AN EMPIRICAL STUDY OF CONTRACTS ON RENT SHARING IN TRANSPORT

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ABSTRACT. Transport service providers are part and parcel of a supply chain. As such, they also have to calibrate their capacity to the necessities of the members of the supply chain they serve. Transport cost is the second in importance after the production cost in industry. It is the purpose of the present paper to study the impact of information sharing and contractual instruments between a supply chain and its transport suppliers. After reviewing the literature, we propose a model to measure the benefits in terms of transport cost, standard deviation of transport cost and effective order fill rate. We evaluate three scenarios for a two-shipper single-carrier two-echelon model with a mix of long-term and short-term procurement strategies: perfect information, asymmetric information and private information at one level of the supply chain. [2]

Keywords:

supply chain management; contracts; transport; information sharing; coordination.

1. INTRODUCTION

The transport sector is a key service provider of all industrial supply chains. Transport intervenes at all nodes of the industrial supply chain: from the primary raw material to the final delivery of the finished product at the end-customer's premises. Transport cost is the second in importance after the production cost in industry. In the USA transport costs represent almost 6% of GDP (8.6% in the EU) of which road freight represents around 75%. If one remembers that the service sector now represents about 60% of the GDP in the USA, transport looms even more as a component of the costs of the industrial sector. From the supply chain management vantage point, the impact of its costs and distinguishing properties on the overall performance of the supply chain merit to be looked at in a unifying and distinctive way. As opposed to other suppliers, all forms of transport are homogeneous in their characteristics: pure service, non-stockable products to meet demand and no production facilities (consumption-value only good as in Routledge 2000). However, transport services require highly specific long-life assets and its fixed costs represent an important share of total costs. Transport is principally a capacity-constrained, fixed-cost service industry.

Because of its highly specific nature and ability to share costs and investments among several clients, transport is overwhelmingly provided by third parties, independent from users of transport. The terminology in use distinguishes between the "shipper", the client, from the "carrier", provider of transport services. In this paper, we further distinguish carriers by the contractual nature of the relationships that link them to shippers: we distinguish the "usual" carriers from the "sporadic", governed by different contractual obligations, prices and time horizons.

Usually carriers and the shipper draw up long term contracts with periodical quantity stationary commitments, limited flexibility (the shipper can exceed contracted capacity per period by paying progressively higher prices), rolling horizon flexibility (Anupindi 1998) as to volume, frequencies,

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prices, quality of service and eventual penalty or compensatory clauses. To the shipper, these are the core of the pool of transport service providers.

Carriers use the spot market to sell their capacity on a "per job" basis. The contractual characteristics are: short term, short lead times, no pre-contractual price specifications, no obligation to deliver on the part of the carrier. To the shipper, these represent the next tier of transport service providers; their services have been used in the past and have been rated. They are necessary for special tasks or for meeting peaks in demand. The prices of such transactions are pegged to a "spot" market where available capacity meets an uncertain demand.

Backed by easy financing, E-marketplaces in transport launched in 2000 made the mistake, borne from insufficient knowledge, that enormous transport capacity could be made available online to shippers on a "spot" basis and that transactions would ensue. Grieger (2003) shows, building on Wise and Morrison (2000), that suppliers do not want to be anonymous contestants in a ruthless bidding war, they prefer to belong to a hierarchical co-ordination of the supply chain, involved in hierarchical transactions. In this line of thought: "co-operative supply chains aim to reduce the number of suppliers and form long-term strategic alliances that 'lock in' suppliers and 'lock out' competition" (Grieger, 2003). The transport industry falls neatly into this category, proportionately little cargo can be moved by taking advantage of excess capacity (usually the backhaul leg of a truck's trip coming back empty) because the shipper has to respect strict delivery times and cannot just wait for the possibility of a truck becoming available for just that trip, that day and that cargo.

Our purpose here is not to try and solve the problems faced in any carrier – shipper relationship but rather to bring to light the particularities facing each one and bring attention to some mechanisms and behaviours that alter supply chain efficiency.

This paper is organized as follows. After reviewing the literature, we describe a model involving one single tier in the supply chain: the relationship between two shippers as clients and one carrier as transport supplier. The interest of studying this particular type of node in the supply chain is that in a chain where real products are delivered (i.e. not services) transport is necessary all along the different levels, from raw material producer to end-customer distribution. One shipper has a contractual arrangement with the carrier and we will focus more on the behaviour of both this shipper and the carrier. We create three scenarios of behaviour for them: in the first, base scenario, the information is common to both. In the second scenario, we consider that the carrier retains a certain measure of information from the shipper. In the third, both shipper and carrier hide information from each other. In the next part, the numerical study, we generate a sample of instances of demands and transport spot prices and run each scenario on that sample. We sum the cost of operation and efficient fill rate for shipper and carrier. In the light of the comparison of the results we draw conclusions as to the importance and impact of both information and contractual arrangements between shipper and carrier. Finally, we conclude and point to further avenues of exploration.

2. LITERATURE REVIEW

Supply chain performance depends critically on how its members coordinate their decisions. And it is hard to imagine coordination without some form of information sharing, as Fangruo Chen remarked in Chen (2002). In the supply chain management literature, transport service providers as suppliers are not usually individualized as such. In one line of literature, the transport industry is seen as a cost-centre in its own right. This approach leads research on efficient planning of routes, networks, warehouse location etc. Hosts of software packages have been developed to address the necessary calculations to optimize on a daily or on a strategical basis the deliveries and transport of cargo. In the other line of literature, the transport industry is bundled with the other suppliers to the supply chain and, as such, its efficiency can be increased by coordination, truth-inducing mechanisms, contractual engineering and information sharing (see Chen's review of 2002 and 1998, 2001a, 2001b, Chen – Yu 2001a, Chen – Yu 2001b, Anupindi 1998, Porteus and Whang 1991, Lee and Whang 1999, Cachon et al. 1999, Zhao 2002). However, since their supplier definition entails back-logging of orders and inventory management, not all results apply to carriers or shippers. Ertogral et al. (1998) bridges both lines of thought: a single model integrates production and transportation planning, taking into account transport costs and schedules. This approach does not take into account the impact of imperfect information and decentralized decisions. Neither does it take into consideration the eventual over or under utilization of the transport capacity involved. The integer program set up optimizes transport costs, routing, scheduling by integrating distances, transport time, time-windows and full or partial truck loads costs to the basic production planning.

The transport industry characterises itself by the non-scalable capital intensive production investments needed and a high share of fixed costs within total costs. Capacity can be expanded only well in advance of output requirement. Full capacity utilization is thus one of the primary objectives. Supply chain management dedicates commendable space to capacity as a limiting factor; authors have modelled that constraint in several papers. Gilbert and Cvsa (2000) model the behaviour of the client who under-invests in cost-reduction so as to escape being held up by the supplier. That model looked at the trade-off faced by a firm when its downstream channel partner has opportunities to invest in making relationship specific marginal cost reductions. The case of 7-Eleven and Frito Lay serves as illustration. Should 7-Eleven invest in reducing its variable costs in distributing certain Frito Lay products and see Frito Lay profit by it? The authors propose to construct a wholesale pricing contract that Frito Lay will extend to 7-Eleven to encourage investment in variable cost reduction in the presence of market uncertainty. By crafting this ex-ante pricing contract, the retailer's interests are aligned with the manufacturer's and eliminates or at least reduces supplier opportunistic behaviour.

A paper that has modelled contracting arrangements for capital-intensive, capacity-constrained goods is Wu – Kleindorfer et al (2002). In it, the authors have specifically targeted the energy sector but have tried to enlarge the results to other capacity-constrained sectors like hotels, airlines, plastics, chemicals and other dated/perishable capital-intensive service providers like transport. They have put in the limelight the "two-goods problem", the first of which is the availability of capacity itself, pre-committed to a specific buyer, and the second is the output actually delivered on the day to the buyer. This gives rise to the existence of two different markets where prices are formed: spot pricing where "on-the-day" demand meets offer and pre-arranged bilateral contracting. The paper provides valuable insights on the optimal balance between selling capacity in the forward contract market versus selling on the spot market. This paper provides an answer to industries where conditions of storability are not given. Their results give a structure where a buyer and a seller can derive guidance on the optimal strategy between optimal forward contracting and spot buying of capacity. This model applies aptly to energy and other bulk products that have standard quality, interchangeable buyers and sellers and that rely on relatively efficient spot markets. This is not exactly the case of transport: parties to a contract have to iron out several operational details as to execution, quality criteria, etc that make each contract unique and entails greater transaction costs.

Spinler and Huchzermeier (2003) propose a variation of the preceding model by using options in lieu of futures contracts and spot market to increase capacity utilisation in the presence of state-contingent demand. The purpose is to effectively offset part of the risk posed by fluctuating demand by a strategy which combines buying options on capacity ahead of revelation of demand and complementing by spot transactions upon the period of requiring that capacity. They show that such a strategy effectively is Pareto improving for both the seller of the option (transport supplier) and the buyer (the shipper). Both reduce their risk and the volatility of their costs. To circumvent the liquidity problem of transport as a non-standardized service, the model assumes that options will be traded on electronic marketplaces where information and transaction costs are lesser. As Grieger (2003) reported (Cf supra), carriers and shippers may be wary to trade with partners of unknown quality and customer-satisfaction drive, jeopardizing the forecast efficiency and welfare. This issue does not arise for electricity, the other industry specifically addressed in Spinler and Huchzermeier, because of the more standardized nature of the traded good.

Agrell et al (2002) model a 3-stage, 2-period supply chain in the telecom sector. A supplier can decide to invest into certain new capacity and may share the economies by lowering his price. This model specifically excludes long-term partnerships that encourage parties to engage in activities that are unfavourable in the short term but have substantial payoffs over time. The game between the shipper and carrier typically has to carry on for a long period (typically 2 to 5 years, coherent with the life-span of the specific asset) which practically eliminates the hit-and-run tactics that the authors might observe in their model due to asymmetric information.

We build upon the model of the *quantity flexibility contract clause mechanism* under retailer uncertain demand (Tsay et al. 1999a, Tsay 1999, Tsay – Lovejoy 1999, Anupindi 1998, Tsay 2000, Cachon 2002), designed to align the behaviour of the supplier. "The Quantity Flexibility clause defines terms under which the quantity a buyer ultimately obtains may deviate from a previous planning estimate. The conditions can include limits on the range of allowable changes, pricing rules, or both." (Tsay et al 1999a). As in our setting, capacity has to be planned well in advance, the carrier has a strong incentive to encourage the buyer to forecast and plan honestly the cargo to be effectively transported. We should therefore model the incentive that the carrier has to include in the contract for that coordination to take place. One of the simplest mechanisms is for the shipper to pay the carrier a penalty when realized demand comes in at a level inferior to contracted capacity. This mechanism has been studied in Cachon- Lariviere 1997: the manufacturer pays a cancellation fee per unit not purchased if he takes delivery of fewer than the agreed-upon number of units. Another would be for the carrier to extract from the shipper a commitment for a given capacity, whatever the realized demand. A third is for the carrier and shipper to agree to a given cumulative capacity K_n over a number N of periods: if in one period the realized demand is less than predicted, the shipper is committed to make it up to the carrier in future periods (as in Bassok – Anupindi 1997).

Similarly, the shipper must obtain the maximum capacity at the least price given demand risk. In other words, he must angle for risk sharing with the carrier. Just settling for a given capacity at a set price is not enough for him to achieve low transport cost variance over a long time horizon. Thus some measure of flexibility in capacity has to be introduced. Several mechanisms can be implemented. One of these would be to set up a menu of extra capacities at pre-arranged prices: if the demand effectively exceeds the base contractual capacity, the shipper calls up extra capacity to meet it using this clause to set the premium price. Another would be to set a penalty clause for the carrier when he is unable to meet the capacity thus committed: whenever the carrier fails to meet the shipper's demand, he pays a penalty proportionate to the shortcoming. In Moinzadeh – Nahmias 1997 that same general problem is treated: Q, the minimum commitment per period is given and there are both fixed and proportional penalties for adjustments, over an infinite horizon. The authors contend, but do not formally prove, that a type of order-up-to policy (s,S) is optimal. In that model, the fixed delivery contract with penalties serves as a risk sharing mechanism.

Because the demand, when realized, directly results in a transport requirement, there can be no time-flexibility arrangements as those described in the literature (Li – Kouvelis 1997, Barnes – Schuster 1997).

It has to be mentioned that, in our approach, we have elected to consider that transport capacities are not freely substitutable, ruling out "overbooking" (Karaesmen et al. 2002). In other words, a carrier cannot just overbook his fleet on a given time slot because cargo available for that time slot cannot just be moved to the next available time slot and there are few cases of "no-shows".

Our market mechanism draws on the model in Seifert et al. (2003) for simultaneous long-term and short-term (spot) buying of commodities by a client from one or various suppliers. They study the impact of different buying strategies, involving different spot vs. contract buying proportions under various conditions of volatility of the spot price and also according to whether or not the client can eventually resell the commodity. They show that buying a "moderate" fraction of total needs on the spot market significantly improves profits over the contract-only behaviour. Their model contemplates both the possibility to buy and sell the commodity on the part of the buyer and also the "buy only" situation which is our case (it is not economically feasible for the shipper to resell unwanted transport capacity). We follow along the same path in modelling the behaviour of the shipper: he can simultaneously buy through long term contracts and through spot transactions the needed transport capacity to face the realized demand addressed to him, giving him added flexibility. Whereas previous research applies to commodities and thus takes into account stocks and inventory, we extend the results to the case of transport services after due modifications.

Our general model follows a similar pattern to that adopted in Gavirneni et al (1999). That study set up three scenarios that differ by the information level of the participants. In this case, the information is the distribution of the sales addressed to the retailer and whether or not the supplier can be aware of the law of that demand, and whether he can further benefit by receiving immediately sales data from the retailer. To study the impact of information on capacity and inventory, each scenario evaluates the level of information affecting the optimum capacity and inventory at the supplier level. Penalties for the supplier are included when demand addressed to him goes unsatisfied. Contrary to Gavirneni (1999), the simulations in this work do not consider different demand distributions nor different standard deviations of demand faced by the shipper. Further, the carrier does not need to evaluate sales data distribution laws because we suppose that the realized demand addressed to the shipper can be immediately satisfied by the carrier with no lead time and no inventory. The results of this paper and those of Gavinerni (1999) could be joined however in a further research into the advantages that could eventually be gained if the carrier could share with the shipper the inventory/sales data at the demand level. Take the case for example of the shampoo manufacturer having to deliver products to supermarkets; the carrier could benefit by knowing in advance the supermarket's ordering policy, inventory or sales.

In this paper, we show the importance and effects that both information sharing and coordination can have on the profitability of the carriers and the shippers. We have chosen to stick as closely to actual industrial practice so as to enable readers in transport procurement to easily apply the conclusions and calibrate better their bargaining with transport and logistic companies. The relative importance of information is clearly marked out so as to give information sharing and trust building the share they should have in a well thought out strategy. Given the variety of information which must be shared in a normal shipper-carrier relationship, the opportunities to enhance efficiency in the supply chain abound. This area is probably the one where the most progress will be made in the years to come bringing to the firms who will master it valuable nuggets of efficiency as well as increased responsiveness.

3. TRANSPORT MARKET MODEL

Transport, as an industry, is at once very standardized in its service and very diverse in its physical infrastructure and this makes for difficult modelling. Standard features, at least across industrial sectors, are the basic measures of transport as a service as outlined by Morash (2001): fill rate, stockouts, cycle time, complete orders, on-time deliveries, backorders. Due to the geographic infrastructure in place, some physical aspects do have some very common traits: road transport is divided among small units that often share common warehouse and handling infrastructures even though transported products can be very diverse. The interface between shipper and carrier is also very standardized across product types (same procurement procedures, same billing and payment norms, common cost structures, international terms of trade, common legal and regulatory framework). Our model tries to build upon the most general features and not depend upon special ones so as to enable possible empirical validation in the most various settings.

We assume that two shippers S_L and S_s are in close industrial sectors and require the same specific transport infrastructure. They contend with uncertainty on two fronts: the first is a stochastic demand. The second is a market for transport services where spot prices can vary, substantially affecting their costs.

Because of uncertainty on these two fronts, the shipper S_L chooses to minimize at least one source of uncertainty by tendering for a long term contract among several carriers he has been able to select by some order qualifying test. This feature is standard practice among all major industrial or otherwise B2B shippers. The ensuing contract is signed for a long period, proportionate to the life-span of the assets that both the carrier and the shipper will have to invest in to fill in their respective engagements. So S_L buys transport services through an *ex-ante long term multi-period contract* whereas S_s buys on the spot market (equivalent to short term contracts, Seifert 2003). The motivation for S_s to buy on the spot market may be in fact that his necessities may vary in such a degree from period to period as to render ex-ante contracting uneconomical.

Let C be the carrier who has signed the ex-ante contract with S_L and who further serves S_s as just another client in the market. Every period, C first serves the demand from S_L than from S_s. However, capacity is not binding for the shippers: whenever they cannot purchase the necessary capacity from C, they turn to the spot market for the remainder. Our interest is not in the allocation game. The shippers' objective function is a composite function of minimization of cost and maximization of client satisfaction.

3.1. *Motivation of shipper and carrier behaviour*

This model is set in the transaction cost economics (TCE) stream of economic literature. Therefore, the contract is an effort to craft order, thereby to mitigate conflict and realize mutual gains. Under this view, the contract cannot be more than an attempt at incompletely predicting future outcomes and present each partner with a set of pre-arranged guides to the other's behaviour. Building upon both past experience transport practice in industry and TCE theory, we include in the model the possibility that one or both parties will behave opportunistically during the lifetime of the contract. This can happen especially since both carrier and shipper have to invest in specific assets to be able to comply with the contract requirements: specific transport vehicles, specific quality-enhancing procedures, personnel training, warehouses, software, logistical equipment, etc. These assets have low redeployable value and effectively should contribute to strong inter-dependency and allow post-contractual opportunism. We have neglected to consider the asymmetry in dependency which comes from one party being "stronger" or having more bargaining power than the other (e.g. due to higher competitive pressure on the carrier, specific asset investment asymmetry, or shipper image integrity hostage to carrier among others). This has been on the specific purpose of enabling further empirical study to apply to both cases where the shipper is the stronger and hence more likely to engage in opportunistic behaviour as to cases where the opposite is true.

Both theory and practice share the observation that "[p]arties to a transaction that are bilaterally dependent are "vulnerable", in that buyers cannot easily turn to alternative sources of supply, while suppliers can redeploy specialized assets to their next best use or user only at a loss of productive value" (Williamson 2002, p.176).

In view of the preceding comments, how can each party still engage in opportunistic behaviour?

First it has to be noted that both shipper and carrier are risk averse: the shipper wishes to avert the transport price volatility inherent in the spot market, the carrier wishes to ensure steady and sufficient revenues to match his financial and commercial costs over the long term. Both have as objective to reduce volatility when negotiating the ex-ante contract and reduce transport cost / increase revenue on a per period basis during the life of the contract.

As both practice and theory reveal, a common attitude is to retain information from the other that could enable the other party to claim compensation or assume a retaliatory attitude. The range of information liable to this kind of claim is vast: early or timely information of future transport needs, subsequent changes in schedules, delays in delivery, type or quality of transport capacity available, prices etc. It would have been best to include the largest possible array of information gauges in our model, but effects of some kind of information on costs or profits are distinctly difficult to quantify. We have chosen for simplicity's sake to restrict our demonstration to just two forms of information amenable to modelling: information about the available capacity that the carrier can offer to the shipper and information on the exact demand addressed to the shipper. If information about available capacity is kept from the shipper he may not know that the carrier is in fact redeploying it for better profit elsewhere. On the other hand, if the carrier is not cognizant of the exact demand addressed to the shipper, he may not be able to observe that capacity has been bought from some competitor at a lower price.

At issue are not only the ex-ante bargaining and crafting of the contractual arrangements but also the ongoing contractual relations. We will study both under different scenarios: under the most favourable one, trust is comforted by observability of information. The shipper S_L observes the exact available capacity at each period of carrier C and C observes the realized demand addressed to S_L. This is our base scenario, consistent with the literature's definition of central control in the power of a single decision-maker with access to all available information as could be the case if both entities were part of the same corporation. In the second scenario, S_L cannot observe the capacity of C, but C does observe S_L's realized demand (or S_L makes that information available to C). In our third scenario, S_L cannot observe C's capacity and C cannot observe S_L's realized demand. In effect, we assume that there is no common knowledge of payoffs, or at least that this knowledge comes at a price. We do not model or attempt to include in our model the cost of such information gathering.

We assume in this paper that both parties will be better off (and will recognize that such an attitude has long term pay-offs) if they commit to informing truthfully. We venture that given today's competitive pressures put on all industrial manufacturers, given the emphasis put on dependability, given the high density of the meshing binding supplier and client, neither a carrier nor a shipper will risk antagonizing the other by consciously retaining information. In today's markets, because of the sunk investments and specific assets involved, such an attitude entails risks of client loss, reputation loss and other unquantifiable damage. We further venture to suggest that the contractual hazards increase inversely to technological development of the transport market (a testable empirical hypothesis would then be that less developed countries have higher relative transaction costs).

The model also takes into account diverse contractual arrangements because of their influence on the behaviour of both parties. No optimal contract design approach has been chosen. We have chosen some that are considered of importance by their impact on the behaviour of contracting parties. Behaviour is guided by profit in both the short *and* the long term so we concentrate on the three repetitive and constant attitudes described earlier during the lifetime of the contract. We further consider that if one party behaves opportunistically, he will never be caught, so that the renewal of the contract should be independent of the behaviour. However, it is obvious that both parties will draw conclusions as to the past benefits and effective service rates (both observable) during the life of the expired contract when renegotiating terms.

By the construction of our model, the gains of one party are the losses of the other, meaning that globally, social welfare does not increase except perhaps by lowered transaction costs in the following contract (if there is one).

3.2. *Client satisfaction measure*

This important concept is operationalized, for simplicity's sake, as the effective fill rate (EFR). We justify this choice by building upon Morash (2001). That research looked into the practices of the best logistical firms in the USA and Canada in 2000. Among the top tier of these best-of-breed firms, out of eleven customer service measure criteria, the most important to top management is the fill rate. An inspiration for our study is the technologically minded firm whose primary focus is on client (shipper) satisfaction and efficiency, so we will assume that the firms we wish to model are using the fill rate as their primary quality gauge measure.

3.3. *Contract characteristics*

The importance of contracts in co-ordinating a supply chain and improving system efficiencies have been highlighted in a number of papers: Seifert (2003), Gilbert et al (2000), Van Mieghem (2001), Tsay et al (1999a). We have used a contract as a coordination mechanism because of its popularity in the transport industry and because we recognize that the information structure in the transport industry shows wide asymmetry and conflicting objectives between carrier and shipper.

The contract results in most cases from a tender offer set up by the shipper and where a limited number of carriers are invited to bid. This first set is selected because of their experience and/or ability in transporting goods for other shippers in the same industrial sector (or an adjacent one). In the first round, the shipper qualifies on technical grounds a group of carriers. Among the qualifying criteria used by the shipper, one of the most common is the capacity that the carrier will be able to allocate to the shipper in the course of the contract. In a second round, these qualified carriers will receive an invitation to bid according to a schedule of conditions or terms of reference. The shipper selects the best bid and signs a contract where a number of conditions about quality, quantity, penalties and duration of the contract are fixed. The unselected carriers that have qualified for the second round can, however, still hope to share somewhat in part of the shipper's business: they become the second tier carriers and will receive orders pegged to the spot market price in instances when the winning carrier cannot take all the cargo the shipper has to ship.

We must now engage in setting the aspects of the optimal contract given the current theoretical setup. We have chosen the taxonomy of contracts in Tsay et al (1999). According to this taxonomy, contracts are classified by contract clauses and we now discuss each one in turn.

3.3.1. Long versus short term

To shadow more closely practical thought in transport industry, we have considered that any contract will extend over a large, finite number of periods. This means that each party can and will take into consideration both the long and short term. So, they will behave so as to maximise profits in the short term (each period) and also retain some possibility of achieving profits over the long term (possibility of being an insider when competition starts to renegotiate a new contract upon renewal of the present one). Issues concerning appraisal and calculation of reputation effects, trust and other intangible benefits of a self binding behaviour have not been settled satisfactorily in the literature on contracts. We have chosen not to include in our model calculations of the impact over the long term of such behaviours, but just assume some degree of reputation preserving behaviour. As observed in Tsay et al (1999): "the lengthening of the time horizon may encourage parties to engage in activities that are unfavourable in the short term but have substantial payoffs over time." In effect, "stable partnerships can reduce transaction costs and allow for greater cooperation (e.g. information sharing and collaborative product and process improvement)". The present model is more of a multiple period, finite horizon structure.

3.3.2. Decision rights

In our setting, the decisions in each period are few: S_L can choose to solicit C for additional capacity under the terms of the menu of prices, as described later. The base transport price is set and S_L has no control over the demand that is being addressed to him. C has the obligation to comply with the capacity requirements and quality levels in accordance with contract specifications. The advantage of such restriction of decision rights is to enhance stability and visibility in costs and reduce on-going negotiations during the contract's life. Both parties are better off if they can plan far ahead with no haggling. Any extra capacity or cargo is off loaded onto the spot market or can be freely traded between shipper and carrier using the spot market price as reference.

3.3.3. Pricing

Pricing plays a role for both parties. To the carrier, it enables him to match his long term capacity and quality-enhancing investments plans with his workload and revenue projections. To the shipper, it sets a reference to guide his budgetary planning process over various periods. Both have an interest in fixing for the longest possible period the price of the service to be delivered. We have chosen to set a price per unit of cargo up to a fixed capacity over the life of the contract. The carrier is committed to taking the cargo the shipper has at each period for that price per unit. The terms of the contract will specify the capacity that the carrier has to reserve for his use. This capacity is the object of ex-ante verification by the shipper. Refusing to honour this basic capacity requirement is a motive to reopen the contract and eventually to terminate it. Some contracts specify a price for a given capacity whatever the real cargo effectively transported up to that capacity. This is called capacity reservation and applies to very specific activities where the cost of unused capacity bears no comparison to the cost of long lead time or inability to deliver the service to the shipper (case of a standby plane or helicopter for medical urgencies). Using a price per quantity transported also makes it a variable cost to the shipper.

The case of the two-part tariff, so dear to most authors in supply chain literature, would be awkward in this setting for the shipper because he would not be able to make the cost totally variable. Further, it would displace some of the risk of demand variance onto him, instead of shifting it to the carrier. We argue that the shipper enjoys sufficient power over the carrier (and eventual competitors) to force the carrier to accept a totally variable cost. There is, however, a compensation to the carrier which we cover later in the form of a penalty for overestimating the realised demand that the shipper pays to the carrier.

Periodic reviews as well as other forms of indexation of this base price are covered in our model, because such automatic price changes are not subject to haggling and are fixed and known within each period, not affecting either party.

3.3.4. Minimum purchase commitments

The minimum purchase commitment clause included in most contracts takes the form here of a target of cargo to be transported at each period. It is for this capacity that the shipper pays a set unit price, basic object of the contract. The capacity corresponds to the average demand that the shipper hopes to receive over the life of the contract. It can be seasonal or take any other form of evolution, according to the shipper's forecast. The shipper would be tempted to overestimate the real capacity needed if that might help him garner a lower price from the carrier. To encourage credible information as to expected demand from the shipper (who is privately informed of his demand when negotiating the contract), we have taken into account the results from Cachon – Lariviere (1997) and Cachon – Zipkin (1999), where penalties are imposed to achieve Nash equilibria. The adjustment mechanism we have chosen for its simplicity and because it relies on observable information on each part is a penalty imposed on the shipper for the unused contracted capacity in each period. With such a penalty in place, the carrier can hope to obtain the necessary information as to the average demand expected by the shipper. This penalty alone will not suffice in guaranteeing his necessary capacity investments that are required to meet the capacity commitments. Only part of the risk arising from demand variance is mitigated. The level of such a penalty, relative to the base price per unit is the subject of negotiation between the shipper and carrier and reflects their power leverage.

We are conscious that this is a somewhat artificial coordinating mechanism so we have included in the numerical study the case where the penalties are set to zero.

3.3.5. *Quantity flexibility*

The quantity flexibility (QF) described in the taxonomy of Tsay et al (1999) describes the benefit the buyer receives under such a clause as being the advantage of deviate from previously planned estimate thus allowing for a degree of liberty where previously there was none. They describe the clause as a way for the buyer to forecast and plan more deliberately and honestly. The seller gives the buyer a price break to give the buyer an incentive to participate. To Tsay et al, the "QF clause has risk-sharing intent, and the hope is that the agreement can make both parties better off". Tsay (1999) models the behaviour of a client and supplier who would each have an incentive to overstate intended purchases and underestimate necessary capacity but whose conduct is effectively coordinated by penalties imposed both ways: on over-forecasting and on under-producing, leading to a system-wide optimal outcome. Following along the same tracks, to allow for some flexibility in the demand that the shipper receives, we have included a menu of prices that give some additional capacities that the shipper can call upon under certain conditions of price. This menu of prices encourages the shipper to call upon the carrier for the unforeseen demand received[1]. This added flexibility is of increasing value to the buyer as market environment becomes more volatile, according to the description in Tsay et al (1999) of Tsay – Lovejoy (1998).

3.3.6. *Buyback or return policies*

This type of clause does not apply in our context, since transport is not a stockable product.

3.3.7. *Allocation rules*

No clause of this nature has been allowed for in our model. There could be an interesting study to be done however in the case where a large number of clients in the same sector face the same highly seasonal demand routinely exceeding the whole transporting providers' capacity[2].

3.3.8. *Lead time and quality*

In our model lead time is not an issue since revelation of demand to shipper S_L is immediately followed by his order of capacity to C. In the same "simultaneous" moment, C knows how much of his capacity is left and he can serve S_s on his own demand at spot market price. This is of course a simplification of reality: orders for capacity from S_L to C may arrive at 15h00 of one day for service on the next and S_s may require by 17h00 an answer for his own request for capacity. By 18h00, all available spot capacity in the market may be allotted. Any slip-up in this tight schedule may cause costly delays and juggling of orders. Advance knowledge of capacity demand becomes a highly desirable/valued feature to a carrier. This lead time scheduling and capacity allotment, distinct from yield management already the subject of numerous studies, should be investigated further.

As to quality, we have considered in our model, perhaps too simply, that carrier C has been elected among a set of similar carriers and qualified on all required quality yardsticks that both S_L and S_s may impose.

3.3.9. *Notation*

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[1] The price is higher than the base capacity price because the marginal cost to the carrier of such capacity is higher than the average and constrains his overall capacity and ability to meet other commitments. Remember that the capacity is non-scalable unless notified well in advance.

[2] When grain harvest season is in full swing in Argentina, both the truck fleet and port silo capacities of the country are saturated.

C and S_L have negotiated ex-ante and are bound by a contract extending over n periods with known and fixed parameters. S_L agrees to buy at each period capacity q_L at price c. The shipper has to pay a penalty p_s for unused capacity up to q_L at each period. The carrier suffers a penalty p_c if he cannot (or chooses no to) carry the contracted capacity q_L at each period for non-performance of contracted service. The contract includes a menu of prices p_{La} at quantities q_{La} that the carrier offers to the shipper S_L to help him meet demand in excess of the contracted capacity commitment q_L up till q_{La} (fig.1). The menu is a list of prices linear with the capacity offered. This seems counter intuitive: one would expect that the higher the capacity sought by the shipper, the lesser the marginal cost to the carrier, so that the carrier would be motivated to make a volume discount to capture the excess demand. We will revisit this matter when discussing the coordinating power of the contract. Each price in the menu is the going price for all the excess capacity required by the shipper. This menu is a list of options that the carrier presents on a "take it or leave it" basis to the shipper for the length of the contract and which the shipper can exercise at each period. The shipper will ask for more capacity if the demand addressed to him exceeds the committed capacity q_L, thus giving him added leeway to meet unforeseen demands that could not be predicted when drawing up contract specifications. This is not an option in the true sense since there is no premium to be paid but rather an option on a forward contract as the shipper is committed to taking the available capacity offered under the terms of the menu (quantity and price); even if the spot price is less than the price in the menu for that given additional capacity.

3.4. *Opportunistic behaviour*

Opportunistic behaviour occurs in our case when either the shipper S_L or the carrier can escape from their contractual engagements without incurring retaliation from the other party. Retaliation can happen in one of two ways: either the party victim of the moral hazard has the possibility to obtain compensation through some previously agreed upon compensation or he does not and his recourse can be either to bring his case to some court of justice (often specified in the contract) or not to renew the contract when it comes up for renewal. In any case, if truthfulness is a priori reigning in the relationship, all retaliation depends upon verifying opportunistic behaviour. The party wishing that verification incurs a cost to perform this information collecting process. This cost can be large in the case of two arms-length entities like the ones in our case. We will focus in this paper on certain pieces of information which can be hard to come by and which can make a significant impact on the cost functions of either party. There are a number of other items of information which can be verifiable only at a cost and that can result from moral hazard (precise delivery date and time for example).

The first piece of information belongs to the carrier and is the size of the transport capacity he owns or otherwise controls. Ex-ante the shipper verifies the basic available capacity of the carrier (among the due-diligence that the shipper did to qualify the carrier for the second round of the tender). Thereafter, no further control is undertaken by the shipper in the course of the contract. So, in the course of the life of the contract, this information is no longer observable and the shipper incurs a cost in verifying it. In some countries, the capacity under the carrier's control can extend to sub-contractors which are not linked to the carrier in a formal way but by affinity or other commercial links (this is the case of owner-operated trucks that can take spot engagements for other larger carriers on an ad hoc basis). The shipper cannot easily verify that the carrier has more than the basic contracted capacity to ensure correct execution of his contracted commitments. It is not even verifiable ex-post. Only when the contract comes up for renewal can the shipper use records of past shipments to assess the capacity of the carrier. In a way, this is the only possible recourse the shipper has: not to renew the contract with this carrier.

The second piece of information involves the size of the available transport requirements of the shipper: the carrier may not be able to verify period after period that the orders handed him by the shipper represent his entire necessity. This information is also neither observable directly nor verifiable without cost to the carrier. The shipper may contract added capacity with other carriers whenever its suits him financially.

Depending upon the spot price in the market and since the carrier's total capacity is non-verifiable and non-observable by the shipper, the carrier can engage in hidden action by refusing to comply with the demand from the shipper, pay the corresponding penalty p_c and sell this excess capacity in the spot market. In this case, the shipper has no other recourse than to offer his cargo on the spot market. We have not modelled the loss of lead time that ensues, but it clearly has an impact to the shipper that could be evaluated and included in a future study.

The shipper S_L can also deviate when her realized demand is not observable by the carrier. When the spot price is lower than the menu of prices less the penalty, the shipper can deviate from standard contractual behaviour by refusing to purchase capacity in excess of q_L from the carrier and instead buy the necessary complement from the spot market. She can also deviate when the spot market price is less than the contractual price less the penalty for not complying with the basic volume in the contract.

We have modelled all three deviations in our scenarios.

3.5. *Demand and capacity characteristics*

State of nature is represented using three variables: P is the market price for immediate transport. The demands that the shippers meet individually and non-competitively are two exogenous, stochastic variables ζ_L ζ_s. All three are defining a probability space $\Omega(P, \zeta_L, \zeta_s)$. $\Omega(P_s,Q_L,Q_s)$ is the set containing the possible realizations of the triplets of transport spot price, and of demands addressed to shipper S_L and S_s. $F_L(.)$ and $F_s(.)$ are the continuously differentiable, invertible and monotonous probability distribution function of demand addressed to, respectively, S_L and S_s. $f_L(.)$ and $f_s(.)$ are the density functions of $F_L(.)$ and $F_s(.)$. $F_p(.)$ is the continuously differentiable, invertible and monotonous probability distribution function of the spot market price and $f_p(.)$ its density function. Let $\rho_D \in [-1,1]$ be the correlation factor between $F_L(.)$ and $F_s(.)$ and let $\rho_p \in [-1,1]$ be the correlation factor between $F_L(.)$ and $F_p(.)$. Often, ρ_D and $\rho_p \geq 0$ reflect the fact that both shippers are in close industrial sectors and the carriers are specialized, leading to spot market prices rising in accordance with realized demands addressed to the shippers because of tightening capacity all around. This causes stronger constraints on the capacity of the carrier as well as higher variance of transport costs to the shippers. Each shipper knows ex-ante the mean μ and standard deviation σ (μ_L,σ_L for S_L and μ_s, σ_s for S_s) of the cumulative distribution function of their demand. The demands have to be satisfied in full at each period; meaning that there is no backlogging: any unsatisfied demand is lost, reflected in a reduced EFR.

All other production costs of S_L and S_s are ignored.

The total capacity of C is W. C has a variable cost per unit transported V_c and a fixed cost F_c. No assumption is made regarding W.

Following Seifert (2003), we assume there is a transaction only when P_s is less than the corresponding lost sales cost to either shipper (maximum sustainable transport price for shipper S_L = Cut_L Seifert 2003), bounding use of capacity to C, affecting the EFR for S_L but also reducing the overall transport cost and standard deviation of this parameter to the shippers.

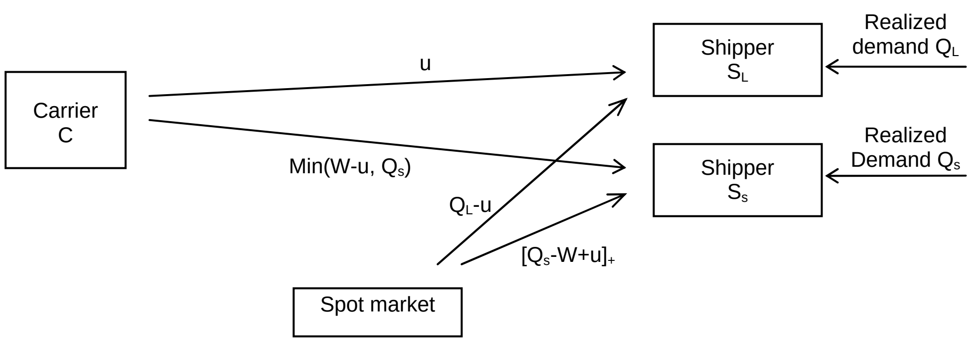

Fig. 1: Capacity allocation

In figure 1, u means that the quantity effectively transported for S_L by C.

3.6. *Objective functions*

3.6.1. *Carrier objective function*

In our setting, carrier C has just two customers: S_L and S_s. We could have included in our model the possibility by the carrier to sell his excess capacity on the spot market. We felt, however, that this would have been a too great departure from real practice as the lead time to be able to sell excess capacity depends upon the advance knowledge of this level of capacity. This advance knowledge depends upon advance knowledge of the demand that S_s, the spot market buyer of capacity, will address to the carrier. By construction, this advance knowledge is not given. If the summed demands from these two do not reach total capacity, the excess capacity is lost for all intents and purposes: carrier C cannot sell this excess capacity on the spot market. This is not a peculiar quirk of our model but the reflection of true market reality. This unused capacity impacts the carrier's profitability and ability to support the long-term investments that he must incur to face the demands at least from S_L. We have not included it as a separate objective to carrier C as all components are already present in the above objective function.

The objective function of the carrier is to increase revenue and reduce standard deviation of revenues over all periods. His best efforts should therefore be to focus the search of long term clients and assure constant volume of business so as to mitigate the risk he assumes by investing in new capacity. To that end, signing a contract with a shipper that guarantees periodic volumes at fixed prices covering both fixed and variable cost is the best strategy. His decision variables are the capacity he allots to each shipper: x_L is the allotted capacity to S_L and x_s to S_s. $W - x_L - x_s$ is the wasted capacity. His profit function is thus:

$$\prod\nolimits_c (x_L, x_s) = R\left(x_L\right) + P_s x_s - V_c\left(x_L + x_s\right) - F_c \tag{1}$$

Where R is a revenue function of the form:

$$R\left(x_L\right) = \begin{cases} x_L c - \left(u - x_L\right) p_c & : 0 \le x_L < q_L \\ q_L c + \left(x_L - q_L\right) p_{La} & : q_L \le x_L \le q_L + q_{La} \\ q_L c + \left(x_L - q_L\right) p_{La} + \left(x_L - q_L - q_{La}\right) P_s & : x_L > q_L + q_{La} \end{cases} \tag{2}$$

q_L, q_{La}, c, p_{La} and p_c are the parameters defined by the contract. P_s is the spot market price (fig. 2).

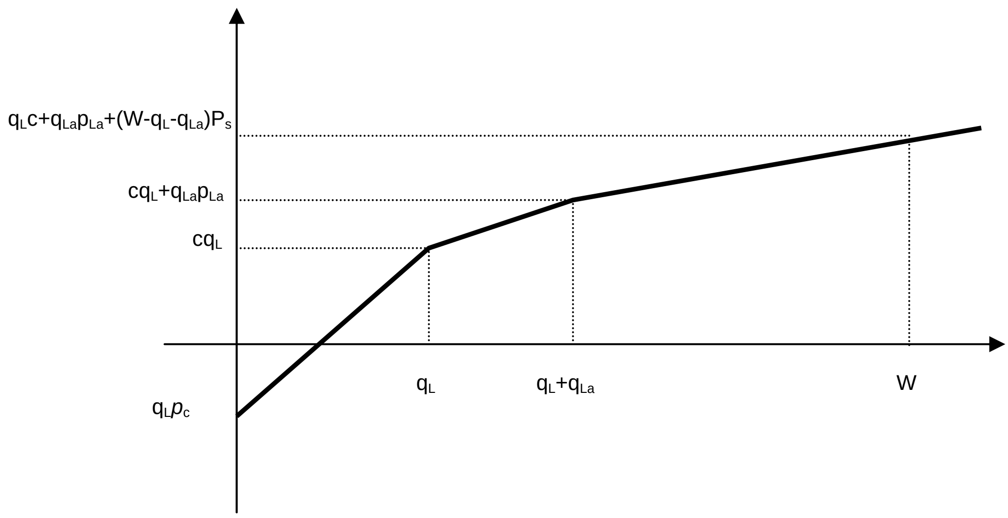

Fig 2: Behaviour of f(x_L)

3.6.2. *Shippers objective functions*

Shipper S_L faces the following situation: she produces and sells a product that requires transportation, either in the internal supply chain process or in the relationship with his clients. For obvious budgetary reasons, she has to ensure that transport costs remain as constant and predictable as possible. To ensure that budget cost constraints are met, her best option is to negotiate beforehand a contract with a duly selected carrier whereby the average predicted level of demand that she has budgeted can be transported for a known and defined price. When that contract is in place, she must decide whether to allocate his necessity to her chosen contractual carrier at the ex-ante contractual price or to the spot market at the going spot market price. As she is adverse to transport cost variance, we must also account for the variance of the cost in the objective function. We reflect this by minimizing:

$$Z(u) = C(u) + \alpha Var\left(C(u)\right) \tag{3}$$

Where $\alpha \geq 0$ is a risk aversion factor and u is the chosen allocation to carrier C.

This form of *Z(u)* is widely used in portfolio theory and yields mean-variance efficient outcomes (Markowitz 1952). Similarly, the inclusion of higher moments into the objective function has been widely advocated in the inventory control literature. An in-depth discussion of the justification and limitations of this approach is provided by Bar-Shira and Finkelshtain (1999), Myer (1987) and Tsiang (1972).

The decision variable u can take all values between 0 and total received demand Q_L. Whatever transport necessity is not being allocated to C will be offered to the spot market at the going spot price. The cost function that shipper S_L has to minimize is further conditioned by Cut_L the cut-off price past which it becomes uneconomical for the shipper to have cargo delivered as in Seifert (2003) :

$$0 \leq u \leq Q_L, \qquad P_s \leq \text{Cut}_L$$

$$C(u) = \begin{cases} cu + (q_L - u)\, p_s + (Q_L - u) P_s & : \quad 0 \leq u < q_L \\ cq_L + (u - q_L)\, p_{La} + (Q_L - u) P_s & : q_L \leq u \leq q_L + q_{La} \\ cq_L + q_{La} p_{La} + (Q_L - q_L - q_{La}) P_s & : \quad u > q_L + q_{La} \end{cases} \tag{4}$$

When $P_s > \text{Cut}_L$, the cost function becomes:

$$0 \leq u \leq Q_L \qquad P_s > \text{Cut}_L$$

$$C(u) = \begin{cases} cu + (q_L - u)\, p_s & : \quad 0 \leq u < q_L \\ cq_L + (u - q_L)\, p_{La} & : \quad q_L \leq u \leq q_L + q_{La} \\ cq_L + q_{La} p_{La} & : \quad q_L + q_{La} < u \leq Q_L \end{cases} \tag{5}$$

Shipper S_s either cannot predict future volumes for his product or cannot be bothered with a long term relationship or contract with carrier C (possibly because he already has such a long term contract in place with some other carrier and cannot take on the engagements of volume that such a contract would entail with C).

The objective function of shipper S_s to be minimized is basic:

$$\begin{cases} \text{Cut}_s \geq P_s & \rightarrow \quad C_s = P_s Q_s \\ \text{Cut}_s < P_s & \rightarrow \quad C_s = 0 \end{cases} \tag{6}$$

Where Cut_s is the maximum acceptable transport price over which S_s will forfeit delivering his cargo to his customers at that period (reducing EFR).

We suppose that, if S_s cannot buy enough capacity from carrier C, he still has time to turn to the spot market and buy whatever additional capacity he needs at the spot Price, so the *Efficient Fill Rate* (EFR) for shipper S_s is only limited by the cases where the spot price exceeds the maximum acceptable transport price.

The EFR for shipper S_L is given by:

$$EFR(x_L) = \frac{1}{Q_L}\left(x_L - \left[x_L - q_L - q_{La} \right]_+ \left(\frac{\left[\text{Cut}_L - P_s\right]_+}{\left(\text{Cut}_L - P_s\right)} \right) \right) \tag{7}$$

4. INFORMATION SCENARIO ANALYSIS

We can now start modelling each behaviour and see analytically how each impacts the objective functions of both carrier C and shipper S_L. Figure 2 describes the chain of events in time.

Each scenario is based on a different information assumption earlier described. In the first scenario, the information about the realized demands for the shippers is common knowledge to both shippers and the carrier, so is the spot market price for carrying that particular cargo at that particular period. In the second scenario, the capacity of C is unknown to S_L. In the third scenario, C's capacity is unknown to S_L and S_L's demand is unknown to C.

We will put a superscript index for each scenario on the carrier profit, shipper cost and standard deviation functions ($\Pi_C^1; C_L^1; \sigma_L^1; EFR_L^1$ for scenario 1 for example).

4.1. *Scenario 1: Perfect information:*

In this benchmark scenario, the carrier and shippers share information truthfully, as if coordinated by a single centralized organization. We assume common knowledge of: W, total capacity of C; p_c, penalty incurred by C for not performing contractual service to S_L; p_s, penalty incurred by S_L for not calling on the contracted services of C; Q_L and Q_s, the realized demands received by S_L and S_s respectively; and of course the spot price P_s. We calculate the cost, standard deviation of this cost and the EFR for each. This scenario generates the maximum total profit. We consider it as the "benchmark" efficiency scenario against which we measure the differences induced by asymmetrical information and strategic action.

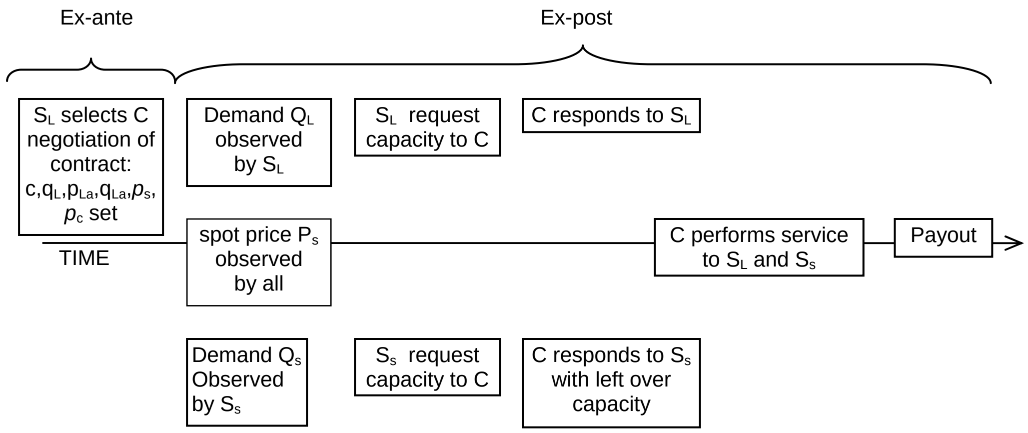

Fig. 2: Chain of events

According to the observed demands and spot price, shipper S_L allocates the maximum of the realized demand to C and C allocates the maximum of his capacity to satisfy S_L.

$$u = Q_L, \quad x_L = \min\left(W, Q_L\right) \tag{8}$$

So, their situation can be resumed below:

- $Q_L < q_L$: realized demand is less than contracted capacity. C offers remaining capacity to S_s which buys according to revealed demand Q_s. Any capacity of C left over is lost. C performs the transport of Q_L and Q_s. S_L and S_s pay for transport, Shipper S_L pays a penalty to C for committed capacity unused.
- $q_L \le Q_L \le q_L + q_{La}$: realized demand is more than contracted capacity but still within range of menu of prices included in the contract. Shipper buys additional capacity to C at the corresponding price in the contract menu. The excess capacity of C is offered to S_s. Ss buys in accordance with his own realized demand. Any remaining capacity of C is lost. Transport is performed and paid for. No penalties are due.

- $Q_L > q_L + q_{La}$: realized demand exceeds not only contracted capacity but also the extra capacity of the menu of prices included in the ex-ante contract. Shipper S_L must complement the committed capacity of C by buying from C extra capacity at the going spot market price of that period. If Q_L>W than S_L can still buy any remaining necessity from the spot market as we have considered that it has an unlimited capacity. S_s buys any necessary capacity at the spot price. If the spot price is higher than the maximum price over which transport becomes uneconomical for the shippers, transport is not bought. Only $q_L + q_{La}$ get transported. Payout occurs.

The revenue function R for C varies according to the different values of P_s:

$$R^1(x_L) = \min(x_L, q_L)c + \min([x_L - q_L]_+, q_{La}) p_{La} + \min(W - x_L, x_s) P_s \tag{9}$$

This function can be optimized by intervals, according to the values of P_s:

$$R^1(\overline{x_L}) = \begin{cases} min(Q_L, q_L)c + [q_L - Q_L]_+ p_s + min([Q_L - q_L]_+, q_{La}) p_{La} + min(W - Q_L, Q_s) P_s & : P_s \le \text{Cut}_L, P_s \le \text{Cut}_s \\ min(Q_L, q_L)c + [q_L - Q_L]_+ p_s + min([Q_L - q_L]_+, q_{La}) p_{La} + min(W - min(Q_L, q_L + q_{La}), Q_s) P_s & : \text{Cut}_L < P_s \le \text{Cut}_s \\ min(Q_L, q_L)c + [q_L - Q_L]_+ p_s + min([Q_L - q_L]_+, q_{La}) p_{La} & : P_s > \text{Cut}_L, P_s > \text{Cut}_s \end{cases} \tag{10}$$

The cost function of S_L becomes:

$$C^1(u) = \min(u, q_L)c + [q_L - u]_+ p_s + \min([u - q_L]_+, q_{La}) p_{La} + [u - q_L - q_{La}]_- P_s \tag{11}$$

The optimization of which, by intervals, gives:

$$C^1(\overline{u}) = \begin{cases} min(q_L, Q_L)c + [q_L - Q_L]_+ p_s + min([Q_L - q_L]_+, q_{La}) p_{La} + [Q_L - q_L - q_{La}]_- P_s & : P_s \le \text{Cut}_L \\ min(q_L, Q_L)c + [q_L - Q_L]_+ p_s + min([Q_L - q_L]_+, q_{La}) p_{La} & : P_s > \text{Cut}_L \end{cases}$$

(12)

As can be seen, the resulting optimal choice of allocation of cargo by S_L now only depends on Q_L and P_s. By using the corresponding probability functions, we can deduce the probability function of the optimal allocation.

We first write the probability functions according to their preceding definitions:

$$\begin{aligned} P(Q_L \le q_L) &= F_L(q_L) = \int_0^{q_L} f_L(x)dx \\ P(q_L \le Q_L \le q_L + q_{La}) &= F_L(q_L + q_{La}) - F_L(q_L) = \int_{q_L}^{q_L + q_{La}} f_L(x)dx \\ P(Q_L \ge q_L + q_{La}) &= 1 - F_L(q_L + q_{La}) = 1 - \int_0^{q_L + q_{La}} f_L(x)dx \end{aligned} \tag{13}$$

The probability function of the optimal allocation for C according to Q_L subject to P_s when $P_s \le Cut_L$ comes to:

$$P(C^1(\overline{u}) | P_s) = cF_L(q_L) + F_L(q_L) p_s + (F_L(q_L + q_{La}) - F_L(q_L)) p_{La} + (1 - F_L(q_L + q_{La})) P_s$$

The probability function changes to the following when $P_s > Cut_L$:

$$P(C^1(\overline{u}) | P_s) = cF_L(q_L) + F_L(q_L) p_s + (F_L(q_L + q_{La}) - F_L(q_L)) p_{La}$$

The probability function of the spot price can be written as:

$$P\left(P_s \le \mathrm{Cut_L}\right) = F_p\left(\mathrm{Cut_L}\right) = \int_0^{\mathrm{Cut_L}} f_p\left(x\right)dx$$

We can write now the probability function of the optimal allocation cost using both probabilities:

$$\begin{aligned} P\left(C^1\left(\bar{u}\right)\right) &= cF_L\left(q_L\right) + F_L\left(q_L\right)p_s + \left(F_L\left(q_L+q_{La}\right) - F_L\left(q_L\right)\right)p_{La} + \left(1-F_L\left(q_L+q_{La}\right)\right)F_p\left(\mathrm{Cut_L}\right) \\ & F\left(q_L\right)\left[c+p_s-p_{La}\right] + F_L\left(q_L+q_{La}\right) + F_p\left(\mathrm{Cut_L}\right) - F_L\left(q_L+q_{La}\right)F_p\left(\mathrm{Cut_L}\right) \end{aligned} \quad (14)$$

The expected cost to S_L given that he has allocated optimally his cargo is thus:

$$\begin{aligned} E\left(C^1\left(\bar{u}\right)\right) &= E\left(F_L\left(q_L\right)\right)\left[c+p_s-p_{La}\right] + p_{La}E\left(F_L\left(q_L+q_{La}\right)\right) \\ & -Cov\left(F_L\left(q_L+q_{La}\right), F_p\left(Cut_L\right)\right) - E\left(F_L\left(q_L+q_{La}\right)\right)E\left(F_p\left(Cut_L\right)\right) \end{aligned} \quad (15)$$

$$\begin{aligned} Var\left(C^1\left(\bar{u}\right)\right) &= Var\left(F_L\left(q_L\right)\right)\left[c+p_s-p_{La}\right]^2 + Var\left(F_p\left(Cut_L\right)\right) \\ & -E\left(\left[F_L\left(q_L+q_{La}\right)F_p\left(Cut_L\right)\right]^2\right) - \left[E\left(F_L\left(q_L+q_{La}\right)F_p\left(Cut_L\right)\right)\right]^2 \end{aligned}$$

4.2. *Scenario 2: Asymmetric information:*

In the second scenario, C has private information on W, the transport capacity. When negotiating for the contractual capacity in the contract, S_L has verified that C has at his disposal sufficient capacity to comply with qL. He did not or could not verify the existence or size of the additional capacity S_L has to invest in to meet the commitments of the menu of prices. The exact demand Q_L of S_L is here assumed observable by both S_L and C. So C has an opportunity to deviate when P_s is higher than $p_{La} + p_c$. In this scenario, the deviation is one-sided and limited to the carrier; in the next scenario, we will also take into account deviation on the part of the shipper S_L. The cost function of S_L and the revenue function of C are the following:

$$R^2\left(x_L\right) = \min\left(x_L, q_L\right)c + \left[q_L - u\right]_+ p_s + \min\left(\left[x_L - q_L\right]_+, q_{La}\right)p_{La} - \min\left(\left[x_L - q_{La}\right]_+, q_{La}\right)p_c + \min\left(W - x_L, x_s\right)P_s \quad (16)$$

$$C^2\left(u\right) = \min\left(u, q_L\right)c + \left[q_L - u\right]_+ p_s + \min\left(u - q_L, q_{La}\right)p_{La} + \left(u - q_L - q_{La}\right)P_s \quad (17)$$

The optimized results have to be calculated according to the different values of P_s. The distinct cases can be summarized as follows:

- $P_s > p_{La} + p_c$: We further have to consider two cases:
    - $P_s > \mathrm{Cut_L}$: S_L wishes to allocate $\min(Q_L, q_L+q_{La})$ to C, but C decides to deny his capacity in excess of q_L to S_L so pays the required penalty and sells onto S_s and the spot market at the P_s going price. S_L receives the penalty from C and cannot have $[Q_L-q_L]_-$ transported.

      $$C^2\left(\bar{u}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s - \min\left(Q_L - q_L, q_{La}\right)p_c \quad (16)$$

      $$R^2\left(\overline{x_L}\right) = \min\left(Q_L, q_L\right)c - \left[q_L - Q_L\right]_+ p_s - \min\left(Q_L - q_L, q_{La}\right)p_c + \min\left(W, Q_s + \left[Q_L - q_L\right]_+\right)P_s$$

    - $P_s \le \mathrm{Cut_L}$: S_L wishes to allocate $\max(Q_L, q_L+q_{La})$ to C.C decides to allocate all his capacity in excess of q_L to the spot market, he pays a penalty to S_L. S_L turns to the spot market for the remainder, and receives the penalty from C.

      $$C^2\left(\vec{u}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s - \min\left(Q_L - q_L, q_{La}\right)p_c + \left[Q_L - q_L\right]_+ P_s \quad (17)$$

      $$R^2\left(\overline{x_L}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s - \min\left(Q_L - q_L, q_{La}\right)p_c + \min\left(W, Q_s + \left[Q_L - q_L\right]_+\right)P_s$$

- $P_s \le p_{La} + p_c$: We again consider two cases:
  - $P_s > Cut_L$: S_L allocates all he can of his necessity to C within the limits of the contract: q_L and q_{La} and forgoes having the remainder transported. C chooses to allocate as much capacity to S_L as the prices of the contract warrant it compared to the spot market. No penalties change hands. C offers the remainder of his capacity to S_s.

$$C^2\left(\bar{u}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s + \min\left(Q_L - q_L, q_{La}\right)p_{La} \quad (18)$$

$$R^2\left(\overline{x_L}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s + \min\left(Q_L - q_L, q_{La}\right)p_{La} + \min\left(W, Q_s + \min\left(Q_L, q_L + q_{La}\right)\right)P_s$$

  - $P_s \le Cut_L$: S_L chooses to allocate only $Min(Q_L,q_L)$ to C at price c and derives the rest to the spot market. C receives a penalty in the case that the demand of S_L is less than q_L. C serves demand Q_s of S_s at P_s.

$$C^2\left(\bar{u}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s + \min\left(Q_L - q_L, q_{La}\right)p_{La} + \left[Q_L - q_L - q_{La}\right]_+ P_s$$

$$R^2\left(\overline{x_L}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s + \min\left(Q_L - q_L, q_{La}\right)p_{La} + \min\left(W, Q_s + \left[Q_L - q_L - q_{La}\right]_+\right)P_s \quad (19)$$

The EFR is affected by the new cases that arise of cargo not being transported when the spot price exceeds the Cut_L ceiling.

4.3. *Scenario 3: Private information*:

In this scenario, C has private information on W, S_L has private information on the demand Q_L: so both have an option to behave opportunistically according to the spot price P_s. Both carrier and shipper monitor whether the counterparty effectively sticks to the letter of the contract, but they cannot ensure that each receives the most out of the other. So each sticks to q_L, basic capacity contracted for. In this last scenario, the menu of prices is unenforceable. In effect, for any spot price either higher or lower than the menu price p_{La} according to the additional capacity necessary, either the shipper or the carrier decides to go to the spot market. The other party, for lack of knowledge of capacity or cargo, cannot ask for nor receive any compensation.

The function for S_L is now reduced to:

$$C^3\left(u\right) = \begin{cases} \min\left(u, q_L\right)c + \left[q_L - u\right]_+ p_s + \left[q_L - x_L\right]_+ p_c + \left[u - q_L\right]_+ P_s & : P_s \le \mathrm{Cut_L} \\ \min\left(u, q_L\right)c + \left[q_L - u\right]_+ p_s + \left[q_L - x_L\right]_+ p_c & : P_s > \mathrm{Cut_L} \end{cases} \quad (20)$$

The revenue function of C is also reduced to:

$$R^3\left(x_L\right) = \min\left(x_L, q_L\right)c + \left[q_L - u\right]_+ p_s + \left[x_L - q_L\right]_+ p_c + \min\left(W - u, Q_s\right)P_s \quad (21)$$

These functions are piecewise linear and their optima can be written according to the intervals of value for the spot price P_s:

- $P_s > c$: the carrier deviates and refuses to carry any cargo from S_L over q_L arguing about his lack of capacity, he does not pay the carrier's penalty for cargo above q_L. He opts to sell his capacity on the spot market. S_L has to buy the needed capacity from the spot Market at P_s. If P_s is higher than the maximum transport price (over which he forfeits the delivery to his own clients), no cargo is taken, impacting the total transport cost and the EFR. S_L suffers from a lower EFR and a higher transport bill. C increases his revenues.

$$C^3\left(\bar{u}\right) = \begin{cases} \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s - \left[q_L - Q_L\right]_+ p_c + \left[Q_L - q_L\right]_+ P & : P_s \le \mathrm{Cut_L} \\ \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s - \left[q_L - Q_L\right]_+ p_c & : P_s > \mathrm{Cut_L} \end{cases} \quad (22)$$

$$R^3\left(\overline{x_L}\right) = \min\left(Q_L, q_L\right)c + \left[q_L - Q_L\right]_+ p_s + \left[Q_L - q_L\right]_+ p_c + \min\left(W - q_L, Q_s\right)P_s \quad (23)$$

- $c - p_s \leq P_s \leq c$: neither carrier nor shipper deviate, both conform to the behaviour as in Scenario 1 except for the menu of prices (unenforceable).

$$C^3\left(\bar{u}\right)=\begin{cases}\min\left(Q_L,q_L\right)c+\left[q_L-Q_L\right]_+ p_s+\left[Q_L-q_L\right]_+ p_c+\left[Q_L-q_L\right]_+ P_s & : P_s \leq \mathrm{Cut_L} \\ \min\left(Q_L,q_L\right)c+\left[q_L-Q_L\right]_+ p_s+\left[Q_L-q_L\right]_+ p_c & : P_s > \mathrm{Cut_L}\end{cases} \quad (24)$$

$$R^3\left(\overline{x_L}\right)=\min\left(Q_L,q_L\right)c+\left[q_L-u\right]_+ p_s+\left[Q_L-q_L\right]_+ P_s+\min\left(W-Q_L,Q_s\right)P_s \quad (25)$$

- $P_s < c - p_s$: the shipper deviates by sub-declaring the capacity needed and buys the necessary transport capacity from the spot market. We have modelled total deviant behaviour from S_L, meaning that she gives *no* work to C under the pretence that the realized demand was null.

$$C^3\left(\bar{u}\right)=q_L p_s+Q_L P_s \qquad : P_s \leq \mathrm{Cut_L} \quad (26)$$

(no other case as by construction $\mathrm{Cut_L} > c$)

$$R^3\left(\overline{x_L}\right)=q_L p_s+\min\left(W,Q_s\right)P_s \quad (27)$$

The revenue function of C and the cost function of S_L are both piecewise linear in function of P_s.

4.4. *Conclusion*

4.4.1. Comparison between scenario 1 and 2

The differences between scenario 1 and scenario 2 come down to the following for C and S_L:

$$R^2\left(\overline{x_L}\right)-R^1\left(\overline{x_L}\right)=-\min\left(\left[Q_L-q_L\right]_+,q_{La}\right)p_c+\left[Q_L-q_L\right]_+ P_s \quad (20)$$

$$C^2\left(\bar{u}\right)-C^1\left(\bar{u}\right)=\left[p_{La}-P_s\right]_+\min\left(Q_L-q_L,q_{La}\right)p_{La}+\left[P_s-p_{La}\right]_+\min\left(Q_L-q_L,q_{La}\right)\left(P_s-p_c\right) \quad (21)$$

Both results are positive if there is but one instance of both the spot price higher than the menu of prices fixed in the contract plus the carrier penalty and existence of cargo to be taken in excess of base commitment q_L. It can be readily supposed that the shipper knows that the spot price will fluctuate and might go over the menu of prices. Further she will also suppose that the demand received will also exceed the base commitment q_L of the contract, so, by construction, that situation will arise often:

$$R^2\left(\overline{x_L}\right)-R^1\left(\overline{x_L}\right)>0$$
$$C^2\left(\bar{u}\right)-C^1\left(\bar{u}\right)>0$$

So there is a transfer of resources from S_L to C when C can deviate from truthful behaviour by hiding the exact capacity he has at his disposal and withhold extra capacity from S_L to sell it to the spot market at a higher price.

The variance of the transport cost of S_L increases with the variances of the component laws: ζ_L and P_s affected by the values given to the contractual parameters. When evaluating the impact of the contractual parameters however, one should bear in mind that the transport cost variance varies as a quadratic function of these parameters.

4.4.2. Comparison between scenario 1 and 3

We write the differences between scenario 3 and scenario 1 according to the value of P_s relative to c and p_c:

- $P_s > c$:

$$R^3\left(\overline{x_L}\right)-R^1\left(\overline{x_L}\right)=\min\left(\left[Q_L-q_L\right]_+,q_{La}\right)\left(P_s-p_{La}\right) \quad (22)$$

$$C^3\left(\bar{u}\right)-C^1\left(\bar{u}\right)=\min\left(\left[Q_L-q_L\right]_+,q_{La}\right)\left(P_s-p_{La}\right) \quad (23)$$

- $c - p_s \leq P_s \leq c$:

$$R^3\left(\overline{x_L}\right) - R^1\left(\overline{x_L}\right) = 0 \quad (24)$$

$$C^3\left(\overline{u}\right) - C^1\left(\overline{u}\right) = 0 \quad (25)$$

Neither deviate, no difference between third and first scenario.

- $P_s < c - p_s$:

$$R^3\left(\overline{x_L}\right) - R^1\left(\overline{x_L}\right) = \min\left(Q_L, q_L\right)\left(P_s + p_s - c\right) + \min\left(\left[Q_L - q_L\right]_+, q_{La}\right)\left(P_s - p_{La}\right) \quad (26)$$

$$C^3\left(\overline{u}\right) - C^1\left(\overline{u}\right) = \min\left(Q_L, q_L\right)\left(P_s + p_s - c\right) + \min\left(\left[Q_L - q_L\right]_+, q_{La}\right)\left(P_s - p_{La}\right) \quad (27)$$

The carrier receives less in scenario 3 than in the first whereas the shipper receives more. There is a transfer of resources from the carrier to the shipper.

Let $Diff\left(3,1\right) = R^3\left(\overline{x_L}\right) - R^1\left(\overline{x_L}\right)$

$$= P_s\left(\min\left(Q_L, q_L\right) + \min\left(\left[x_L - q_L\right]_+, q_{La}\right)\right) + \min\left(Q_L, q_L\right)\left(p_s - c\right) - \min\left(\left[Q_L - q_L\right]_+, q_{La}\right) p_{La}$$

$$= P_s\left(\min\left(Q_L, q_L + q_{La}\right)\right) + \min\left(Q_L, q_L\right)\left(p_s - c\right) - \min\left(\left[Q_L - q_L\right]_+, q_{La}\right) p_{La}$$

The probability function can be written as:

$$E\left(Diff\left(3,1\right) \mid P_s, Q_L\right) = E\left(P_s\left(\min\left(Q_L, q_L + q_{La}\right)\right) + \min\left(Q_L, q_L\right)\left(p_s - c\right) - \min\left(\left[Q_L - q_L\right]_+, q_{La}\right) p_{La}\right)$$

$$E\left(Diff\left(3,1\right) \mid Q_L\right) = \left(\min\left(Q_L, q_L + q_{La}\right)\right) E\left(P_s\right) + \min\left(Q_L, q_L\right)\left(p_s - c\right) - \min\left(\left[Q_L - q_L\right]_+, q_{La}\right) p_{La}$$

As E(Ps) is known to be equal to µp, we can write the equation:

For this expected difference to be null would mean that:

$$\left(\min\left(Q_L, q_L + q_{La}\right)\right) E\left(P_s\right) + \min\left(Q_L, q_L\right)\left(p_s - c\right) = \min\left(\left[Q_L - q_L\right]_+, q_{La}\right) p_{La}$$

As we have no way to resolve such uncertainties, we have found that applying the preceding reasoning through a numerical study would help clear the debate and give some indications as to the importance of the different parameters on behaviour by S_L and C.

5. NUMERICAL STUDY

5.1. *Elaboration of the sample*

In this section, we perform a numerical study to gain further insight into how the 3 scenarios affect the overall efficiency of the supply chain, revealing the impact that both contract characteristics and information sharing have on the overall profit and EFR of the supply chain.

We have taken the most general case for the demands addressed to the shippers and the price for spot transportation: exogenous stochastic variables with possibilities that they can be correlated. This study has been based upon a sample generated through the normal distribution random number generator of Microsoft Excel XP. The demand for the second shipper S_s is derived from the generated numbers for shipper S_L through the formula for bivariate normal distribution:

$$X = \mu_1 + \sigma_1 U$$

$$Y = \mu_2 + \sigma_2 \sqrt{1 - \rho^2} V$$

Where $X \sim N(\mu_1, \sigma_1)$, $Y \sim N(\mu_2, \sigma_2)$, U and V are independent random variables, each with normal distributions, and $\rho_D = 0.60$ the correlation factor between X and Y.

The spot price distribution is also normal and correlated with the demand Q_L addressed to S_L by a factor of 0.20 (Annex A).

$Q_L \sim N(100,25)$

$Q_s \sim N(100,25)$

$P_s \sim N(5,1.2)$

We have generated 1000 occurrences of triples (Q_L,Q_s,P_s) (Annex A). When further analysis into a particular result which has an important bearing on the final conclusion of the reasoning, we have fixed the corresponding parameters for the contract and repeated the sample 250 times. We then compare the 250 averages and calculate their confidence intervals and corresponding p-values.

We first evaluate the base scenario given the costs and other parameters detailed in Table 1 for the shippers and the carrier. Later, we study the impact produced by the variation of different parameters and conclude as to the resulting supply chain efficiency.

5.2. *Setting of other variables of the model*

The other variables have been set as follows:

	Q_L (S_L demand)	**Q_s (S_s demand)**	**P_s spot price**
Mean (μ_L, μ_s, $\overline{P_s}$)	100	100	5
Standard deviation ($\sigma_L, \sigma_s, \sigma_P$)	25	38	1.21
Correlation factor		0.6	0.2

Table 1: Base demand distribution parameters for numerical study

The contract characteristics are as follows:

Capacity q_L	**Contract price c**	**Shipper penalty p_s**	**Carrier penalty p_c**	**Additional capacity limit q_{La}**
120	4	1	1	25

Table 2: Base parameters for numerical study

The menu of prices offered by the carrier C to the shipper S_L for demands exceeding contracted capacity:

For an additional demand of	**< 5**	**6 to 10**	**11 to 15**	**16 to 20**	**21 to 25**
The price is	4.25	4.50	4.75	5	5.25

Table 3: Base parameters for numerical study

The carrier internal cost and capacity:

Capacity W	**Variable cost per unit Vc**	**Fixed cost Fc**
200	2	400

Table 4: Base parameters for numerical study

Further, the maximum transport cost over which the shipper will not move cargo is set for both shippers at:

$$Cut_L = Cut_s = 7$$

The total cost for the carrier if the total capacity is used is 400 + 2 * 200 = 800. We consider that one unit of demand is carried at the transport price.

When the limitation of transport price is included (Ss cannot buy transport capacity at prices over this limit for economical reasons, Cf. Seifert 2003), the cargo is not transported at all which reduces the EFR. It also automatically increases the standard deviation of the transport cost and reduces the average transport cost for S_s. This is the price of the trade-off between customer service and cost. The maximum transport cost is fixed at 7 for both shippers (Cut_L and Cut_s), or the average spot price plus almost two standard deviations ($\mu_P + 2\sigma_P \cong 7.42$). This means that in 44 cases out of the 1000 of the sample, the transport could not be executed, in total for shipper S_s, or in part for S_L.

The EFR shown in the calculations is the average of the EFR calculated for each instance in the sample.

5.3. *Impact of contract characteristics as coordination factors of the supply chain*

In this section, we study the impact of the different contract characteristics on the principal elements of the objective functions of the carrier and shipper. We approach the influence of the same contract characteristics on the information scenarios only in the next section.

Three stages of coordination can be defined (table 5): the first is the case of shipper S_s: no contract, total dependence on spot markets. The second is the case of the shipper S_L in scenario 3: he can't have the penalties limiting deviation on both sides enforced, so only the basic commitment on capacity and price exist. The third is the case of S_L in scenario 1, when all necessary information is common knowledge. Using 250 samples of 1000 triplets to calculate the following results, we can show that EFR increases with coordination:

p-value < 0.01	**EFR**	**Average Transport Cost**	**Std Deviation**
No contract	97.58% (±0.08%)	485.93 (±0.9)	181.14 (±0.7)
Contract no penalties	99.91% (±0.007%)	426.05 (±0.4)	87.85 (±0.4)
Contract & penalties	99.99% (±0.002%)	425.46 (±0.4)	86.56 (±0.4)

Table 5: Impact of coordination on three criteria

5.3.1. *Penalties*

In the present case, incentive compatibility given by the contract is through the penalties that either the shipper or the carrier can suffer. We have quantified this impact by varying the size of both penalties at the same time.

In the scenario of complete information, as both the contract capacity price c and penalties p_s and p_c go down, the standard deviation of the cost to shipper S_L goes up which is intuitive. At a given contract price c, standard deviation of cost increases inversely to the penalties (fig. 3 has p-values of 0.01, no thicker than the width of the lines). As can be expected, the average cost of transport follows the evolution of penalties. A not so intuitive result however, is that the EFR is independent of change both of the contract price and of the penalties: we have not been able to detect any change from an EFR of 99.987% over the 250 samples of 1000 triplets with a confidence interval of 0.002% at a p-value< 0.01. Even when there are no penalties applied, the resulting EFR is just the same as with positive penalties.

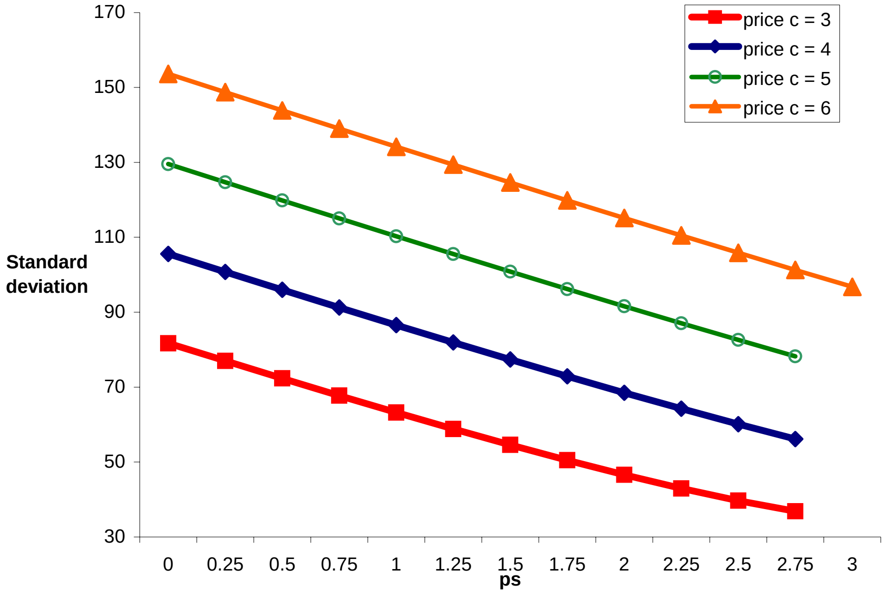

Fig. 3: Impact of penalties on the standard deviation of transport cost for shipper S_L at given c

5.3.2. *Maximum transport price limit*

To see how this limit on transport prices affects the total cost of transport for the shippers, average cost, standard deviation and EFR, we calculated the results in table 6 with the central assumptions displayed in tables 2 and 3.

p-value <0.01		Scenario 1			Scenario 2			Scenario 3		
		Avge cost	Std. Dev	EFR	Avge cost	Std. Dev	EFR	Avge cost	Std. Dev	EFR
S_L	**no** max	425.62 (±0.44)	87.06 (±0.40)	100% (±0)	426.19 (±0.45)	88.03 (±0.40)	100% (±0)	427.06 (±0.46)	89.64 (±0.43)	100% (±0)
	with max	425.46 (±0.44)	86.56 (±0.38)	99.99% (±0.002%)	425.18 (±0.44)	86.44 (±0.38)	99.91% (±0.007%)	426.05 (±0.44)	87.86 (±0.40)	99.91% (±0.007%)
S_s	**no** max	504.81 (±0.85)	172.36 (±0.59)	100% (±0)	Same results as scenario 1					
	with max	485.92 (±0.91)	181.13 (±0.69)	97.59% (±0.08%)						

Table 6: Effect of maximum transport price limit on cost and EFR

We can see from table 6 that S_s suffers a disadvantage both in terms of average as well as in standard deviation of cost compared to S_L. The maxima Cut_L and Cut_s induce a lowering of the EFR and of the variance of transport costs in all scenarios. There is no noticeable effect on the average transport cost as the confidence interval is too large. Notice the difference between transport cost standard deviation for S_s and S_L.

5.3.3. *Contract price*

As another coordinating lever, what influence does the contract price have on the EFR and the variance of the transport cost to the shipper? Would a higher price offered to the carrier suffice to induce better incentive compatibility?

Let us consider first the variance of transport costs (table 6). Thanks to the contract in place and the maximum price limit, S_L has a transport cost variance of 86.56 vs 181.13 for S_s, 50% lower. But the strongest advantage to the shipper S_L is in the improved EFR when ceilings to maximum transport prices are in place (Cut_L and Cut_s). In our central example, with both maxima set at 7, contract price at 4, and penalties at 1, we have an improved EFR for S_L of 99.96% as opposed to 97.59% for S_s.

These results are independent of the level of the contract price (table 7), showing the increased advantage of the long term contract to S_L.

Let us now turn to the EFR that shipper S_L enjoys. Bear in mind that, in our model, the capacity of the carrier cannot cause constraint by itself on the EFR of S_L as we have credited C with enough capacity to cover S_L's demand by more than the mean plus 3 standard deviations.

p-value<0.01	Contract price			
	3.5	4	4.5	5
Average cost	375.6	425.4	475.2	525.0
Std Deviation	74.8	86.5	98.4	110.2
EFR	99.99%	99.99%	99.99%	99.99%

Table 7: Shipper S_L statistics with long-term contract in place scenario 1

However, the EFR does not increase neither with the price paid for contract capacity nor with the penalties.

5.3.4. Contract capacity and additional capacity

What is more interesting is the influence of both contracted capacity q_L and additional capacity q_{La} on the EFR of S_L (in fig. 4, we have the graph of one sample of 1000 triplets represented).

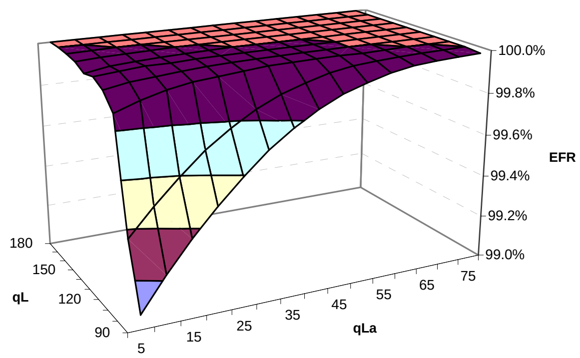

Fig. 4: EFR when contract capacity and additional capacity very

As both contracted capacity and additional capacity increase, the EFR of S_L increases to the maximum of 100%. So S_L has an incentive to contract for the highest capacity and the highest additional capacity but has to take into account the penalty that he has to pay for unused capacity p_s. A rate of 100% in EFR is achieved in our sample with capacity plus additional capacity starting at 175 (representing average expected demand addressed to SL plus 3 standard deviations of demand):

$$q_L + q_{La} \geq 175 \Rightarrow EFR = 100\%$$

The average transport cost (which reflects the added penalty cost to the shipper) grows both when capacity and additional capacity contracted grow, which is intuitive since this reflects the latitude that the shipper has in asking for more capacity and lessening the impact of the penalty. Almost as intuitive is the result that the variance of the cost diminishes as capacity and additional capacity increase. All these parameters should lead the shipper to try to negotiate a "sweet spot" of compromise between cost, variance and EFR. In our numerical example, this sweet spot would be in the region of a contract capacity of 120 with an additional capacity of 15 (Fig. 5):

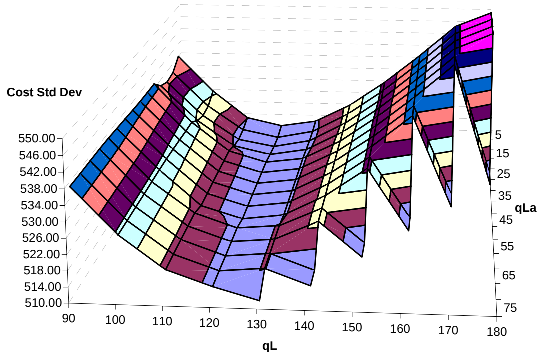

Fig. 5: Average cost + 1 standard deviation according to capacity and additional capacity

But this result does not take into account the cost of this capacity. To include this parameter, we have devised an "efficiency ratio" defined by the formula:

$$Efficiency = \frac{(\mu_{cost} + \sigma_{cost})}{Min(\mu_{cost} + \sigma_{cost})} \frac{1}{EFR}$$

Where μ_{cost} is the average cost of transport for each duple (capacity, additional capacity) and σ_{cost} is the standard deviation of the average cost of transport for each duple (capacity, additional capacity); $Min(\mu_{cost} + \sigma_{cost})$ is the minimum observed of the average costs for all combinations of capacity and additional capacity.

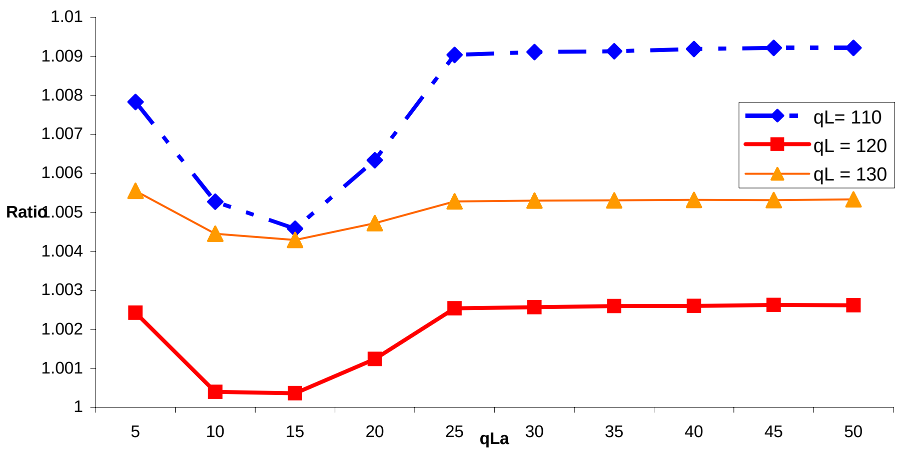

Fig. 6: Graph of efficiency ratio for 3 capacities and all additional capacities, p-values <0.01

According to the graph of these efficiency ratios (fig. 6), the optimum contract for the shipper has the following characteristics:

q_L=120

q_{La}=15

penalty p_s=1

penalty *pc*=1

contract price c=4

menu of prices: from 4 to 5 in steps of 0.25

The optimum contract for the shipper S_L is:

$$q_L = 120; q_{La} = 15 \Rightarrow EFR = 99.970\%, \text{Confidence interval} = \pm 0.0012\%, \text{p-value} < 0.01$$

If, however, he needs absolutely to achieve the highest possible EFR, he can easily do so by increasing the additional capacity to 30 where the EFR is 99.992% with a confidence interval of 0.002% (p-value <0.01).

5.3.5. *Menu of prices hierarchy*

The menu offered to the shipper in our central numerical example is the following (table8):

q_{La}	c
0 - 4	4
5 - 9	4.25
10 - 14	4.50
15 - 19	4.75
20 - 24	5.00
25	5.25

Table 8: Menu of prices in contract

The prices increase with the demand from the shipper: if the shipper observes a demand Q_L of 144, he can get from shipper S_L a contract capacity of:

$$q_L = 120$$

and additional capacity:

$$Q_L - q_{La} = 24$$

For that capacity, the menu price is:

$$p_{La} = 5.00.$$

Why doesn't the carrier offer some kind of volume rebate as an inducement?

One must remember that transport is a non-scalable capital-intensive production facility. If one admits that the available capacity is divided into discrete facilities (whether trucks, vessels, conveyor belts, rail carriages, pipelines) with different cost structures and usable lives, then of course the lowest cost facilities are used first and progressively higher cost facilities are brought into use as demand increases. Hence, marginal costs increase with demand.

On the other side of the equation, giving additional flexibility to the client has been established to increase his "willingness-to-pay" by Tsay – Lovejoy 1999.

On average, the shipper is marginally better off accepting the offered menu price rather than buying the needed capacity from the spot market (not so much because he thus lowers his average cost as because he reduces the standard deviation of such cost from 87.86 (scenario 3, S_L) to 86.56 (see table 6) and increases EFR significantly from 99.91% to 99.99%. So he will accept *ex ante* the menu in the contract. Of course, the carrier is also worse off offering the menu, but less than if he were to offer volume discounts! In effect, the carrier might not offer any menu at all (his revenues would increase slightly). The menu is in fact another way to coax the shipper S_L into allocating him extra work, enabling him to increase his capacity utilisation over the whole life of the contract. A situation which is always better than having to look for cargo in the spot market. The forfeited revenue can be more than compensated by added transaction costs and lack of transparency in the spot market.

5.3.6. *Carrier's point of view*

The interest of a contract to the carrier is clear as he has to commit capital over the long term in new capacity to satisfy the shipper's demand. The transport market being illiquid and commercial relationships being very tradition-bound, the carrier probably would not have invested in additional capacity just to satisfy the spot market.

The contract allows him to invest in the transport capacity necessary to comply with shipper S_L's demands. He turns a profit because he can further leverage the available capacity to win more business from S_s in the cases when S_L does not receive enough demand. Considering that his total assets have a capacity of 200, that he has a fixed cost of 400, it can be said that the total cost "allocated" to the contract is:

$$\text{Fixed cost in contract} = \frac{400}{200}.125 = 250$$

$$\text{Variable cost in contract} = 125.2 = 250$$

$$\text{Total cost per unit} = \frac{250 + 250}{125} = 4$$

When c = 4, the carrier makes a tidy profit of 135.71. He even makes a profit when c = 3.75 ceteris paribus, as shown below (table 10), because he can “subsidize” the contract by selling excess capacity onto the spot market at a much higher mean price. So his real profit lies in his ability to build upon the sunk capacity to look for other commercial opportunities outside the relationship to shipper S_L. He can allow the contract price to be less than the “allocated” total cost because of the reduced variance of his revenues as can be concluded by the following table where we have calculated the variance of the carrier’s revenues in the case he works with a contract with S_L and in the case where he sells his total capacity on the spot market (no contract) (table 10). His revenues are lower but he has the security of a substantially longer term view over a period designed to last the life of the specific assets acquired.

c = 3.75, p_s=p_c=1, q_L=120	**contract**		**no contract**	
	Mean	**Confid. Interval p <0.01**	**Mean**	**Confid. Interval p <0.01**
Average revenue	812.4	0.66	918.4	1.22
Standard Deviation	132.5	0.54	241.6	0.82
Profit	47.6	0.5	49.7	0.5
EFR	91.20%	0.06%	91.20%	0.06%

Table 10: Impact of contract on carrier performance under full information

The results induce a false sense of security because the reduced profit does not cushion him against adverse price movements of other inputs during the life of the contract.

One might be induced into asking why the carrier would link himself to the shipper in the first place, since he can make a better profit by selling all capacity he has in the spot market. Here is where the added transaction costs and lack of transparency of the spot market in transport capacity coupled to the long-term character of the investment stop the carrier from adopting this strategy. In reality, the carrier also has to contend with other risks as well:

- Client availability: the carrier may not find at every period the necessary clients to sell his capacity to;
- Competitive environment: direct or indirect can generate substantial changes in the profitability of the long-term investment.
- Long-term price of transport trend due to technological evolution.

Overall, he is much better off ensuring a stable and reliable stream of revenues by linking the investment to the contract with the shipper.

5.3.7. Conclusion on contractual coordination

We observe that to the shipper, average transport cost, variance of transport cost, and EFR can be noticeably improved by replacing a pure spot buying of transport capacity by a suitable mix of two procurement strategies: one taking a long-term approach by a designed contract between the carrier and the shipper, another by complementing this long-term approach by a short-term one that consists of spot-market buying for a fraction of every period’s transportation needs. A similar conclusion has been reported in Seifert (2003).

Another aspect we haven’t touched on heretofore is the fact that a shipper will not even evaluate carriers who do not meet order-qualifying minimum acceptable levels in four performance dimensions: logistical cost, logistical productivity, customer service and quality. Edward Morash (2001) in his field study of north American and Canadian Council of Logistics Management Association (CLM in the US and CALM in Canada) has ranked seven major types of supply chain capabilities according to their importance, once minimum levels have been met. Customer service, quality and information systems support came top ahead of logistics cost and productivity. These quality or reliability of service clauses are of paramount importance to the shipper and override cost considerations.

The case for contractual coordination to the shipper does not seem as watertight as the cost to him is higher for a marginal increase in EFR; but he makes that up by a much improved reliability of revenue flow over the long term (table 11) as can be gathered by the standard deviation of the revenues.

No attempt has been made to quantify the impact of variations of the spot market price volatility in the numerical study. Further study should be put in measuring the difference in efficiency between the pure spot strategy and the contract/spot one by changing transport price volatility.

Procurement strategy (p-value <0.01)	Pure spot buying (no coordination)			Mix contract + spot (coordination)		
	EFR	Std Dev of cost/Rev	Average Cost /Reve	EFR	Std Dev of cost/Rev	Average Cost /Reve
Shipper	97.59% (±0.08%)	181.13 (±0.69)	485.92 (±0.91)	99.99% (±0.002%)	86.56 (±0.40)	425.46 (±0.44)
Carrier	91.20% (±0.06%)	137.66 (±0.54)	838.79 (±0.69)	91.20% (±0.07%)	135.71 (±0.54)	837.35 (±0.68)

Table 11: Comparative of contractual coordination vs no coordination

We now have established how a carefully crafted contract and appropriate spot buying can enhance the overall efficiency of the supply chain, we proceed to demonstrate how sharing information between carrier and shipper S_L impacts their profitability and variance of results or costs.

5.4. *Impact of information sharing on shipper and carrier*

We now come around to the study of the combined influence of the coordination factors across the information scenarios defined earlier.

Our model has been limited to studying the impact of only three parameters of information on the performance and efficiency of the supply chain:

- W : total transport capacity of C
- Q_L: realized demand of S_L
- P_s: spot price.

Shipper S_s with or without the above information does not have any decision to take and cannot deviate; his role is purely passive and serves as reference. He typifies the rest of the market. The study concentrates on the interactions between S_L and C and on the influence of sharing the above three types of information. To give an idea of the order of the differences involved, we first begin with the central numbers in all three scenarios (table 12). The σ/μ ratio is a measure of the kurtosis of the distribution: we have divided the transport cost standard deviation by the average transport cost. The higher the ratio, the flatter the distribution curve of the means and thus the thicker the tails of the distribution. Throughout the three scenarios, the carrier's average revenue and standard deviation of revenues remain relatively constant with a correspondingly constant kurtosis.

p-value<0.01	Shipper S_L				Carrier C			
	Mean cost	Std Dev	EFR	σ/μ	Mean rev	Std Dev	EFR	σ/μ
Scenario1	425.45 (±0.44)	86.56 (±0.38)	99.99% (±0.002%)	20.35%	837.35 (±0.68)	135.76 (±0.56)	91.20% (±0.006%)	16.21%
Scenario2	425.18 (±0.44)	86.44 (±0.38)	99.91% (±0.007%)	20.33%	838.79 (±0.68)	137.33 (±0.56)	91.20% (±0.006%)	16.37%
Scenario3	426.05 (±0.44)	87.86 (±0.40)	99.91% (±0.077%)	20.62%	837.35 (±0.69)	135.71 (±0.54)	91.20% (±0.007%)	16.21%

Table 12: Results of 3 scenarios with parameters fixed in central case

Common knowledge scenario betters the EFR for the shipper, it reduces the variance of revenues for the carrier. It is immediate that the influence of information overall is much less than the coordination induced by the carefully crafted contract mentioned earlier.

This section is divided into three subsections. In the first one, we vary capacity and additional capacity and fix all other contract parameters and study EFR and standard deviation of transport cost among the three scenarios. In the second subsection, we vary the contract price and penalties to see how their combined effects change with access to information. In the third, we vary the contract price and capacities and see the effects across the scenarios.

5.4.1. *Influence of capacity and additional capacity*

We calculated for all three scenarios the level of EFR and the standard deviation of transport cost for S_L when both contracted capacity c and additional capacity q_{La} vary. The purpose is to try and link the absence of information on the part of the shipper (scenario 2) and on the part of both (shipper and carrier) in scenario 3 with the full knowledge scenario.

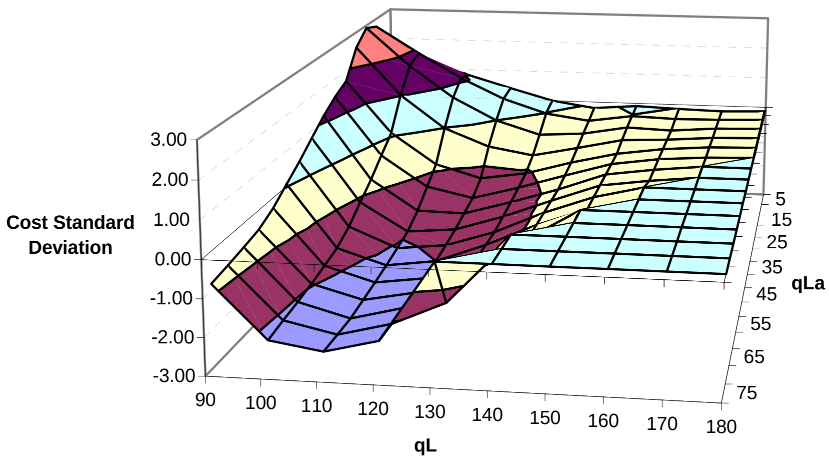

Fig. 7: Transport cost standard deviation as a function of capacity and additional capacity, comparison scenario 2 – scenario 1

We see in one sample of 1000 triplets (fig. 7) that under tight capacity and no additional capacity, the second scenario increases transport cost variance to shipper S_L. On the contrary, we observe that the higher the additional capacity relative to contract capacity, the lower the variance for shipper S_L in the second scenario. There is a maximum difference at a contract capacity of 110 and additional capacity of 65: scenario 2 beats the variance of the common knowledge scenario. In all, there is an ample area where the second scenario achieves lower transport cost variance for shipper S_L.

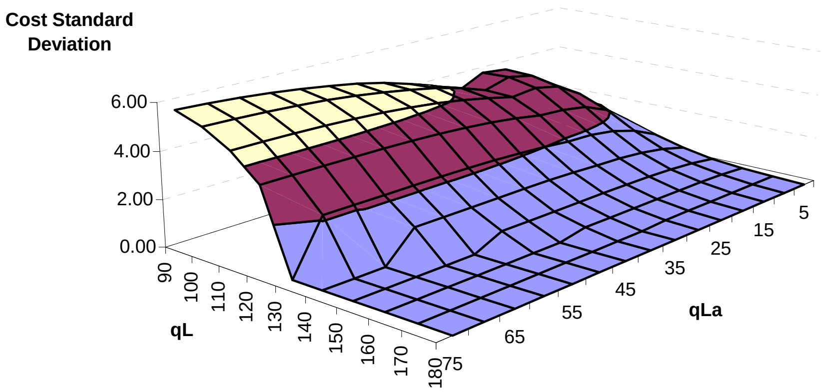

Fig. 8: Transport cost standard deviation as a function of capacity and additional capacity, comparison scenario 3 – scenario 2

The third scenario shows a distinct degradation of transport cost variance at all levels against scenario 2, and consequently against scenario 1 (fig. 8).

The other dimension of efficiency is the EFR that shipper S_L can achieve through the three scenarios. In both scenario 2 and scenario 3, the EFR does not depend on the additional capacity, which is as expected since the shipper uses the spot market when the carrier refuses by opportunism to honour the menu of prices. The following graph (fig. 9) shows the difference between scenario 2 and scenario 1. The EFR in scenario 1 dominates any capacity/additional capacity combination of scenario 2 or 3.

We conclude that the shipper can make up for lost EFR under private information scenarios by adjusting ex-ante in the contract both capacity and menu of prices to the upside. With contracted capacity of 140 and 40 in additional capacity in the menu of prices, S_L achieves almost a 100% EFR. In effect, this means that the shipper S_L can counterbalance the negative effects of lack of common knowledge by carefully tuning the capacity he contracts and the additional capacity he includes in the ex-ante contract.

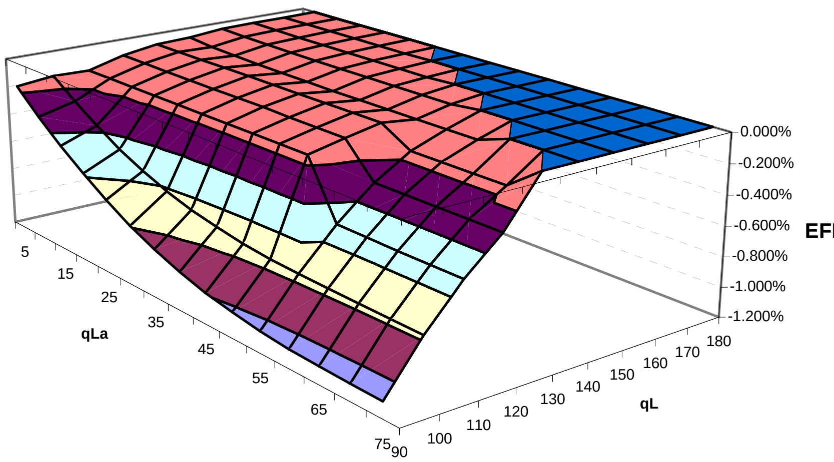

Fig.9: EFR as a function of capacity and additional capacity – difference scenario 2- scenario 1

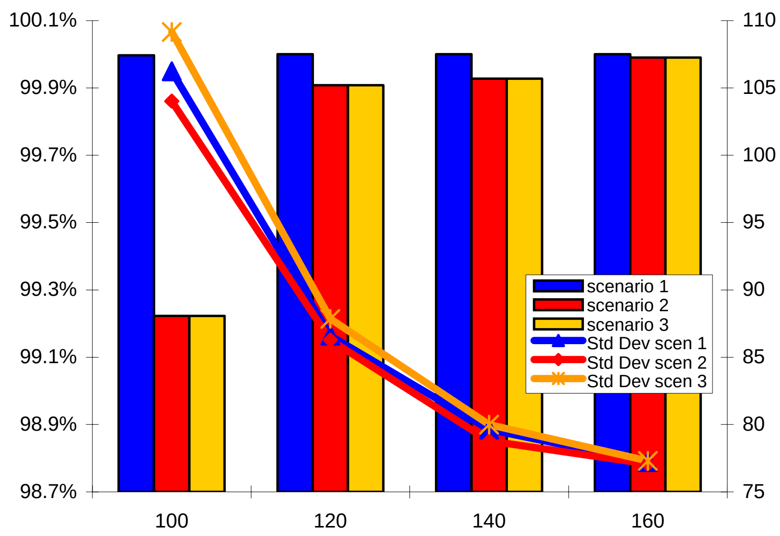

Fig. 10: Representation of EFR at given additional capacity in 3 scenarios

5.4.2. Influence of contract price and penalties

We now give the results of the standard deviation of transport cost and the EFR in function of the contract price c and the penalties p_s and p_c.

5.4.2.1. EFR

The first result is that the EFR in each scenario is independent either of the contract price or of the penalty levied in the range of prices we have considered to be "feasible". We have evaluated contract prices between 2 and 6 by a step of 0.5 and the penalties between 0 and 3 by a step of 0.25. We will not show the corresponding table because of its lack of interest. The impact of the contract price and penalties on the EFR are only felt in the second scenario, otherwise, either it is already high (first scenario), or it does not pick up (third scenario).

5.4.2.2. Average transport cost and standard deviation of cost

When the average transport costs are compared, the picture becomes more contrasted. One can distinguish three phases: in the first, average costs in scenario 2 are higher than in scenario 1. In the second phase, this is reversed up till an extremum. The third phase shows how the costs between the second scenario and first slowly converge again. This extremum is achieved when the contract price is set at 5 and the penalty at 0.8. At this point, the average costs in scenario 1 are higher than the average costs in scenario 2, as well as scenario 3. In other words, at that level of contract price plus menu of prices (you remember that it increases starting at the contract base price level) S_L has to go through the specifications of the contract, whereas in scenario 2 C refuses capacity when the spot price warrants it, forcing S_L to do so too. The whole reduction in the average cost of transport comes from cases when cargo can't be transported because the spot price is higher than Cut_L. This offsets the economies that are achieved in scenario 1 compared to scenario 2 in all the cases when the menu of prices is lower than the spot price. (fig. 11 and 12).

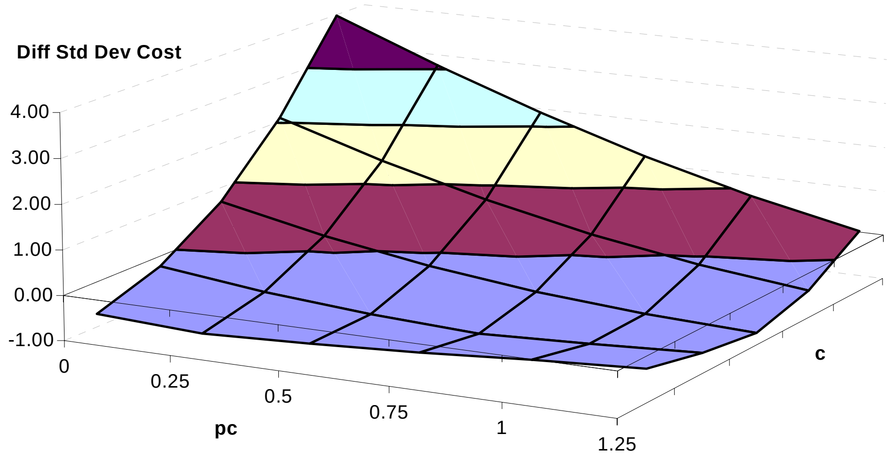

Fig. 11: Influence of contract price and penalties on the average transport cost: difference between scenario 2 and 1(p-value<0.01)

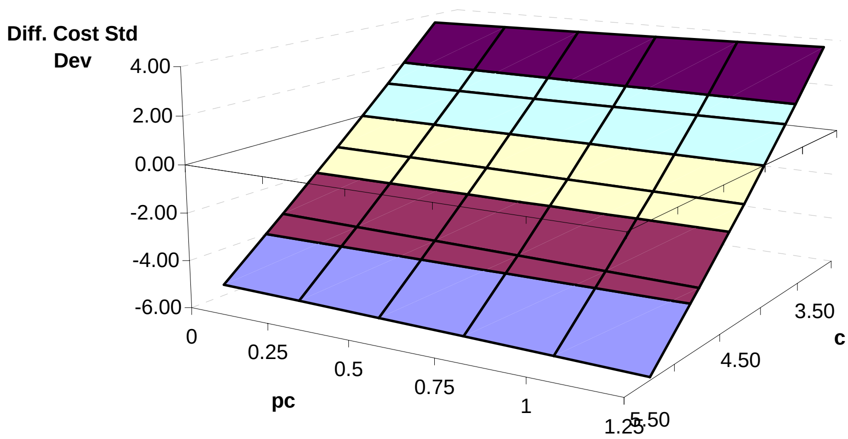

Fig. 12: Influence of contract price and penalties on the average transport cost: difference between scenario 3 and 1 (p-value<0.01)

The standard deviation of the transport cost reacts much sooner to increases in contract price. To enhance the readability of the results, we have divided the standard deviation thus obtained by the average transport price. We have a better notion of the kurtosis of the distribution of the transport costs (fig. 13).

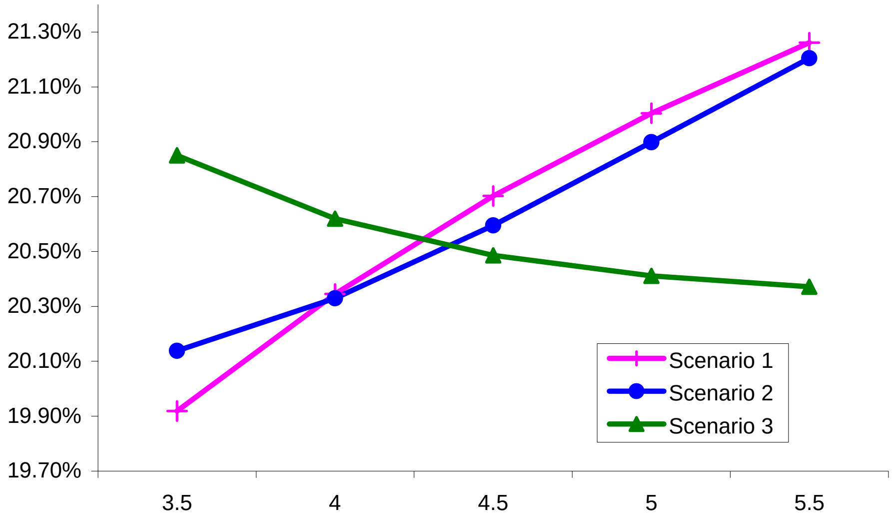

Fig. 13: Kurtosis of transport cost distribution : three scenarios (p_s=p_c=1, p-value < 0.01)

The first important comment is that the ratios all come in in a very small range: the kurtosis of distribution does not change a lot whether information is being shared or not. Even when the contract price is higher, the standard deviation of the transport cost increases even more, lifting the overall ratio in both the first and second scenarios. Only in the third case does the increased price bring higher coordination and lower variance of cost to S_L. A second conclusion that comes to mind is the fact that the total information scenario does not bring proportionately better standard deviation of cost as compared to the second scenario. Said differently: the information gap in the second scenario is more than offset by lower standard deviation. To get a better picture of the overall result in terms of standard deviation, we have graphed the difference of both standard deviations in the first two scenarios. (fig. 14).

We see that the distribution of the cost around the mean becomes more concentrated as c and p_s increase, which is intuitive. However, a plateau is reached: cost standard deviation in each scenario move in step at higher levels of c and p_s.

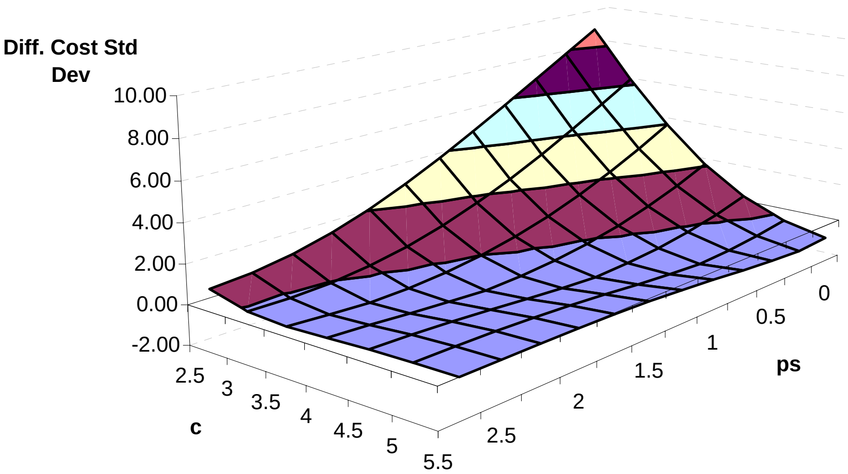

Fig. 14: Influence of contract price and penalties on the standard deviation of transport cost, difference between scenario 2 and 1. (p-value<0.01)

5.4.3. *Influence of contract price and capacity*

Moving on to influence of contract price and capacity with information scenarios, we start by showing the difference between scenario 2 and 1 of the average cost of transport. Common information brings singularly high advantages when a contract price is low and coupled with a low contracted capacity (fig. 15). On the contrary, when S_L has underestimated his needs when negotiating capacity levels in the contract, but negotiated a c nearer to the average spot price, his average transport cost is much lower in a scenario where C hides his exact capacity from S_L and sells in the spot market. In fact, this advantage comes at the expense of lower EFR: S_L cannot move all his cargo because of the Cut_L trigger when $Ps > Cut_L$, (especially acute when q_L is insufficient).

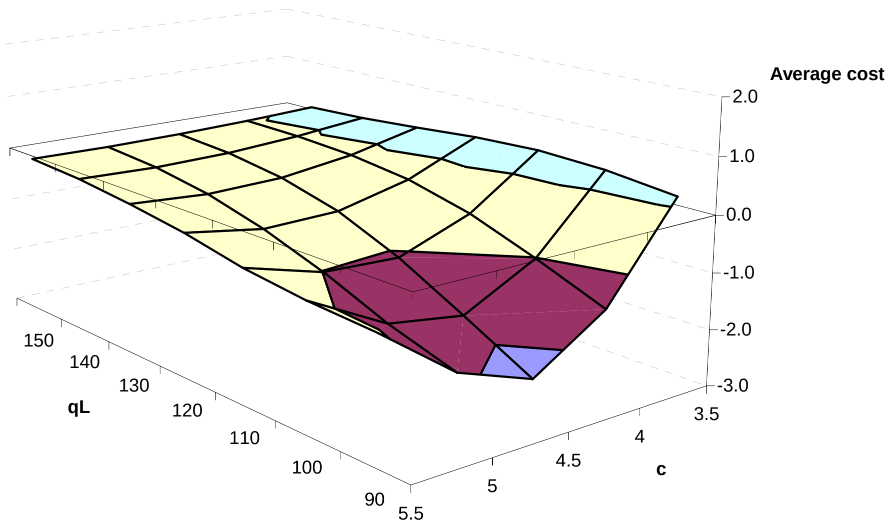

Fig. 15: Average cost of transport to S_L as a function of capacity and contract price, difference between scenario 2 and 1

Even when considering the third scenario, information brings an advantage only when committed capacity is insufficient (fig. 16).

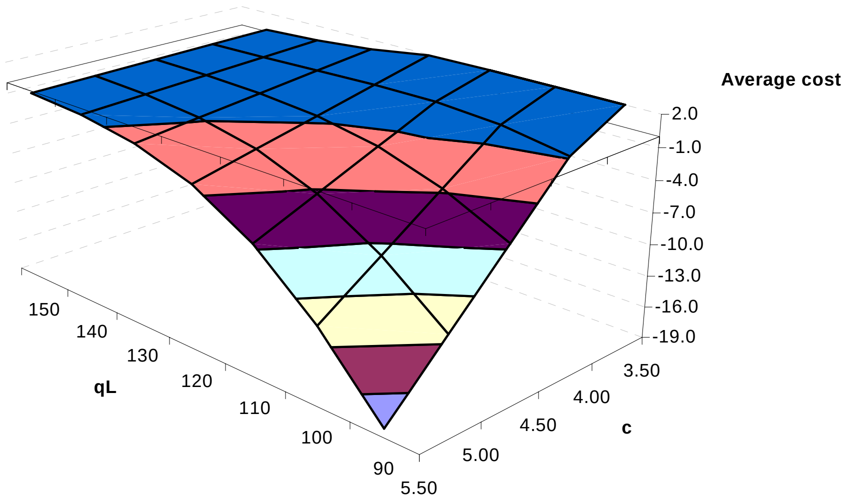

Fig. 16: Average cost of transport to S_L as a function of capacity and contract price, difference between scenario 3 and 1

Given the behaviour of shipper S_L and carrier C in the three scenarios, it is interesting to establish how the varying contract price c and contracted capacity q_L affects EFR and Standard Deviation of transport cost.

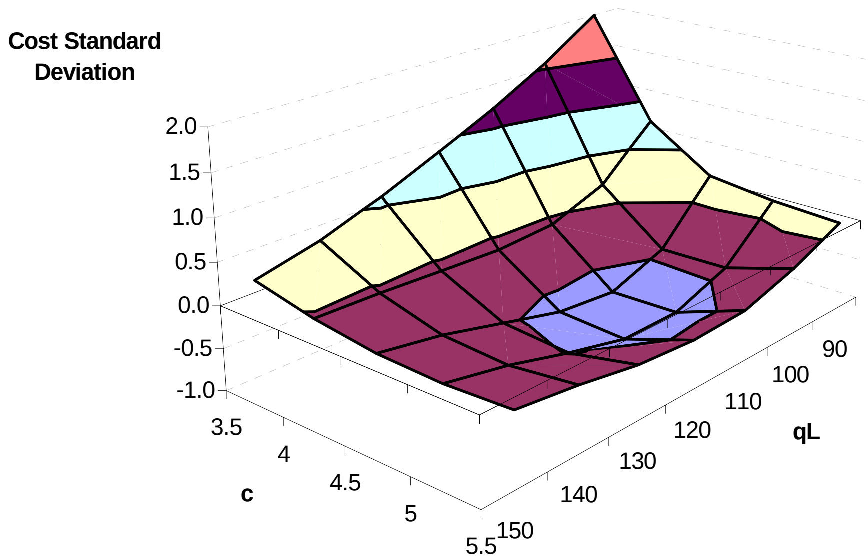

Fig. 17: Difference between scenario 2 and 1 of Standard Deviation of transport cost for S_L

The second scenario (fig. 17) dominates the first scenario when c is set at 4.5 and q_L at 110. The first only comes to dominate in settings where capacity is tight and contract price low, as would be expected.

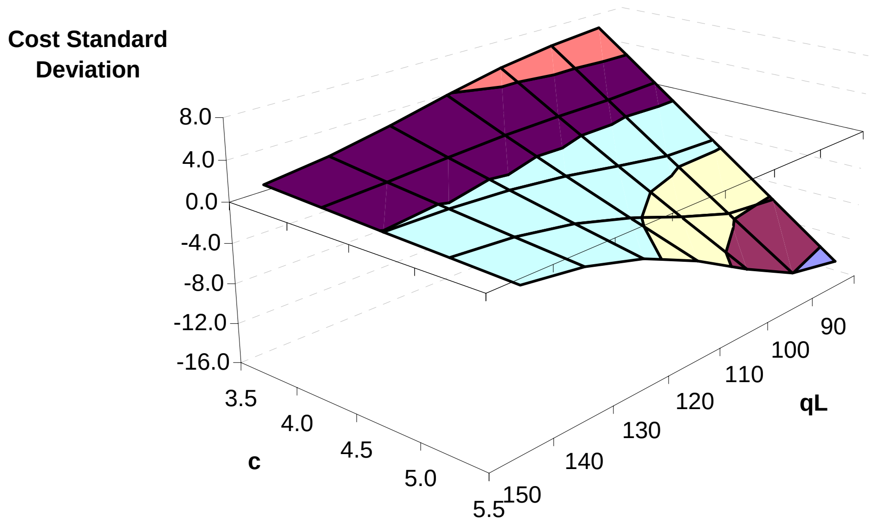

Fig. 18: Difference between scenario 3 and 1 of Standard Deviation of transport cost for S_L

In the comparison between the third and first scenario (fig. 18), the advantage in the standard deviation of transport cost is significant when the capacity is set at 100 and the contract price at 5.50. This result is not too obvious at first sight but corresponds to deviation by the shipper in cases where the spot market is lower than the menu of prices in the contract, thus encouraging her to understate the transport requirements she would otherwise have directed to C. This shows up when one compares the carrier's revenues in both instances (higher total revenue over all 1000 instances in scenario 1 than in scenario 3). The average cost to shipper S_L of transport also drops in scenario 3, only offset by a lower EFR (99.77% against 99.22% in scenario 3). The impact of Cut_L is negligible compared to this one.

Looking at the situation of the EFR, we see that, in the ranges we consider likely (from 2.25 to 5.5), it is only a function of the capacity contracted and independent of the contract price, as earlier noted. The EFR increases as knowledge asymmetry diminishes (fig. 19).

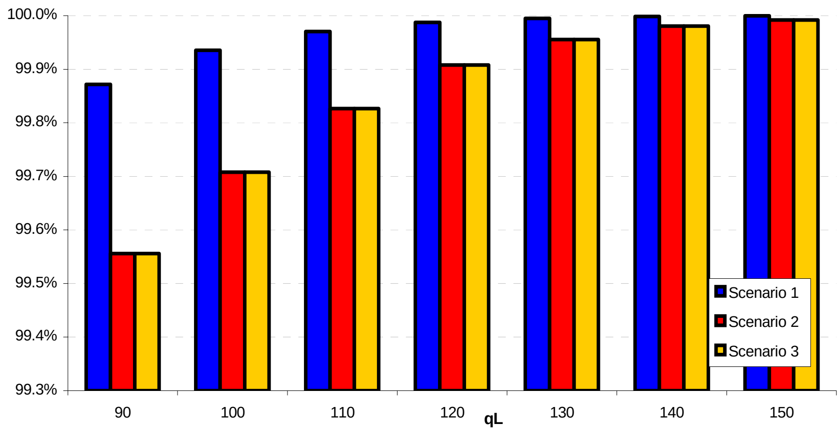

Fig. 19: EFR as a function of capacity for c=4 in 3 scenarios (p-value<0.01)

Once again, we conclude that the information asymmetry can almost be bridged by coherent contractual ex ante arrangements. The third efficiency criteria shows that lack of information can be counterbalanced by coordination induced by a contract that specifies committed capacity equal to the average expected demand plus two standard deviations (in our numerical example this is 100 + 2x25 = 150) and for a price set at the average spot market price minus half a standard deviation of spot market price (5.00 – 1.20 /2 = 4.40).

5.5. *Conclusion to numerical study*

The scenario of full information or common knowledge is always superior when the shipper cannot commercially let down any customer at a bearable cost. The shipper who must bring about simultaneously a topmost EFR and low average transport cost must at once signal truthful behaviour by sharing truthfully the demand she receives AND elicit similar behaviour from her carrier. This truthfulness should enable her to build a trust relationship and her reputation in the sense of Williamson 1996 (“a farsighted approach to contracting (in which credible commitments, or lack thereof, play a key role)”).

The ideal contract in this configuration is when she combines this attitude with a contracted capacity equal to the average of demand plus 2 standard deviations and at a price more or less equal to the average of the spot price minus half a standard deviation of the spot price (table 13). In all cases her cost is higher than the cost of the shipper who only buys from the spot market under maximum transport price limit condition.

p-value <0.01	100	120	140	150
scenario 1 cost	468.62 (±0.57)	475.24 (±0.50)	490.80 (±0.46)	500.16 (±0.45)
scenario 2 cost	466.92 (±0.58)	474.65 (±0.49)	490.66 (±0.46)	500.10 (±0.45)
scenario 3 cost	485.90 (±0.91)	485.90 (±0.91)	485.90 (±0.91)	485.90 (±0.91)
S_s cost	485.90 (±0.91)	485.90 (±0.91)	485.90 (±0.91)	485.90 (±0.91)
EFR scenario 1	99.935% (±0.005%)	99.987% (±0.002%)	99.998% (±0.001%)	99.999% (±0.0004)
EFR scenario 2	99.708% (±0.012%)	99.908% (±0.006%)	99.98% (±0.003%)	99.992% (±0.002%)
EFR scenario 3	97.59% (±0.008%)	97.59% (±0.008%)	97.59% (±0.008%)	97.59% (±0.008%)

Table 13: Average transport cost and EFR to SL among 3 scenarios as a function of contract capacity, for a fixed contract price of 4.5

6. CONCLUSION AND POSSIBLE EVOLUTION

There is a lack of research and practice in approaching transport as a full fledged member of a supply chain. In this paper, we present transport as an individualized supply chain member and supplier to the chain. We have modelled the impact and influence that information sharing and coordination has on the efficiency of the supply chain. The present model only studies the influence of three information factors and six coordination factors on the cost, standard deviation of such cost and EFR of the transport supplier to the supply chain. To quantify the gain or loss of efficiency, we have chosen to concentrate on the levels of transport cost, the standard deviation of such costs and on the Effective Fill Rate (EFR) of the shipper's orders. We have not considered agglomerating these three gauges into one sole efficiency index as we believe that this would entail a loss of information from the point of view of application to special cases. Another dimension which we have totally obviated but which singularly influences the behaviour of both shipper and carrier, and hence the supply chain efficiency, is the lead time between revelations of demand addressed to the shipper and realization of the transport by the carrier. This lead time is influenced by whether the shipper receives an immediate response from the carrier or if he has to go out and buy transport capacity on the spot market; it is also influenced by the time that the carrier has to wait for orders to come in from other shippers before answering to the shipper with which he is linked by a contract.

Given these limitations, however, the conclusions we arrive at are interesting in advancing the debate about the influence of information asymmetry and contractual coordination in the supply chain for such an important element as transport.

Our results confirm that the supply chain suffers when one of several causes come in play.

- When the carrier and shipper are not truthful or lack mutual trust. Whatever the levels of the other variables (contract price, spot price, contracted capacity, penalties, additional capacity), the EFR of the shipper suffers. This means that the shipper cannot ensure total quality of service towards his customers. A situation which is deemed of much greater importance than the cost of transport (Morash 2001).
- When the ex-ante contractual coordination mechanism has been poorly designed. We have proved that if the committed contract capacity fixed in the contract is too low (less than the estimated average of demand plus 2 standard deviations), when the contract price is set too low compared to the current average spot price observed, when the additional capacity is insufficient, the carrier has a strong incentive to deviate and fail the shipper, causing increase of cost and standard deviation of transport cost, not to mention lower EFR. In this case, penalties, whatever their level, bear only incidental influence.
- When no ex-ante contractual arrangement exist between a shipper and a carrier, we have proved that the shipper pays lower average transport cost but at a price of high standard deviation of cost, and of reduced EFR.

The information gap induced by keeping private information as to the real transport capacity by the carrier, the real demand received by the shipper is detrimental to the overall efficiency of the supply by encouraging deviant attitudes both from the carrier and the shipper. The dimension most affected by this asymmetry in information is the overall Efficient Fill Rate of the shipper.

Carefully crafted ex-ante contractual arrangements can substantially correct this information asymmetry but increases the overall transport cost to the shipper. The most influential factors in the contract are the committed capacity, the contract price for this committed capacity and, to a lesser degree, the additional capacity with an increasing menu of prices offered by the carrier.

Another avenue to be explored is study how EFR and Standard deviation of transport cost are affected by different levels of the variance of both the spot price Ps and the demand QL (along the lines of Seifert 2003 or Gavinerni et al 1999).

It would be interesting to enlarge the study by adding further information variables germane to the transport industry: time schedules of the carrier, projections of future demand (entails sharing sales forecasts by the shipper), advance knowledge of points of delivery among others. In all cases, the most interesting point to study is to allow the carrier to increase capacity utilization and thus share with the supply chain the economies. The net effect to the supply chain would be to reduce the total investment cost of the transport capacity contracted and hence the total transport cost component. In fact, the logistics industry as a whole is investing and developing tools to enhance the circulation of information among the interested parties as has been shown in the survey in Peters 2002. All these sets of information demand a much higher of level of trust and cooperation between shipper and carrier but are key to further unlock value in the supply chain. Modelling of such parameters has so far been insufficiently taken account of in the supply chain management literature.

Taking into account the specific characteristics of transport services should open up an area for further research into increasing the efficiency of the supply chain as a whole.

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ANNEX A – CHARACTERISTICS OF THE NUMERICAL EXAMPLE OF THE STUDY

This is the graph of the distribution of Q_s vs Q_L:

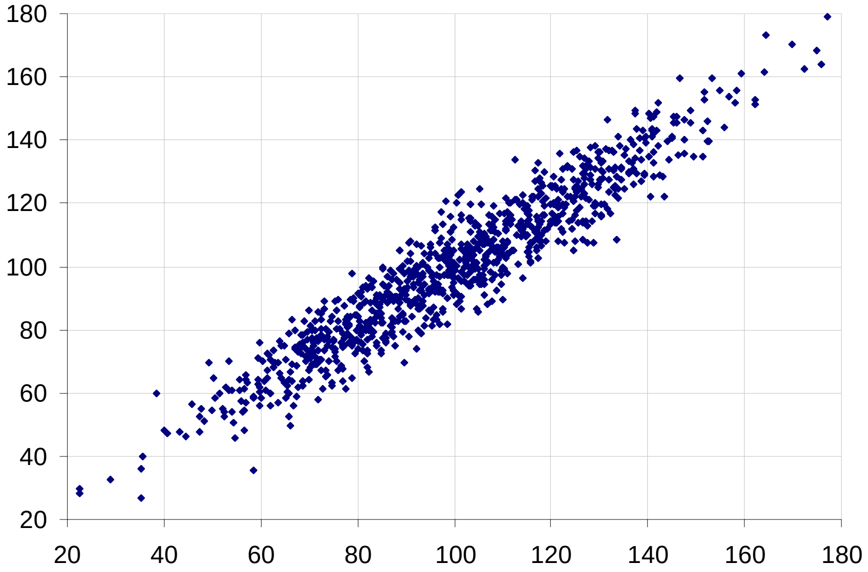

Fig. 1: QQ plot of Q_s over Q_L

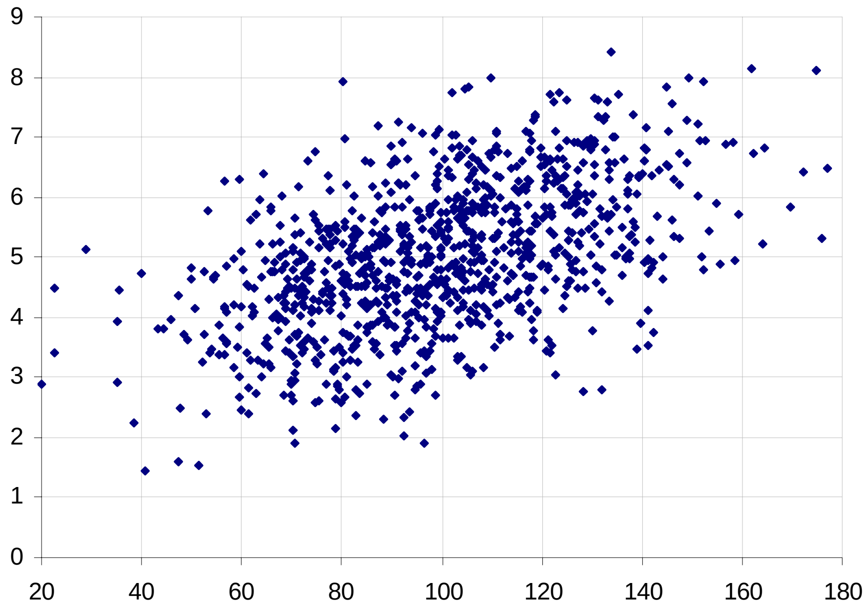

Fig 2: QQ plot of P_s over Q_L

We have grouped the demands in categories of 6 from less than 22 to more than 172 (Fig 5):

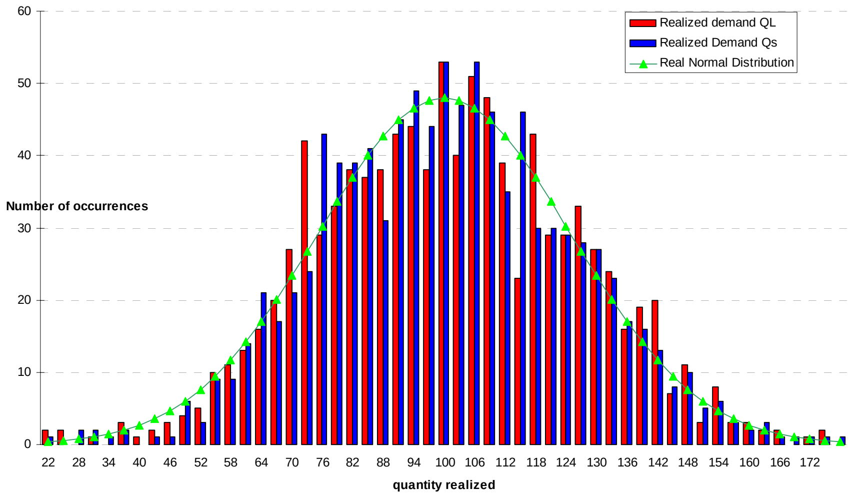

Fig. 3: Graph of the distribution of the 1000 occurrences of Q_L and Q_s

These samples have the following statistics:

Q_L : $\mu_L = 99.486$, $\sigma_L = 25.624$

Q_s : $\mu_S = 99.269$ $\sigma_S = 24.566$

P_s : $\mu_p = 5.005$ $\sigma_p = 1.20$

Due to an identified and documented bias in the Excel number generator, the left hand side distribution tail is slightly too thick compared to the normal one, but the result is not affected and we could even argue that this skewness is more life-like (Fig. 6).

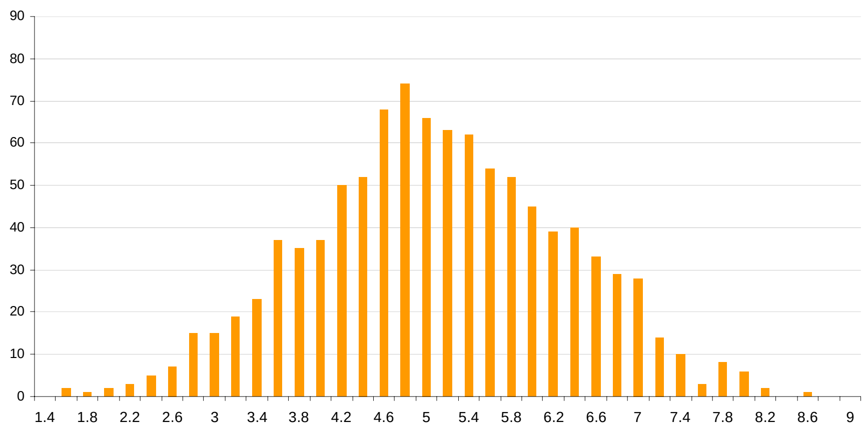

Fig. 4: Graph of the spot transport price distribution

The volatility level that has been chosen for this numerical study has entailed a range of prices from a low of 1.43 and a maximum of 8.41. We have been exposed through industrial practice to other examples of spot market volatility in the transport industry. Though our choice is not borne out by statistical evidence, the one we have simulated seems to have only slightly exaggerated tails and is probably too "flat" compared to reality. This is both a product of design to enhance visibility of results and a product of an intent for generalisation to other cases. We hope that the reader will agree with us that this choice but does not impair the validity neither of the reasoning nor of the conclusions.