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Energy analysis of e-commerce and conventional retail distribution of books in Japan

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Abstract

Energy use associated with distribution via e-commerce and conventional retail is compared for book sales in Japan. The simulation of energy consumption includes the following factors: fossil fuel used by trucks in distribution from distributor to bookstore or e-commerce firm, transport fuel used by the consumer or courier service production of packaging, and energy for appliances and climate control at the point of sale (home or bookstore). Results indicate a crossover in environmental performance according to population density. Conventional retail uses less energy than e-commerce in dense urban areas, mainly due to avoided packaging, but can consume more in suburban and rural areas due to the inefficiency of personal automobile transport.

1. Background

The transport sector is a priority area for mitigation of climate change and other energy-related environmental impacts. Energy demand accorded to transport is both significant and increasing; it represented 26.5% of world energy demand in 1995, up from 24.2% in 1985 (WRI, 1998, 336). The rate of increase in transport energy is particularly high in developed nations. For example, in the US, Germany and Japan the increases in transport share over the period 1985-1995 were 3.8%, 7.0% and 3.0% respectively (WRI, 1998, 336-7).

In dealing with the challenges associated reducing environmental impacts associated with transport, it is natural to focus attention on the dominant technological shift of our era, Information and Communication Technologies (ICTs). One aspect of the connection between transport and the ICT revolution is the emergence of a new set of modes or "technologies", such as e-commerce, telecommuting, teleconferencing and intelligent transport systems. While use of these modes is steeply increasing, it is not yet clear at this point to what extent they represent environmen-

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tally friendly technologies. Stating the issue more precisely, we must understand the connections between conditions of implementation and the environmental performance of ICT-based transport modes. This suggests the need for a set of micro-level evaluations of these technologies based on a systems, or life cycle, approach.

2. Case study: energy use in distribution of book e-commerce vs. conventional retail in Japan

In this article we analyse the environmental performance of business-to-consumer (b2c) e-commerce relative to distribution and sales via traditional retail stores. Environmental performance in this context is defined as the energy consumption associated with distributing, packaging and selling a good. Two conditions thought to substantially affect the environmental performance of b2c e-commerce are population density, which affects transport modes and distances, and the amount of goods purchased per order.

To realize a problem tractable to quantitative analysis, we choose a specific commodity and locale: book sales in Japan. Books were selected due to their early emergence as a commodity traded via e-commerce. However, it should be noted that the current penetration of e-commerce in the Japanese market is still low, around .7% of total book sales. Still, Japan makes an excellent geographical choice for the case study as it contains both densely populated urban regions with extensive public transport and rural regions where the automobile is the main form of transport. It is also worth mentioning at the outset that purchasing a book via e-commerce or at a bookseller are not entirely equivalent "goods". The recreational aspect of visiting a bookshop, for instance, is an important factor. However, there are overlapping aspects of book demand where e-commerce can potentially substitute for traditional booksellers.

3. Structure of the book sales/distribution system in Japan

In this section we review the Japanese book sector in order to set the stage for analysis. The industry functions under a fixed price system in which discounting below the retail price is not permitted (for domestic books) and the profit margins for bookstores and distributors and fixed at 20% and 10% respectively. The central players in the book industry are the distribution companies, who in fact decide the inventories of bookstores and orders made to publishing houses. There are 7 distribution firms that could be characterized as "large", and the two major ones, Nippan and Tohan, control 80% of the book market. The publishing and bookstore industry is by contrast quite diffuse, with a few large firms but no clear dominating group.

79% of publishing houses are located in the Tokyo area or outskirts of Tokyo. Transport of books between publisher, distributor, and bookstore is generally contracted out to trucking firms. Shipping from the e-commerce company to consumer is handled by courier services, which are dominated by 3 large firms: Yamato Transport, Nittsu Pelican, and Sagawa. Trucking is the favoured mode of transport for book shipments, with little use of rail and essentially no shipments via air. This is in contrast with the US case in which air shipments are not uncommon (Matthews/Hendrickson/Soh 1998).

4. Simulation of energy use in distribution

This section takes up modelling energy use in the distribution of books in Japan. The two systems for e-commerce and traditional retail distribution are depicted pictorially in Figure 1. The analysis of energy includes the phases falling within the system boundary marked in the figure. Earlier phases of distribution can be safely neglected since they are identical for e-commerce and. conventional retail cases.

The four factors included in the simulation of energy use are:

1. fuel used in transport by shipping and courier services,
2. fuel used by the consumer in travel to and from bookstore,
3. energy to produce packaging,
4. electricity and fuel consumed at the sales point, either at the bookstore or by the consumer at home making e-commerce purchase.

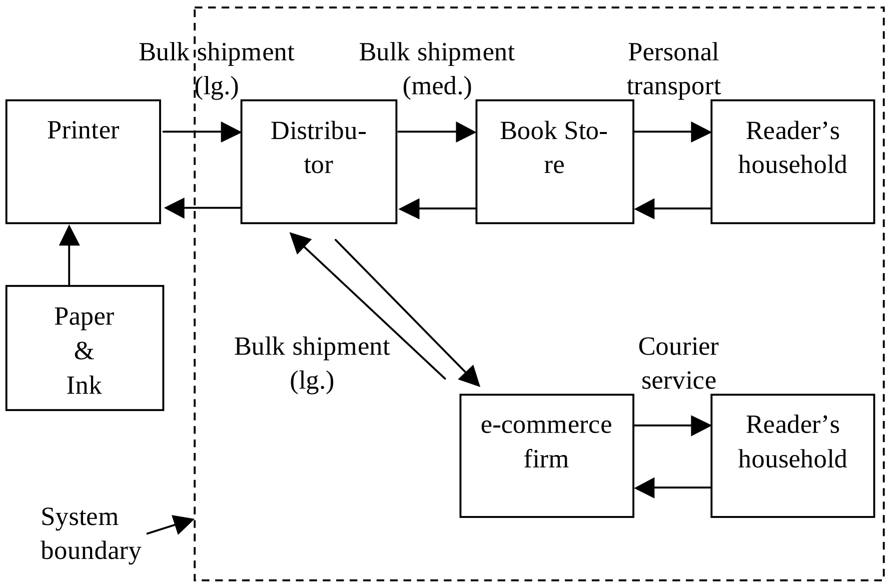

Figure 1: Structure of distribution systems

In order to evaluate the dependence on population density, distribution and sales in three different regions in Japan were considered: Tokyo, Tochigi and Hokkaido. Tokyo is taken as representative of a densely populated urban region (5,600 inhabitants/km^2), Tochigi as a suburban area (310 inhabitants/km^2), and Hokkaido as a rural area (68 inhabitants/km^2).

4.1 Fuel used in transport by shipping and courier services

The two main pieces of information needed to estimate the consumption of fuel by shipping and courier vehicles are the typical distances between nodes in the distribution network and the type of truck used between each node. This data was gained through a set of interviews with seven major firms involved in publishing, distribution, sales, and transport of books. The basic formula used was:

Energy per book [M] = Σ distance [km] × 1/truck fuel efficiency [l/km] × energy content of fuel [MJ/l] × volume share in truck [%],

where the sum is over legs of the distribution path. In the e-commerce case, shipments between distributor and e-commerce firms are carried in large (10-ton) trucks. At the e-commerce firm's distribution centre, individual customer orders are placed into small parcels and shipped via courier service. The courier service uses large trucks to transport packages to regional distribution centres, after which small (2-ton) trucks carry to individual's residences. For conventional retail, the leg connecting distributor and bookstore is handled by large trucks (10-ton) as far as nodal distribution centres, after which shipments were divided and placed in small (2-ton) trucks for delivery to local bookstores. Fuel efficiencies were assumed to be 3 km/l and 5 km/l for large and small trucks respectively. The amount of energy allotted to transport of a book shipment was calculated according to the volume (not weight) fraction of the parcel of compared to the capacity of the truck. In the courier service leg of the e-commerce case, the volume was calculated assuming 2 books are shipped in box of volume 7,290 cm^3 (measured from actual boxes used by Amazon.co.jp).

4.2 Fuel used by the consumer in travel to and from bookstore

The mode of transport used and distance travelled by the consumer was estimated based on information on the number of bookstores located in different regions (Regional databases, 1999). Typical distances between bookstores were calculated assuming stores are on average uniformly distributed in a prefecture. The resulting store-to-store distances are 1 km, 5.2 km and 13.4 km for Tokyo, Tochigi and Hokkaido respectively. The consumer typically travels half this distance to reach the nearest store. We assumed that the total travel distance was that for a round trip to and from the nearest bookstore, solely for the purpose of purchasing books (i.e. not part of other shopping). This is admittedly a crude estimation, only intended identify the order of magnitude to energy use. In general consumers travel further than the closest store and shopping trips are often combined. However, estimation to a higher order faces substantial methodological and data obstacles.

Given the above assumptions on typical distances, the short distance to the nearest bookstore in Tokyo suggests that walking or bicycle is the preferred mode of transport, while personal automobiles are used in Tochigi (suburban) and Hokkaido (rural) cases. The typical fuel efficiency of automobiles was taken as 13 km/l (EDMC 2001).

4.3 Energy to produce packaging

Packaging is potentially an important factor for the comparison, as the amount and type used differs considerably in e-commerce and conventional retail cases. Packaging for shipping from distributor to e-commerce warehouse or bookstore is apparently the same: distributor firms report that medium sized cardboard boxes holding about 40 books are used. Bookstores generally put books in light paper bags or wrap in a paper cover for the customer. e-commerce firms ship books in small cardboard boxes. We obtained representative samples of actual packaging used and measured their weight and volume. The energy used to produce the packaging was calculated according to life cycle process data from the European BUWAL database (BUWAL 1996). BUWAL data reports that energy to produce 1 kg of cardboard (paper) is 25 MJ (45 MJ). Physical characteristics of packaging and estimated energy investment are summarized in Table 1.

Type	Use	Weight (g)	Energy (MJ)
Medium cardboard box (40 books)	distributor to bookstore or e-commerce firm	734	18
Small cardboard box (1-3 books)	e-commerce to home	329	8.1
Small paper bag	bookstore to consumer	9	.41
Book cover (paper)	bookstore to consumer	7	.32

Table 1: Packaging characteristics and energy investment

4.4 Sales point energy

Energy is also consumed at the sales point, either at the bookstore or the home. The bookstore case was calculated combining macro statistics on energy consumption for utilities per unit area in retail stores (EDMC 2001), the total area of bookstore space in Japan (Publishers 2000), and data on number of books sold (Shuppan 2000). The result of this calculation is that .68 MJ of energy for lighting, heating, and air-conditioning was consumed per book.

Estimation of point-of-sale energy for e-commerce is more difficult as there is little existing data on the differential *increase* in residential energy consumption due to additional time spent at home. We approached the problem by constructing a simple model of residential energy consumption. The purchase of one book via e-commerce was assumed to take 20 minutes, with an additional 10 minutes per additional book purchased. Residential consumption includes electricity used by computers and lighting as well as energy for heating or cooling. Central heating is rare in Japanese homes, climate is generally controllable room-by room. It is assumed that making an e-commerce purchase involves heating or cooling one room, one third of an average residence. The energy consumption for computer use is taken at 65.5 W, which averages consumption of desktop and laptop models (Miyamoto/Tekawa/ Inaba 1998). We assumed that lighting of one room typically takes 200W of power. Annual per household use of energy for climate control is 14,250 MJ (EDMC 2001); this is converted to wattage/room by assuming 12-hour/day usage 365 days/year. The resulting average power consumption for climate control is 303 W per room. Combining the above results yields that home energy consumption associated with purchase of one book via e-commerce is .7 MJ.

The estimations indicate that point-of-sale energy consumption at the bookstore and home are very similar in scale. This underlines the importance of including increased residential energy consumption in analysis of ICT modes, a factor often neglected. For instance, Romm and collaborators cite a comparison of business energy expenditure of e-commerce and traditional booksellers as evidence that e-commerce is energy efficient (Romm, 1999, 26). We suggest that the energy savings at the firm level is lost due to increased residential consumption.

5. Results

Calculations of the energy use associated with each of the four factors for the case of one book are presented in Table 2. The case of two books per sale is shown in Table 3. The results suggest a crossover in performance as population density changes. The conventional system uses less energy in dense urban regions due to additional packaging and courier fuel use for e-commerce. As the population density decreases, e-commerce saves energy because courier services are apparently more efficient than „shipping“ via personal automobiles. Also, the energy efficiency per book improves substantially as the number of books in an order increases.

Unit: MJ		Shipping, Courier	Personal transport	Package	Point-of-sale	Total
Tokyo	E-commerce	0.15	0	8.5	0.7	9.3
	Traditional	0.013	0	0.85	0.68	1.6
Tochigi	E-commerce	0.66	0	8.5	0.7	9.9
	Traditional	0.10	6.8	0.85	0.68	8.5
Hokkaido	E-commerce	3.1	0	8.5	0.7	12
	Traditional	0.37	14	0.85	0.68	16

Table 2. Per book energy use (1 book per purchase)

Unit: MJ		Shipping, Courier	Personal transport	Package	Point-of-sale	Total
Tokyo	E-commerce	0.075	0	4.5	0.5	5
	Traditional	0.013	0	0.65	0.68	1.35
Tochigi	E-commerce	0.33	0	4.5	0.5	5.5
	Traditional	0.10	3.4	0.65	0.68	5
Hokkaido	E-commerce	1.5	0	4.5	0.5	6.5
	Traditional	0.37	7	0.65	0.68	9

Table 3. Per book energy use (2 books per purchase)

We briefly discuss the reliability of these results in terms of factors possibly misaccounted for and those not considered. Clearly each of the estimations for the above four factors could be made more accurate given additional data. While this would change numerical values, qualitative aspects are unlikely to be affected. Factors not accounted for are a larger source of concern. Matthews and collaborators argue that the lower rate of returns for e-commerce booksellers could imply less wasted production of books (Matthews/Hendrickson/Soh 1998). We neglected this factor in the analysis as the main agents in the Japanese book industry, the distributors, practice sophisticated supply chain management. There is no obvious link in this case between increased b2c e-commerce and overall efficiency of the chain. Another factor not included is the energy consumption associated with constructing bookstores. This was believed to be small in comparison to the use phase energy as life cycle studies of building generally allocate a small fraction to the production phase. But these and other factors do merit closer attention, and are topics to be addressed in future work.

6. Summary and conclusions

Although the study addresses a single commodity and a particular region, the results may reflect some general lessons on the conditions under which b2c e-commerce becomes an environmentally friendly transport technology. Packaging is evidently a key issue, both in terms of the energy investment to produce it and for courier services to realize efficient load factors. Minimization of packaging should thus be a priority for e-commerce firms. Population density and number of books per order are also important factors. Both are addressable to some extent through consumer choice, although it is unclear to what extent behaviour can be changed. This is the long-standing challenge of green consumerism. Policies and prices for shipping give e-commerce firms some influence over the size of an order.

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