped given the 35% remainder rate. The total weight of shipments in the traditional model is 455 Mg (501 short tons)– including 420 Mg (463 short tons) of books and 34.5 Mg (38 short tons) of bulk packaging. A base production of $1 million of bestseller books in the e-commerce (no remainders) model requires only 286,000 books to be shipped. The e-commerce model ships a total of 338 Mg (371 short tons) in bulk (including 343 short tons of books and 29 short tons of packaging) and a total of 403 Mg (443 tons) individually. A comparison of these costs is shown in Table 2. We present estimates for two traditional models - with and without remainders. We use the 35% remainder rate to scale up costs where appropriate.

With a zero return rate, the traditional system has a slightly higher overall cost than e-commerce but can provide immediate service to customers. But generally, a certain proportion of the books published will remain unsold, and will be either returned to the publisher to be recycled or sold to discount stores. Assuming the average return rate for bestsellers of 35%, our estimate of e-commerce retailing costs is far lower than the traditional system. Our estimates do not include any costs associated with stock-outs in the traditional system; the e-commerce model places books not immediately available on back-order for eventual delivery. Also, there are benefits associated with immediately purchasing and perusing books. Finally, on-line booksellers may have a wider selection than conventional bookstores.

5. Comparative Environmental Costs

E-commerce logistics systems involve more reliance upon airfreight service than truck or rail modes. Airfreight requires much higher energy and fuel usage, with corresponding large air pollution emissions. Table 3 shows some supply chain environmental effects from $1 Million of trucking, airfreight and book publishing (CMU GDI 2001). Table 4 shows the use of energy, emission of conventional air pollutants, hazardous waste generated and greenhouse gas emissions for the trucking, air freight, packaging, fuel production and book production for the traditional and e-commerce retail models.

In order to quantify the environmental impacts associated with the production of the fuel used in passenger vehicles, a producer price of $0.90/gallon was assumed for our calculations. This figure was then combined with the values for the fuel efficiencies of passenger cars and light trucks above to arrive at the dollar amount of fuel used for passenger trips to the bookstores. Using a fleet composition of 35% light trucks and 65% passenger cars (NHTSA 1998), the dollar cost of fuel for one round trip to the bookstore is $0.225. For 286,000 trips to the bookstore, the monetary cost of the fuel used is $64,400.

Our results indicate significant differences between the retail fulfillment modes, with e-commerce having less of an environmental impact in all categories when

Item	Traditional Retailing			E-Commerce Retailing	
		Without Returns	W/ 35% Return		
	Calculation Notes	Cost ($1000)	Cost ($1000)	Calculation Notes	Cost ($1000)
Packaging	$1.33 x 286,000 books/10 books per box	38	51*	($1.33 x 286,000 books/ 10 books/box) + ($0.41 x 286,000 books)	155
Bulk Truck Shipments to Warehouse	3 trips*805 km/ trip (500 mi) of 338 metric tons (371 short tons) at $0.18/mt-km ($0.26/ ton-mile) (US DOT 1999)	144	195*	Only one 805 km (500 mile) shipment of 338 metric tons (371 short tons)	48
Air Freight	None	0	0	One 805 km (500 miles) trip - 403 tons (443 short tons) at $0.55/mt-km ($0.80/ ton-mile) (US DOT 1999)	177
Local Delivery/ Pickup	8 km (5 miles) at $0.21/ km ($0.33/mile) for 286,000 pickups.	472	472	Local delivery charge of $1.50 for 286,000 books	440
Retailing Overhead Cost	12% revenue with average $15/book (Meeker 1997) for 286,000 books	515	695*	4% of revenue with average $15/book (Meeker 1997) for 286,000 books	172
Return Shipping from Retailer	805 km (500 mi) of returns (100,000 books *10 books/box * $0.26/mi)	0	17		
Return Production Cost	$3.5 of 100,000 books	0	350		
Total without private auto		697	1,308		992
Total with private auto		1,169	1,780		992

Table 2
Comparative Estimated Costs of Logistics and Returns for Traditional versus E-Commerce Book Retailing

compared to the traditional model with returns. The comparison between e-commerce and the traditional model without returns is less clear. Overall, emissions from passenger vehicle trips (including fuel production) contribute significantly to the environmental impacts. By eliminating these trips, emissions of greenhouse gases and conventional air pollutants are significantly reduced in the e-commerce model. However, the increased air freight and packaging of the e-commerce system reduce much of the benefits from reduced passenger trips.

Effect	Trucking	Air Freight	Book Production	Paperboard Containers and Boxes	Fuel Production
Energy (TJ)	25	39	7	23	109
Conventional Air Pollutants (mT)	42	16	6	22	27
RCRA Hazardous Waste (mT)	43	53	17	69	465
Greenhouse Gas Emissions (CO_2 Equivalents, mT)	1672	2483	453	1640	5234

Table 3
Some Effects of $ 1M of Trucking, Air Freight and Book Publishing Production

As seen in Table 4, the e-commerce impacts lie roughly between the zero and 35% return traditional models. Thus, the e-commerce model is at worst comparable to the traditional model, and under normal conditions, superior. The only effect of concern is greenhouse gas emissions, which are a result of the substitution of air freight and increased packaging.

A sensitivity analysis of the results was performed between the traditional model with 35% returns and the e-commerce model. No sensitivity analysis was done against the zero returns traditional model given the already clear tradeoffs. Thus, if the air freight distance is 870 km (540 miles) rather than 805 km, the emissions of greenhouse gases in the e-commerce model would equal those in traditional (with remainders). Likewise, if the round-trip allocated distance to local retailers drops 66% to 2.7 km (1.7 miles), conventional pollutant emissions are higher in e-commerce. This analysis reinforces the importance of which environmental effects cause concern. As greenhouse gas emissions are currently unregulated, and thus unlikely to be the focus of any decision, the sensitivity analysis suggests that significant changes in the assumptions would be needed for the traditional retail model (with returns) to be superior than the e-commerce model.

As noted above, this paper assumed that all shipping of e-commerce book orders were done by airfreight (a worst case scenario). However, many orders are shipped exclusively by truck. This means that the actual effects from e-commerce delivery would be generally lower because of the trucking. This would make e-commerce even more competitive when comparing energy and environmental effects.

		Energy (TJ)	Conventional Air Pollutants (mT)	RCRA Hazardous Waste Generated (mT)	Greenhouse Gas Emissions (CO2 Equivalents, mT)
Trad. Retail (35% returns)	Trucking (inc. returns)	5.3	8.9	9.1	354
	Production	9.45	8.1	23	612
	Packaging	1.2	1.1	3.5	84
	Passenger Trips[a3]	9.7	42	0	611
	Passenger Fuel Production	7	1.7	30	337
	Total	**33**	**62**	**66**	**2000**
Trad. (no returns)	Trucking	3.6	6	6.2	241
	Production	7	6	17	453
	Packaging	0.9	0.8	2.6	62
	Passenger Trips	9.7	42	0	611
	Passenger Fuel Production	7	1.7	30	337
	Total	**28**	**57**	**56**	**1704**
E-commerce	Trucking	1.2	2	2	80
	Air	7	2.8	9.4	440
	Production	7	6	17	453
	Packaging	3.6	3.4	10.7	254
	Delivery Trips	11	18.5	19	736
	Total	**30**	**33**	**58**	**1963**

Table 4

Comparative Effects of Trucking, Air Freight and Returns Book Production for Traditional Retailing (with and without returns)

Examples of potential spillover effects from electronic commerce that were not analyzed include structural changes to the economy, substitution of manual or physical processes to digital systems, et cetera (Romm 1999).

[3] For Passenger Trips, this includes only Carbon Monoxide, Nitrogen Oxides and Hydrocarbons. For other categories, the figure includes Carbon Monoxide, Nitrogen Dioxide, Sulphur Dioxide, VOC, Lead and PM10 (particulates less than 10 microns in diameter).

6. Conclusions

We have analyzed a generic scenario for traditional versus E-Commerce retailing of a single commodity, best-selling books. For further results, see Matthews (2001). Our analytical approach can be adjusted for different assumptions about shipping distances, return rates or shopping allocations. By altering these critical parameters, E-Commerce can be found to be more or less costly than the traditional system. It is noted that different assumptions about population density (and thus, distances to retail stores) and order sizes would significantly change the results. Nevertheless, our base analysis case suggests that E-Commerce sales have a cost advantage and environmental benefits.

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