MODELLING FREIGHT OUTSOURCING DECISIONS

Toka S.Mostafa, and Matthew J. Roorda
University of Toronto

Introduction

Agent-based models have been recently introduced as a tool for transportation behavioural modelling. Earlier, freight transportation models were based on the conventional four-stage or commodity based approaches that are aggregate and were originally introduced using passenger demand approaches (e.g. Cambridge systematics, 1996). The accuracy of such models for freight analysis is questioned as they fail to capture the interaction between system agents. Agent-based models represent interacting agents whose interrelations result in transportation dynamics. Within freight systems, firms (including shippers, carriers, and logistics service providers) are the key interacting agents whose decisions and interrelations result in the complex system of goods movements.

One of many decisions firms make, which directly impacts freight systems and the economy at large, is outsourcing of freight related activities (such as logistics, and intermediate goods production). Firms can either choose to perform all of their activities in-house, own separate subsidiaries to perform different activities, or outsource part/all of their activities to other firms (Abdur Razzaque and Chen Sheng, 1998; Deepen, 2007). Generally, firms choose to outsource to minimize the cost and maximize profits, as outsourcing reduces capital investments in facilities, equipment, information technology, and workforce (Foster and Muller, 1990; Sheffi, 1990; Richardson, 1992; Fantasia, 1993). Freight outsourcing helps firms to increase profits by allowing them to gain competitive advantage, improving customer deliveries, expanding in new markets, and providing dedicated resources (Foster and Muller, 1990).

Outsourcing of freight logistics (including transportation, distribution, warehousing, inventory management, and material handling), and intermediate goods production have strategic importance. They affect labour demand elasticities (Senses, 2004), transportation network efficiency (Abdur Razzaque and Chen Sheng, 1998), and growth of economy (Richardson, 1993). As a consequence of globalization, firms could also choose to outsource intermediate goods production internationally to low-cost subcontractors (Lommerud et al., 2009). When that happens, there is a possibility that the local labour market is harmed (Lommerud et al., 2003) which influences overall national economic growth.

Freight outsourcing decisions are driven by different groups of factors, firm specific (e.g. firm strategic focus, firm size, production size, and shipment frequency), industry related (e.g. the nature of the supply chain, the average size of the industry, and market competition), economic conditions, location characteristics (e.g. access to resources, and proximities to highways), and advances in innovation and technology (Rao and Young, 1994; Abdur Razzaque and Chen Sheng, 1998; Bienstock and Mentzer, 1999).

In this paper, we introduce discrete choice models of freight outsourcing for Canadian manufacturers which account for a large part of the Canadian's Gross Domestic Product (GDP) (Snoddon et al., 2014). No previous attempts were found in the literature that introduce discrete choice models for freight outsourcing decisions in a Canadian context. The models consider different factors with potential influence over freight outsourcing such as firm characteristics and strategic focus, market competition, GDP growth, and international relations. Some of the models also examine the outsourcing type (international vs. local). The ultimate goal of this research is to formulate parts of the underlying elements of a firm microsimulation platform called "The Firmographic Engine of Canada"; an agent-based

microsimulation that tracks individual firm decisions and evolution, and explicitly models interrelated behaviour (Mostafa and Roorda, 2015).

Data description

Two cross-section data sets of the Survey of Innovation and Business Strategy (SIBS), acquired by Statistics Canada, are used. Each data set covers an interval of three years; 2007-2009 and 2010-2012. The survey was stratified according to 14 industry sectors defined according to North American Industry Classification System (NAICS) for enterprises that have at least 20 employees and annual revenue of at least $250,000. The two data sets include information about business strategies, and innovation and technology usage of 6,233 and 4,559 enterprises across Canada for the years 2009 and 2012 respectively (Statistics Canada, 2012). Around 8,000 manufacturers are surveyed in both years. The survey collected information about long term strategies, strategic focus, performance measures, operational activities, expansion/contraction and outsourcing of business activities, international activities and relationship with main suppliers, competition, use of advanced technology and innovation, and use of government support programs for innovation related activities. The data are combined with an external data source that includes GDP growth for the studied years (CANSIM, 2015).

Methodology and model structures

Outsourcing of goods production and logistics can be formulated in several structures. It can be seen as a two independent binary decisions, while considering the effect of the other decision exogenously (Figure 1), a joint simultaneous decision, or as a nested structure where one decision is consecutive to the other. The nested structures may be a better representation of the addressed outsourcing decisions. However, estimating such structures requires enough data to cover all the nests in the tree. Due data limitations, we focused our study on modelling the outsourcing using the first structure (Figure 1).

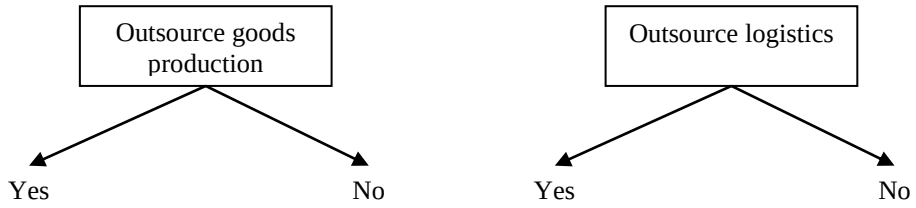

Figure 1

Model results and interpretations

This research focuses only on modelling outsourcing decisions of for-profit industries, i.e. excluding non-for-profit industries of educational services, health care, and public administration. A binary logit model structure is estimated to represent the behaviour of each outsourcing decision independently using maximum likelihood method, as explained in Eliason (1993). We have estimated three types of models for the two freight related activities of study:

1) A simplified model which includes available generic variables
2) A behavioural model, which explains outsourcing decisions in detail by including information about the firm structure and strategic focus
3) A model for explaining international outsourcing

The model estimates of the three model types are summarized in Table 1 and Table 2 for each outsourcing decision. We hypothesise that outsourcing decisions are different from one industry to the other. As such, industry effects are considered by including dummy variables to identify sub-industry 3-digit NAICS code. It is noted that industries such as wood product, and computer and electronic product manufacturers are less likely to outsource their logistics compared to beverages and tobacco product manufacturers.

Firm size (represented as the number of employees) is found to have an influence over outsourcing of both decisions; the larger the firm, the more likely they are to outsource their freight related activities. This finding is in agreement with Kurz (2006) for U.S. manufacturers. This can be interpreted in such a way that when firms are focused on the core competency of their products, they are likely to outsource their logistics to other firms, in addition to outsourcing part of their intermediate goods production as well. When firms outsource intermediate goods production, they hire more highly-skilled workers (explained by the positive sign of the percentage of university degree employees) to perform a firm's core activities.

Strategic focus of the firm is found to have an impact on goods production outsourcing; when firms are focused on producing significantly improved or new goods, they are less likely to outsource production activities, whereas firms that target to minimize operating cost, expand market share growth, or increase the sales of their new products are more likely to outsource some or all of their production activities.

Growth in the GDP has a positive impact on outsourcing of logistics, when the economy is growing, manufacturers are more focused on increasing their market shares by focusing on the production side, and hence are more likely to outsource their logistics. Moreover, firms that outsource part or all of their goods production are more likely to outsource the associated logistics and vice versa.

The decisions of expansion and contraction of production facilities are found to have almost the same impact on the logistics outsourcing. Firms that close production facilities may also want to close some of their logistics as well. On the other hand, firms that expand their production facilities, may want to focus on the production side, and hence would also want to outsource logistics. Similarly, closing production or logistics and distribution facilities increase the likelihood of outsourcing goods production.

The use of advanced communication technologies is found to have a positive influence on logistics outsourcing. Use of advanced technologies in general indicates an interest in enhancing the production quality to gain higher market shares. Hence, outsourcing of logistics is more plausible. When a firm is using process innovation in introducing new or significantly improved logistics operations, it is logical that they are focused on administrating their own logistics operations as they are already investing in it, as most likely it is within their goals to enhance their delivery times (explained by the negative sign in the use of process innovation in Table 1).

Government programs of tax credit are found to have a positive influence over logistics outsourcing. One example of such programs is the Ontario innovation tax credit program. Briefly, this program allows businesses to claim a 10% of their tax credit for expenditures on scientific research and experimental development performed in Ontario (Ministry of Finance, 2016). Manufacturers that dedicate part of their efforts for scientific research might outsource part or all of their logistics operations as they are more focused on enhancing their production performance or product quality.

Competition is found to have a positive impact on goods production outsourcing; the higher the number of the competitors, the more likely firms would outsource their goods production activities to cope with the competition and maintain their market shares. Also, firms with international activities/subsidiaries or who have an international market are more likely to outsource any of their freight activities internationally, as this might be more cost effective.

Table 1. Models for outsourcing of logistics

		Simplified model			Behavioural model			International outsourcing model		
	Variables	**Coef.**	**P >|Z|**	**Odds ratio**	**Coef.**	**P >|Z|**	**Odds ratio**	**Coef.**	**P >|Z|**	**Odds ratio**
	_cons	-1.090	0.000	0.336	-1.79	0.000	0.167	-2.617	0.000	0.073
Industry	Beverage and tobacco products	0.670	0.014	1.960	1.092	0.001	2.98	--	--	--
	Textile products	--	--	--	-0.34	0.124	0.712	--	--	--
	Apparel, leather and allied products	-0.348	0.093	0.706	-0.367	0.096	0.69	--	--	--
	Wood products	-0.440	0.015	0.644	--	--	--	--	--	--
	Plastics and Rubber Products	--	--	--	0.308	0.041	1.360	--	--	--
	Non-metallic Mineral Products	-0.548	0.008	0.578	--	--	--	--	--	--
	Computer and Electronic Products	-0.467	0.003	0.627	-0.569	0.001	0.567	--	--	--
	Furniture and Related Products	--	--	--	0.33	0.072	1.39	--	--	--
Size	Medium-sized firm (100-250 employee)	0.413	0.000	1.511	0.217	0.024	1.242	--	--	--
	Large-sized firm (>250 employee)	0.516	0.000	1.675	0.250	0.021	1.28	0.443	0.065	1.558
Location	Ontario	0.242	0.001	1.273	--	--	--	--	--	--
	GDP growth on naics-3 level	--	--	--	0.009	0.022	1.009	--	--	--
Other operational strategies	Outsource of goods production	--	--	--	1.415	0.000	4.115	--	--	--
	Opened a new production facility	--	--	--	0.467	0.000	1.595	--	--	--
	Closed an existing production facility	--	--	--	0.355	0.002	1.426	--	--	--
	Use of advanced communication tech.	--	--	--	0.245	0.018	1.278	--	--	--
	Process innovation in logistics	--	--	--	-0.270	0.013	0.764	--	--	--
	Government tax credit programs	--	--	--	0.140	0.097	1.151	--	--	--
Long term strategy and strategic focus	Mass market strategy	--	--	--	--	--	--	-0.602	0.128	0.548
	Gross/margin operating growth	--	--	--	0.181	0.053	1.198	--	--	--
	Organizational and management practices	--	--	--	-0.130	0.104	0.878	--	--	--
International activities	Outsourcing of goods production(intl.)	--	--	--	--	--	--	2.090	0.000	8.087
	International activities	--	--	--	--	--	--	0.841	0.001	1.327
	Canada being the main market	--	--	--	--	--	--	-0.480	0.029	0.619
	Competition from multinational firms	--	--	--	--	--	--	0.599	0.021	1.821
	Direct exports	--	--	--	0.217	0.011	1.242	0.433	0.097	1.541

Table 2. Models for outsourcing of goods production

		Simplified model			Behavioural model			International outsourcing model		
	Variables	**Coef.**	**P>|z|**	**odds ratio**	**Coef.**	**P>|z|**	**odds ratio**	**Coef.**	**P>|z|**	**odds ratio**
	_cons	-0.763	0.000	0.466	-2.978	0.000	0.051	-0.029	0.937	0.972
Industry	Food Manufacturing	-1.435	0.000	0.238	-1.213	0.000	0.297	--	--	--
	Beverage and Tobacco Products	-0.940	0.006	0.391	--	--	--	-1.434	0.114	0.238
	Apparel, leather and allied products	--	--	--	0.668	0.001	1.951	3.253	0.003	25.856
	Wood products	-1.409	0.000	0.244	-0.773	0.002	0.462	--	--	--
	Paper Manufacturing	-0.689	0.001	0.502	--	--	--	--	--	--
	Printing and Related Support Activities	--	--	--	--	--	--	-1.378	0.039	0.252
	Petroleum and Coal Products	-1.209	0.026	0.298	--	--	--	--	--	--
	Chemical Manufacturing	-0.805	0.000	0.447	-0.835	0.000	0.434	--	--	--
	Plastics and Rubber Products	-0.650	0.000	0.522	-0.424	0.017	0.655	--	--	--
	Non-metallic Mineral Products	-1.483	0.000	0.227	-1.011	0.000	0.364	--	--	--
	Primary Metal Manufacturing	-0.620	0.001	0.538	--	--	--	--	--	--
	Fabricated Metal Products	-0.263	0.040	0.769	--	--	--	--	--	--
	Transportation Equipment Manufacturing	-0.569	0.000	0.566	--	--	--	--	--	--
	Furniture and Related Products	-0.623	0.001	0.536	--	--	--	--	--	--
Employment size	Medium-sized firm (100-250 employee)	0.401	0.000	1.493	--	--	--	--	--	--
	Large-sized firm (>250 employee)	0.501	0.000	1.650	-0.306	0.008	0.736	--	--	--
Production size	# of products and services (log)	--	--	--	0.068	0.000	1.070	--	--	--
	# of product lines (log)	--	--	--	--	--	--	0.190	0.068	1.209
Other characteristics	Employees with university degrees (%)	--	--	--	0.007	0.003	1.007	--	--	--
	The head office location in Canada	--	--	--	--	--	--	-1.451	0.000	0.234
Long term strategy and strategic focus	Mass market strategy	--	--	--	-0.310	0.039	0.734	--	--	--
	Improved goods/services	--	--	--	-0.218	0.017	0.804	--	--	--
	Gross/margin operating growth	--	--	--	0.297	0.005	1.345	--	--	--
	Market/customer share growth	--	--	--	0.191	0.034	1.211	--	--	--
	Sales of new products	--	--	--	0.208	0.024	1.231	--	--	--

Table 2. Continued

		Behavioural model			International outsourcing model		
	Variables	**Coef.**	**P>|z|**	**odds ratio**	**Coef.**	**P>|z|**	**odds ratio**
Other operational strategies	Outsource logistics	1.330	0.000	3.780	--	--	--
	Expand production facility by M&A	--	--	--	1.052	0.009	2.863
	Close or contract capacity of production facilities	0.447	0.001	1.564			
	Expand logistics by M&A	--	--	--	-2.074	0.000	0.126
	Close logistics facilities	0.355	0.086	1.426			
Competition	Number of competitors 3-10	0.328	0.007	1.389	--	--	--
	Number of competitors >10	0.341	0.010	1.406	--	--	--
Innovation	Product innovation	--	--	--	0.477	0.049	1.611
	Process innovation of new manufacturing methods	0.218	0.002	1.243	--	--	--
International activities	Outsource logistics (internationally)	--	--	--	2.164	0.000	8.708
	International subsidiaries	--	--	--	0.925	0.001	2.522
	International activities	0.660	0.000	1.935	--	--	--
	International suppliers	0.392	0.023	1.480	--	--	--
	Canada being the main market	--	--	--	-0.496	0.039	0.609

Table 3. Model validation

Outsourcing of logistics				
	McFadden pseudo R2 (rho-square)	Observed total probabilities	Predicted total probabilities	% Difference
Simplified model	0.019	25.4%	29%	3.90%
Behavioural model	0.108	32.0%	31%	-0.90%
International outsourcing model	0.250	47.7%	47%	-0.70%
Outsourcing of goods production				
Simplified model	0.040	25.1%	25.5%	0.40%
Behavioural model	0.170	26.7%	27.7%	1.00%
International outsourcing model	0.250	58.2%	58.0%	-0.20%

Model validation

A holdout sample (a validation set) of 20% of the whole sample size was extracted for model validation. Cross validation techniques are widely used in discrete choice model validation to evaluate the predictive performance of model estimates by comparing predicted choice probabilities against observed choice probabilities (Roorda et al., 2008; Robin et al., 2009; Habib, 2013). Model performance is evaluated at the aggregate level by comparing the predicted shares against the observed shares of each choice in the holdout sample (Table 3). The validation results show an accepted overall predictive performance of the presented models. For outsourcing of logistics decisions, the simplified model over predicts by 3.9%, and the behavioural and international outsourcing models slightly under predict by a 0.9%, and 0.7% respectively. The models for goods production outsourcing over predict by 0.4% and 1% in the simplified and behavioural models respectively, and under predict by 0.2% in the international model.

Conclusions

Freight outsourcing decisions influence freight system dynamics. In this paper we tried to answer some basic questions related to outsourcing such as: what influences outsourcing, how the economy affects outsourcing, what influences the decision of international outsourcing, and whether innovation and technological advancements are significant to outsourcing. We present models of outsourcing of goods production and logistics. The models consider the effect of firm characteristics and strategic focus, industry related variables, economic conditions, location characteristics, and advances in innovation and technology on outsourcing. Generally, when a firm is focused on the core competency of their production, they are more likely to outsource their freight related activities. This can be explained by the positive sign of the effect of employment size, economic indicator, and the use of advanced technologies in the production process on outsourcing decisions. The models are to be used in a microsimulation platform for the purpose of agent-based firm micro-modelling.

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