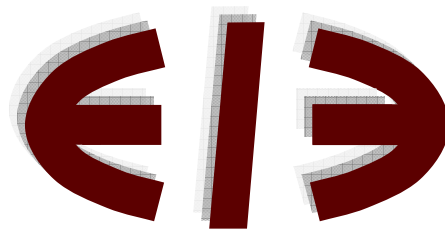


**Can we use hedonic pricing
to estimate freight value of time ?**

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Can we use hedonic pricing to estimate freight value of time?

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Abstract

In this article, we investigate the use of hedonic pricing method to measure freight value of time. We concentrate on the demand side of the freight market (that is shippers) and give a precise definition to transport duration. We analyse the different temporal dimensions of freight transportation and examine how equilibrium forms on the freight market. This equilibrium is defined in reference cost and duration of the transport operations. Subsequently, we analyse how standard hedonic pricing technique has to be customised to be implemented on freight value of time. In a final section, we implement hedonic analysis on a data set consisting of shippers' interviews. We test different specifications and find information on the distribution of shippers' willingness to pay for transport time savings.

Keywords

Hedonic pricing, freight value of time

JEL : R41 (Transportation: Demand; Supply; Congestion; Safety and Accidents), D61 (Allocative Efficiency; Cost–Benefit Analysis).

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1. Introduction

1.1 Presentation of hedonic pricing

Hedonic pricing is widely used in economics as a tool to investigate the value that consumers place on different attributes of goods. Hedonic pricing assumes that goods are desired for their different qualities or attributes, from which the consumer gets utility. This technique originates in the pioneering works by Waugh (1928) on the determinants for asparagus' prices on Chicago's marketplaces and Court (1939) on automobile industry. It has been further refined based on Rosen's 1974 milestone article "Hedonic prices and implicit markets: product differentiation in pure competition", which gave more formal and theoretical backgrounds to the analysis of covert preferences underlying the market hedonic equilibrium. It has been used in a variety of fields and for a variety of purposes. Regarding the purposes, the mainstream implementation of hedonic pricing regards the estimation of consumer's willingness to pay for the qualities of a given good. It has also been used to estimate prices of non existing multi-attribute goods. The last approach was often used as an intermediate result to compute price indexes net of the quality effect. It has also been used in the analysis of multi-attributes or multi-goods production functions (see for instance, Spady and Friedlander (1978)). Regarding the fields of application, the overwhelming majority of works using this technique deals with urban or housing economics. This technique has also been applied on industrial goods (automobile, computers) and on the labour market (Lucas (1972)). We also found some applications in the field of transportation services. Maggi and alii (2000) in Switzerland recently made a hedonic analysis of passenger transportation services including an estimate of the value of time for professional trips. Regarding freight, Sepulveda J. and Sepulveda C. (1994) in Spain; Szpiro (1996), Jeger and Thomas (1999) in France have performed hedonic analysis. But these estimates failed to include – partly due to data limitation - time as a price explaining variable.

In this article, we try to investigate whether hedonic pricing can be used to reveal underlying preferences for one attribute of freight transportation. The idea behind this approach is that, if shippers value faster delivery, this will be reflected in the prices they pay for faster transportation services.

There are different reasons why one may wish to use hedonic pricing. First, hedonic pricing overcomes one of the shortcomings of SP (Stated Preferences) techniques because the former relies, like other RP (Revealed Preferences) data, on real market data. Compared with other Revealed Preferences approaches, hedonic pricing is more economical in data and hypothesis: namely, it does not rely on the construction of potentially unreliable pseudo observations for the unused alternative. Another interesting feature of hedonic pricing is that it is based inherently on the heterogeneity of tastes among demanders and on the heterogeneity of production conditions among suppliers. This may contrast with discrete choice technique where the introduction of heterogeneity is possible but not immediate.

1.2 What do we want to measure?

We focus our research on (i) a single attribute of freight service: the travel time savings and on (ii) the demand side of the freight market. This requires additional comments.

First, considering the role of time in freight transportation, one should recognise different dimensions:

- The value that arises from the possibility to assign a certain time to a certain task. This is the more general dimension of time value (an “Ur-Value of Time”, as it is the one from which other definitions originate). This applies, for instance, when firms' production costs can vary in relation with the availability of production factors at instant t . This will be commented further below.
- The value of reducing the time necessary for the transportation of goods.
- The value of the reliability in consignment hours.
- The value of the flexibility in organising consignments at request,
- The value of the frequency for fixed schedule transport services,
- The value of the continuity of transport services (against meteorological conditions, strikes or any event that can impend the service),
- The value of the information on the time attributes of transport services (for instance, real time information on the likely arrival time),

One could easily refine and detail this coarse classification. We could also add more dimensions, giving right to more organisational aspects of the value of time; like, for instance, the power of stakeholders to decide when a certain transport related task can take place.

In the subsequent part of the present article, we will focus on a single aspect which relates to the *duration* of the transport operations. But, again, this notion should be made more explicit and we should distinguish between at least two kinds of duration. The first one is the *travel* itself, where the good is actually moved from one location to another. This may represent correctly the transportation time for some consignments but, for a large majority of them, the actual time that is "consumed" by the transport operations also includes some additional logistic operations, like intermediate warehousing, loading and unloading, cross-docking, border crossing etc, that occur between the moment where the good leaves the origin location and the moment when it is actually available at destination. This defines a second duration that we can refer to as *transportation* time ¹. Usually the shipper does not know much about the trip in itself and is interested in the sole transportation time. This is why, in the subsequent sections of this paper, we will concentrate on the second of these durations and investigate the value placed on *transportation* time savings.

Second, we will focus on the demand side of the market. While, traditionally, value of time is derived from production conditions, and is computed based on the reduction of the transportation production costs, regardless of the demand, we will consider here the value that demanders, i.e. shippers, place on faster transportation.

Considering these two clarifications we define our object as the Value of Transportation Time Savings for the shippers. One of the implications of such a definition is that those Transportation Time Savings are not based on the same definition as the more traditional Travel Time Savings used in Cost Benefit Analysis. *Transportation* Time can sometimes be reduced without reducing *Travel* Time. And the contrary can happen as well. In this article we will not consider this question more in depth (for a more in-depth analysis see Massiani, 2003), but we will focus on the question of how Value of Transport Time Savings for the shippers can be measured based on hedonic approach.

¹ One could also introduce a third duration, to take into account the delay that is necessary between the moment when shipper is making an arrangement with an haulier for a consignment, and the time when the good has to be available for loading. Adding this extra duration to transport time would define what may be called "*delivery time*".

2. Relevance of hedonic pricing for freight value of time

In applying hedonic pricing to measure the value of time, one should carefully consider whether this method, which has previously been applied to other fields, is also relevant for freight transportation. There are several concerns here.

2.1 Time, a peculiar good

First, time is a very peculiar "thing" when compared with traditional attributes of heterogeneous goods.

This peculiarity has often been underlined in the context of passenger transportation. But one needs to recognise that the peculiarities of freight transportation time are not the same as the ones of passenger transportation. For instance, it is often underlined, in the context of personal trips, that time cannot be traded but only switched from one activity to another. This holds for personal travel, where individuals have to choose within a fixed time allocation framework. For business travel and freight transportation, time can be traded; and organisations can buy time from other organisations or from individuals, making time not a constrained resource but a priced input to the production process.

Having said this, we can try to show some peculiarities of time in the production process. We should also recognise the ambivalence of the term "time" itself, which can be used to refer to the temporal co-ordinates of an event (in this case time is a date) and to the duration that occurs between two "dates".

If we concentrate on the point definition of time (time as a date), the most challenging question is that time is not a mere quantity (like the surface of the garden attached to a house), neither a quantified quality (like the level of safety of a certain neighbourhood), but it is rather a framework for all activities. Time should be considered, in a Kantian perspective, one could add, as a transcendent framework for all other attributes. In such a prospect, the transportation time can be seen as a set of t indexes for the goods X_t , when the good is unavailable for the production process. In this view, each production input X_t can be written with a time index t . The marginal profit associated with X_t is not constant over different values of t . The value associated with a reduction of transportation time, would in this representation be equal with the increase in profit associated with the change of the set of t indexes for which the good is available. Note that theory should allow for the case where the marginal profit does not change neither monotonously, nor continuously for different values of t .

2.2 The formation of equilibrium on freight transport market

2.2.1 Shipper's trade off

Now, the understanding of time as a duration in the production and logistic process stems from these variations of the utility or profitability of goods depending on their availability at instant t . Consider a shipper faced with the demand of a client. Consider d_p as the duration available for the production of a given good, d_t as the duration for transport. Suppose the shipper is the decision maker regarding the transportation of the good. With these notations, the shipper has to maximise his profit considering:

- The relation between d_p and production cost. This arises from the fact that allowing for a longer production process makes it possible to introduce cheaper but longer production processes. In other words it is possible to substitute time to other priced inputs in the production process (for more detail see Massiani, 2005). The relation between production duration and production costs can be represented by a function $cp(d_p)$, which we assume differentiable. This function is expected to be decreasing for low values of d_p , and possibly increasing for high values of d_p reflecting the warehousing costs that may occur at the origin of the transport when loading of the good takes place late.
- The relation between d_p+d_t and firms' revenues. This reflects the fact that the recipient of the good could have a willingness to pay those changes in relation with the delivery time. This can conveniently be represented by a differentiable function $r(d_p+d_t)$. This function can usually be assumed to decrease with arrival time (d_p+d_t) ².
- The relation between d_t and the cost of transportation. This relation can be represented as a generalized transport cost function $gtc(d_t)$ that takes into account the price paid by the shipper for the transport service, and the other costs (immobilization costs, cost of damages insofar as they relate to transport duration, depreciation of the shipment during the transport due to its perishability). This function can be assumed to be differentiable and decreasing, although the theory should also allow for the possibility to have $gtc' > 0$ for large values of d_t .

² Again, we are not talking here about the value placed by recipient on reliability. That recipient prefers to receive a good at expected time is something; that the value placed by the recipient on receiving a good varies with the expected time of arrival is something else. In this article we only deal with the latest effect.

The important consideration is that the profits of the shippers change with the duration of transportation. In this context, the shipper has to maximise the expression $r(d_t+d_p) - (cp(d_p) + gtc(d_t))$, choosing optimal durations d_t^* and d_p^* . This will result in the equality:

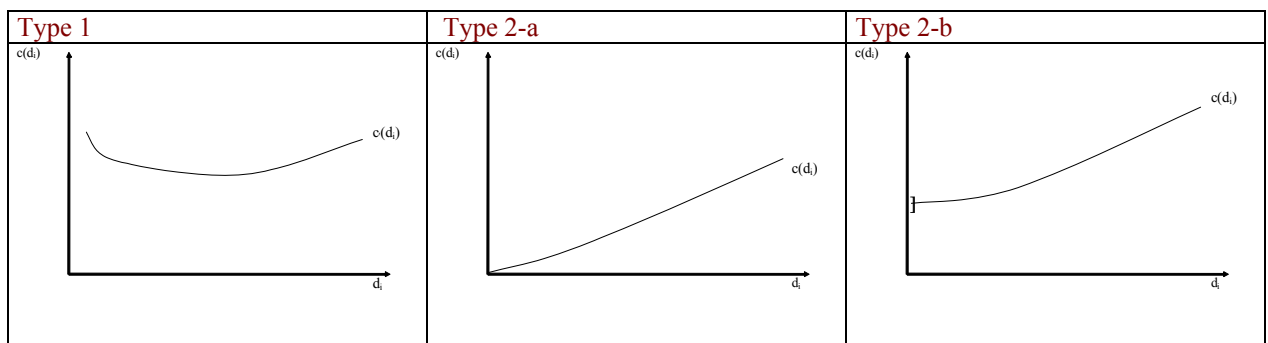
$$r'_{dt} = cp'_{dp} = gtc'_{dt} \quad (1)$$

The optimal durations will be so as to equate the marginal (generalised) costs of reducing transport time gtc'_{dt} and the marginal benefits of this time reduction that will consists in increased benefits due to earlier delivery and/or to diminished costs due to relaxed production duration; these two quantities being equal when shipper maximises profit.

2.2.2 Transport operator's trade off

Although our article focuses on shippers' value of time, a short description of the trade off made by the hauliers is necessary as hedonic price relies on the analysis of market equilibrium conditions.

The profit maximising trade off of the transport operator can be presented in terms similar to the one of the shipper, where costs and revenues depend on the duration of various operations. Label i different subsequent operations (travel, cross docking, border crossing, warehousing, sorting, etc.) that the transport operator has to perform in order to meet a transport requirement from a shipper. Label $c_i(d_i)$ the cost of each operation as a function of its duration. Suppose that the functions $c_i(d_i)$ are of two sorts (1) some of them are U shaped, (2) some of them are monotonically increasing. In this latest category, we distinguish (2-a) operations whose costs have a continuity in zero, (2-b) with discontinuity in zero. Furthermore, we suppose that the set of operations is predefined and cannot be changed based on the trade off of the operator.



We also consider that some of the operations (denoted with $k \in K \subset I$) will have a constraint on their duration, so that: $d_k \geq d_k^{\min} > 0$. This is especially relevant for travel operations whose

duration is limited by a minimum travel time. Other operations will not have constraint (at least not a binding one), they will be labelled with the j index.

We posit that, by definition, $c_i(d_i) = 0$, iff $d_i = 0$: the cost of an operation is zero when the duration dedicated to this operation is 0 (in other words, the operation is not done).

The program of the transport operator will be as :

$$\text{Max } \Pi(d_1, \dots, d_N) = r\left(\sum_{i=1}^N d_i\right) - \sum_{i=1}^N c_i(d_i)$$

s.t. $d_k \geq d_k^{\min} \forall k \in K$. where K is the subset of I where the constraint on minimum duration is binding.

with $\Pi(d_1, \dots, d_N)$ = profit as a function of total duration of the transport operation

d_i duration of operation i,

$c_i(d_i)$ cost of operation i,

$r\left(\sum_{i=1}^N d_i\right)$ revenues as a function of total duration.

This program will result in the following first order conditions:

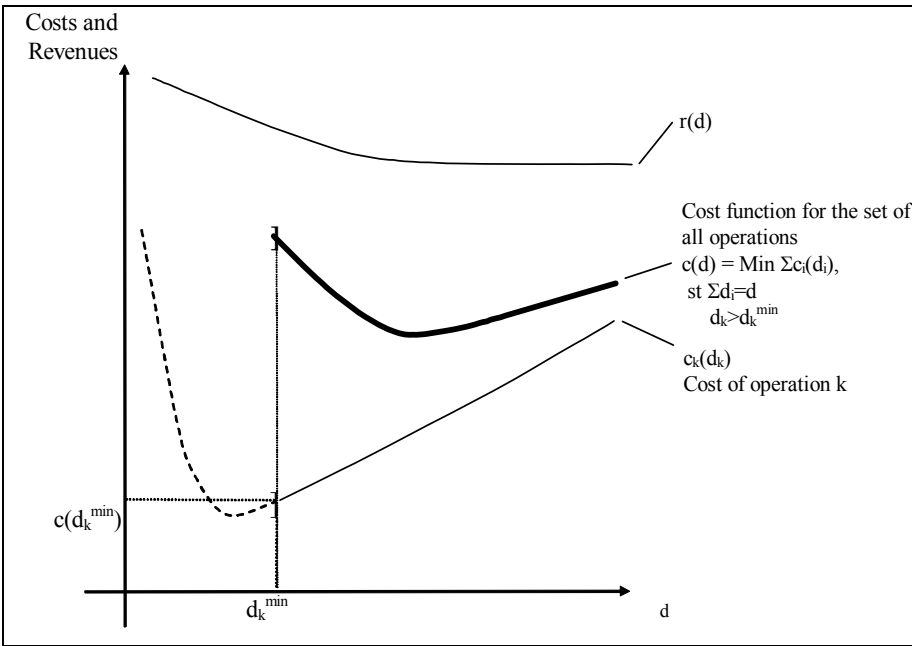
$$r'_{d_j} = c'_j{}_{d_j} \forall j \in J,$$

$$d_k = d_k^{\min} \forall k \in K.$$

In particular, the operation that are in the K subset, are such that $c'_k{}_{d_k}{}^{\min} > c'_j{}_{d_j}{}^{\min}$

The resulting situation is illustrated on Figure 1. On this figure, we suppose that only one operation (type 1) has its duration constrained. The minimum cost function for the set of all transport operations will be described by a single convex curve (labelled c(d)). This curve "rests" on the truncation of $c(d_k)$ in d_k^{\min} ; and, on each point of this curve, the marginal temporal costs of the different operations are equal.

Figure 1: cost function in relation with the total duration of the transport operations

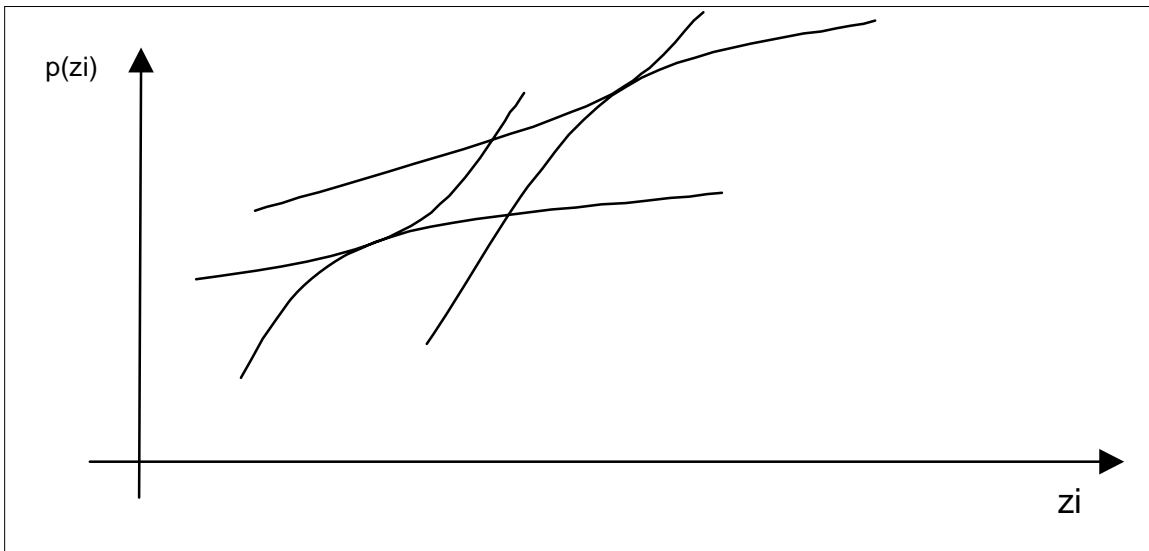


Once, the trade offs, made by shippers and hauliers, are described, it is possible to represent the transport market equilibrium and to implement the hedonic analysis.

2.2.3 Representation of market equilibrium

We present in the figure hereafter a standard representation of the hedonic equilibrium. This graph represents acceptance curves and reservation prices for two pairs of supplier-demander, where Z_i represents the i^{th} attribute of the good and $p(z_i)$ is the implicit price of the attribute. Each demander has a curve that represents a set of iso-utility locations, and each supplier has a curve representing iso-profit locations. Where transactions take places, two of these curves are tangent. The set of all transactions draws a function relating attributes to market price. This curve is the hedonic function.

Figure 1 : Acceptance and reservation price curves and transactions for standard hedonic good.



However, a peculiarity in applying hedonic pricing to transactions on the freight market is that the curves representing demand and supply do not have the same aspect as in the standard hedonic analysis.

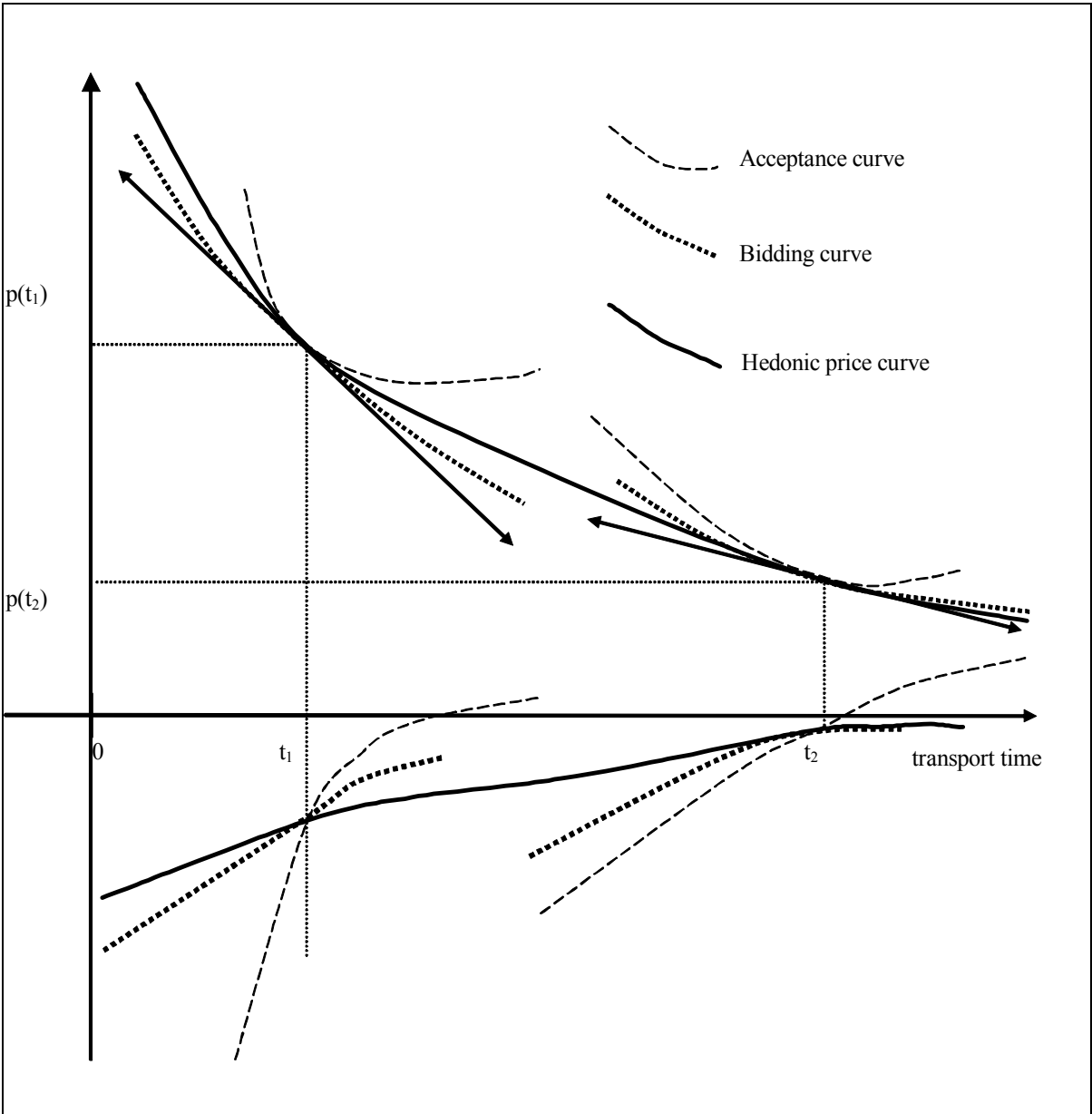
First, transport time is not a good, but it is a “bad”. This means that firms are willing to pay to reduce transport time. Rather than using cumbersome variable substitutions, we propose to stick to the original form of the variable and to use a representation of the market equilibrium where acceptance curves are decreasing.

Second, it is usually assumed, as illustrated on Figure 1, that acceptance curves are monotonous and convex and bid curves are monotonous and concave. In the case of freight transport time the situation is more complex as both curve sets are convex (the acceptance curves of the shippers having a larger curvature than the bidding curves of the hauliers).

Figure 2 represents the pattern of acceptance and bid curves for freight transportation, where we can see the peculiarities of this market: acceptance curves are decreasing ; bid functions are also decreasing. Both curve sets exhibit the same concavity. The expected sign of the hedonic price function is negative.

We also represent on Figure 2 the marginal bid and acceptance curves. These marginal curves are negative. Where transactions take place the tangency of the bid and acceptance curve is illustrated by the equality of marginal bid and marginal cost.

Figure 2 : Acceptance and bid curves and hedonic function for freight transportation



2.3 Relevance of the hedonic representation

The use of hedonic pricing to measure the value of time for shippers, raises several issues, The first question relates to the fact that freight transportation **clients are mainly firms**. While hedonic pricing is usually used for final consumers market, we propose, in this article, to implement it for "BtoB" relations where clients, as well as providers, are firms. There may be some occurrences where shipments are sent to final clients, but these occurrences probably represent a limited fraction of the goods that circulate on the roads or on the tracks. However,

this fact is probably not a hindrance to the implementation of hedonic pricing, because what is necessary to the application of this method is the equalization of marginal costs with marginal benefits on the two sides of the market, irrelevant of whether they are final customer or firms.

The second point on which freight transportation diverts from traditional hedonic analysis, relates to the **economic properties** of the good. First, transportation goods are services bundles that can be untied with regard to some attributes. This diverts from traditional multi-attribute goods where each variety has to be consumed as a whole, and cannot be combined with other varieties to create a new variety. In transportation, two average distance trips can be compared with one long distance trip and two medium weight shipments can be compared with one heavy weight shipment³. Second, transportation services are not bought by demander on a single variety. In Rosen's approach, the multi-attribute good is typically bought as one single unit by the household. Rosen's approach then extends the framework to the purchase of several units of the same variety. This contrasts with the situation in freight transportation, where each shipper can buy readily different transportation services. This could imply that a Lancasterian approach (Lancaster 1966, Gorman, 1980), where the consumer combines attributes of sets of heterogeneous good, could also be suitable to the analysis of freight transportation.

Eventually, it is useful to **compare the typical hedonic good, housing**, with freight transportation. Quigley (1979) has underlined housing specificity: durability, heterogeneity, locational fixity, and large transaction costs. Some other features could be added like: short term exogeneity of the attribute quantities proposed on the market, and discontinuity of the attributes for the varieties offered on the market. Among these features, only heterogeneity can also be found to characterise freight transportation, which in turn can be characterised by: non-durability, frequent purchase of the services, low transaction costs, continuity and endogeneity of the attributes, multiplicity of the buyers and sellers. Note that all these latest features are rather favourable to the implementation of hedonic analysis. Notably, the fairly continuous nature of freight transport attributes and the possibility to arrange very varied mixtures of the service can avoid some problems occurring in housing economics as underlined by Harrison and Rubinfeld (1978).

Having presented these analytical features we propose to switch to the next step of this paper, where we examine the need for a two steps approach for hedonic pricing.

³ Regarding this possibility to untie packages, an appealing solution would be to consider as a multiattribute good, not the shipment per se, but the Tonne x kilometre of shipments. But we still think that this would probably not solve the problem, as whatever manipulation is made on the data, a freight consignment can by nature be untied.

2.4 The two steps of the analysis

The next issue with hedonic pricing is not specific to freight transportation, but relates to the general analytical framework of the theory. The question here is whether the coefficient of the hedonic function, or the differential of the hedonic price function with regard to one of the attributes, can be interpreted "as is".

Theory warns that hedonic prices only provide information on the marginal valuation of the attributes, and does not provide explicit information on the demand (and supply) functions (an information that would be necessary to derive welfare measures such as surplus). The difficulty behind this issue is that market equilibrium expressed in the hedonic prices, reflects the interaction of supply and demand. For this reason, one cannot interpret hedonic price function as an inverse demand or inverse supply function⁴. Instead, **a second step**, based on the estimation of demand function, is necessary to derive these functions. In this second step, the marginal prices are regressed on all variables thought to be determinant of the demand. However, the feasibility of these second steps is often impeded by econometric difficulties. The first difficulty is based on the general observation that the marginal prices are contingent to the specification selected for the hedonic price function. Another problem is that the second phase results will replicate the results of the first phase unless some restrictions (like giving the inverse demand function a specification different from that of the price function) or additional data (like including extra variables in the estimate) or multi-market data are included. These difficulties are so important that most of the empirical applications stop at the first step. Freeman (1979) noted that in the field of air pollution valuation, only two studies among fifteen were proceeding to the second step.

Another implication of the nature of the market equilibrium regards the first step of the method. The hedonic equation specification of the first step does not have to, and can not, in

⁴ One should note that in **some particular cases**, the coefficients can be interpreted as inverse demand function. This holds true when bid curves are the same for all demanders. Symmetrically, they can be interpreted as supply function if the acceptance curves are the same for all suppliers. In the first (resp. 2nd) situation the set of transactions will describe the envelope of suppliers (resp. bidders) functions. However in transportation services, the bidders are not likely to possess identical bid functions. If one side of the market was to show homogeneity this would rather be supply side, at least if we were to consider one single mode. This relies on the informal conjecture that technology is not highly diversified in each mode. The conclusion here is that when considering one single mode, the coefficient of the hedonic function will tend to reflect the underlying acceptance functions, and will certainly not reflect the underlying bidding function of the shippers. When several modes are considered, the presumption that hedonic equation coefficients reflect the cost function of the suppliers also falls.

the general case⁵, be derived from economic properties of preferences and costs. It should, on the contrary, aim at providing the best statistical adjustment to the available data, using a wide range of variable transformations.

To conclude, the hedonic marginal prices do not give information on the inverse demand function, but only a distribution of the marginal costs and benefits of an attribute. This has implications both for the first step and the second step of the analysis. For the first step it implies that there is generally no a priori specification for the hedonic price function. For the second step it implies a number of econometric difficulties in the estimate of the inverse demand function. Whatever the magnitude of these difficulties, it still holds true that, in equilibrium, the marginal cost of time reduction equates with the marginal benefits of time reduction. For this reason, marginal prices give correct information about the distribution of marginal costs and marginal benefits of time among suppliers and demanders.

3. Application of hedonic pricing to a data set

In this section, we try to estimate the value placed by shippers on faster transportation based on interview data collected in France. After presenting the data, we proceed with the estimate of hedonic equation. We then investigate the possibility to proceed to the second step.

3.1 Presentation of the data

3.1.1 The survey

For this purpose we use a shipper interview that was made in Nord-Pas de Calais region in 1998. A questionnaire was passed during face to face interviews within 215 company plants. These plants were all counting more than ten employees and belonged to the following industries: metalwork, chemistry and plastic, agriculture and food industry, wholesale of food products, textile. Among the latest shipments sent by the company, 20 were recorded. Three of them were randomly selected for more detailed data collection. Investigated shipments were those weighing more than five kilos (excluding pipeline). These three shipments were

⁵ Tinbergen (1959) gives an example of hedonic function that reflects the coefficients of demand and supply function. But his example relates to very restrictive hypotheses about the functional specification of supply and demand.

subsequently traced within the limits of the European territory, up to the customer, through telephone interviews to all the successive actors of the transport chain.

The final data base consisted of 652 shipments. Of these shipments we could only use 58 observations due to missing values in the shipper interviews. This figure is quite limited, when compared with the data available in Guilbault and alii (2000) reporting the main outcomes of the survey, and is due to the fact that we did not complement the data missing in the shippers' interview, with corresponding data gathered in the telephone interviews to hauliers. These 58 observations may not be representative of the interviewed population. As compared with the whole sample, they, in particular, relate to shipments with significantly higher value, tonnage, transport price and duration, and with lower distance and transport speed. For this reason, numerical results obtained can be interpreted as providing an indication rather than a precise estimate of the phenomenon under scrutiny.

A reduced number of the shipments (seven) are railway shipments. Ordinary approach would recommend excluding these observations from the data on the basis that they belong to a different mode, and that the underlying price determination mechanisms are different. However, hedonic approach is very suitable to heterogeneity of suppliers and demanders⁶ ; said intuitively, large differences in the supply conditions allow revealing the demand for the different attribute levels.

3.1.2 Variables of interest

Among the many variables collected, the ones of interest for us were :

- Price paid for the transport. This question was phrased as "how much did you pay for the part of transport that was made by third part ?" We did not consider the observations relating to own account transport.
- Weight of the consignment.
- Distance of the shipment.
- Duration, defined as the time occurring between the departure of the good, and the delivery of the consignment.

⁶ We also find that the fitting performs much better, judged on adjusted R² and F statistic, when we include these observations that when we exclude them.

- Additional logistic services, that were recorded during the survey like grouping, degrouping, rental of the container, warehousing, etc.
- Value of the consignment.

Table 1 provides the main descriptive statistics for these shipments.

Table 1 Descriptive statistics about shipments.

Variable	Mean	Median	Standard deviation
Price (Euro)	588,1	65,9	2214,81
Price / km (euro/km)	6,5	0,6	34,96
Val (k. Euro)	26632	1524	118875
Distance (km)	275,2	184,7	237,32
Weight (tonnes)	36,5	0,225	169
Time (hours)	34,2	18	48,60
Value / kg (Euro/kg.)	41436	4236	182850
Speed (km/ hours)	14,7	9,2	13,11

3.2 Data processing and results

In this paragraph, we discuss the selection of the functional form and present the estimates of hedonic equation.

3.2.1 Specification of the hedonic price equation

A first issue regards the selection of the variables of interest for the hedonic price equation. One should be careful to use variables that affect the costs and revenues of both the demanders and the suppliers. While all the variables listed in **Table 1** apparently affect the costs and revenues of the demander, the Value attribute could be considered not to enter the cost function of the supplier, although one could argue that the value attribute can be a base of strategic pricing by the hauliers (who would tend to price higher the transportation of high value goods). This raises a question on whether the Value attribute should be introduced in the hedonic function estimate or kept for the second phase. This issue will be dealt with empirically, based on data evidences.

A second issue regards the choice of the functional form for the hedonic equation, considering that there is generally no link between the underlying behaviours of suppliers and demanders, and the formal specification of the price equation, one has to look for the best fitting specification. Cassel and Mendelsohn (1985) insist however that best fitting should not be the dominant criteria in model selection, but that quality of estimates for the variables of interest should receive consideration. Based on this concern, one should derive the standard deviation of \hat{p} (estimated price) for each specification.

In selecting best model specification, Cropper and alii (1988) compare the validity of 6 different specifications (linear, semi-log, double log, quadratic, Box-Cox Linear, Box Cox quadratic) to estimate the parameters of underlying utility functions. They find that in absence of errors on the exogenous variables, the Box-Cox quadratic specification over-performs the others. When measurement errors are present in the data, Box-Cox linear is preferred to the others⁷. Halvorsen and Pollakowski (1981) recommend using the most flexible possible form. The quadratic Box Cox transformation they propose can be written as:

$$P^{(\theta)} = \alpha_0 + \sum_{i=1}^m \alpha_i Z_i^{(\lambda)} + \frac{1}{2} \sum_{i=1}^m \sum_{j=1}^m \gamma_{ij} Z_i^{(\lambda)} Z_j^{(\lambda)} \quad (2)$$

With, $P^{(\theta)}$ and $Z^{(\lambda)}$ being Box-Cox transform of the data, such that:

$$P^{(\theta)} = \begin{cases} (p^\theta - 1) / \theta & \text{if } \theta \text{ (resp. } \lambda) \neq 0, \\ \text{Ln}(P) & \text{if } \theta \text{ (resp. } \lambda) = 0. \end{cases}$$

In the present work, a tractable compromise has to be found between the need to allow flexibility for the specification and the practical limitations. For this reason we tested 4 specifications: lin-lin (corresponding to θ and $\lambda = 1$), log-log (θ and $\lambda = 0$), lin-log (1;0), log-lin (0;1). All these specifications include quadratic terms that are the cross-products of the different (sometimes transformed) variables. This allows the model to replicate non linear effects⁸. For

⁷ However the generality of Cropper and alii (93) recommendation is questionable. The simulation made by the authors is based on quadratic utility functions, and exogenous supplied quantities.

⁸ We also recognise that the first of these four specifications, being linear in parameters, could imply a constant marginal price for some attributes, those whose coefficient of quadratic terms would be excluded out of the equation based on significance test. This would make it impossible to proceed to the second step. We include however this potentially linear specification in our estimate due to the fact that the two traditional rationales for banning linearity a priori ("*linearity of $p(z)$ is unlikely so long as there is increasing marginal cost of attributes for sellers and it is not possible to untie packages*" Rosen (1974)) do not seem relevant in the context of freight

instance, if the underlying relationship defines price per tonne, and not price alone, as a function of, say, distance, then the parameter of the quadratic term Distance.Weight will replicate this effect in the estimate. Variables in each equation were selected based on a backwise procedure.

Eventually, one has to recognise the correlation among the exogenous variables, time and duration on the one hand, value and weight on the other hand. For this reason, we tried to include some ratio variable in the specifications. So speed (Distance/Time) is included when the right hand term is linear⁹. We also tried to introduce a variable defined as value / weight, but this proved not very effective and provided no useful improvement to the adjustment.

3.2.2 Results

Table 2 provides information about estimation of the 4 models. This includes estimate of the coefficient, critical probability of the T test on the coefficient (0,05 means a 5 % probability). This also includes F test result and adjusted R² for each model.

This table suggests the following comments. The variable Time is never found to be significant (at a 10 % confidence level). Time enters the relation with price in the lin-lin and lin-log models through quadratic variables. Namely when combined with Weight (once with positive sign, once with negative sign), Value (twice, both with positive sign) or Distance (once with negative sign). Speed is retained by the backwise selection process with both lin-lin and lin-log specifications, and enters the specification when cross multiplied with Weight (once with a negative sign), Distance (twice with negative sign) and Value (once with negative sign). There remains one specification, the log-log equation, where time is absent, whether as such or as speed. For this reason, we discard the log-log specification of the analysis that is made further.

We also note that the lin-lin specification performs well. This result contrasts with the findings of Jeger (1999) who rejected the linear specification.

transportation. First, we found that marginal cost of the sellers are not univocally increasing. Second, as commented above, it is possible to untie transportation services packages as far as certain characteristics are concerned, mainly distance, time and weight. Considering these reasons and the fact that linearity cannot be precluded on the sole basis that it makes second step impossible, we have chosen to fit the model on this specification as well.

⁹ When the right hand term is of a logarithmic form, we do not proceed to this inclusion as it would introduce exact collinearity among regressors as $\ln(\text{speed}) = \ln(\text{dist}) - \ln(\text{duration})$.

Table 2 Estimates of hedonic price equation (variables selected based on backwise procedure, railway included, explained variable is price in FF 98).

Explaining Variable	Lin lin.	Lin log.	Log lin.	Log lin.
	Coefficient. (critical. Prob)	Coefficient. (critical. Prob)	Coefficient. (critical. Prob)	Coefficient. (critical. Prob)
Intercept	-195,8 (0,3831)	104279,0 (<,0001)	4,6 (<,0001)	-2,9 (0,2017)
Weight (kg)	0,05 (<,0001)	-10555,0 (<,0001)	-	-
Value (FF)	-	-16661,0 (<,0001)	1,18E-05 (<,0001)	0,7712 (0,001)
Distance (km)	-	-	-	0,7425 (0,0803)
Time (hours)	-	-	-	-
Speed (km./h)	81,6253 (<,0001)	-	0,0981 (<,0001)	-
Logistic prest	-	-	-	0,4786 (0,0148)
Weight* value	-	1480,9 (<,0001)	-1,48E-11 (<,0001)	-
Weight* distance	0,0008 (<,0001)	-	2,68E-07 (<,0001)	0,0740 (<,0001)
Weight* time	-	-1233,6 (0,0315)	1,40E-06 (0,0012)	-
Value* distance	-0,00007 (<,0001)	686,3 (0,0009)	-1,48E-08 (0,0013)	-0,0945 (0,032)
Value* time	0,0005 (<,0001)	2043,7 (0,0018)	-	-
Distance* time	-	-2538,7 (0,0001)	-	-
Weight* speed	-0,0042 (0,0021)	-	-	-
Dist* speed	-0,0995 (0,0004)	-	-0.00011 (0,0027)	-
Speed* value	-	-	-5,13E-07 (0,0001)	-
Adjusted R ²	0,99	0,77	0,69	0,85
F test.	2057,43	28,99	17,43	65,94

The multiple occurrences of the Time attribute in the equation below makes it difficult to interpret the quantitative estimates on their own. We proceed to the computation of the differentials. **Table 3** summarizes the different hedonic price functions, and the corresponding expression of the marginal price.

Table 3 : different hedonic price functions and corresponding marginal price of time

Specification	Hedonic price function	Marginal price of the duration attribute
Log-log	(3) $\hat{p} = \hat{\beta} + \hat{\beta}_P \cdot P + \hat{\beta}_{Spe} \cdot Spe + \hat{\beta}_{Val.Dur} \cdot Val.Dur + \hat{\beta}_{P.Dist} \cdot P.Dist + \hat{\beta}_{ValDis} \cdot Val.Dist + \hat{\beta}_{P.Spe} \cdot P.Spe + \hat{\beta}_{Dist.Spe} \cdot Dist.Spe.$	(4) $\hat{p}'(Dur) = -\hat{\beta}_{Spe} \cdot Dist \cdot (1/Dur^2) + \hat{\beta}_{Val.Dur} \cdot Val - \hat{\beta}_{PSpe.P} \cdot Dist \cdot (1/Dur^2) - \hat{\beta}_{DistSpe} \cdot Dist^2 \cdot (1/Dur^2).$ (5) $\hat{p}'(Dur) = (-\hat{\beta}_{Spe} \cdot Dist - \hat{\beta}_{PSpe.P} \cdot Dist - \hat{\beta}_{DistSpe} \cdot Dist^2) \cdot (1/Dur^2) + \hat{\beta}_{Val.Dur} \cdot Val.$
Lin - log	(6) $\hat{p} = \hat{\beta} + \hat{\beta}_P \cdot Ln(P) + \hat{\beta}_{Val} \cdot Ln(Val) + \hat{\beta}_{P.Val} \cdot Ln(P) \cdot Ln(Val) + \hat{\beta}_{P.Dur} \cdot Ln(P) \cdot Ln(Dur) + \hat{\beta}_{Val.Ln} \cdot Ln(Val) + \hat{\beta}_{Val.Dur} \cdot Ln(Val) \cdot Ln(Dur) + \hat{\beta}_{Dist.Dur} \cdot Ln(Dist) \cdot Ln(Dur).$	(7) $\hat{p}'(Dur) = \hat{\beta}_{P.Dur} \cdot Ln(P) \cdot (1/Dur) + \hat{\beta}_{Val.Dur} \cdot Ln(Val) \cdot (1/Dur) + \hat{\beta}_{Dist.Dur} \cdot Ln(Dist) \cdot (1/Dur).$ (8) $\hat{p}'(Dur) = (1/Dur) \cdot \{ \hat{\beta}_{P.Dur} \cdot Ln(P) + \hat{\beta}_{Val.Dur} \cdot Ln(Val) + \hat{\beta}_{Dist.Dur} \cdot Ln(Dist) \}.$
Log - lin	(9) $\hat{p} = \exp(\hat{\beta} + \hat{\beta}_{Val} \cdot (Val) + \hat{\beta}_{Spe} \cdot (Dist/Dur) + \hat{\beta}_{Pval} \cdot (P) \cdot (Val) + \hat{\beta}_{Pdist} \cdot (P) \cdot (Dist) + \hat{\beta}_{PDur} \cdot (P) \cdot (Dur) + \hat{\beta}_{ValDist} \cdot (Val) \cdot (Dist) + \hat{\beta}_{SpeDist} \cdot Dist \cdot Spe + \hat{\beta}_{SpeVal} \cdot Val \cdot (Dist/Dur)).$	(10) $\hat{p}'(Dur) = \{-\hat{\beta}_{Spe} \cdot (Dist/Dur^2) - \hat{\beta}_{Spe.Dist} \cdot (Dist^2/Dur^2) - \hat{\beta}_{SpeVal} \cdot Val \cdot (Dist/Dur^2) + \hat{\beta}_{PDur} \cdot P\} \cdot \hat{p}(Dur)$

3.2.3 Analysis of marginal prices

Table 4 provides the main descriptive data regarding estimates of the marginal price of time.

Table 4: Marginal price of time for various model specifications (Euro/hour per shipment)

Model	Median	Mean	Max	Min	Std-deviation	% negative values
Lin - lin	-1,12	18,47	1310,07	-111,5	176,24	62 %
Lin - log	-9,78	18,63	515,98	-94,29	104,49	66 %
Log - lin	-0,35	273,52	15189,96	-195,01	2013,16	72 %

For instance, a mean of 18,47 Euro/shipment (1998 prices) in the lin-lin model indicates that, on an average, the price paid for one shipment *increases* approximately of 18 Euro (1998 prices) when shipment time *increases* of one hour.

One should recall that a negative marginal price of time reflects the fact that the profit of the shippers, or the costs of hauliers, is decreasing with the duration (and increasing with speed). A positive marginal value would in turn reflect the fact that the profit of shippers, the cost of the hauliers, can be increasing with regard to duration (and decreasing with transport speed). The a priori expectation is that the marginal price should be negative: while it can be accepted that, on a single observation, the marginal price for one hour could be either positive or negative, one should however expect a negative mean or median marginal price for transportation time. This expectation is met only for the median, but not for the mean of the different specifications tested.

Also, our findings confirms that the marginal prices are depending of the formal specification assumed for the hedonic equation, although we note that lin-lin and lin-log specification provide a surprisingly similar mean marginal price of time.

4. Conclusions

In this paper we have implemented hedonic pricing to evaluate the value placed by shippers on transport time savings, where transportation time is defined as travel time plus the time necessary for all other logistical operations between the loading of the good at origin and the unloading at destination. We find that freight transportation services are different of other goods usually analysed through hedonic pricing. Main differences are: non monotonous bid functions and acceptance function, possibility to buy different varieties of the service, continuity of the attributes level for suppliers and demanders, high number of suppliers and demanders. None of these features makes freight transportation unsuitable to hedonic analysis. More difficulties arise from the nature of the different characteristics of transport: apart from duration, whose peculiarities can be sorted out ; the weight could be seen not as an attribute of transport but as a quantity of transport consumed ; while the value of the shipment could be treated not as a transportation service attribute but as a firm characteristic.

We find that hedonic pricing has been hardly implemented to measure value of transport attributes, and that such attempts usually failed to retain duration as an explaining variable for transport price. When trying to apply hedonic pricing to a shipper interview data, we find that it is possible to find correctly fitted models including time or speed as a price determining attribute. Although we find that there are still some questions about the formal specification of the price equation, we find that a linear formula provides a suitable fitting with the data on hand.

We also find that a profit optimising shipper will equalise the (typically decreasing) marginal price of duration with the marginal benefits of transport duration that consists in good departure time depending productions costs and destination arrival time depending revenues (equation 1). When single period data are used (and infrastructure endowment is fixed), the shippers' benefits and costs of transport time reduction cancel out. However, when time savings occur due to an exogenous shift of production costs (like, for instance, when a new infrastructure is built) the marginal benefits of time savings will not cancel out with the marginal costs, and p'_{dt} can be used to estimate the net benefits accruing to the shippers.

Interestingly, we also find that a majority of transactions imply an acceptance curve that is decreasing with transport duration (increasing with time savings) which is conforming to expectations. However, contrary to the *median*, the *mean* marginal price of the duration attribute has a counterintuitive sign.

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