AN ANALYSIS OF AIR CARGO LEAKAGE IN QUEBEC

Submitted by

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Phuong, Le Thi Mai

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ACRONYM

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BACI	Base pour l'Analyse du Commerce International
BOP	Balance of Payment
CASS	Cargo Account Settlement Systems
CBSA	Canadian Border Services Agency
CEPII	Centre d'Etudes Prospectives et d'Informations Internationales
COD	Country of Destination
CRP	Continuous Replenished Programs
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
HS	Harmonized System
IATA	International Air Transport Association
ISO	International Organization for Standardization
LASP	Leeds Adaptive Stated Preference
NEA	Northeast Asia
QR	Quick Response
R&D	Research & Development
RCA	Revealed Comparative Advantage
U.S. & MEX	United States and Mexico
WIP	Work In Progress

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ABSTRACT

Since the past few decades, the rise of Global Value Chains has gradually changed the organization of international trade. Production activities are geographically separated around the globe, generating higher need for transportation as well as longer distance travelled for intermediate goods from one country to another. In addition, the increasing use of time-sensitive strategies of firms such as CRP, QR and ECR requires shorter order cycle time or higher delivery frequency. When both travel distance and frequency of merchandise increase, the management of global supply chain favors the use of air shipping as it has the greatest time advantage. However, airway also incurs the highest transportation cost in comparison to other modes such as truck, rail and ship. Therefore, manufacturers/shippers often combine different modes in order to compromise time advantages of air transport and reasonable costs. This may include trucking goods to a further away airport for airlift. In this case, we speak of leakage, which is the shipping practice where manufacturers located in a certain place bypass the airport that is closest to them to transport their merchandises elsewhere for subsequent airlift. Intra-national leakage refers to the situation where products are trucked to other airports within national boundary while international leakage happens when airports in other countries are used for air shipments.

Recently, there is a growing interest among academics and policymakers to understand the drivers of leakage. Besides a number of case studies or industry-specific studies, however, empirical research on leakage has been quite limited due to a significant lack of data. As a result, we know little why companies choose to conduct leakage and whether it has become more important over time. The goal of this thesis is to obtain more insights into the drivers of leakage. In our literature review, we identify that besides freight rates, airport capacity, airport connectivity, and product characteristics can be such important drivers. We empirically test this using Québec's export statistics from 2008 to 2012 and the results of the test suggested that there is a negative relationship between product's value to weight ratio and the propensity that merchandises are leaked both nationally and internationally. In addition, it is also showed that as the freight rates in Montreal increase relative to that in U.S., international leakage of Quebec increases subsequently. Lastly, when effective capacity of the Montreal's airports increase compared to that in other regions, there will be less chance that that products are shipped to neighboring areas or countries for subsequent airlift.

From these outcomes, several implications have been given to numerous stakeholders including manufacturers/ shippers, air carriers/ airports and government/ policy makers.

1. INTRODUCTION

'Globalization' has long been an interesting subject for numerous groups of people, from policy makers, scientific researchers, and investors to manufacturers since a century ago. The history of globalization dates back to the second half of nineteenth century, when '*there was hardly a village or town anywhere on the globe whose prices were not influenced by distant foreign markets, whose infrastructure was not financed by foreign capital, whose engineering, manufacturing, and even business skills were not imported from abroad, or whose labor markets were not influenced by the absence of those who had emigrated or by the presence of strangers who had immigrated…'*(O'Rourke, 1999).

Notwithstanding that early history, it was not until the mid-1980s that this phenomenon became widespread and that the term 'globalization' was widely used among those interested in the international economy.

During that time, there was an emergence of a concept, which is also gaining much attention from researchers nowadays, namely, Supply Chain Management. The concept was believed to includes *'managing inter-organizational operations, systems integration research, and sharing information and exchange of inventory for information'*(Pagh, 1997).

Since then, there has been an increasing number of academic works concerning globalization from the perspective of value chain, which is currently known as Global Supply Chain Management. Global supply chain management combines the functions of product procurement, production, warehousing and distribution, from raw material suppliers to consumers on the global scope.

It is now widely accepted that trading across borders has changed in many ways. International economy is no longer the situation described by Adam Smith in his comparative advantage theory. Trading among countries around the world is no longer the simple trade of merchandises, which are completely and thoroughly produced within the country's border, but the exchange of both finished and intermediate goods including raw materials and work in progress (WIP). Such changes in types of merchandise flowing from one country to another have resulted from the situation where large companies, especially those in developed countries, are increasingly outsourcing their production activities to manufacturers in other (normally developing) countries.

Eventually, it necessitates the movement of intermediate goods. Moreover, it is not only production but also marketing, research and development (R&D), design, post sales services, etc. are also dispersed all over the world, creating what is referred to as ‘the slicing up of value chain’. Instead of focusing on what they produces most effectively and efficiently, each country is now specializing in steps along the value chain, where they can do the best. Hence, the global economy is seeing the movement from ‘trade in goods’ to ‘trade in tasks’ (Van Assche, 2012) across national boundaries.

Given the aforesaid rise of ‘trade in tasks’ and the improvements in information and communication technology, the focus of many lead firms on product development and marketing while outsourcing production and production-related functions to suppliers is forecasted to be a notable shift in global value chains in the future. The largest suppliers provide these services for multiple lead firms, giving rise to significant economies of scale (Gereffi, 2001). This trend will more likely happen in buyer-driven chains, where large retailers and brands play the lead role sourcing from decentralized networks of independent suppliers, defining product and process specifications and standards (APEC, 2012). A typical characteristic of this type of value chains is labor-intensive, hence, it includes industries such as consumer goods, apparel, and consumer electronics. Requirements for participants in this type of chain (e.g. technical capability and sophistication) are relatively low, therefore, providing huge opportunities for producers from developing countries, where labor cost is much cheaper. When the production activities are geographically separated from higher value added ones and the end customers, the travel distance of raw materials, work in progress (WIP) and finished goods will be increasing consequently.

In addition, the increasing use of time-sensitive strategies of firms such as Continuous Replenished Programs (CRP), Quick Response (QR) and Efficient Consumer Response (ECR), which are based on the just-in-time philosophy, also requires shorter order cycle times as well as faster transportation modes and cross-docking facilities to improve frequency. The application of such business strategies can be partly explained by the increasing complex and sophisticated demands of customer, who are requiring reductions in cycle times, more reliable delivery, wider variety of products and packages while maintaining cost and quality levels(Roy, 2006).

When both frequency and travel distance of merchandise increase, the management of global supply chain requires faster transportation modes at a reasonable cost. Therefore, the use of air shipping is often favored as it has the highest time advantage. In addition, shipments that go by air also benefit from higher frequency, hence lower the cost of holding inventory for the business. This is essential for implementation of the time-sensitive strategies discussed above.

1.1. Problem Identification

Based on historical data, international use of airway in freight transportation, excluding mail has grown steadily at an average rate of 3.7 percent a year in the period of 1995-2009 (Morrell, 2011). However, since then, air cargo and airline industry (in general) has suffered a significant downturn. According to Franke and John(2011), *"the post 2008 global recession has taken a toll on airlines' finances both for passenger and air cargo activities. Although dropping demand had been expected as part of a cyclical downturn for some time, the crisis came more quickly and struck more deeply than most experts had anticipated".* In addition, there are also other potential drivers that could have downward impacts on this industry such as rising fuel cost and long delays in customs clearance. While certain scholars did consider the rising fuel costs as a part of the global economic crisis (i.e. Franke and John(2011)), the longer delays in customs clearance is definitely another possible explanation. Under the circumstance of rising terrorist attacks, especially after September, 11^{th}, 2001, the security issues at airports around the world have been strongly emphasized. The focus was on screening against terrorist acts. Since August 2010, for example, the U.S.A Congress mandated that the Transportation Security Administration must screen 100 percent of all cargo carried by passenger planes. Investigating each and every piece of cargo would take a huge amount of time. Regarding cargo shipped by freighter aircrafts, there is also a lot of work to do with checking and introducing merchandises into containers or pallets (Morrell, 2011). Such more complicated procedures extend the total amount of shipping time, hence, degrading the time advantage of air transport.

When investigating the data on Canada import and export in aerospace industry from 2002 to 2010, Jacques Roy and Ari Van Assche (2013) also observed the same pattern. The use of air transport in this country during the period of 2002-2008 increased gradually but stagnated to some extent since then. As specified by the two authors, one reason behind this may be the ability of manufacturers in the industry to better manage their inventory by modifying production process to quickly react to change in customers demand, hence reducing the need for emergency transportation. Global economic slowdown since 2008 can be another cause, along with rising fuel cost and long delays in customs clearance.

In addition, the authors' most interesting finding in their work is the identification of the last driver behind that stagnation, namely "Leakage". This is a shipping practice in which shippers are inclined to truck their merchandises to a further airport for subsequent airlift instead of using the one that is closest to them. In fact, there was an increasing share of aerospace products, produced within Canada, has been shipped by truck to United States before being airlifted to its final destination. Such transportation practice was believed to partly cause the decrease in Canada's air transport.

Actually, even though airway has the highest time advantage, as discussed, it also incurs the highest transportation cost in comparison to other modes such as truck, rail and ship. Therefore, manufacturers/shippers often combine different modes in order to take time advantages of air transport at a reasonable cost. Leakage can be considered as a special transportation approach where aircrafts and trucks are used to deliver goods from origins to destinations. However, it is expected that freight rate is not the unique driver behind the use of this shipping practice. Airport capacity, airport connectivity, and product's characteristics might be other reasons that induce companies to truck their merchandise to a further airport for subsequent airlift.

1.2. Research Significance and Objectives

Understanding the reasons why manufacturers would rather route their export to airports in a further locations as in such aforementioned shipping practice is a problem that interests different stakeholders such as manufacturers, air carriers, and government and policy makers.

First and foremost, as it will be discussed later on in the study, regardless of the proactive factors that force shippers to truck their merchandises from Canada to U.S. before airlifting to the final destinations such as lack of direct flights and inadequate aircraft capacity, transportation cost can also be an initiator of leakage. In fact, cost effective transportation is always among the most crucial targets for practitioners, or shippers. Therefore, manufacturers and carriers may want to investigate the situation: if the freight rate is cheaper in a further airport and the cost advantages of using that airport is more than enough to offset for the cost of trucking merchandises there, bypassing the nearby airport is highly preferable.

Secondly, given the rising competition in the air cargo industry, carriers, especially airports, may wish to understand the decisions of shippers to prefer one airport over the other, regardless of the proximity to their location. For instance, within national boundary, managers of Montreal- Pierre Elliot Trudeau International Airport may want to know which types of merchandises are usually moved from Montreal to Toronto Pearson International Airport for subsequent airlift and what are the factors that lure shippers away from them. More importantly, in international scope, Montreal airports may question why Montreal based companies prefer using air cargo services of John F. Kennedy International Airport, New York? And whether this happens for certain types of goods or country of destinations or both?

Lastly, Government and policy makers may want to investigate why merchandises are taken away from domestic airports and poured into another foreign airport and vice versa to plan on future actions to promote the country's air cargo industry. Specifically, Canadian policy makers will be keen on figuring out the causes of their merchandises influx into U.S.'s airports to find the solutions for improving national airfreight stagnation.

This study has been conducted with the purpose of identifying the factors that induced companies in Quebec to ship their merchandises by truck to airports in other Canadian provinces, or countries (i.e. U.S. & Mexico) instead of using their own airports in Montreal and Quebec City. Under such general objective, this study aims to identify the relationship between the percentages of air export leaked from Quebec and the freight rate, the product characteristics, and the airport's air cargo effective capacity. Canadian merchandise export data from 2008 to 2012 has been deployed, focusing on Quebec's air-intensive industries, in combination with regression analysis using STATA. The answers for all the research questions are expected to be helpful to the above mentioned stakeholders in their decision making process.

1.3. Research Questions and Hypothesis

Under the above objectives, this study aims to answer the following questions: 'What are the drivers behind leakage?' -'Is it caused by the differences in freight rates, airport capacity, or product characteristics? And 'Does leakage tend to be different across industries and countries of destination?'

As it will be discussed in literature review, there are several possible explanations to the existence of leakage, including: relative price among airports, capacity of airport, airport connectivity and the product characteristics. With respect to airport charges, it is expected that the higher the freight rate applied the regional airports in comparison to those in neighboring areas, the higher the chance that the regional one will be bypass. Besides, for some certain types of products, which require large aircraft capacity or special handling equipment, it is possible that airlines in regional airports are unable to meet those requirements. This necessitates the use of another airport, regardless of its proximity to the production sites. Therefore, it is also expected that product characteristics and airport capacity do have certain impacts on the level of leakage.

1.4. Research Structure

This paper will be divided into six main parts, including introduction, literature review, methodology, research findings, discussion of findings and conclusion. The second section of this paper presents the study of Roy and Van Assche (2013), from which this research has been inspired. Besides, related researches including influencing attributes to modal and carrier selection, air cargo and transshipment are also reviewed. The third section explains the framework that the author applied to conduct the study. Within this part, data used for this research will be described in detail. In addition, initial analysis to support identification of explanatories to the occurrence of leakage is presented along with establishment of multiple linear regression model to test all the above - stated hypothesis. Results of the regression analysis will be presented in the fourth section. Information reported in this part will help answers those questions stated in the first section. The next section will compare the actual research findings with those hypotheses presented by the author in the first section of this research before the conclusion ends the study with the summary of all the key points and lessons learned. Moreover, limitations and suggestions for further researches will also be stated.

2. LITERATURE REVIEW

2.1. Modal selection in freight transportation

Given the rising demand for movement of intermediate goods across national boundaries in longer distance yet higher frequency, one of the most important decisions in supply chain management is the selection of the transportation modes to ship the firm's inbound and outbound freight. In general, practitioners typically consider multiple attributes when making decision of whether to combine or how to combine different modes of transport. The importance of each attribute to the final decision often differs from country to country, industry to industry, company to company and destination to destination.

There are numerous researches conducted to identify the decisive factors to modal choice decision since decades ago. It has been 40 years since Baumol and Vinod (1970) first investigated shippers' choice of transport and developed a model to determine the optimal choice of mode as a trade-off among freight rates, speed, dependability and en-route losses (Meixell & Norbis, 2008). Following their lead, Stock & La Londe (1977) have clarified the decision making process involved in mode selection. There, the authors had to identify the dimensions of mode choice. A selected sample of 357 firms in three industry groups were sent mail questionnaires and only 74 firms responded. The industry groups selected for the study varied from cosmetics and perfumes to canned fruits and vegetables and radio and television transmitting equipment. After that, an additional 13 firms within these industry groups were selected for interviews, making a total of 87 firms, were used in the data analysis. In relation to the identification of the importance of several procedures used by the companies in evaluating mode performances, the main outcome showed that reliability, freight charges, and transit time are the three most important elements.

Later, another research was conducted by McGinnis (1979) aiming to access the relative importance of different variables on modal choice based on shippers attitudes toward them. Mail questionnaires were sent to a random sample of 1000 traffic executives in United States. Out of that, 351 usable questionnaires were returned. The respondents had to assess the importance on a five point scale for 30 statements associated with eight predetermined attributes. The list and resulted order of those eight variables are the following:

1. Freight rates

2. Speed

3. Reliability

4. Loss and damage

5. Inventories

6. Company policy

7. Shipper market conditions

8. Influence of the shipper's customers.

Twenty years later, Jeffs & Hills (1990) have proposed that in the past, researchers concentrating on the development of modal split models[1] relied too heavily on the economic cost factors and too little on behavioral factors. This failed to explain adequately the prevalence of road freight in the United Kingdom. Therefore, according to two authors, the identification of other attributes besides economic cost factors is required to build an accurate and reliable modal split model. By applying survey and factor analysis in UK's printing and publishing sector, which mostly used rail and road transportation, the authors have found many variables that appeared to exert an influence on modal choice decision making-process. However, it is possible to categorize them into six main groups, namely: customer requirements, product characteristics, company structure/organization, government interventions, available transport facilities, and the perceptions of the decision maker himself. The authors, after all, concluded that it is the interaction and inter-relationships between these attributes which ultimately determine freight modal split and the specification of future behavioral modal-split models should incorporate these parameters.

Another study, which was also mainly focused on rail and road transportation, was implemented by Shinghal & Fowkes (2002). The authors have presented the empirical results for finding the determinants of mode choice for freight services in India. The Leeds Adaptive Stated Preference (LASP) software was used for the main survey on the Delhi to Bombay corridor. After that, a series of simulations were carried out to ensure that the problems associated with LASP method

[1] In transportation planning, modal split represents a method used for determining either the potential number of trips by mode or the share of different modes of transport and pedestrian trips in the total transport needs.(Basarić & Jović, 2011)

did not exist. The aforesaid survey included a total of 41 firms, of which 32 successful interviews were obtained. The data was first modelled at the individual firm level using a logit model with the independent variables including cost, service frequency, scheduled journey time and reliability of transit times. The individual level models were then aggregated by sectors using weighted means of the individual attribute valuations with weights set as inverse of the variance of the individual estimates. There were six sectors including exporters, freight forwarders and transporters, chemicals, electrical/electronics, auto parts, and food. The final results of the study showed that the frequency of service appears to be an important factor in mode choice, especially for the manufactured goods sectors. The value of scheduled journey time appears to be quite similar in percentage terms with most sectors. The reliability of transit times appears to be very important for exporters and also important for the auto parts sector due to the effect it can have on the production process.

It will possibly take too much paper to enumerate every single research which tried to identify important factors in modal selection. So far, there have been several scholars who tried to do so by summarizing findings from related literatures. A study conducted by Cullinane & Toy (2000) using content analysis has showed a comprehensive result about existing literature on determinants of modal selection. Actually, content analysis, as explained by the authors, is ‘a set of research tools for the scientific study of written communications with the objective of determining key ideas and themes contained within them’(Cullinane & Toy, 2000). Those written communications were broadly categorized into type-public documents, archival records, personal documents, administrative documents and formal studies and reports, which were most relevant to this study. The results of the analysis showed that what have been often considered to be the most influential factors in mode choice decision making were cost/price/rate, speed, transit time reliability, characteristics of goods and services, being ranked in respective order.

A similar review was conducted by Meixell & Norbis (2008) using library databases that cover the top logistics journals. The research focused on articles published since de-regulation, and largely over the past twenty years. There were 48 articles selected on the topic of mode choice and carrier selection. These can be classified into three categories of research: Attribute identification (identifying important attributes, primarily for the carrier selection decision); Decision process development (study of the mode choice and carrier selection processes); and Supply chain integration (pertains to supply chain management). From those papers, the authors have pointed out five typical industry trends that current literature is trying to address. The first trend refers to problems related to capacity, which include: Driver shortages, and the strain of truck capacity in road transportation; Inadequate investment which translated into a reduction in service reliability in rail transportation; Cutting of capacity by airlines during economic downturn which lead to shortage in recovery; and unequal upsurge between demand for marine transportation and its containers distribution networks. The second industry trend is international growth, in which the increasing volume of material, information and money flowing across international borders also poses a challenge for managing activities associated with international trade, such as storage and custom procedures, in a timely fashion. Thirdly, the problems associated with economy of scale and scope such as empty back haul and shipment size, as usual, require a lot of effort from practitioners. The last two trends that were found to be addressed in selected literature are security and environment and energy concerns. Findings of the review showed that the topic of capacity is well addressed in this literature. International growth, economies of scales and scope, security gained light concerns and environmental and energy had very little attention.

In conclusion, regarding the influencing factors to modal choice, findings from existing literature are quite different from each other.

The following table summarizes what has been reviewed so far:

Authors	**Year**	**Country**	**Industry**	**Methodology**	**Identified attributes (ranked)**
▪ Baumol & Vinod	▪ 1970	▪ N/A	▪ N/A	▪ Inventory model	▪ trade-off among freight rates, speed, dependability (variance in speed) and en-route losses
▪ Stock & Lalonde	▪ 1977	▪ U.S.	▪ Cosmetics & Perfumes ▪ Canned fruits & vegetable ▪ Radio & Television transmitting equipment	▪ Mail Questionnaire ▪ Interview	▪ Service reliability ▪ Freight Charges ▪ Transit time
▪ McGinnis	▪ 1979	▪ U.S.	▪ Vary	▪ Mail Questionnaire	▪ Freight Charges ▪ Speed ▪ Reliability ▪ Loss & Damage

					▪ Inventories ▪ Company policy ▪ Shipper & market conditions ▪ Customer requirement
▪ Jeff & Hills	▪ 1990	▪ UK	▪ Printing & Published	▪ Survey ▪ Factor analysis	▪ Customer requirement ▪ Product Characteristics ▪ Company Structure ▪ Government intervention ▪ Available transportation facilities ▪ Perception of decision maker
▪ Singhal & Fowkes	▪ 2002	▪ India	▪ Vary	▪ Survey (LASP)	▪ Service Frequency ▪ Speed (Total journey time) ▪ Transit time (reliability)
▪ Cullinane &Toy	▪ 2000	▪ N/A	▪ N/A	▪ Content analysis	▪ Cost/price/rate ▪ Speed ▪ Transit time (reliability) ▪ Product Characteristics
▪ Meixell & Norbis	▪ 2008	▪ N/A	▪ N/A	▪ Content analysis	▪ Capacity ▪ Speed/ Total Journey time (affected by international growth) ▪ Cost (Economies of scales & scope) ▪ Security ▪ Environment & Energy concerns

Table 1- Transport mode selection literature review

This table claims for the fact that the importance of each attribute to the final decision often differ from country to country, industry to industry, company to company and destination to destination. As proved by the two comprehensive reviews of existing literature on transport mode selection (i.e. Cullinane & Toy in 2000 and Meixell & Norbis in 2008), cost and time are almost always the attributes that gained most interest. However, there is always the trade-off between them that decision makers have to deal with before coming up with the final answer for the question of which mode to use. Indeed, the higher the speed of the transport mode, the higher the freight rates that shippers will have to pay.

2.2. Time-cost trade-off and the rising of air cargo

As mentioned from the beginning, the geographically separated production activities around the globe along with the increasing use of time-sensitive strategies of firms such as CRP, QR and ERC have given rise to the development of air cargo industry. Indeed, given the more frequent movement and longer distance travelled for merchandises, yet reducing production cycle time, it is now obvious that balancing between transportation cost, and travelling time is critical for firms to respond quickly to customers, avoiding loss of sales while still maintaining their profits. Solving that trade-off requires planners to consider the most effective and efficient mode of transport; and it is believed that the balance between time and cost supports the air cargo business (Eyerdam, 2010). Even though air transport incurs highest transportation cost in comparison to other modes such as truck, rail, and ship, it has the greatest time advantage; and long distant shipments favor the use of air way. The further the distance travelled of air cargo, the lower the transportation cost per unit, and the higher the time advantage will be.

In fact, investigation by Morrell (2011) of ‘Air Carrier Financial Statistics’ in 2008 showed that there is a reasonable good correlation between unit operating cost and average sector distance operated by all-cargo airlines such as FedEx, UPS, British Globe, Cargolux, Kalitta and Atlas Air. The higher the average sector distance, the lower the unit cost. Moreover, the longer the route, the greater the time advantages for air as flying takes a much larger percentage of total time, and has more scope for influencing door-to-door delivery time than short trips (Morrell, 2011).

Besides, shipments that go by air also benefit from higher frequency, hence, they lower the cost of holding inventory for the business. This is essential for the implementation of the time-sensitive strategies mentioned above. Indeed, it is obvious that a slower mode of transport generates much larger in-transit inventory compared to a faster one. Moreover, longer transit time also brings about trouble for the consignee if there is an unanticipated upsurge in demand. In such cases, consignee often have to maintain a certain amount of safety stock to guard against contingencies. The longer and the more uncertain the transit time is, the higher the level of safety stock must be kept in the warehouse and holding inventory does incurs more costs. Baumol and Vinod (1970) has realized that the determination of the demand for freight transportation can be described in terms of a profit maximization model which incorporates both demand for the commodities and inventory theoretic consideration. According to these authors, since gross revenue is unaffected by modal choice, the selection of mode becomes a matter of determining which of the alternatives promises to complete the delivery at lowest cost. However, in analyzing such cost, the opportunity cost of lost orders and cost of holding higher safety stock to compensate for slower speed and time delays should be included. From that point of view, the authors have used an inventory theoretic model of freight transport demand to explain the choice when making trade-off between speed and economy of shippers. It is then concluded that inventory theory make it possible to directly compare between time and cost related attributes, on which mode selection is based and leads to a model of rational choice in transport demand.

Furthermore, it is now believed that using a cheaper but slower mode of transport does not guarantee cost saving even when more time is sacrificed. In fact, several researchers have recently proved that longer shipping times may incur unnecessary added costs that induce shippers to pay more for a faster transportation mode to avoid such costs. Djankov et al. (2010) have illustrated that point by regressing relative exports of similar countries - by location, endowment, and facing the same trade barriers abroad – on relative time delays and other standard variables using data set on time to move containerized products from the factory to the ship in 126 countries. The results of the study suggested that on average, each additional day of delay will reduce water export by at least 1%, which means less use of seaborne transportation.

Having the same objective of testing the impact of time delays, which support the use air freight, on shippers' demand for seaborne transportation, Hummel and Schaur (2013) have mentioned airplanes as fast, expensive but increasingly important to trade after observing that the use of air cargo grew 2.6 times faster than use of ocean cargo during 1965-2004 period. Based on these facts, the two authors decided to test two hypothesis: lengthy shipping times impose costs that impede trade, and firms engaged in trade exhibit significant willingness-to-pay to avoid these cost. This can be understood as longer shipping time of ocean borne incurs added costs during transportation that shippers are willing to pay higher rates for airborne to avoid such costs. In order to test for these hypothesis, exporters' choice has been modeled between fast, expensive air cargo and slow, cheap ocean cargo, which depends on the price elasticity of demand and value the consumers attach to fast delivery, using US imports data from 1991 to 2005. The results suggested that each day in transit is worth 0.6 to 2.1 percent of the value of the goods, and that long transit delays significantly lower the probability that a country will successfully export a goods. Under the circumstance when many products are time sensitive due to inventory holding costs, perishability, rapid technological obsolesce, and uncertain demand, such a problem (costs incurred when transportation time is extended) will be magnified in the presence of increasing fragmented productions across multiple locations. It is, therefore, concluded that the sharp reduction in the cost of linking separated production sites through fast moving airplanes has been an important factor in growing fragmentation worldwide.

To sum up, from existing literature on modal selection, it is seen that the time-cost trade-off is always in the top list of factors affecting shippers' choices of transport mode. However, it is important that practitioners assess the cost of using a certain mode of transport thoroughly since there might be other added costs, either real or opportunity, incurred besides freight charges. Air transport has been used increasingly worldwide. It's not only because of the time advantage that it brings about but also due to the possibility for manufacturers to avoid unnecessary extra costs incurred by long delays.

However, even in the case that practitioners decide to use aircraft as their principal transport mode for product shipments, there are still ways to reduce the total transportation cost. For instance, sometimes merchandises are trucked to a further airports where airfreight costs are much lower instead of using the closer airports to lower the total transportation costs. This shipping practice has been named as "leakage" by Roy and Van Assche in one of their recent researches on Canada's aerospace industry.

2.3. Leakage

2.3.1. Intra-national and international leakage:

Leakage, as defined by Roy and Van Assche (2013),happens when:

'A significant amount of air transport that originated in a Canadian province, is carried by truck to other airports before subsequent airlift.'

The following example for a Montreal-based company, who wants to export its product to France by air, was used to illustrate the definition:

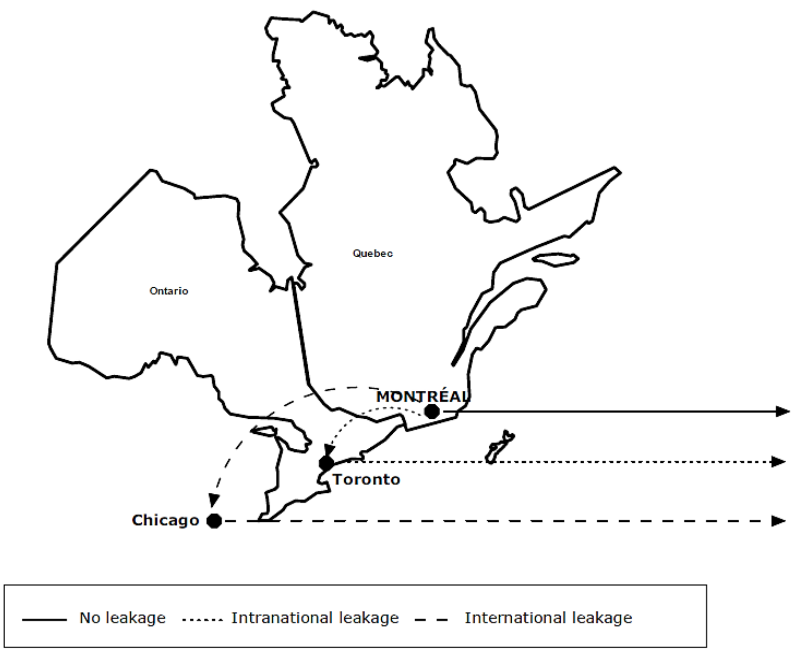

Figure 1- Illustration example of leakage(Roy and Van Assche (2013))

- If the product is directly airlifted from a Montreal-based airport to France, there is no leakage
- If the product is carried by truck to another Canadian airport (e.g. Toronto) before subsequent airlift to France, there is intra-national leakage
- If the product is carried by truck to a U.S. airport (e.g. Chicago) before subsequent airlift to France, there is international leakage

According to the authors, international leakage is among the causes of stagnation in Canada's air cargo industry since an increasing amount of aircraft components produced within Canada are now shipped using air transport services provided by U.S.'s airports as mentioned in the following section.

2.3.2. Results

The results of the study showed that intra-national leakage in aerospace industry is on the rise. Besides, the two beneficiaries from intra-national leakage are Ontario and British Columbia and those who were leaking the most are Quebec and less populated Canadian provinces.

Regarding international leakage, in order to measure its magnitude, the authors have differentiated between products exported to U.S. and non U.S. countries. Thanks to the geographical position of Canada, which is surrounded by oceans and U.S.'s territories, combining with the fact that aircraft components are mostly transported by air, such differentiation becomes reasonable. This means that all aerospace parts that were exported to non-U.S. countries by road would be considered to be leaked internationally since they must have been trucked to an U.S. airport before being transported by air to the final destination. The results of the analysis illustrated that international leakage is also increasing.

In their attempt to figure out what was behind the increase of leakage, the authors have identified that not only freight rates but also the absence of direct flights, lack of cargo capacity, and higher costs of holding inventory in Canada that caused leakage.

Indeed, lower freight cost in some airports relative to others may induce shippers to bypass their regional airports and truck their products to those in other provinces or country. Comparison of landing fees and charges between Toronto's Pearson airport and those in Chicago as well as between Vancouver and other west coast airports such as Los Angeles and Seattle by the authors showed relatively higher freight rates in Canadian airports. This indicates a comparative advantage for U.S. airports over Canadian ones.

Moreover, manufacturers located in some certain provinces where there is no direct flight from their suppliers or to their customers, have to truck aerospace products from or to airports in nearby provinces for airlift. For example, since there is no direct flight from Montreal to China, exports and imports of Montreal to/from China have to go through Toronto Airport before arriving in Montreal.

In addition, the fact that most Canadian airports have a lack of upper deck capacity due to the absence of regular air cargo freighter services has contributed to the rise of leakage. Given the large size of aircraft components, which does not fit in the belly of passenger planes, many Canadian shippers have to truck their components across the borders to U.S. airports, where there are freighters with adequate capacity, for subsequent lift to final destinations.

Last but not least, the higher cost of holding inventories in Canada was believed to induce shippers to consolidate shipments in the U.S, near the Canadian border and truck imports to their plants located in Canada.

2.4. Carrier selection in air cargo industry

As the air cargo industry is growing, the competition among freight airlines, forwarders, and integrators is becoming stronger and stronger, hence, figuring out why practitioners prefer one airport over the other is essential to all stakeholders.

Ohashi et al. (2005) have tried to identify how airport service quality and transport cost factors affect the choice of air cargo transshipment location (i.e. airport) with an application to the air cargo traffic to/from Northeast Asia (NEA). Those countries researched include China, Korea and Japan, the three largest air cargo markets in the region. Based on a unique data set of 760 air cargo transshipment routings to/from NEA region in 2000, the authors have applied an aggregate form of a multinomial logit model, focusing on the trade-off between monetary cost and time cost to decide the more influential factor to choice of transshipment airport. The monetary cost includes two main components: line haul cost (aircraft operation cost, published by IATA) and airport charges (landing, and/or takeoff fees, aircraft parking and hangar charges, security charges, noise related charges, cargo handling charges and waiting time caused by schedule delay). Besides, time cost is composed of three elements: cruising/flight time, loading/unloading, and custom clearance time. After running the model, a series of simulation exercises is also conducted using the estimated model to further measure the effect of changes in airport charges and service quality attributes on the transshipment location choice. Results of the study showed that the choice of transshipment location is more sensitive to connecting time at an airport than airport charges. Therefore, investing money and efforts in reducing connecting time at airports would be a more effective strategy than subsidizing airports to reduce airports charges; even if it means that airports have to increase their charges to raise the necessary capital for capacity expansion and automation including EDI system in order to reduce connecting time.

In conclusion, from what have been discussed in existing literature, multiple answers were given to questions such as “Which attributes affect shippers’ choices of transportation mode?”; “Why airway is increasingly preferred for merchandise transportation?” and “Which factors are essential in choosing an airport as a transshipment location?” Specifically, almost all of the results centered on what was known as "cost-time trade-off" and time tend to be placed more weight by shippers. However, in the shipping practice known as "leakage" described in this study, routing merchandises through airports in neighboring areas using road transportation will even takes more time than airlifting directly to the final destination. This seems to be a common practice to manufacturers but the answers to the question of what drives shippers to do so has not been verified yet. While lowering freight rate is believed to be the primary initiator, it is not the whole story.

Tretheway and Kincaid (2005), mentioned about this practices when describing the competition between airports in the new millennium. As stated by the two authors, cargo traffic, both origin/destination and transshipment/connecting traffic, is highly competitive. Today, much of the North America courier traffic to the Greater Toronto region flies to nearby Hamilton Airport (Ontario) and is then trucked to/from Toronto (Ontario). Hamilton airport handles approximately 100,000 tonnes of cargo each year that otherwise would likely have passed through Toronto International Airport. As Hamilton has lengthened its runway, it is now competing for international cargo flights as well. It is also claimed that, cargo traffic is highly price sensitive and can easily shift to alternative routings. If cargo rates for direct service from Amsterdam to Tokyo are too high, or if capacity at Amsterdam is limited, then the cargo can be trucked and flown via Brussels, Frankfurt, Paris, or Liege. It can also be flown from Amsterdam to Hong Kong, Vancouver, San Francisco, and so forth for onward carriage to Tokyo.

As it can be seen, this is exactly what was described by Roy and Van Assche (2013). However, besides freight rate and airport capacity, the two latter authors suggested also airport connectivity and cost of holding inventory as the sources of leakage.

The results, however, have not been tested. This study is designed for the purpose of testing what have been stated about the drivers of leakage to confirm the experts' opinions so far. Moreover, instead of focusing only on aerospace industry as Roy and Van Assche (2013), this study looks at leakage of all merchandises in the air-intensive industries exported from Canada to the rest of the world in 2008-2012 period.

3. RESEARCH FRAMEWORK

3.1. Data description

3.2. The Canada International Merchandise Trade Statistics

The primary source of data used in this research is ‘The Canadian International Merchandise Trade Statistics’ – *Customs basis*, which was provided by Statistics Canada. It is composed of exports from Canada to other countries around the world from 2008 to 2012. The detailed information provided includes:

1. Year of export
2. Harmonized System (HS) code of products
3. Detail description of products
4. Country of destination
5. Province of origin
6. Province of exit
7. Port of exit
8. U.S. state of destination
9. Mode of transport
10. Unit of measure
11. Quantity
12. Value

A small sample of this data is provided in the **Appendix 1**.

<u>Custom basis & Balance of Payment basis</u>

In general, the international trade statistics are reported and presented on two different bases, namely “Customs basis” and Balance of Payment (BoP) basis”.

“When goods are imported to or exported from Canada, declarations must be filed with the Canadian Border Services Agency (CBSA) and include the description and value of the goods, their place of origin and port of clearance and the mode of transport of the goods into or out of the country. These Customs declarations are used in compiling Customs-basis statistics.”

(StatisticsCanada, 2014).

Besides, information regarding imports and exports are also input for the Canadian Systems of National Accounts (i.e. in BoP and GDP) to formulate the national trade and budgetary policies. Therefore, import and export values from Customs basis are adjusted on the coverage, time of recording, valuation and classification of transaction to form the BoP basis. Essentially, the difference between the two bases is that customs based merchandise trade statistics cover the physical movement of goods coming in and out of Canada as stated in customs documents, while BoP adjusted data is intended to cover all merchandise trade transactions between resident and non-residents.

Harmonized System

The Harmonized System or the HS (officially named Harmonized Commodity Description and Coding System) is a commodity classification system used by many countries, territories, and economic unions around the world as the basis for their customs tariffs and for the compilation of international trade statistics.

"The HS is a highly structured nomenclature comprising a series of 4-digit headings, most of which are subdivided into 6-digit subheadings. The headings are grouped into 96 Chapters which are themselves arranged into 21 Sections. Most of the sections and chapters contain Notes which form an integral part of the HS and have the same legal force. These notes serve to define the precise scope and limits of each unit. In an effort to ensure that any commodity can always be simply and clearly assigned to a specific heading, to the exclusion of all others, the HS incorporates a series of rules upon which all classification decisions must be based…

Canada and most other users of the HS further subdivide the HS headings and subheadings to meet their own requirements for increased detail and specificity. Under the terms of the Convention, users are free to do this as long as the scope of the HS headings and subheadings remains unchanged. In the Canadian context, imports are classified using a 10 digit, HS-based commodity code whereas exports are classified using an 8 digit code. Both structures' first 6 digits match the HS Heading/Sub-heading coding standard set forth by the WCO. There is a 2-digit statistical annotation component that appears as the last 2 digits of the most detailed level of the HS. The meaning of the statistical annotation digits differs between imports and exports. In the case of imports, there is also a 2-digit tariff item annotation code that is located between the 6th digit and the statistical annotation suffix. Export classification, for which there is no tariff item identification requirement, uses the HS-8 which is structurally analogous to the import classification's HS-10 without the 7th and 8th digits".

(*Statistical Data Documentation System Reference number 2201*, 2014)

Since its invention in Jan, 1st, 1988 by The Customs Co-operation Council, the HS has been changed several times in the year 1996, 2002, 2007 and 2012. In order to make it more convenient for the research conduction, data has been chosen in 5 years period from 2008 to 2012. In addition, details on exports merchandise classification were provided up to HS8.

Countries of Destination

The data includes all countries and territories around the world that have had imports and exports transactions with Canada from 2008 to 2012.

Province of Origin and Province of Exit

There are in total thirteen provinces and territories in Canada:

1. Alberta
2. British Columbia
3. Manitoba
4. New Brunswick
5. Newfoundland and Labrador
6. Northwest Territories
7. Nova Scotia
8. Nunavut
9. Ontario
10. Prince Edward Island
11. Quebec
12. Saskatchewan
13. Yukon

Below are their relative positions across the country:

Figure 2- Canada's Provinces (Source: http://www.trailcanada.com/provinces/)

"Province of origin" represents the province in which the goods were grown, extracted or manufactured while "province of exit" refers to where the goods were cleared for customs.

Mode of transport

For exports, which is the concern of this paper, the mode of transport recorded represents the mode by which the international boundary is crossed. This may be different from the mode of transport within Canada. Merchandises can be transported in more than four different ways including Rail, Road, Water, Air and Other modes of transport[2].

Unit of Measures

Unit of measures are represented by three-character, alphabetic abbreviations, which were developed by the International Organization for Standardization (ISO).

The following table summarizes units of measure for different types of merchandise in Canadian export classification.

Abbreviations	Meaning
CTM	Carat
MTQ	Cubic Metre
DZN	Dozen
DPR	Dozen Pairs
GBQ	Gigabecquerel
GRM	Gram
GRO	Gross
KGM	Kilogram
KSD	Kilogram Air Dry
KNS	Kilogram Named Substance
LTR	Litre
LPA	Litres of Pure Alcohol
MBQ	Megabecquerel

[2] The category "Other modes of transport" refers to all modes by which merchandises are shipped across international boundaries other than "Rail", "Road", "Water" and "Air". It mostly represents the movements of oil, petroleum, gas, slurry, etc., through pipelines.

MWH	Megawatt Hour
MTR	Metre
TNE	Metric Tonne
TSD	Metric Tonne Air Dry
NMB	Number
NAP	Pack
PAR	Pair
CMK	Square Centimetre
MTK	Square Metre
MIL	Thousand
TMQ	1000 Cubic Metre

Table 2- Unit of measures under Canadian Export (Source: http://www.statcan.gc.ca)

Value

"Data are disseminated in Canadian dollars and are converted from foreign currencies using a number of methods depending on the data type and source. These data types and sources include:

• Imports

• Exports to U.S. destinations,

• Exports to non-U.S. destinations that are reported electronically

• Exports to non-U.S. destinations that are reported non-electronically (i.e. 'paper' export declarations)"

(*Statistical Data Documentation System Reference number 2201*, 2014)

3.2.1. IATA Cargo Account Settlement System (CASS)

Freight rate

In general, it is hard to find a comprehensive database of freight rates. Nowadays, more and more pricing is done under contracts between large forwarders and airlines, therefore, the rates agreed are confidential. Basically, the record of all cargo rates and rules that are agreed by airlines is provided by the IATA three times a year in a publication namely "The Air Cargo Tariff" (TACT)[3]. It includes three types of rate: The general cargo rate, the class rates or commodity classification rates and the specific commodity rates. General cargo rates apply to transportation of merchandises that have not been allocated a specific commodity rate or commodity classification rate from one place to another. Class rates apply to carriage of particular commodities from a specified origin to a specified destination. These rates are applied to shipment of commodities such as live animals, valuable goods, perishable goods, and newspapers. Specific commodity rates are also published for shipment of particular merchandises on a certain origin-destination pair. However, this type of rate is used to encourage some certain commodities to be air transported. Hence, it is usually lower than general cargo rates. In reality, much more attractive rates can be negotiated by large forwarders directly with airlines and heavier shipments can take advantage of lower rates. The rates described above only cover for the cost of shipping the goods from its origin to its destination, without fuel surcharges, security and air navigation, etc. There are also handling charges applied based on the additional services required and tariffs charged by integrators if shippers want to combine shipping with handling, customs procedures and some other related activities.

Data on freight rates used in this study is the general cargo rate, provided by IATA from the Cargo Accounts Settlement System (CASS).This system, firstly launched in 1976, was designed with the objective of simplifying the settling accounts between cargo intermediaries and carriers, thus, reducing the costs while at the same time improving service quality to both agent and carrier. Traditionally, exporters reach airlines via cargo agents. The agents collect freight charges from shippers for payment over to the carrier. The carriers produce invoice back through cargo agents. Each carrier receives a report from and prepares invoice to each agent individually. Checking and consolidation of all invoices and reports became a burden on administration. Therefore, the introduction of CASS has significantly reduced expensive and time consuming functions for airlines and freight forwarders.

The freight rates used in this research are composed of the general cargo rates applied by airports in big cities of Canada and the U.S. from 2010 to 2012. Those includes Montreal, Toronto, Vancouver, Chicago, New York, Seattle and Los Angeles. These rates are quoted in unit of

[3]information regarding freight rate is based on what was presented by Morrell (2011).

dollar/kg and will be used to analyze its impacts on the level of leakage. Sample of data will be found in **Appendix 2a.**

<u>Capacity</u>

Air cargo effective capacity refers to the volume (in metric tonnes) of cargo available for scheduled flights from a certain airport to selected countries of destination on weekly basis. For example, if capacity from Montreal PET, Canada to Bordeaux, France is 376, it means that the number of metric tonnes available on flights from Montreal PET airport to Bordeaux is 376 per week.

Such information on capacity was provided for major airports in Canada's and U.S.'s cities to top 9 Canada's trading partners, including: China, France, Germany, Hong Kong, Italy, Japan, Mexico, Poland, and United Kingdom. However, information related to Mexico will be excluded as explained later on. Sample of data will be found in **Appendix 2b**.

3.2.2. CEPII's BACI

As it will soon be explained, value to weight ratio will be used in this study to represent product's characteristic, which is believed to be a factor that causes the occurrence of leakage. In fact, the "Canada International Merchandise Trade Statistics" does provide the value and quantity of goods exported from Canada to the rest of world that can be used to calculate such ratios. However, the unit of measures are different across merchandises, creating challenges in computing proper ratios for all products. Therefore, CEPII's BACI is deployed.

Centre d'Etudes Prospective et d'Informations Internationales (CEPII) is the French research center in international economics that produces studies, researches, databases and analyses on the world economy and its evolution.

BACI is the world trade database developed by the CEPII at a high level of product disaggregation. This database is constructed using data provided by the United Nations Statistical Division (COMTRADE). BACI is constructed using an original procedure that reconciles the declarations of the exporters and the importers because when both exporting and importing countries report to COMTRADE, there are two different figures for the same flow. This harmonization procedure enables the considerable extension of the numbers of countries for which data are available, as compared to the original data set. BACI is updated annually to provide bilateral values and quantities of exports at HS 6-digit product disaggregation, for more than 200 countries since 1995.

The value and quantities of exports collected from BACI was used in this research to calculate the value to weight ratio of different merchandises up to HS 4 level, as following:

$$\text{Value to weight} = \frac{value}{quantities}$$

Sample of data will be found in **Appendix 3.**

3.3. Data analysis

3.3.1. Data Sampling

The primary reason that Canada has been chosen as the object of this research is that its geographical location makes it more convenient to identify international leakage. Situated in North America, Canada is surrounded by North Pacific Ocean to the west, North Atlantic Ocean to the east, Arctic Ocean to the north, and United States to the south. In addition, as noted earlier in data description, the mode of transport recorded for exports represents the mode by which the international boundary is crossed. Therefore, any exports that were documented as leaving Canada to other countries around the world by rail or road transportation must at least pass through United States or Mexico (MEX). From these countries, exported goods can be subsequently lifted by either air or marine transportation to its final destinations. Based on the definition proposed, if airborne is used, it is when international leakage happens.

Similar to what has been done by Roy & Van Assche (2013), this study also makes a distinction between exports going to U.S. & MEX and non-U.S. & MEX countries. In this study, not only U.S. but also Mexico is excluded from the rest of the world since a lot of trade between Canada and Mexico goes by truck (for example aerospace components) and doing so will ensure that this type of trade does not bias the measurement of leakage. Thus, any exports that have been recorded as being transported by rail and road to non-U.S. & MEX countries will be considered to have been leaked internationally *if it leaves U.S. or Mexico by air*. Unfortunately, the given data of Canada's exports does not allow the identification of how merchandises left these two countries. The assumption and method by which international leakage is identified will soon be discussed.

At a more detailed level, Quebec has been chosen as the province of origin to explain leakage. As it has been found from the study of Roy and Van Assche (2013), Quebec had not only the highest intra-national leakage as compared with other biggest provinces in Canada but also the largest share of aerospace exports to non-U.S. countries that leaves Canada by rail or road (or inter-leakage). Therefore, it is expected that investigating Quebec's leakage situation will bring about interesting and solid results. The sample used for the test includes all exports that originated from Quebec to the rest of the world from 2008 to 2012 in different modes of transport.

Furthermore, as mentioned earlier in the definition, the concept of leakage used in this study focuses only on air cargo. As a consequence, air-intensive industries will be emphasized during the implementation of this research.

3.3.2. Initial Analysis

<u>Specification of leakage</u>

In this study, intra-national leakage is identified as all the *air export* that was transported to different countries around the world that have *province of origin different from province of exit*.

However, identification of international leakage is more complicated. As discussed in data sampling section, any exports that have been documented as being transported by rail and road to non-U.S.& MEX countries will be considered to have been leaked internationally if it left U.S. or Mexico by air. However, the given data does not specify under which mode of transport that merchandises were subsequently shipped out of U.S. and Mexico. Based on these countries' geographical locations, it can only be either water or air transportation. It is necessary to identify the value of exports that left U.S. and Mexico by air in order to calculate the share of international leakage in total Quebec's air export. It is, therefore, assumed that the percentage of air exports that left Quebec directly over water and air exports will be equal to the percentage of indirect air exports over indirect exports from Quebec.[4]

As a consequence, the procedure includes two steps. The first step is the calculation of relative percentage between Quebec's direct air exports and its sum of direct air and water exports. The second step is the identification of Quebec indirect export, or those that went to non U.S. and

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[4]***QC direct air exports:*** *Air exports from Quebec to non U.S. & MEX countries.*

QC direct water exports: *Water exports from Quebec to non U.S. & MEX countries.*

QC indirect exports: *Road & Rail exports from Quebec to non U.S. & MEX countries.*

QC indirect air exports: *Exports from Canada that left US&MEX to the rest of the world by air.*

Mexico countries under rail and road. The total amount of international leakage will then be found afterward, based on the assumption made above by multiply the ratio found in the first step with the indirect exports found in the second step. The share of international leakage in total air exports is equal indirect air exports divided by sum of direct and indirect air exports.

Based on what have been explained so far, intra- and international leakage can be calculated on different bases such as province of origin, country of destination, and type of merchandise. The following section provides an overview of Canada's leakage situation in 2008-2012 period.

Intra-national leakage

Canada wide's data showed a similar pattern for the country's total export, air export and share of intra-national leakage in its air export from 2008 to 2012, as showed in figure 3.

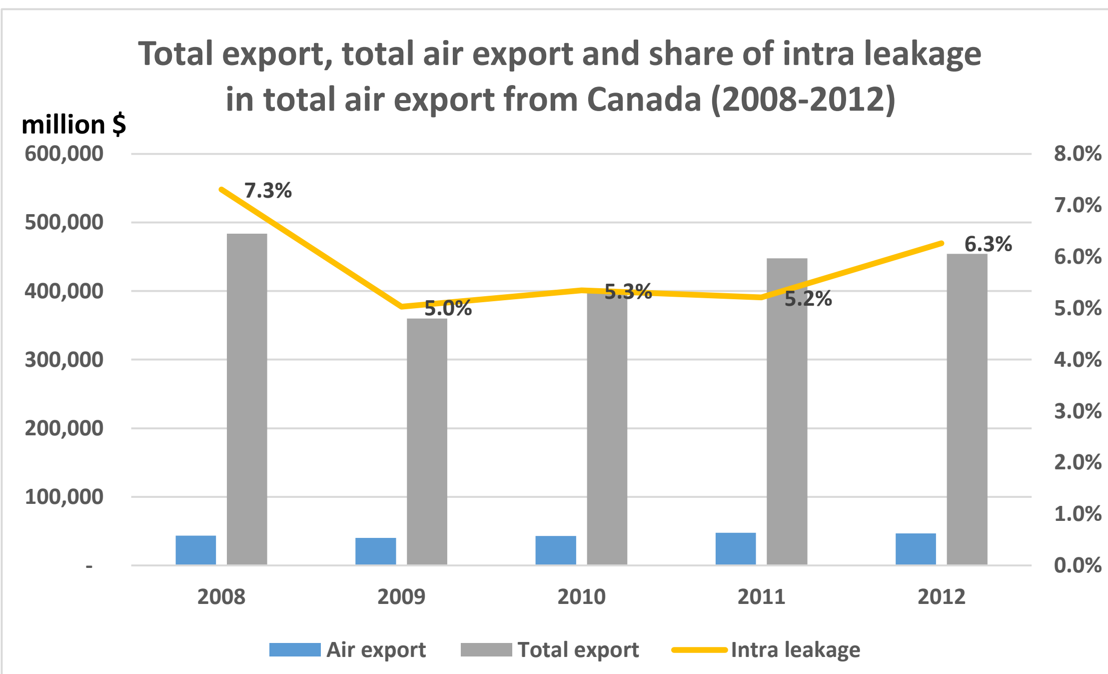


Figure 3- Total air export, total export and share of intra leakage in total air export from Canada (2008-2012)

As it can be seen, there was a deep decrease in the year 2009, followed by a gradual increase afterward in all three measures. Regarding the percentage of leakage within national boundary, after declining more than 2% from 2008 to 2009, when the global economy was under crisis and extremely unstable, it started to rise gradually since then.

By computing the intra-national leakage as percentage of provincial air exports for each Canadian province, what is also found is that the tendency to use airports in different provinces to transport merchandises is higher in less populated provinces such as Nunavut (99%), Yukon (55%) and New Brunswick (44%), while the percentages are much smaller for big and densely populated ones such as British Columbia (2%), Ontario (3%) and Quebec (5%). (See table 3). This finding is foreseeable because the three latter provinces are home to international large airports.

P.O.O	**Average**	**Rank**
Nunavut	99%	1
Yukon	55%	2
New Brunswick	44%	3
Prince Edward Island	41%	4
Northwest Territories	38%	5
Newfoundland and Labrador	32%	6
Manitoba	25%	7
Saskatchewan	22%	8
Nova Scotia	21%	9
Alberta	12%	10
Quebec	5%	11
Ontario	3%	12
British Columbia	2%	13

Table 3-Share of intra-leakage value in Canada air export by province of origin (2008-2012)

In addition, most of those leaked merchandises actually flew into international airports in Canadian large provinces such as Alberta, British Columbia, Ontario and Quebec. Those four provinces received almost all exports from around the country for air transport.

P.O.E / **P.O.O**	**Alberta**	**British Columbia**	**Ontario**	**Quebec**	**Total**	**Others**
Alberta	0%	62%	33%	4%	**99%**	1%
British Columbia	28%	0%	60%	9%	**98%**	2%
Manitoba	17%	13%	63%	6%	**100%**	0%

New Brunswick	0%	1%	25%	47%	**74%**	26%
Newfoundland and Labrador	0%	1%	46%	37%	**84%**	16%
Northwest Territories	21%	0%	78%	0%	**100%**	0%
Nova Scotia	0%	3%	48%	47%	**99%**	1%
Nunavut	0%	12%	83%	5%	**100%**	0%
Ontario	3%	7%	0%	75%	**85%**	15%
Prince Edward Island	0%	1%	15%	47%	**64%**	36%
Quebec	6%	6%	80%	0%	**91%**	9%
Saskatchewan	40%	24%	17%	7%	**88%**	12%
Yukon	15%	63%	19%	2%	**99%**	1%

Table 4- Intra-national leakage in Canada from 2008-2012

International leakage

International leakage, when measured as share of Canada's total air export, fell gradually from 2008 to 2011 but rose again in 2012. The extent of the decline grew from 0.1 % in 2008-2009, to 0.5% in 2009-2010 and up to 2.2 % in 2010-2011. (Figure 4)

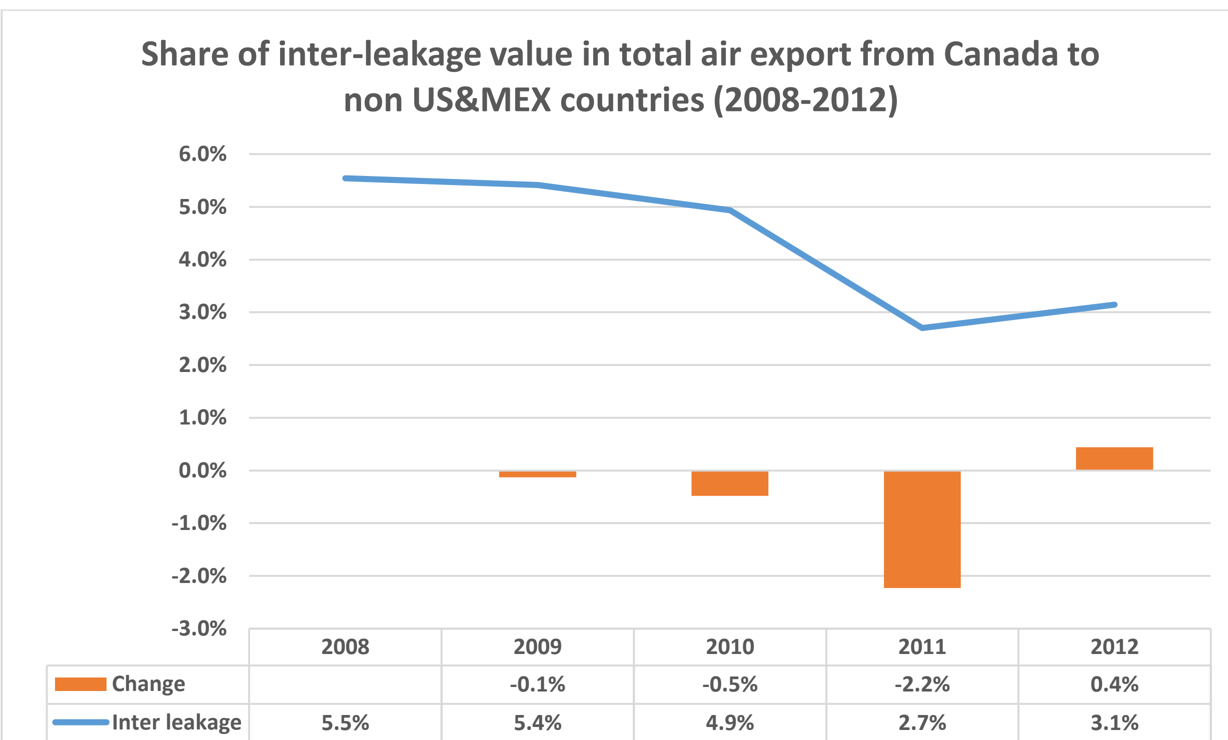


Figure 4- Share of inter-leakage value in total air export from Canada (2008-2012)

Alberta, Quebec and Ontario leaked the largest share of its air export to non U.S.& MEX countries with the average percentage in 2008-2012 period is 10%, 6% and 5% respectively.

P.O.O	**Average**	**Rank**
Alberta	10%	1
Quebec	6%	2
Ontario	5%	3
Manitoba	5%	4
Nunavut	4%	5
New Brunswick	2%	6
Prince Edward Island	2%	7
Saskatchewan	1%	8
British Columbia	1%	9
Nova Scotia	0%	10
Yukon	0%	11
Newfoundland and Labrador	0%	12
Northwest Territories	0%	13

Table 5- International leakage from 2008-2012, rank by province of origin

As it has been explained, international leakage should gain more concerns as it is one of the causes to stagnation in a country's air export. In addition, from the above general capture of Canada's leakage, it is showed that both Alberta and Quebec are worth for investigation due to their high level of leakage. However, the volume of air export from Quebec ($ 55,762,907,094) in 2008-2012 period was 7 times higher than that of Alberta ($ 8,080,198,903); therefore, the decision of choosing Quebec as the province of origin to focus is more proper.

<u>Quebec intra- and inter- national leakage</u>

Generally, Quebec's air export decreased gradually from 2008 to 2012 while the percentage of merchandise transported by truck to other provinces for subsequent airlift increased from 4.01 % to 5.38 %.

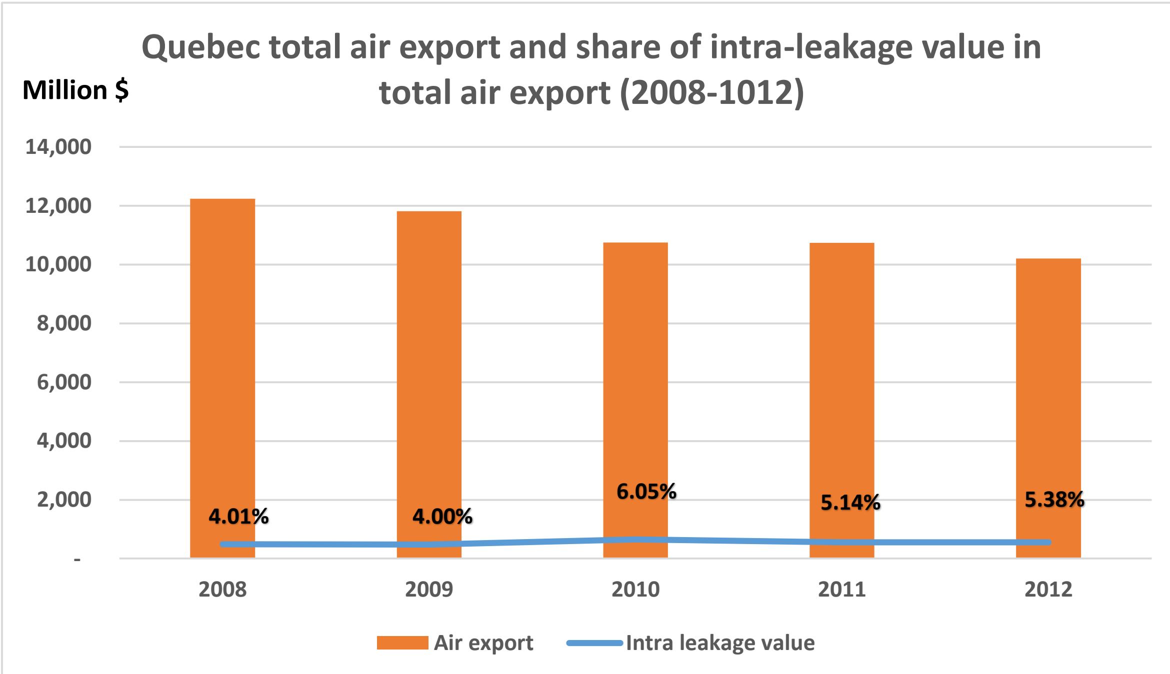


Figure 5- Quebec total air export and share of intra-leakage value in total air export (2008-1012)

Of all the air cargo that leaked from Quebec, 79% cleared customs in Ontario, another 18% equally divided among British Columbia, Manitoba and Alberta, while the last 3% went out of Canada from Newfoundland and Labrador.

Province of Exit	Share of export originated from Quebec
Ontario	79%
British Columbia	6%
Manitoba	6%
Alberta	6%
Newfoundland and Labrador	3%

Table 6- Air cargo originated from Quebec that cleared customs in other provinces and territories in Canada.

In contrast to intra leakage, Quebec's international leakage did not have such a quite stable pattern. It highly fluctuated during the five year period (2008-2012) as showed it the following figure.

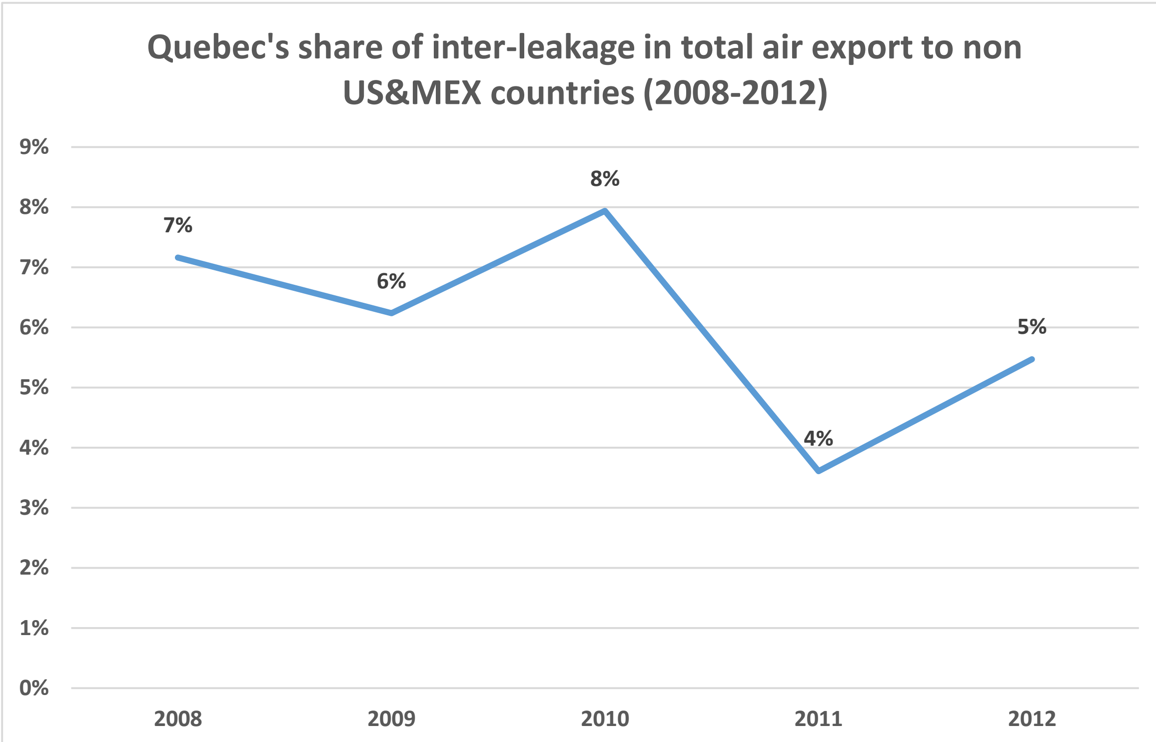


Figure 6- Quebec's share of inter-leakage in total air export (2008-2012)

However, since the definition of leakage emphasizes air freight, data has been refined to identify air-intensive manufacturing industries from the total of 99 HS2 codes with the hope to find a better reflection of leakage.

Revealed competitive advantage (RCA) and air-intensive industries

Firstly, from the original data set of Canada International Merchandise Trade Statistics, The HS codes with 8 digits were broken down to take the first 2 (HS2) and 4 digits (HS4) for more general product levels. There are 99 HS2 codes, ranked from 01 to 99. The HS4 code is formed by HS2 code, followed by another 2 digits of subdivision. For example, the code 01 represents "live animals" and code 0101 represents its first sub-category of "horses, asses, mules and hinnies". The second division of this HS2 code is 0102, which is encoded for "bovine animals".

Secondly, in order to identify Quebec's air-intensive industries, the RCA of each industry (or HS2) will be calculated as:

$$RCAi = \frac{\frac{Quebec's\ direct\ air\ exports\ of\ industries\ i\ to\ non\ US\&Mex\ countries}{Quebec's\ direct\ exports\ of\ industries\ i\ to\ non\ US\&Mex\ countries}}{\frac{Quebec's\ direct\ air\ exports\ of\ all\ industries\ to\ non\ US\&Mex\ countries}{Quebec's\ direct\ exports\ of\ all\ industries\ to\ non\ US\&Mex\ countries}}$$

Each of a HS2 codes was considered as one industry and only those that are manufacturing products would be kept. This lead to the exclusion of codes 01 to 27 and 97 to 99. The RCA of each industry was calculated on annual basis from 2008 to 2012. Only those that have RCA greater than or equal to 1 during the whole five year period would be kept.

Results from calculation of the denominator indicate that Quebec's exports shipped by air account for about 36% of its total export on average from 2008 to 2012. The share of air export in total export on yearly basis is showed in this following graph:

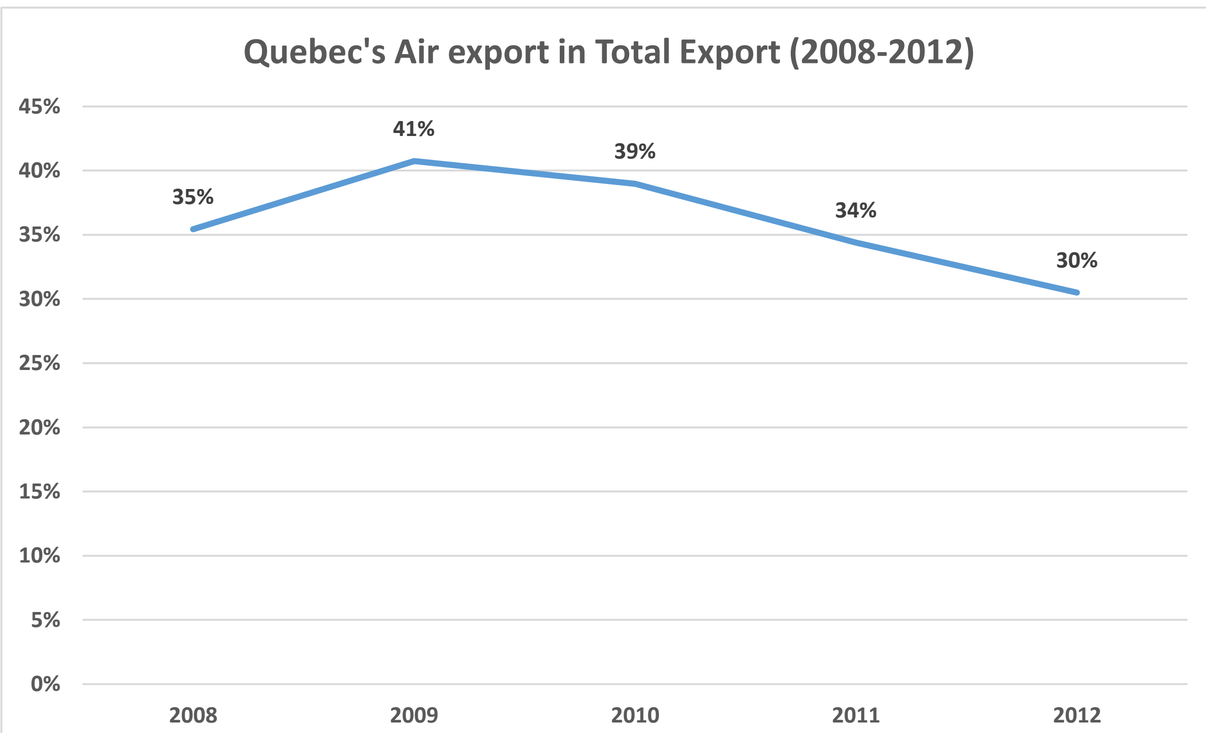


Figure 7- Quebec's Air export in Total Export (2008-2012)

As a consequence, any manufacturing industry that has the percentage of its products shipped by air freight higher than these thresholds in all five years will be labelled as 'air-intensive'. The final list includes 14 industries as presented below:

HS2	Description	Air export/ total export
30	Pharmaceutical products	76.03%
42	Articles of leather, saddler & harness, travel goods, handbags, articles of gut	62.50%
43	Furskins & artificial fur, manufactures	95.04%
61	Articles of apparel & clothing accessories-knitted or crocheted	78.37%
62	Articles of apparel & clothing accessories- not knitted or crocheted	59.24%
67	Prepared feathers, human hair & articles thereof, artificial flowers	88.27%
71	Pearls, stones, prec. Metals, imitation jewelry, coins	87.60%
75	Nickel & articles thereof	68.39%
82	Tools, spoons & forks of base metal	62.09%
84	Nuclear reactors, boilers, machinery & mechanical appliances, computers	65.49%
85	Electrical machinery & equip. & parts, telecommunication equip., sound recorders, television recorders	78.48%
88	Aircraft, spacecraft, & parts thereof	82.83%
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments & accessories	87.93%
91	Clocks & watches & parts thereof	88.69%

Table 7- Quebec air-intensive industries

Quebec's leakage – air-intensive industries

It is found that both Quebec's national and inter-national leakage of air-intensive industries had the same patterns with those measured for all industries described above (Figure 8 and 9). Of these fourteen industries identified, during five years, the percentage of air cargo originating from Quebec that cleared customs in other provinces has increased approximately 1% (from 4% in 2008 to 5% in 2012) and those that were trucked to another countries for subsequent airlift has climbed from 5% to 7%.

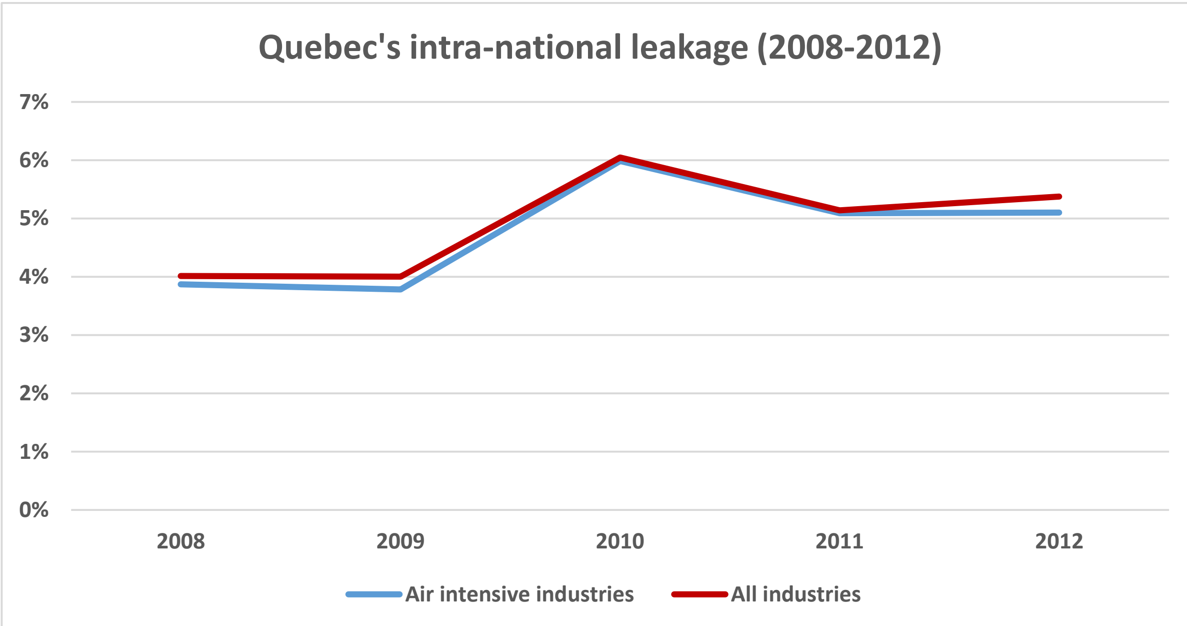


Figure 8- Quebec's intra-national leakage (2008-2012)

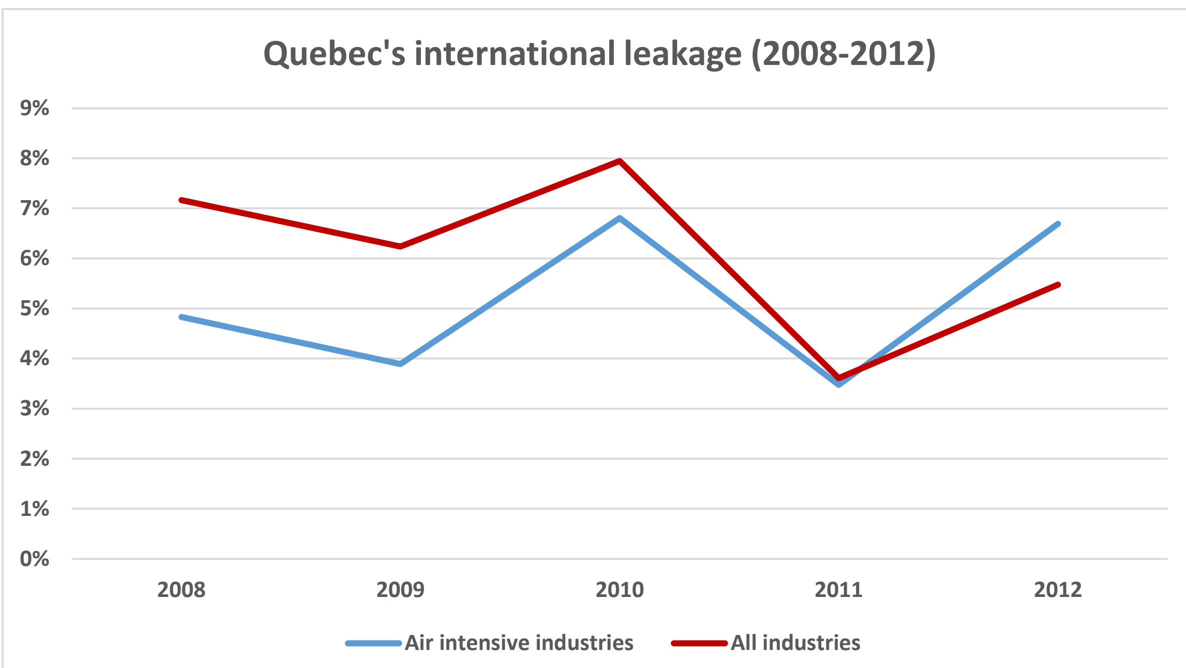


Figure 9- Quebec's international leakage (2008-2012)

A break-down by air-intensive industries in two periods (2008-2010 and 2011-2012) showed a general decrease in both intra and inter-national leakage in Quebec (Figure 10 & 11).

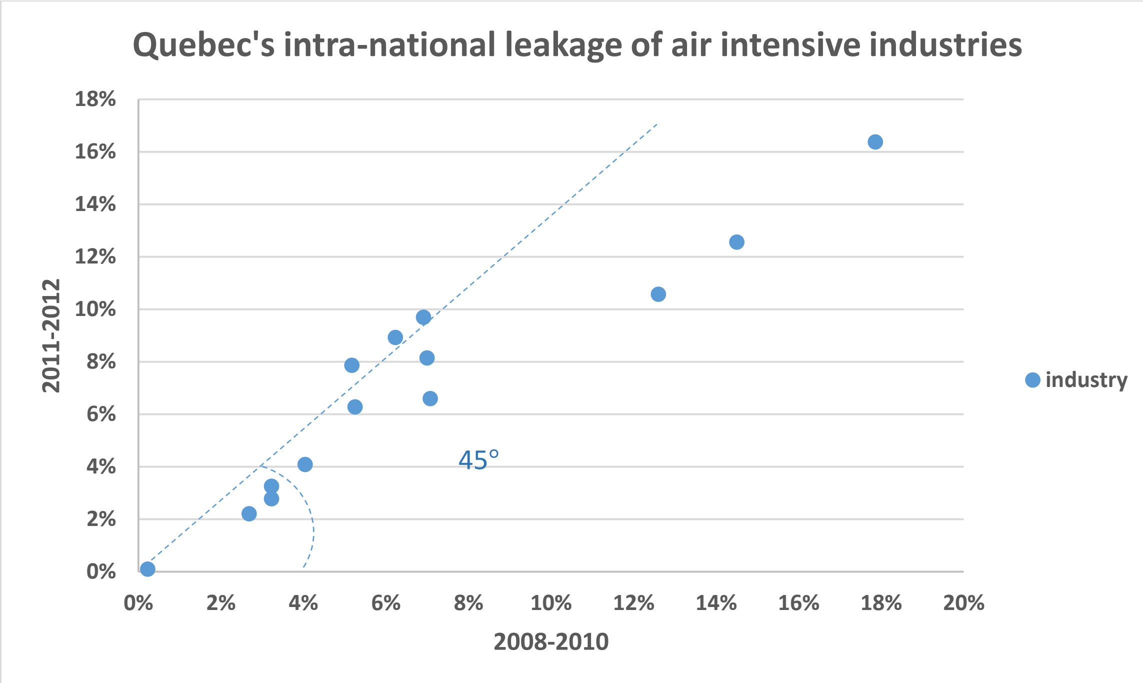


Figure 10- Quebec's intra-national leakage of air-intensive industries

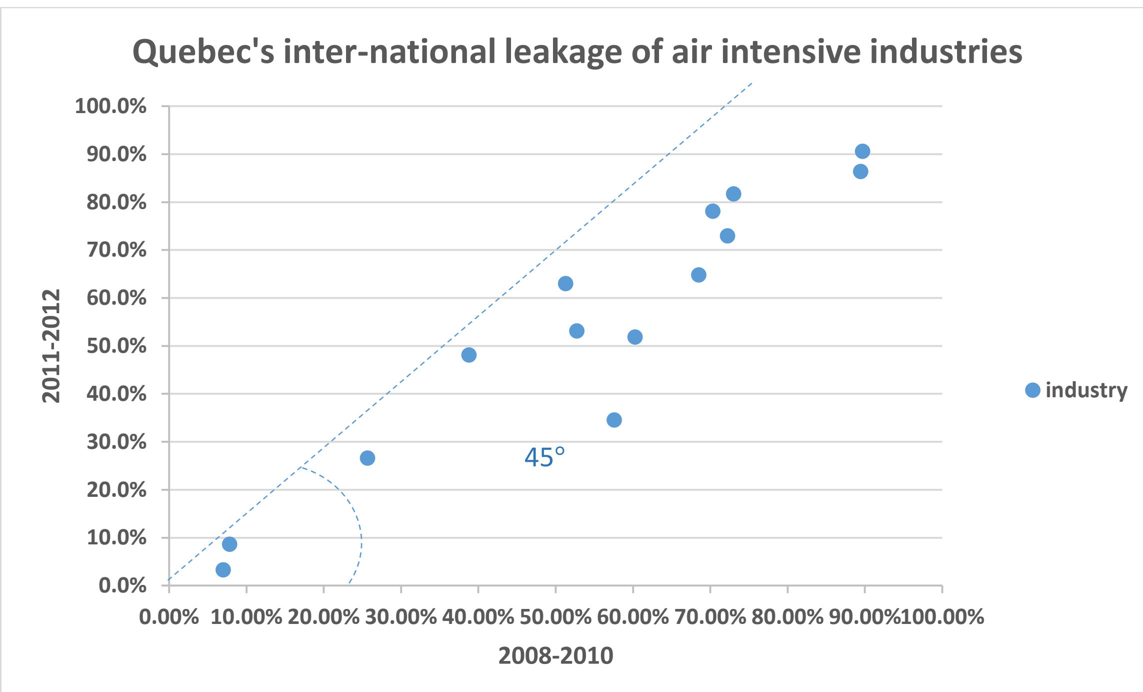


Figure 11- Quebec's international leakage of air-intensive industries

As it can be seen, the identified industries were plotted in a plane with horizontal axis represents 2008-2010 leakage percentage while vertical axis represents 2011-2012 period. As most of the dots appeared under the 45 degree line, a general decline in both intra and inter-national leakage can be concluded for Quebec's air intensive industries.

A rough calculation of leakage for Quebec's air-intensive exports to its top 20 trading partners[5]in two periods (2008 - 2010 and 2011-2012) also suggested a decreasing use of this shipping practice.

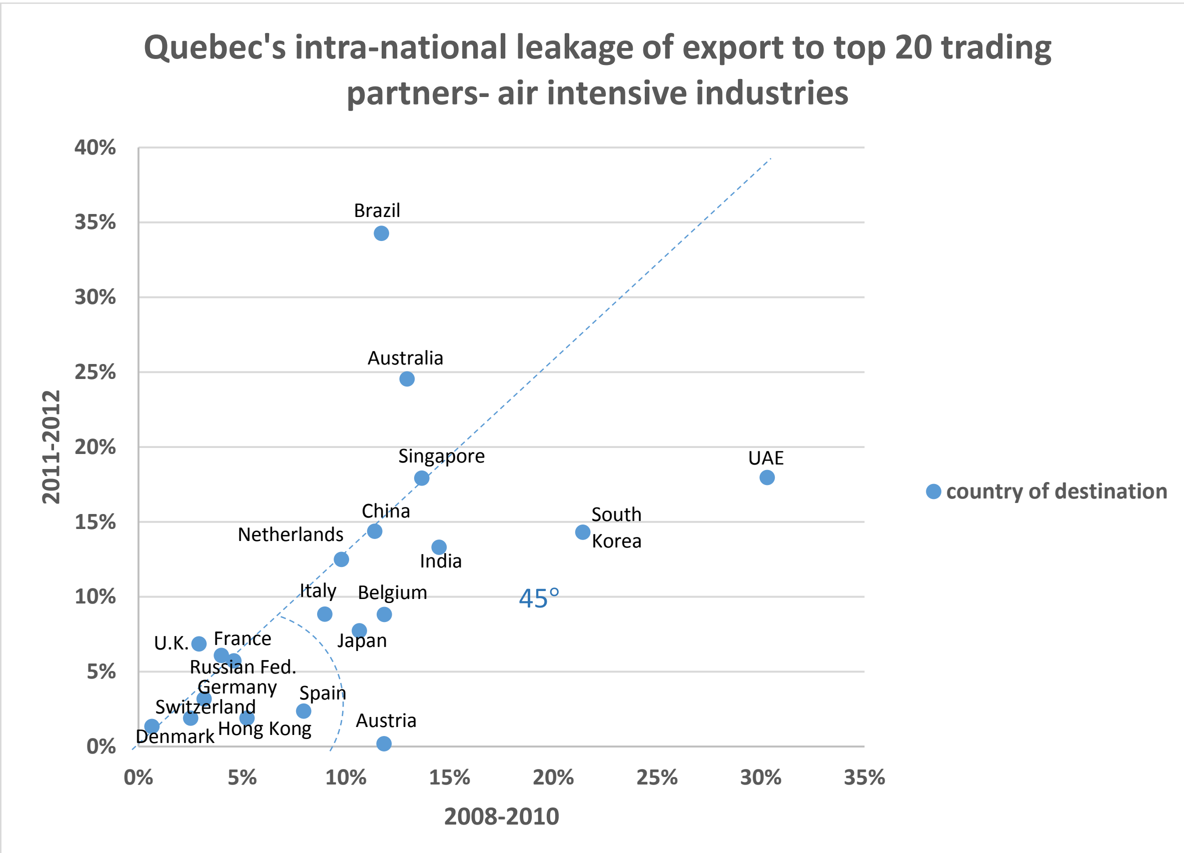


Figure 12- Quebec's intra-national leakage of air exports to its top 20 trade partners, air-intensive industries

[5] Refer to **APPENDIX 6** for Quebec's top 20 trading partners

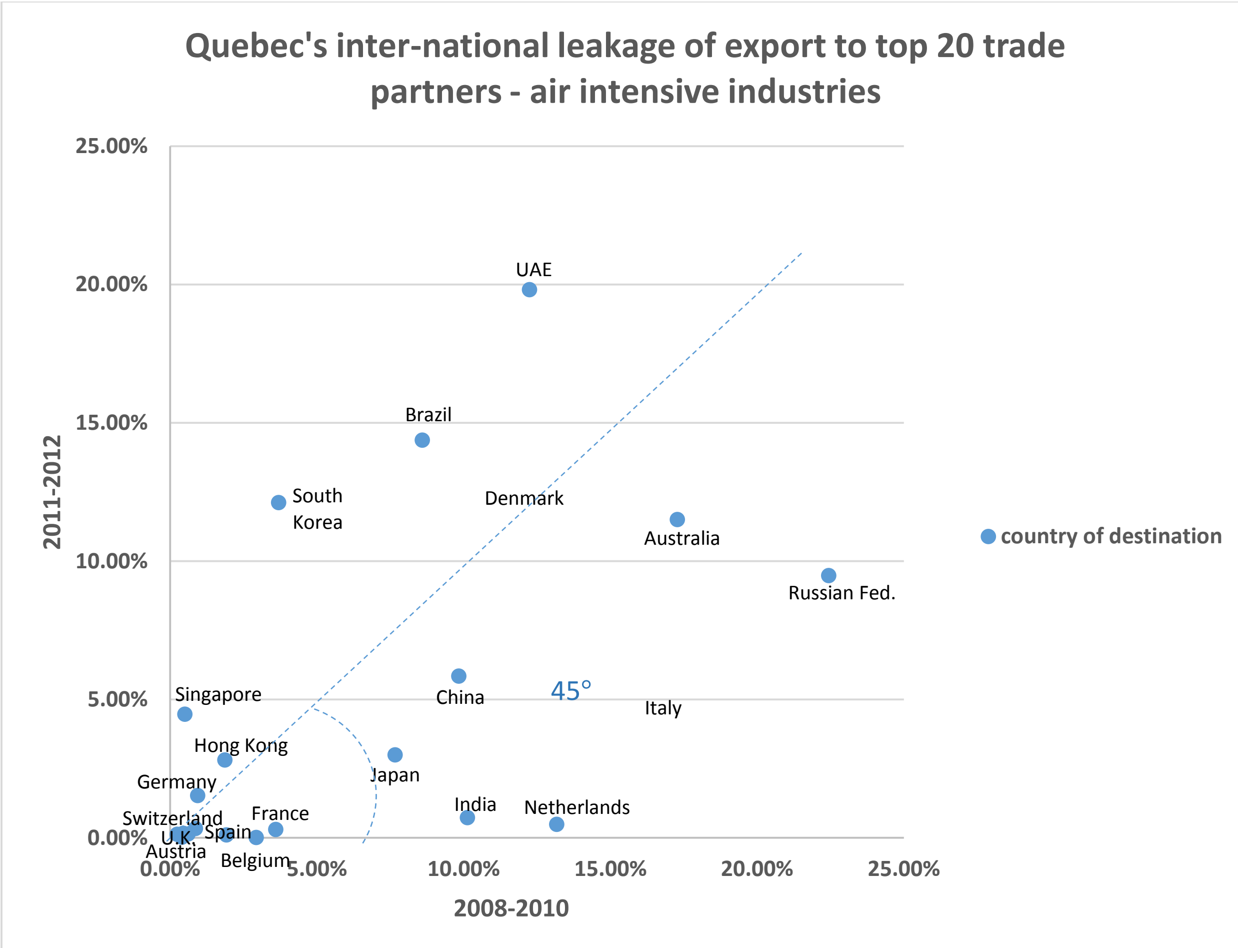


Figure 13-Quebec's international leakage of air export to its top 20 trade partners - air-intensive industries

Such findings are different from what has been found in figure 8 and 9, which showed that the percentage of merchandise leaked from Quebec increase slightly in 2012 compared to 2008. This may be because the significant increase from 2009 to 2010 and the plummet in the year after (see figure 8, 9) have caused the leakage percentages calculated in 2008-2010 period to be higher than that in 2011-2012.

One possible reason that induces manufacturers in Quebec to bypass the closest airports to them and truck their merchandises to those in other provinces or even other countries for subsequent airlift might be freight rate. It is believed that the propensity for leakage to happen will increase if the cost advantage from lower rates provided by further airports is more than enough to offset for the cost of trucking air cargos there. Investigation of the average charges in 2010-2012 periods applied by airports in several large cities of Canada and U.S. showed that the air cargo rates to Quebec's top ten trading partners are almost always higher in Montreal compared to other U.S.

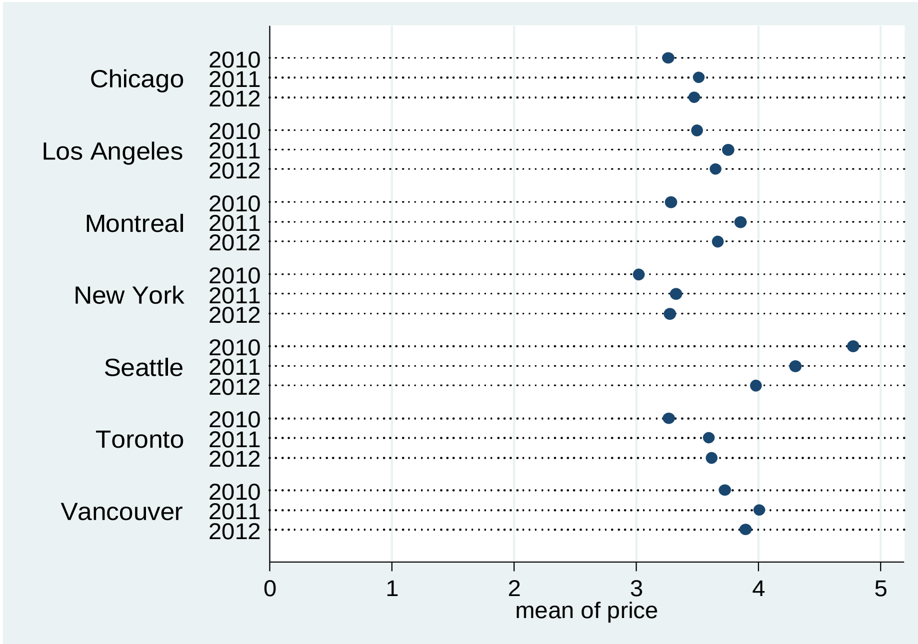
cities, except to France and Austria. Within Canada, the charges applied in Toronto to all destination countries are lower than in Montreal except for exports to France. Merchandises shipped by air from Vancouver to China, Germany, Japan, and Singapore are also cheaper than from Montreal as showed in the following table:

Country of Destination	Vancouver	Toronto	Los Angeles	Chicago	New York	Seattle
Australia	***-0.18***	0.28	1.41	0.24	0.36	0.83
Austria	***-0.01***	0.15	***-0.67***	***-0.05***	0.17	***-0.60***
Brazil	***-0.78***	0.43	0.98	0.80	1.36	0.66
China	0.31	0.44	0.71	0.57	0.28	0.27
France	***-0.27***	***-0.24***	***-0.72***	***-0.39***	***-0.16***	***-0.49***
Germany	0.11	0.15	***-0.36***	0.18	0.17	***-0.29***
Italy	***-0.16***	0.28	***-0.34***	0.12	0.35	***-0.52***
Japan	0.46	0.27	0.52	0.37	0.25	0.25
Singapore	0.91	0.63	0.66	0.76	0.55	0.59
United kingdom	0.13	0.33	0.24	0.38	0.57	***-0.04***

Table 8- Differences6 in average charges applied in Montreal and other Canadian and U.S. cities, 2010-2012 period _Unit: Canadian dollar; data in 2012

In addition, illustration of the average freight rates in 2010-2012 period for large cities in Canada and U.S. shows that while the average prices increased from 2010 to 2011, then decreased in 2012 in all cities, the charges applied in Seattle reduced considerably in these three years. (Figure 14). In addition, Montreal's freight rates are relatively higher than those in Chicago and New York, which are geographically close to Montreal, hence, it may create a good condition for international leakage to happen.

[6] Difference = Montreal's rate – rate in another province/state



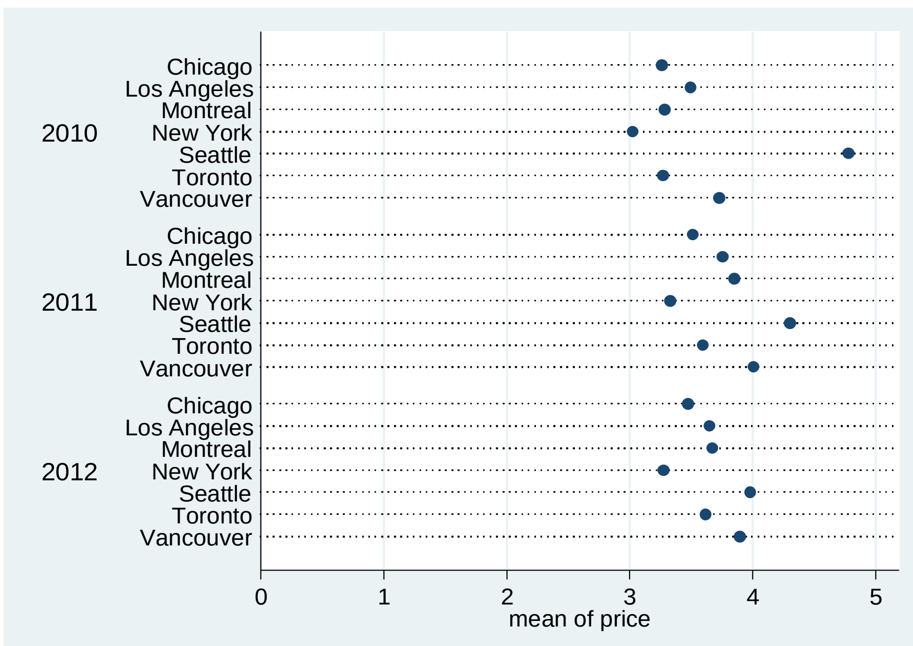


Figure 14- Average freight rates three years 2010, 2011, 2012 in large Canada's and U.S.'s cities

It is also suggested that airport capacity can have an impact on the level of leakage to some extent. Such capacity can refer to elements like the frequency (or maximum number of landings and takeoffs during peak hour) or the maximum amount of cargo that can be transported. Data acquired on the maximum volume of cargo transported in weekly scheduled flights of large airports in Canada and U.S. to Canada's 8 major trading partners showed that Montreal's air cargo effective capacity is lower than that of almost all other Canadian and U.S. cities, except for flights to France (table 9). It is expected that there will be an inverse relationship between Montreal airport's capacity and the amount of merchandises that Montreal based manufacturers shipped to other cities or countries for airlift.

Country of Destination	Toronto	Vancouver	Chicago	Los Angeles	New York	Newark	Seattle
China	***- 7,380***	***- 33,064***	***- 22,230***	***- 131,330***	***- 10,920***	***- 10,635***	***- 7,991***
France	15,390	26,358	8,201	10,988	***- 29,702***	11,280	18,855
Germany	***- 13,916***	3,040	***- 52,110***	***- 22,725***	***- 72,614***	***- 29,029***	4,170
Hong Kong	***- 12,915***	***- 21,770***	***- 11,035***	***- 19,615***	***- 16,440***	***- 5,295***	-
Italy	***- 5,106***	2,517	***- 1,612***	***- 4,995***	***- 31,237***	***- 5,914***	2,517
Japan	***- 5,484***	***- 9,303***	***- 35,615***	***- 107,858***	***- 27,120***	***- 5,415***	***- 19,813***
Poland	***- 3,060***	-	***- 4,428***	-	***- 1,959***	***- 1,944***	-
United Kingdom	***- 26,814***	***- 4,809***	***- 46,404***	***- 31,428***	***- 95,458***	***- 52,066***	582

Table 9- Difference7 in air cargo effective capacity of airports in Montreal and those in other Canadian &U.S. cities_ Unit: Metric tonnes; data in 2012

In addition, the connectivity of an airport may also play a critical part in shippers' decisions of which airport to use. Specifically, when there is no direct flight between a regional airport and the targeted country of destination, manufacturers will have no choice other than trucking their products to a further airport in other places for air shipping to customers. Actually, instead of using trucks, manufacturers can also ship merchandises by air to another airports then transferring there. However, doing so may be much more expensive or even difficult if the products to be shipped are too bulky and the flight does not have enough belly space as in the case of aerospace components shipped from Montreal airports described by Roy and Van Assche (2013). This suggests another driver that can induce companies to use a further away airport regardless of its proximity to their production sites. In this case, even if the freight charges are lower in regional airports, leakage will still happen.

Besides airport connectivity, it is believed that product's characteristic is another external factor that requires merchandises to be transported on road to another location before being airlifted. Aerospace industry can be considered as a typical example since its products are often shipped by air and normally in large sizes, which cannot be stored in the belly of passenger planes. As found

[7] Difference = Montreal's effective capacity – effective capacity in another province/state

in the study of Roy & Van Assche (2013), Canadian airports have a lack of upper deck capacity due to the absence of regular air cargo freighter services in most Canadian airports. Montreal, for instance, is not provided with any air cargo freighter services other than the courier services served by integrators such as FedEx, and UPS. Therefore, even though Montreal is the largest aerospace cluster in Canada, shippers operating in the area have no other choice but to send large aircraft components by truck to Toronto, New York or Chicago for air shipping to the end customers.

To sum up, there are several potential drivers of leakage, which can be either proactive or reactive factors. On the proactive side, the idea of routing shipments through further airports in order to take advantage of more economical airfreight costs in such locations may induce leakage to happen. Sometimes, when weighing it against airports capacity or frequency, shippers, especially those that apply lean manufacturing, may decide to sacrifice the cost advantage for more frequent shipments. However, luckily, such trade-off rarely exist since airports with larger capacity tend to be able to operate at lower cost, hence charging lower freight on shippers. As a consequence, when a regional airport is deficient in capacity while applying higher price, the propensity that merchandises go to large international airports in neighboring provinces or countries becomes even higher. On the reactive side, “leakage” is believed to become a “necessity” when regional airports are limited in connectivity or products characteristics requires special equipment for transportation.

In the coming section, analysis of the aforementioned relationships between leakage and its suspected drivers will be performed focusing on Quebec’s export of air-intensive industries. However, due to the limitations in data collected, it is impossible to test for impacts of airports connectivity on the percentage of air export shipped to another location for airlift. Each of the other three factors (i.e. freight rate, airport capacity, and product characteristics) will be investigated in turn.

4. RESEARCH FINDINGS

4.1. Regression Estimation

Based on the initial analysis of what can lead to the occurrence of leakage, it is expected that there will be linear relationships between that concept and those identified initiators. Therefore, multiple linear regression will be deployed with leakage (measured in percentage of air export) set as the dependent variable. The impacts of relative freight rate, relative capacity and value to weight ratio on the level of leakage will be examined by adding each of the explanatory variables into the regression successively.

Dependent variable: Intra-national leakage (intrlk)

Using STATA, only products of identified air-intensive industries will be kept. Then, all the exports that left Canada in modes of transport other than "Air" will be dropped. This follows the definition which stated that "Leakage occurs when a significant amount of air transport that originated in a Canadian province, is carried by truck to other airports before subsequent airlift' (Roy & Van Assche, 2013). Total air export (**total_airex**) will then be calculated on the basis of HS4 transported to each country of destination in a given year before all the exports that had Quebec as the province of exit were dropped. What were left out are all the air exports that originated from Quebec but cleared customs in other provinces. This amount is also calculated on the basis of HS4 to each country of destination, namely **QC_intrlk_value**. The final share (**intrlk**) of intra-national leakage in Quebec's total air export is calculated as **QC_intrlk_value** divided by **total_airex**. Sample results of those calculations are presented in **Appendix 4**.

Dependent variable: International leakage (interlk)

As described earlier, the identification of international leakage is much more complicated than the intra-national one. In the first step, products that do not belong to identified air-intensive industries will also be dropped.Next, it is important to identify the amount of air and water exports that left Quebec directly to non U.S. &MEX countries. This will help calculate the share of exports going through U.S. and Mexico that was subsequently shipped by air based on the assumption stated in the previous section. In STATA, all the exports destined to U.S. and Mexico are first dropped to get those that were exported to non U.S. and Mexico countries. Then, only those that were exported by "Air" and "Water" are kept to get Quebec's direct export to the rest of the world. Sum of total air and water exports (**air_water_total**) filtered above is calculated on the basis of HS4 to each country of destination in each year. The share (**airshare**) of direct air export in Quebec's air and sea export now can be found by taking air export divided by **air_water_total** after dropping water export.

In the second step, the amount of exports to the rest of the world by "Rail" and "Road" was filtered. Hence, all merchandises destined to U.S. and Mexico and those to other destinations but left Canada in modes of transport other than "Rail" & "Road" will also be dropped. Sum of total "Rail" and "Road" export to each of non U.S. & MEX countries (**rail_road_total)** is, next, calculated on the basis of HS4 to represent Quebec's indirect export of each product to each country of destination in a given year. As discussed in the identification of leakage, these merchandises can either leave U.S. & Mexico to the end customers under air or water transportation.

Finally, the data obtained from the previous two steps are merged together. The value (in dollar) of international leakage from Quebec is the indirect air export (**air_indirect)**, which is calculated as **airshare** multiplied by **rail_road_total**. The ultimate share of inter-leak (**interlk**), now, equals indirect air export divided by total air export (i.e. sum of direct and indirect). Sample results are presented in **Appendix 5**.

Explanatory variable: Relative price (Rev_Price)

On the one hand, in order to identify the impacts of air freight charges on international leakage, a variable named "Rev_Price_1" was developed. It is calculated as Montreal's rate divided by U.S.'s average rate. Specifically, since information obtained includes rates in airports of several large U.S. cities, U.S's average is calculated as the mean of prices applied in such airports, which are composed of Chicago, New York, Seattle and Los Angeles.

$$\textbf{Rev\_Price}_1 = \frac{Montreal's\ rate}{Average\ (Chicago's\ rate;\ NewYork's\ rate;\ \ Seattle's\ rate;\ Los\ Angeles'rate)}$$

Besides, as discussed in previous section, a positive relationship is expected between charges applied in regional airports and the percentage of air exports from that region leaked elsewhere. Hence, it can be inferred that when the price in Montreal increases relative to those in U.S. the tendency of manufacturers in Quebec routing their air exports through airports in U.S. will increase to some extent. The coefficient of independent variable "Rev_Price_1" is, therefore, expected to be positive.

On the other hand, Rev_Price_1 was formulated again as Montreal's rate divided by average rate charged by other Canadian cities, which is the mean rates applied in Toronto and Vancouver to measure impacts of changes in rates on the level of intra-national leakage from Quebec:

$$\mathbf{Rev\_Price_2} = \frac{Montreal's\ rate}{Average\ (Toronto's\ rate; Vancouver's\ rate)}$$

Similar to the case of international leakage, the relative freight rate between Montreal and other major Canadian cities is expected to have an upward relationship with the percentage of air cargo cleared customs elsewhere within national boundary. Thus, the coefficient of Rev_Price_2 in the regression where intra-leakage is the dependent variable is also believed to be positive.

Explanatory variable: Relative capacity (Rev_Cap)

Due to limitations in data obtained, information on capacity is available for only exports going to Canada's top 8 trading partners. Another variable labelled "Cap_diff" (i.e. capacity difference) was formulated and calculated on country of destination basis. The value of this variable is identified based on two steps. Firstly, the differences inflight capacity between Montreal and 7 other cities in both Canada and U.S are calculated. Secondly, Cap_diff_1 and Cap_diff_2 will be found using the following formulae:

Cap_diff_1 = **Average (**Cap_diff Montreal-Chicago; Cap_diff Montreal-Los Angeles; Cap_diff Montreal-New York; Cap_diff Montreal-Newark; Cap_diff Montreal-Seattle**)**

Cap_diff_2 = **Average (**Cap_diff Montreal-Toronto; Cap_diff Montreal-Vancouver**)**

Where **Cap_diff** Montreal – city i = Montreal's flight capacity – city i's flight capacity

The former is used to estimate the impact of average difference in effective capacity between Montreal and U.S.'s cities on Quebec's international leakage while the latter is used to identify how the capacity difference between Montreal and other Canada's big cities affect intra-national leakage.

It is also worth noting that using relative capacity as the independent variable as in the case of relative price is impossible. Indeed, for some certain countries of destination (such as Italy), Montreal's effective capacity is greater than 0 (i.e. 2,517 metric tonnes) while those of other cities is equal to 0 (i.e. Seattle's), making the division undefined.

Since airport capacity is expected to have an inverse relationship with the propensity of shippers bypassing regional/closer airports, the coefficient of these explanatories are forecasted to be negative. This means that when the air cargo effective capacity in Montreal increase compared to those in other cities, the share of both inter- and intra – national leakage in Quebec's total air export will decrease somehow.

Explanatory variable: Value to weight ratio (VtW)

The only measure of product characteristics used for this study is the value to weight ratio of different merchandises, broken down to HS4 level. In this study the value to weight ratio of a product is a measure of its monetary value has per kilogram or pound, which is roughly calculated by dividing a product's export value (in dollar) by its weight (in kilogram). As explained earlier, leakage is more inclined to happen with merchandises that are large in size (such as aircraft components) or require special handling equipment (such as pharmaceutical products). It is, therefore, expected that the higher the value to weight ratio of goods, the lower the possibility that it is routed to neighboring areas for subsequent airlift and the coefficient of (**VtW**) may be negative. These ratios are calculated based on the CEPII's BACI as described in data description.

Explanatory variable: Region of destination (region)

There are in total 218 countries that had transactions with Quebec during 2008-2012 periods. It will be hard to capture the pattern of data when running regressions with all of them. Therefore, countries of destination are grouped into 6 main geographical regions including: Africa, Asia, North America, South America, Europe, and Others. The rationale behind grouping based on geographical location is that major air trade lanes are typically formed within or across regions; and countries within the same regions tend to have similar shipping practices. As proved in the initial analysis of Quebec's air-intensive exports to its top 20 trading partners in two periods (2008 to 2010 and 2011-2012), it is expected that the level of leakage will differ across regions of destination.

Explanatory variable: Industry (HS4)

Since information regarding value to weight ratio was reported on HS4 basis, the regressions will take HS4 as the representatives of industries. It is also expected that leakage will vary across industries as seen in the illustrations of leakage in Quebec for 14 air-intensive industries during 2008-2010 and 2011-2012 period sketched in the initial analysis.

4.2. Regression Results

4.2.1. International leakage

Firstly, the relationship between product's value to weight ratio and the percentage of air export leaked internationally will be examined using the following basic regression:

$$\boldsymbol{Interlk_{t,i,n}} = \beta_0 + \beta_1 \boldsymbol{VtW}_i + u$$

Where:

- $\boldsymbol{Interlk_{t,i,n}}$: is the level of international leakage (measured as percentage of total export) of industry i to country n in year t
- $\boldsymbol{VtW}_i$: is the value to weight ratio of products in industry i

The model was regressed with heteroskedasticity – consistent standard errors by adding the "robust" option in STATA. Testing results showed in table 10 were divided into 4 columns. The first column records the coefficient and SE of VtW, number of observations and R-squared in the basic regression. The rest columns present outcomes with time and destination effects controlled respectively. As it can be seen, the sign of beta coefficient of VtW is negative in all cases as expected. Moreover, its P-values also suggest that this variable is statistically significant at 1% level but cannot explain much of the variation in the level of international leakage since the value of R^2 is small.

Independent Var.	**Dependent Variable: Interlkt,i,n**			
	(1)	**(2)**	**(3)**	**(4)**
$\boldsymbol{VtW}_i$	-.001 ***	-.001***	-.001***	-.001***
	(.000)	(.000)	(.000)	(.000)
Time fixed effects	_	YES	_	YES
Industry fixed effects	_	_	_	_
Destination fixed effects	_	_	YES	YES
Number of observations	4523	4523	4523	4523
R2	0.023	0.025	0.076	0.081

Note: Coefficients of fixed effects are not reported. *, **, and *** denote 10%, 5% and 1% level of significance, respectively.
Interlkt,i,n: is the level of international leakage (measured as percentage of total export) of industry i to country n in year t
$\boldsymbol{VtW}_i$: is the value to weight ratio of products in industry i

Table 10- Effect of merchandise' value to weight ratio on international leakage

It is worth noting that the regression result with industry fixed effects is not reported since VtW ratios vary across industries, causing problems with the testing results. Indeed, diagnosis of collinearity between independent variables proved that adding HS4 as a categorical variable into the model make VtW redundant since it has a very high VIF[8] value (60279.19).

```
. vif
```

Variable	VIF	1/VIF
valuetowei~t	60279.19	0.000017
region		
2	8.05	0.124151
3	9.68	0.103301
4	3.39	0.294909
5	4.92	0.203343
6	6.69	0.149371
year		
2009	1.58	0.634550
2010	1.66	0.601220
2011	1.55	0.643474
2012	1.67	0.597879
hs4		
128	2.96	0.338306
129	1.59	0.629138
130	1.32	0.759772
131	1.12	0.889720
132	1.02	0.979567
213	25006.63	0.000040
214	1890.14	0.000529
329	17.79	0.056207
330	6.02	0.166177
331	2.51	0.397855
332	1.27	0.788272

Figure 15- Collinearity diagnosis, regression with industry fixed effects, extracted results

When HS4 is dropped from the regression, VIF testing presents a much better outcome:

[8] **VIF (Variance Inflation Factor)** quantifies the severity of multicollinearity in an OLS regression analysis. It provides an index that measures how much the variance (the square of the estimate's standard deviation) of an estimated regression coefficient is increased because of collinearity. In other words, the square root of the VIF represents how much larger the standard error is, compared with what it would be if that variable were uncorrelated with the other predictor variables in the model.

```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
valuetowei~t |      1.01    0.992946
        year |
       2009  |      1.51    0.661452
       2010  |      1.59    0.628397
       2011  |      1.50    0.665121
       2012  |      1.58    0.632465
      region |
          2  |      7.77    0.128767
          3  |      9.36    0.106796
          4  |      3.22    0.310149
          5  |      4.70    0.212854
          6  |      6.43    0.155560
-------------+----------------------
    Mean VIF |      3.87
```

Figure 16- Collinearity diagnosis, regression without industry fixed effects

In short, it is clear that VtW was proved to be statistically significant when testing its relationship with the level of international leakage.

In the next step, Rev_Price_1 is added to examine how freight rates interact with international leakage:

$$\boldsymbol{Interlk_{t,i,n}} = \beta_0 + \beta_1 \boldsymbol{VtW}_i + \beta_2 \boldsymbol{Rev\_Price_{1,t,n}} + u$$

Where:

$\boldsymbol{Rev\_Price_{1,t,n}}$**:** is the relative freight rate between Montreal and the U.S. average to country n in year t

Results of the regression are presented in the table below:

Independent Var.	Dependent Variable: $Interlk_{t,i,n}$				
	(1)	(2)	(3)	(4)	(5)
VtW_i	-.001 ***	_	-.001***	-.001***	-.001***
	(.000)	_	(.000)	(.000)	(.000)
$Rev\_Price_{1,t,n}$	_	.078***	.081***	.090***	.051***
	_	(.020)	(.020)	(.020)	(.020)
Time fixed effects	_	_	_	YES	_
Industry fixed effects	_	_	_	_	_
Destination fixed effects	_	_	_	_	YES
Number of observations	4523	2302	2302	2302	2302
R2	0.023	0.007	0.036	0.039	0.07

Note: Coefficients of fixed effects are not reported. *, **, and *** denote 10%, 5% and 1% level of significance, respectively.

$Interlk_{t,i,n}$: is the level of international leakage (measured as percentage of total export) of industry i to country n in year t

$\boldsymbol{VtW_i}$: is the value to weight ratio of products in industry i

$\boldsymbol{Rev\_Price_{1,t,n}}$: is the relative freight rate between Montreal and the U.S. average to country n in year t

Table 11- Effect of merchandise' value to weight ratio and freight rate on international leakage

In this case, both product's value to weight ratio and the relative freight rate have the impacts on the level of inter leakage as expected. The regression with industry fixed effects is not reported due to the same reason explained in figure 15 and 16. Overall, both VtW and Rev_Price are statistically significant at 1% level.

Hierarchical linear regression[9] with "nomiss" option[10] was performed to compare the models before and after adding Rev_Price, and the results showed that both of them are statistically significant with P-values of F-stats reported as 0.000. R_quared in model 1 increased 0.007 (figure 17) after adding freight rate, showing that Rev_Price supports VtW in explaining the level of international leakage.

```
Model  R2      F(df)              p        R2 change  F(df) change      p
   1:  0.029   68.181(1,2300)     0.000
   2:  0.036   43.246(2,2299)     0.000    0.007      17.812(1,2299)    0.000
```

Figure 17- Hierarchical linear regression of interlk on VtW and Rev_Price, models comparison

Lastly, Cap_diff_1 is included:

[9]**Hierarchical linear regression:** the practice of building successive linear regression models, each adding more explanatory variables. It can be used to compare among models to determine the significance that each one has above and beyond the others.

[10]**Nomiss**: no missing, all missing values will be dropped

$$\boldsymbol{Interlk_{t,i,n}} = \beta_0 + \beta_1 \boldsymbol{VtW}_i + \beta_2 \boldsymbol{Rev\_Price_{1,t,n}} + \beta_3 \boldsymbol{Cap\_diff_{1,n}} + u$$

Where:

$\boldsymbol{Cap\_diff_{1,n}}$**:** is the average difference in effective capacity between Montreal and US to country n

The numbers in column 3 and 4 of table 12 showed that differences in effective capacity also have expected impact on inter-leakage. The negative coefficient means that as the differences in capacity between Montreal and U.S.'s cities enlarge, or the higher the effective capacity of Montreal compared to those of other U.S.'s cities, the lower the propensity that merchandise will be moved to U.S. by truck for subsequent airlift. However, in column 5 and 6 when the time and destination effects are controlled respectively, there are certain changes in the coefficients, SEs, and p-values of t-stat of Rev_Price. It is understandable since Rev_Price varies slightly through time and countries of destination. Controlling for those factors will definitely affect the overall estimations, as in column 6, both VtW and Rev_Price becomes insignificant when destinations are controlled. Besides, it is worth noting that when Cap_diff is added, the numbers of observations in the regression reduce significantly from 2302 to 84. Therefore, another possible reason that caused VtW and Rev_Price become insignificant is that it is hard to capture the data patterns when the sample size is small.

Independent Var.	**Dependent Variable: Interlkt,i,n**					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
VtW_i	-.000***	_	_	.001	.001	.000
	(.000)	_	_	(.001)	(.000)	(.001)
$Rev\_Price_{1,t,n}$		.078***	_	.005	.203**	-.059
		(.020)	_	(.092)	(.078)	(.101)
$Cap\_diff_{1,n}$		_	-.000***	-.000***	-.000***	-.000***
		_	(.000)	(.000)	(.000)	(.000)
Time fixed effects	_	_	_	_	YES	_
Industry fixed effects	_	_	_	_	_	_
Destination fixed effects	_	_	_	_	_	YES
Number of observations	4523	2302	137	84	84	84
R2	0.023	0.007	0.106	0.145	0.201	0.186

Note: Coefficients of fixed effects are not reported. *, **, and *** denote 10%, 5% and 1% level of significance, respectively.

Interlkt,i,n: is the level of international leakage (measured as percentage of total export) of industry i to country n in year t

$\boldsymbol{VtW}_i$: is the value to weight ratio of products in industry i

$\boldsymbol{Rev\_Price_{1,t,n}}$: is the relative freight rate between Montreal and the U.S. average to country n in year t

$\boldsymbol{Cap\_diff_{1,n}}$: is the average difference in effective capacity between Montreal and US to country n

Table 12- Effect of merchandise' value to weight ratio, relative price and capacity difference on international leakage

In conclusion, all of the explanatory variables are proved to be statistically significant and have expected impacts on the percentage of Quebec's air export trucked to U.S. for airlift.

4.2.2. Intra-national leakage

Similar testing procedures as above will be applied on Intrlk. The impact of change in product's value to weight ratio on the level of intra-national leakage is estimated using the following basic regression:

$$\boldsymbol{Intrlk_{t,i,n}} = \beta_0 + \beta_1 \boldsymbol{VtW}_i + u$$

Where:

- $\boldsymbol{Intrlk_{t,i,n}}$: is the level of intra-national leakage (measured as percentage of total export) of industry i to country n in year t
- $\boldsymbol{VtW}_i$: is the value to weight ratio of products in industry i

Results of the test is arranged in the following table:

Independent Var.	**Dependent Variable: Intrlkt,i,n**			
	(1)	**(2)**	**(3)**	**(4)**
VtWi	-.000***	-.000***	.	-.000***
	(.000)	(.000)	.	(.000)
Time fixed effects	_	YES	_	_
Industry fixed effects	_	_	YES	_
Destination fixed effects	_	_	_	YES
Number of observations	5043	5043	5043	5043
R2	0.002	0.008	0.24	0.026

Note: Coefficients of fixed effects are not reported. *, **, and *** denote 10%, 5% and 1% level of significance, respectively.

Intrlkt,i,n: is the level of intra-national leakage (measured as percentage of total export) of industry i to country n in year t

$\boldsymbol{VtW}_i$: is the value to weight ratio of products in industry i

Table 13- Effect of merchandise' value to weight ratio on intra-national leakage

The first column of the table reports the basic regression of Intrlk on VtW. The coefficient on the interaction term is always negative and strongly significant, implying that an increase in product's value to weight ratio will have a downward impact on its propensity to be trucked to other provinces for airlift. However, since both the coefficient and standard deviation are too small, the magnitude of such impact is not large. Specifically, in the basic regression, only 0.2 % of the variation in intra leakage can be explained by product's value to weight ratio.

In column 2, 3 and 4, the numbers represent results when time, industry and destination effects are fixed. It is worth noting that the coefficient, standard deviation and t-statistics of independent variable in the third column is reported as missing. This result lives up to expectations since merchandise's value to weight ratios vary across industries, hence, when industry effects is fixed, VtW calculation of statistics for VtW variable suffers.

In the next step, Rev_Price_2 is added into the regression. Impacts of freight rate and value to weight ratio on intra leakage is now estimated as:

$$\boldsymbol{Intrlk_{t,i,n}} = \beta_0 + \beta_1 \boldsymbol{VtW}_i + \beta_2 \boldsymbol{Rev\_Price_{2,t,n}} + u$$

Where:

$\boldsymbol{Rev\_Price_{2,t,n}}$**:** is the relative freight rate between Montreal and the average of other Canadian provinces to country n in year t

The first column of table 14 reports results when intrlk is regressed only on VtW and the next five columns show results when Rev_Price is added. Similar to the case of inter leakage, since data regarding value to weight and intra-national leakage is calculated for five years, from 2008 to 2012 while information of price is only available for 2010-2012 period, the number of observations when freight rate is included reduces in half. As it can be seen in all columns, except for the first one, both VtW and Rev_Price are statistically insignificant, even at 10% level. Therefore, explanatory variable Rev_Price is dropped.

Independent Var.	**Dependent Variable: Intrlkt,i,n**					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
VtW_i	-.000***	_	-.000	-.000	-.000	-.000
	(.000)	_	(.000)	(.000)	(.002)	(.000)
$Rev\_Price_{2,t,n}$	_	.042	.051	.070	.008	.103
	_	(.061)	(.064)	(.065)	(.059)	(.042)
Time fixed effects	_	_	_	YES	_	_
Industry fixed effects	_	_	_	_	YES	_
Destination fixed effects	_	_	_	_	_	YES
Number of observations	5043	2298	2196	2196	2196	2196

R2	0.002	0.000	0.001	0.004	0.232	0.034

Note: Coefficients of fixed effects are not reported. *, **, and *** denote 10%, 5% and 1% level of significance, respectively.

Intrlkt,i,n: is the level of intra-national leakage (measured as percentage of total export) of industry i to country n in year t

$\boldsymbol{VtW}_i$: is the value to weight ratio of products in industry i

$\boldsymbol{Rev\_Price}_{\boldsymbol{2,t,n}}$: is the relative freight rate between Montreal and the average of other Canadian provinces to country n in year t

Table 14- Effect of merchandise' value to weight ratio and freight rate on intra-national leakage

Lastly, the relationship between airport capacity and intra-national leakage is tested by adding Cap_diff_2 into the regression equation, which is now becomes:

$$\boldsymbol{Intrlk_{t,i,n}} = \beta_0 + \beta_1 \boldsymbol{VtW}_i + \beta_3 \boldsymbol{Cap\_diff}_{\boldsymbol{2,n}} + u$$

Where:

$\boldsymbol{Cap\_diff}_{\boldsymbol{2,n}}$: is the average difference in effective capacity between Montreal and Toronto & Vancouver to country n

The result of the regression is now as following:

Independent Var.	**Dependent Variable: Intrlkt,i,n**					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
VtW_i	-.000***	_	-.000	.000	.	.000
	(.000)	_	(.000)	(.000)	.	(.000)
$Cap\_diff_{2,n}$	_	-.000***	-.000**	-.000**	-.000	-.000
	_	(.000)	(.000)	(.000)	(.000)	(.000)
Time fixed effects	_	_	_	YES	_	_
Industry fixed effects	_	_	_	_	YES	_
Destination fixed effects	_	_	_	_	_	YES
Number of observations	5043	147	137	137	137	137
R2	0.002	0.140	0.136	0.270	0.584	0.361

Note: Coefficients of fixed effects are not reported. *, **, and *** denote 10%, 5% and 1% level of significance, respectively.

Intrlkt,i,n: is the level of intra-national leakage (measured as percentage of total export) of industry i to country n in year t

$\boldsymbol{VtW}_i$: is the value to weight ratio of products in industry i

$\boldsymbol{Cap\_diff}_{\boldsymbol{2,n}}$: is the average difference in effective capacity between Montreal and Toronto & Vancouver to country n

Table 15- Effect of merchandise' value to weight ratio and effective capacity on intra-national leakage

Similar to what has been found for Rev_Price, the inclusion of Cap_diff_2 considerably reduce the numbers of observation from 5043 to 137 (table 15) since data on capacity is even more limited. This independent variable turns out to be statistically significant with expected sign of the coefficient, except when industry and destination are fixed.

It is now seen that VtW and Cap_diff can be used to explain intra-national leakage but Rev_Price cannot be. The summary of all the above findings and some discussions will be provided in the next section.

5. DISCUSSION OF FINDINGS

It is now suggested that not only product's value to weight ratio but also relative price and capacity difference between airports have certain impacts on Quebec's leakage. Specifically, the higher the ratio of product's value to its weight, the lower the chance that it will be sent to final destinations through airports in another country. International leakage of Quebec will also decrease if its freight rates are smaller or if the flight capacity here is higher than those in other countries.

In addition, the results from hierarchical regression (with nomiss option) also suggested that VtW can explain the variation in interlk better than Rev_Price (2.9% and 0.7%). It is not viable to run the same regression with VtW, Rev_Price and Cap_diff due to the discrepancies between data available for product's value to weight ratios, freight rates and effective capacity. Indeed, product's value to weight ratio and inter leakage were calculated for 5 year period, from 2008 to 2012. Relative freight rate was calculated for only 3 years from 2010 to 2012, and differences in capacity of each scheduled flight were available for only 8 countries of destination. Therefore, when all three explanatory variables are included in the same model, the number of observations reduce significantly from 4523 to 84, driving VtW and Rev_Price to become insignificant.

The same outcomes were achieved for Quebec's intra-national leakage except for the relative price. It does not explain the changes in intra-national leakage of this province. In fact, this regression result is also understandable since the prices taken from CASS reflect the cost of air cargo transported from one city to a certain country of destination, hence, it may include the connecting flights. For instance, a product originating from Montreal is transported to China through Toronto airports may reflect the price of air shipping from Montreal to Toronto then to China. As a consequence, Rev_Price_2 is insignificant when examining the relationship with Quebec's intra-national leakage.

It is also worth noting that this problem does not appear in testing with international leakage for a reason. As mentioned in the description of Canada's International Trade statistics, for exports, the mode of transport recorded represents the mode by which the international boundary is crossed. Even though a product is exported by air to final destinations from U.S. and Mexico, it is still recorded as export by "Rail" and "Road" as it passed the national frontier on these two modes. Hence, there will be no chance that air freight rate in U.S. reflects also the rates of air shipping from Montreal. Obviously, the price in U.S. may reflect cost of connecting flights within U.S. but it does not affect the calculation of Montreal _ U.S. relative price since the rates of U.S. were calculated on average. In this case, the test failed to answer for whether the relative prices between Montreal and other Canadian provinces impact on the amount of air cargo leaked nationally from Quebec.

However, the results summarized above are sufficient to come up with some practical implications for the stakeholders, including shippers/manufacturers, airports/air carriers, and government/policy makers.

Regardless of all the factors that force products to be shipped elsewhere for subsequent airlift such as lack of capacity and connectivity, shippers/manufacturers can take advantage of leakage by understanding the strength of different airports both in their regions and in neighbouring areas. The ability to weigh cost against proximity will bring about great advantages if merchandises are shipped in large amount. To a further extent, the concept of leakage may not be limited to air cargo. It can be any combination between different modes of transport. For instance, in cruise line operations, due to the short time window constraint during the replenishment of the ships, cruise line companies sometimes have to airlift a full shipment of product to the next port in the ship's itinerary due to late arrival at the turn around port (Véronneau & Roy, 2009). This can be another use of leakage where airborne and seaborne transportation are combined for contingency situations.

From the stand point of airlines, it is obvious now that freight rates is not the primary focus as the products' value to weights ratios can explain much more variations in Quebec's international leakage. Due to limitations in data on capacity, this study cannot compare models before and after adding capacity differences. Hence, it is unable to determine whether capacity or freight rate should be given more attention to prevent air cargo flowing into other airports. However, this brings back a point mentioned by Tretheway and Kincaid (2005), discussed in the literature review. It is said that today, much of the North America courier traffic to the Greater Toronto region flies to nearby Hamilton Airport and is then trucked to/from Toronto. Hamilton airports handles approximately 100,000 tonnes of cargo each year that otherwise *would likely have passed* through Toronto International Airport. As Hamilton has *lengthened its runway*, it is now competing for international cargo flights was well. Notably, unlike Toronto Pearson, Hamilton airport does not have a curfew, hence allowing integrators like FedEx to land during the night. This is not permitted in Toronto Pearson. It is, therefore, referred that by increasing airport capacity, Hamilton International Airport is now competing strongly against Toronto International Airport, and gradually taking air cargo from them. Therefore, placing strong emphasis on capacity development is highly recommended beside lower freight cost. In fact, improving airport capacity may help reduce the operation costs in the long run, hence, drive down the prices charged on shippers.

Government and policy makers should also support national airports in improving service quality and reducing freight charges through capacity improvement to protect their air cargo industry. It is necessary that government officials recognize the strength of their airports (e.g. Quebec is competitive in shipping to France) to have action plans not only to prevent merchandises from flowing into U.S. and Mexico but also to attract air cargo from those countries. However, understanding any weaknesses and coming up with the solutions are no less important. This requires cooperation of all the stakeholders in the air cargo industry from experts/researchers, airports officials, air cargo customers and policy makers. In order to have such collaboration, government should play an active role to facilitate interaction, and exchange of ideas among those parties; by organizing industry events or meetings for example.

6. CONCLUSIONS

Throughout this study, the concept of leakage has been discussed thoroughly. This is the shipping practice where shippers or manufacturers bypass the airport that is closest to them to transport their merchandises elsewhere for subsequent airlift. Intra-national leakage refers to the situation where products are shipped to other airports within national boundary while international leakage happens when airports in other countries are used for air shipments. It is expected that freight rates, airport capacity, airport connectivity, and product characteristics are among the potential drivers of this shipping practice. In order to examine these expectations, Quebec was chosen for investigation as a large amount of its exports are leaked both nationally and internationally. Initial data analyses suggest linear relationships between the percentage of Quebec air exports leaked further away and those suspected initiators. However, due to data limitation, it is not possible to test for the impacts of airport connectivity on the level of leakage. Multiple linear regressions have been deployed to test the relationship between leakage and product's value to weight ratio, relative price, and the differences in effective capacity between Montreal and other Canada's and U.S.'s cities successively. Firstly, results of the test showed that there is a negative relationship between product's value to weight ratio and the propensity that merchandises are leaked both nationally and internationally. Secondly, it is also proved that as the freight rates in Montreal increase relative to those in U.S., international leakage increase subsequently. Lastly, when effective capacity of the regional airport increases compared to others, there will be less chance that products are shipped to neighboring areas or countries for subsequent airlift.

It is, therefore, recommended that shippers/manufacturers should be able to take advantages of leakages to reduce transportation costs, increase shipping frequency, or respond to contingency situations. Airports managers, besides lowering freight rate, should pay attention to improving airport capacity and understanding the need of air cargo users for different types of products to different country of destination. Having a good action plan to prevent air cargo outflow and attract more inflow from other places is essential to the long-term development of any airports. In addition, government can foster national air cargo industry by supporting airports in building their infrastructure or playing a catalyst role to link various industry stakeholders in information sharing and exchange of ideas. This will help them to figure out and foster the strengths they can use to lure air cargo customers from neighboring countries as well as improve the weaknesses that made customers get away from them.

However, this study has some limitations. Firstly, the biggest problem with conduction of the research is the lack of data. The inability to collect data on connectivity of different airports made it impossible to examine the relationships between airport connectivity and the level of leakage. Secondly, the limited price and capacity information is another challenge for running regression since the significant reduction in the number of observations makes it infeasible to compare models before and after each explanatory variable is added. Moreover, as mentioned in the previous section, freight rate provided from CASS cannot be used to examine the impacts of relative prices on Quebec's intra-national leakage. Thirdly, explanatory variables did not represent the best what need to be measured. Even though value to weight ratio is used to represent product characteristics, it is not the best measure. Indeed, one of the reasons that force manufacturers of aerospace industries to ship aircraft components to U.S. for subsequent airlift is the lack of upper deck capacity in Canadian airports while the size of merchandise is too large and does not fit in the belly of passenger planes. Value to weight ratio does not measure such dimension. Furthermore, there are many different ways to measure airport capacity and effective capacity in each scheduled flight is just one of them.

Therefore, it is expected that further researches will be done to correct for such problems. In addition, the concept of leakage can be extended to any combination of transportation modes besides road and air.

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APPENDIX 1: The Canada International Merchandise Trade Statistics (sample)

Year	Codes	Description	Country of Destination	US states of destination	Province of Origin	Province of exit	Port of exit	Mode of transport	Unit of measure	Quantity	Value
2008	200801011000	Horses, asses, mules and hinnies, live, pure-bred breeding	Belgium	N/A	Manitoba	Ontario	Toronto - Pearson International Airport	Air	NMB	2	2500
2009	200907070010	Cucumbers and gherkins, greenhouse, fresh or chilled	United States	Rhode Island	Quebec	Quebec	Lacolle	Road	KGM	3040	2467
2010	201032091000	Paints & varnishes based on acrylic or vinyl poly, dspr in an aqueous medium	Cuba	N/A	Quebec	Nova Scotia	Halifax - Marine Port	Water	LTR	3	30
2011	201128332900	Sulphates of metal, nes	United States	Massachusetts	Quebec	Quebec	Trout River	Rail	KGM	620250	168802
2012	201217049090	Sugar confectionery, not containing cocoa, nes, including white chocolate	Antigua and Barbuda	N/A	Ontario	Ontario	Toronto - Pearson International Airport	Other	KGM	26	140

APPENDIX 2a: Freight rate from CASS (Sample)

year	city	country	price
2010	Chicago	United kingdom	1.23
2010	New York	France	1.23
2010	Los Angeles	Korea, republic of	1.25
2011	Toronto	Belgium	1.29
2011	Montreal	France	1.36
2011	Seattle	Belgium	1.41
2012	Vancouver	France	1.49
2012	Chicago	Germany	1.5

APPENDIX 2b: Air cargo effective Capacity, Scheduled flight, in metric tonnes from CASS (Sample)

Destination Country	Origin Country	Destination	Origin	Total
	Canada	Beijing, CN	Toronto, ON, CA	7380
			Vancouver, BC, CA	6907
		Beijing, CN Total		14287
		Guangzhou, CN	Vancouver, BC, CA	2910
		Guangzhou, CN Total		2910

China		Shanghai, CN	Toronto, ON, CA	4596
			Vancouver, BC, CA	22757
		Shanghai, CN Total		27353
		Shenyang, CN	Vancouver, BC, CA	490
		Shenyang, CN Total		490
	Canada Total			**45040**
	United States	Beijing, CN	Chicago-O'Hare, IL, US	11415
			Los Angeles, CA, US	22680
			New York-JFK, NY, US	5460
			Newark, NJ, US	5325
			Seattle/Tacoma, WA, US	7991
		Beijing, CN Total		52871
		Guangzhou, CN	Los Angeles, CA, US	12375
		Guangzhou, CN Total		12375
		Shanghai, CN	Chicago-O'Hare, IL, US	10815
			Los Angeles, CA, US	96275
			New York-JFK, NY, US	5460

			Newark, NJ, US	5310
		Shanghai, CN Total		117860
	United States Total			**183106**
China Total				**228146**
France	**Canada**	Bordeaux, FR	Montreal-PET, QC, CA	376
		Bordeaux, FR Total		376
		Lyon, FR	Montreal-PET, QC, CA	739
		Lyon, FR Total		739
		Marseille, FR	Montreal-PET, QC, CA	713
		Marseille, FR Total		713
		Nantes, FR	Montreal-PET, QC, CA	383
		Nantes, FR Total		383
		Nice, FR	Montreal-PET, QC, CA	430
		Nice, FR Total		430
		Paris-De Gaulle, FR	Montreal-PET, QC, CA	22288
			Toronto, ON, CA	10866

			Vancouver, BC, CA	210
		Paris-De Gaulle, FR Total		33364
		Paris-Orly, FR	Montreal-PET, QC, CA	1217
			Toronto, ON, CA	312
		Paris-Orly, FR Total		1529
		Toulouse, FR	Montreal-PET, QC, CA	422
		Toulouse, FR Total		422
	Canada Total			**37956**
	United States	Nice, FR	New York-JFK, NY, US	3084
		Nice, FR Total		3084
		Paris-De Gaulle, FR	Chicago-O'Hare, IL, US	18367
			Los Angeles, CA, US	15580
			New York-JFK, NY, US	53186
			Newark, NJ, US	7898
			Seattle/Tacoma, WA, US	7713

		Paris-De Gaulle, FR Total		102744
		Paris-Orly, FR	Newark, NJ, US	7390
		Paris-Orly, FR Total		7390
	United States Total			**113218**
France Total				**151174**

APPENDIX 3: Value to Weight ratios calculated based on data fromBACI (Sample)

HS4	Value to weight ratio
1001	.2516379
1002	.2817101
1103	.3255835
1104	.6046435
1105	1.447603
1209	2.0546
1210	14.3744
1211	18.58332

APPENDIX 4: Intra-national leakage identification (Sample and explanation)

year	HS4	country	provinceofexit	total_airex	QC_intrlk_value	intrlk
2008	0106	China	British Columbia	60588	2116	.0349244
2008	0106	Japan	British Columbia	98559	19163	.1944318
2008	0106	Macao	British Columbia	56218	56218	1
2008	0106	Pakistan	Ontario	14986	14986	1
2008	0106	Taiwan	British Columbia	39034	33110	.8482349
2008	0106	Thailand	Ontario	41509	41509	1
2008	0202	Japan	British Columbia	53714	27257	.5074468
2008	0203	Hong Kong	Alberta	97418	51840	.5321398

Total_airex = Total **air export** (dollar value) of product **i**from **Quebec** to country **x** in year **n**

QC_intrlk_value = Total **air export** (dollar value) of product **i** from **Quebec** to country **x** in year **n** but cleared customs in a province **other than Quebec**

Intrlk = Share of intra-national leakage in Quebec total air export $=\frac{QC\_leakage\_value}{Total\_air\_export}$

APPENDIX 5: International leakage identification (Sample and explanation)

Identification of direct air export and share of direct air export in total air and sea export to non US&MEX countries

year	hs2	hs4	group	country	region	air_direct	airshare
2008	01	0101	Group 1	Morocco	Africa	3200	1
2008	01	0101	Group 1	Belgium	Europe	5300	1
2008	01	0101	Group 1	France	Europe	60450	.5729858
2008	01	0101	Group 1	Germany	Europe	9000	.3956044
2008	01	0101	Group 1	Italy	Europe	27225	1
2008	01	0101	Group 1	Netherlands	Europe	12500	.7575758
2008	01	0102	Group 1	Serbia	Europe	723000	1
2008	01	0102	Group 1	Colombia	South America	452	1
2008	01	0106	Group 1	China	Asia	58472	.9650756
2008	01	0106	Group 1	China	Asia	2116	.0349244
2008	01	0106	Group 1	Hong Kong	Asia	21753	1
2008	01	0106	Group 1	Japan	Asia	79396	.714404

air_direct: Air exports of product **i** from Quebec to country **x** (non U.S. & MEX countries.) in year **n**

air_water_total: Air and Water exports of product **i** from Quebec to country **x** (non U.S. & MEX countries.) in year **n**

airshare $=\frac{air\_direct}{air\_water\_total}$

Identification of export to non US&MEX countries that left Canada on rail and road, or indirect export

year	hs2	hs4	group	country	region	Rail_road_total
2008	01	0101	Group 1	France	Europe	92422
2008	01	0101	Group 1	South Africa	Africa	1
2008	01	0101	Group 1	United Kingdom	Europe	367
2008	01	0103	Group 1	China	Asia	1373050
2008	01	0103	Group 1	Guatemala	North America	54125
2008	02	0202	Group 1	Philippines	Asia	57216
2008	02	0203	Group 1	Angola	Africa	815328
2008	02	0203	Group 1	Armenia	Europe	843616
2008	02	0203	Group 1	Australia	Oceania	10530456
2008	02	0203	Group 1	Azerbaijan	Europe	134874

Identification of international leakage

year	hs2	hs4	group	country	region	interlk
2008	01	0101	Group 1	France	Europe	.4669617
2008	01	0101	Group 1	France	Europe	.4669617
2008	01	0101	Group 1	France	Europe	.4669617
2008	01	0101	Group 1	United Kingdom	Europe	.0458865
2008	02	0201	Group 1	France	Europe	.0739913
2008	02	0201	Group 1	France	Europe	.0739913
2008	02	0201	Group 1	France	Europe	.0739913
2008	02	0201	Group 1	France	Europe	.0739913
2008	02	0201	Group 1	France	Europe	.0739913

rail_road_total: Rail and Road exports of product **i** from Quebec to country **x** (non U.S. & MEX countries.) in year **n**

air_indirect = **airshare*** **rail_road_total**

Interlk = $\frac{air\_indirect}{air\_direct+air\_indirect}$

APPENDIX 6: Quebec's top 20 trading partners (2008-2012), air-intensive industries, U.S. and Mexico excluded

COD	Export value	Rank
United Kingdom	5,168,770,277	1
Germany	4,120,190,200	2
France	3,314,519,651	3
China	2,599,607,697	4
Brazil	1,247,928,393	5
Italy	1,132,576,265	6
Japan	1,059,150,574	7
Austria	1,023,529,899	8
Singapore	935,522,416	9
Australia	916,147,490	10
Netherlands	896,580,646	11
Spain	885,384,787	12
Hong Kong	734,686,685	13
India	726,108,479	14
Russian Federation	721,784,182	15
Switzerland	716,843,259	16
United Arab Emirates	688,634,343	17
South Korea	682,156,930	18
Denmark	600,666,450	19
Belgium	490,617,476	20