XXXV CONFERENZA ITALIANA DI SCIENZE REGIONALI

INTERMODAL RAIL-ROAD EFFICIENCY: RESULTS FROM ITALIAN TERMINALS

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ABSTRACT

As shown by extensive literature referring to intermodal transport infrastructures, the factors characterizing the efficiency analysis are also related to the geographical position with regard to international traffic and this paper sets out to verify if this relationship is observable in the various cases of Italian rail-road terminals. To this end, we investigated the intensity of the mode of transport used for exports at the territorial level of Italian regions.
Using a panel effect model and stochastic frontier model, we study whether the technical efficiency of selected rail terminals is significantly influenced by international freight flows, their direction and the mode of transport used. The paper presents a panel effect and a technical efficiency analysis of Italian rail terminals for the years from 2007 to 2011 considering variables related to production factors with a dynamic vision over time. During a period of strong variability of freight rail-road transport in Italy, we apply several econometric models to assess rail terminal performance in a stochastic frontier framework in order to study the pattern of technical efficiency over time. The results of this study show technical changes have negatively contributed to intermodal productivity growth over the sample period and the models applied also find a decline in technical efficiency.

Keywords: intermodal transport, rail terminal, panel effect model, frontier analysis

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1. Introduction

Intermodal freight transport reflects the combination of two or more modes of transport (e.g., road, rail, water) within a single transport chain. It is generally assumed that the goods moved are containerized and, thus, allow standardized handling during the transfer between any two modes involved in transport. Intermodal freight transport is receiving increasing attention in the European transport economy as it is considered a way of increasing traffic safety and reducing road congestion and air pollution at the same time (European Communities 2002).

Road-rail intermodal transport is one of the main forms of intermodality and represents an important alternative to mono-modal road transport. The spread of this transport system based on rail transport of Intermodal Transport Units (ITUs) requires efficiently operating interchange terminals situated in strategic territorial locations. Public and private policy choices should be driven by economic reasoning such as the search for optimal use of resources and the potential obtainable results. An intermodal terminal needs to be assessed in the same way as any other production process that requires input in order to obtain output and, in the case in question, the best possible combination of production factors typical of intermodal goods transport services. These factors generally comprise elements linked to specific infrastructures (operational areas, length of rail tracks, moving equipment, etc.) over and above the labour factor.

These resources generate output manifesting itself in a complex manner, generally as the throughput of transport, for example, freight traffic measured in ITUs of the modal interchange rail-road terminal.

Over the years analyzed in this paper, the rail cargo sector in Italy suffered more heavily than other forms of transport as a result of the economic-financial crisis. The crisis seriously affected the type of traffic for which rail is most suited (international, raw materials, automotive) and heightened competition with road transport, which recorded a fall in fares and a more frequent use of spot loading and contract renegotiation, bringing about phenomena of modal back shift and the consequent destructuralization of rail services.

The Italian rail network, which is 16,861 km in length, transports 20.2 billion ton-km of goods, equal to about 1.2 million ton-km per km of network, compared to about 3.2 million ton-km in Germany and an EU27 average of about 2.0 million ton-km. Over the period 2007-2011 rail goods traffic in Italy fell by 21.7% in ton-km (Eurostat, 2014).

At the same time, the new equilibrium of foreign trade is stimulating growing demand for advanced logistics services from Italian businesses in order to be competitive on new export markets. The organization of the “ante crisis” logistics model in many Italian regions is no longer adequate for the requirements of domestic businesses, which increasingly require integrated intermodal services and specialized operators capable of managing the entire logistics chain for higher quality products destined for export. This new logistics model calls

for efficient dedicated infrastructures and highly qualified logistics operators capable of managing the whole logistics chain.

Italian businesses have the incentive to find new emerging markets since the international crisis has led to a contraction of traditional markets, especially European ones with advanced logistics services, and these businesses are looking for openings in new and more dynamic markets, but which have outdated logistics services, such as China, India, Russia, South Africa, Brazil, Turkey, etc. In this context intermodality becomes of central importance and acquires greater strength than road or other mono-modal forms of transport. The elements of strength to be found in intermodal transport can be summarized as:

a) suitability to international transport: greater adaptability to long distance and containerized or unitized traffic, of growing importance in a progressively more integrated continental market;

b) reduction of negative environmental externalities: air and noise pollution, climate change, urban and landscape impact;

c) higher levels of safety: reduction of road congestion, border crossings and port transit with a positive impact on accident rates;

d) energy savings: reduced consumption of energy resources;

e) optimization of the gateway function: fully exploiting Italy's geographical position as entry point for goods heading for central Europe;

f) exploiting synergies between the various modes of transport: specialization of transport according to distance and type of goods transported;

g) efficient use of resources: rationalization in the use of staff, vehicles and equipment;

h) rationalization in the use of territory: optimization in the organization of dedicated areas and reduction in land use compared with more widespread models (SRM, 2011).

In this sense, the intermodal function is seen as a sequential activity chain involving various specialized infrastructures for modal interchange, from ports to road-rail terminals and interports. The efficiency of road-rail and sea-rail intermodality therefore becomes of great importance since this traffic also includes container transport between Italian ports and the main origin/destination domestic markets, usually through rail terminals and interports which, in Italy, are generally situated inland from ports and can thus be defined as inland terminals. Indeed, certain critical points in the Italian logistics/transport system prevent the competitive and quantitatively coherent absorption of the flows of goods passing through ports, thereby generating a separation between origin/destination sea flows and origin/destination land flows. Indeed, very few Italian ports are equipped with an "on dock or near dock" rail terminal where containers and other cargo units can be moved directly from the dock or the storage areas to a railcar using the terminal's own equipment, and in many cases these terminals have been dismantled.

This paper uses econometric techniques relating to the estimation of stochastic production functions and of technical efficiency in order to analyze the production performance of road-rail modal interchange terminals in Italy over the period 2007-2011.

2. Terminals and modal interchange functions

The modern organization of global supply chains, and hence national and regional logistical strategies, have changed considerably over the last two decades; the economic-logistical paradigm has been decisively affirmed as being oriented towards international trade and exportation. This has imposed on the global markets the presence of few but large global operators of goods transport (shipping companies, terminal operators, logistics service providers) who are ever more frequently managing the logistical chains as a whole, while ever more constantly searching for higher levels of efficiency. The relationship between maritime and port operations and inland ones for land forwarding and the outlet of internal areas becomes central, and in that sense inland terminals and the rail-hub infrastructure take on strategic importance for example in considering terrestrial intermodal terminals for the early phases in global supply chains: export flows, that is to say for production areas which require an efficient logistics-territorial export-oriented functioning (Notteboom, Rodrigue, 2009).

The basis of intermodal transportation resides in the development of systems that integrate or combine the various elements of the five modes of transportation i.e. motor, railroad, water, pipeline and air transport. However, the various transport modes are not the only parts of the intermodal transportation chain, which also includes several activities during the transportation process. This paper focuses on the production side of the intermodal rail-road transport interchanging process. Different interfaces are found not only between companies but also between different tasks/activities in the chain. Effectiveness and efficiency calls for modularisation of activities in the chain in terms of easy access and interconnectivity of the tasks in order to create reliable, flexible and fast intermodal transport chains.

With regard to standardisation, this means simplifying routines in different interfaces of the chain, using packages that are optimal for container or other intermodal transport unit sizes, and creating clear EU standards. General standards for data and information transmission are also needed. With regard to cooperation, there is a need for improved collaboration at company boundaries or interfaces, matching better opening hours in the chain, total optimization of routes, and more efficient combining of return loads. From an information management perspective, in container sea-land transport, coordination includes an increase in information sharing, availability of advance information, faster feedback from shipping companies to transport inquiries, finding adequate equipment for land transport, and an increase in information management between the port operator and other organisations (Caris *et al.*, 2008).

The intermodal transport chain consists of modular elements that can be linked together; the generic transport service hardly offers the potential for differentiation unless add-ins like logistics services, information management and other special services can be included in the "value adding" multi-service supply. An increasing modularisation of services, combined with appropriate coordination mechanisms and enabling technologies, will improve the opportunities for intermodal transport operators to fulfil variable customer demands from basic transport operations to special deliveries and sophisticated logistics solutions.

With reference to the physical infrastructure dedicated to the main intermodal function, the modal interchange, several evolution trends are clearly visible for the near future. Evolution will lead to increasing concentration of operations in strategic points where transport modes meet and value added services are performed. Intermodal transport growth will lead to development needs in large but also smaller freight centers.

ITUs consist of containers, swap bodies and semitrailers equipped for combined transport, and their movement will take place on fast trunk lines with handling being concentrated in efficient terminals. Terminals must be able to adapt their operations to changing transport requirements. Growth of container use will allow increasing automation. Large container vessels will dominate ocean transport and turnaround times in ports will be very short. Cargo handling technology will be further developed to reduce operating costs. Simultaneous handling of containers will increase operational efficiency (Janic, 2007).

The transport policies to adapt the intermodal system to these trends have varied widely across European countries. While northern European countries, principally Germany and The Netherlands, strongly improved sea-rail and road-rail intermodal systems, Italy did not follow the different geo-economic features of territories. In Northern Italy the terrestrial policy of the networks directed towards import-export flows with Northern Europe through the Alpine mountains passes functioned, while in the South interventions should have been more oriented towards port related logistics and directed towards maritime flows rather than replicating a model valid for the industrialized regions of the North.

At the same time rail cargo transport in Italy, despite its liberalization, is going through its greatest structural and market crisis of recent decades. Between 2008 and 2012, rail goods traffic dropped from 23.8 million ton-km to 20.2 million (-15%), and the railway modal quota represents about 9% of the total of goods transported in Italy, compared to a European average of 16% and a quota of 21.5% in Germany (Eurostat, 2014).

The most important elements of an intermodal transport network are the terminals, i.e., intermodal nodes, which are locations that connect two or more transport modes. Intermodal terminals may be designed to handle different ITUs and to serve different transportation modes depending on the configuration of the transport network, node locations, accessibility for different transport modes, demand characteristics, transport flow volumes, and so on.

The terminal is a place where goods are transferred between any two or more freight transport modes. In this interface unit loads are collected, exchanged, stored and/or distributed. The handling operations at the freight terminal may include the same transport mode or two different transport modes. The core activity of the intermodal terminals is transshipment of goods between different transport modes. The transfer between transport modes has been a critical attribute of transport terminals since the appearance of terminals in the development of distribution logistics.

Inter alia, rail–road terminals consist of a wide range of installations, ranging from simple terminals providing transfer between two or three modes of transport, to more extensive centres providing a number of value-added services such as storage, empties depot, maintenance, repair, etc.

A major part of intermodal transport consists of transport performed by rail and railway intermodal terminals are preferred. Two main types of intermodal railway terminals can be distinguished:

- inland terminals (located in freight villages, transport and logistics centres, shunting stations, inland ports);
- port terminals (located in maritime and inland waterway ports).

The competition and effectiveness of freight platforms may increase with the establishment of a network of collaborative platforms. In this way the competition of the railway, and indirectly intermodal transport, also increases. Rail is competitive only under conditions in which the transshipment times are minimal when direct and regular trains are used. Terminals connected effectively positively affect not only the volume of freight and the extent of economic success of individual platforms but of the whole network (Jencek, Twrdy, 2008).

In Italy the road-rail intermodal option, which during the nineteen-nineties was thought to be capable of competing with all-road transport for the purpose of modal rebalancing, has been partly positive only for certain poles of terrestrial cross-frontier traffic in Northern Italy, first and foremost for crossing the Alps. In Southern Italy such a uniform option for the entire national territory has proved to be totally inadequate, as it contributes towards distancing transport and logistics operators from ports and from maritime transport which, in contrast, represents the main mode of transport for international and inter-Mediterranean trading.

Italian public intervention was therefore principally oriented towards the "interport model" logistics centre for the entire country, without considering the heterogeneous economic and geographic regional territories (Iannone *et al.*, 2008).

Europlatforms, the European association of freight villages, provides a definition of interports very close to that which several authors have defined as inland freight centre, or rather a concentration of independent business concerns operating in the transport and logistics sector in a complex structure in which it is possible to carry out operations of modal exchanges among cargo units (Roso et al. 2009). According to Europlatforms, in fact, a "freight village"

is a defined zone within which activities are present relating to transport, logistics, and to the distribution of goods both by national as well as by international transit, carried out by various operators. These operators may be owners or renters of buildings and structures (warehouses, storage areas, offices, parking lots, etc.). In order to respect the rules of free competition a freight village should allow access to all operators and should be provided with all the necessary public services. Finally, in order to facilitate intermodal transport for the handling of goods a freight village should preferably be served by a multiplicity of means of transport (road, rail, sea, internal waterways and air) and it is fundamental that it is managed by a single public or private body. In short, a village planned and built to best manage all the activities involved in freight movement (Europlatforms, 2004). Usually only a large-scale intermodal logistic centre is called a freight village.

From this definition a prevalently inland localization of European freight villages emerges doubtlessly inspiring the main Italian interports in consideration of the transport policy trends of the first Italian General Plan of Transport (Law 245/1984) and of the Interports five year plan (Law 240/1990).

A typical inland rail-road terminal, not a freight village, includes the following elements:

(a) Rail sidings for train/wagon storage, marshalling and inspection purposes.

(b) Transhipment tracks (also termed loading tracks) for train loading/unloading operations.

(c) Storage or buffer lanes for ITUs.

(d) Loading and driving lanes for trucks.

(e) Gates, internal road network.

In the simplest type of operation, the train arrives on the transshipment line, is serviced (unloaded and/or loaded) and remains there until departure. This type of operation enables almost exclusive direct transshipment between wagon and trucks without intermediate storage on the ground. The unloading and loading sequence is dictated mainly by truck arrivals at the terminal. Real-life operations are generally more complicated and therefore we assume that each terminal produces less than its optimal output due to a degree of technical inefficiency (Ballis, Golias, 2004).

3. The empirical model and data

In this paper we use a sample of 34 Italian rail terminals to assess the developments over time of technical efficiency in the Italian rail-road terminal sector over the period 2007-2011. We apply the production frontier models that indicate the maximum production capacity given the combination of available resources. Inefficiency is measured by the extent that a firm deviates from the possible production frontier. Aigner *et al.* (1977) are among the pioneers proposing the stochastic frontier model (SFM) with maximum likelihood estimators. Since then, the SFM has been applied extensively in industrial analysis. Battese and Coelli (1995) is one of

the guiding examples using SFM in evaluating efficiency of transport infrastructure, specifically container ports.

The construction of the stochastic frontier model and estimate of technical efficiency is based on a hypothesis of a relationship between the technical facilities of the terminal and traffic performance, by estimating the relationship with a Cobb-Douglas log-linear type production function. In the estimated function different structural configurations bring about the respective levels of outcome measured by the traffic handled. An attempt has been made to show more especially the level of efficiency of inland Italian rail terminals in relationship to studying their capacity to attract and handle intermodal rail-road and rail traffic, as a dependent variable, by considering a set of independent variables referable to the factors of production used all expressed in logarithms.

The sources examined for the construction of the dataset were: the business websites of the Interports and the *Terminali Italia* company of *Ferrovie dello Stato* group, the *Unioncamere TRAIL* portal, Europlatform freight village portal, UIR *Unione Interporti Riuniti* website, the Transport and Infrastructure National Account of the Italian Ministry of Infrastructures and Transport. More especially dimensional data and traffic statistics for individual freight rail terminals were directly obtained from the terminal operators through a survey[4].

The definition of an output variable descriptive of the production process may prove reductive with respect to the multi-functionality of a structure capable of generating value with heterogeneous and multimodal services. In these terms, the output generated by a rail terminal is comprehensively described by the variable which expresses the measure of cargo traffic, Intermodal Transport Units (ITU) throughput.

In the parametric stochastic frontier approach and in the technical efficiency model, the variable chosen for the definition of output size is represented by the measure of rail productivity index (RPI) defined by intermodal road-rail traffic, in the number of ITUs, divided by the length of rail tracks (in meters)**.** This is a productivity measure that better depicts the technical dimension of the technology/configuration in order to describe terminal design, especially in the case of high variability of dimensional data between the infrastructures of the sample. Empirical studies in Italy show that an intermodal terminal that is not over utilised should not exceed the measure of 25-30 ITU per meter of rail tracks (Ministero dell'Ambiente, 2013).

Following the parametric approach, for the purpose of determining functional dependence, Pels *et al*. (2001 and 2003) carried out an analysis in 34 European airports and evaluated the stochastic frontiers of productivity.

With reference to input variables, the explanatory variables selected to represent the labour factor and the physical and structural (capital factor) characteristics for the *i-th* terminals are:

- Employment at the intermodal terminal (log of units)**;**

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[4] We would thank Dr Fedele Iannone for collection and construction of survey's dataset.

- Intermodal Terminal Area (log of sq.m.).

With regard to the entrepreneurial environment, the variables selected for the *i-th* intermodal terminals are:

- HHI ratio: log of an index measuring the concentration of the terminals and the competition among firms in the industry is applied as one of the efficiency determinants.
- Interport (yes/no): a dichotomous variable equal to 1 if the terminal is inside an interport and equal to 0 if it is not.

The HHI ratio is invariable among different participants in the same market, but it will vary over time. A relatively high HHI ratio shows a high market power with a low level of competition. We calculate the HHI ratio as the throughput of each terminal out of the total throughputs in the market for each time period. Therefore, the production frontier was estimated on these variables. All the models also include a linear time trend variable (*year*); by capturing neutral technological progress it allows us to distinguish productivity improvements induced by technological change, the movements of the frontier over time, from those deriving from efficiency improvements, which are movements along the frontier (Yan *et al.* 2009).

The frontier-shift time effect, represented by the shift of the productive efficiency frontier in a production function, may occur because of significant change such as technological progress. Since transport infrastructure investments are lumpy and thus transport infrastructures have little control over adjusting inputs in a short period, terminals should practice a maximization of outputs given input levels. This perspective is a basis of the output-oriented model. This study adopts the output-oriented model as the method of projection to frontiers based on the observation concerning the Italian rail freight terminal sector. In the real world transport infrastructures are closer to being throughput maximizers rather than input minimizers, an example being container terminals and ports (Cullinane *et al.*, 2004; Cheon *et al.* 2010).

As we assume that technical efficiency can be estimated by using the logarithm of the productivity ratio between throughput and rail terminal tracks, the results show the effect of employment, terminal area surface extension, competition and inclusion in a logistic multi-service environment on production efficiency. Table 1 reports descriptive statistics of variables included in the study.

Table 1 - Descriptive statistics of variables

Variable	Observations	Min	Max	Mean	Std. Dev.
Intermodal rail freight traffic (ITUs)	167	0.00	427416.00	58716.287	91710.332
Rail track length (meters)	167	300.00	24000.00	3676.695	4616.856
Rail productivity index (RPI)	167	0.00	50.276	16.091	12.416
Employment at the intermodal terminal (units)	167	1.00	229.00	23.132	37.597
Intermodal terminal area (square meters)	167	6000.00	350000.00	103491.096	95698.596
HHI index	167	0.00	21.728	2.990	4.695

4. Time invariant and time varying econometric models

The estimation of stochastic production frontiers for cross-sectional data was simultaneously proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). There are many potential econometric benefits when panel data are available. If information is available on a group of rail terminals over time there will be more variability in the data, less collinearity and more degrees of freedom available (Baltagi, 1995). This will lead to more consistent estimation of technical efficiency in stochastic frontier analysis. The goal of this paper is not to investigate all existing panel data models, since we know, a priori, that different models give different results. So we have selected some pooled and panel data models, and investigated the results from these when applied to the same data set. To analyze these models, we gave them the same expression, but different models are specified for different parameter assumptions. The function is given as:

$$y_{it} = \alpha + f(x'\beta) + \varepsilon_{it} \quad (1)$$

where f is a function that indicates or Cobb Douglas or translog, ecc. i=1,2,…,N, indicates the rail terminal in our sample, t=1,2,…,T indicates the time, and $\varepsilon_{it} = v_{it} - u_{it}$. The random error term v_{it} is assumed to be normal distributed, denoted as $v_{it} \sim iidN(0, \sigma_v^2)$. The inefficiency term is assumed to be one-sided distributed. If it is half normal, it is denoted as $u_{it} \sim N^+(0, \sigma_u^2)$. These eight models are briefly specified in table 2:

Table 2 - Models specification

Pooled Model	Panel Time Invariant Model	Panel Time Varying Model
• Aigner, Lowell and Schmidt, 1977 • Stevenson, 1980	• Pitt and Lee, 1981 • Battese and Coelli, 1988	• Battese and Coelli, 1992 • Battese and Coelli, 1995 • True Fixed Effect • True Random effect

According to the relationship between technical inefficiency and time, panel data is separated into two types: one is the time-invariant model, which assumes that technical inefficiency is

constant through time, without any technical change over time, labeled as u_i; the other is the time-varying model, which allows technical inefficiency to change over time, labeled as u_{it}. Under a panel data generating process, the inefficiency component is assumed to be correlated over time; when this is applied to the inefficiency component, it results in one of two general forms:

1. $u_{i1} = u_{i2} = \cdots = u_{iT} = u_i$ Time invariant
2. $u_{i1} = u_i g(1), \ldots, u_{iT} = u_i g(T)$ i.e $u_{it} = u_i g(t)$ Time varying

4.1 Time invariant models

4.1.1 Pitt and Lee (1981) and Battese and Coelli (1988)

Pitt and Lee (1981) and Schmidt and Sickles (1984) were the first to consider stochastic frontier models with panel data. They considered the model with time invariant inefficiencies:

$$y_{it} = \alpha_0 + f(x'\beta) + v_{it} - u_i \qquad i = 1,2, \ldots \ldots, N, t = 1,2, \ldots \ldots, T \qquad (2)$$

This equation can be converted to standard panel data model:

$$y_{it} = \alpha_i + f(x'\beta) + v_{it}, \qquad i = 1,2, \ldots \ldots N, t = 1,2, \ldots \ldots, T \qquad (3)$$

where $\alpha_i = \alpha_0 - u_i$. Note that $\alpha_i \leq \alpha_0$ and $\alpha_i = \alpha_0$ only when $u_i = 0$. Therefore, a smaller individual- specific intercept implies a lower level of technical efficiency.
Pitt and Lee (1981) considered the model (3) under essentially the same assumptions as in the cross-sectional stochastic frontier model. This treatment of the model requires distributional assumptions for the two error terms: $v_i \sim iid\ N(0, \sigma_v^2)$ and half normal distribution for $u_i \sim N^+(0, \sigma_u^2)$, $u, v,$ **and** x are independent of each other.

By contrast, Battese and Coelli (1988) considered the more general truncated normal distribution with $u_i \sim N^+(\mu, \sigma_u^2)$. These authors derived their results for the case of balanced panels, while Battese, Coelli and Colby (1989) generalized the model for the case of an unbalanced dataset.

The assumption of time-invariant inefficiency is somewhat more plausible in very short panels, but it is highly unlikely when the number of years/periods is large. It is reasonable to assume that technical efficiency follows some form of pattern over time. Whether this pattern is common among all rail terminals is also an important assumption to consider. It is possible (or one would like to believe) that inefficient rail terminals become more efficient over time. Likewise, it is also possible that some rail terminals become less efficient before leaving the

sample entirely (shutting down) in long unbalanced panels. The choice of temporal assumptions depends upon the length of the panel and the nature of the sample. Furthermore, the longer the panel, the less likely it is that technology remains constant. Technical progression (or regression) can easily be incorporated by adding a time trend or annual time dummies to the specification.

4.2 Time Varying Model

4.2.1 Battese and Coelli (1992)

Battese and Coelli (1992) propose a stochastic frontier production function for (unbalanced) panel data which has rail terminal effects which are assumed to be distributed as truncated normal random variables, which are also permitted to vary systematically with time. The model may be expressed as:

$$y_{it} = \alpha_i + f(x'\beta) + v_{it} - u_{it} \quad (4)$$

The u_{it} are assumed to be exponential function of time, involving only one parameter, such that:

$$u_{it} = \{\exp[-\eta(t-T)]\}\, u_i \quad (5)$$

where u_{it} is assumed to have truncated normal distribution and η is a unknown parameter to be estimated, which determines whether inefficiencies are time varying or not. If η is positive, $-\eta(t-T) = \eta(T-t)$ is positive for t<T. Therefore, $\{\exp[-\eta(t-T)]\}$ >1, which implies that the techinical efficiency of the rail terminal declines over time. One advantage of this model specification is that the inclusion of a time trend into the production function permits the estimation of both technical change and changes in the technical inefficiencies over time. As many authors note, this exponential function is very rigid.

Another such model proposed by Kumbhakar (1990) has the following specification:

$$u_{it} = \{1 + \exp[(\alpha t + \beta t^2)]\}^{-1} u_i \quad (6)$$

The Kumbahakar function lies in the unit interval and can be non- increasing, non – decreasing, concaveor convex depending on the signs and magnitudes of α and β .

Finally, Lee and Schmidt (1993) proposed an alternative formulation:

$$u_{it} = d_t u_i \quad (7)$$

where d_t is specified as a set of time dummy variables. This model is appropriate for short panels, since it requires estimation of *T-1* additional parameters. Lee and Schmidt estimated both fixed and random-effects versions of the model (5). In the fixed effects case both d_t and u_i are considered as fixed terms, and in the random effects case u_i is treated as a random variable. Lee and Schmidt used a least squares estimator, while a generalized method of moments approach to the estimation of the model has been developed by Ahn, Lee, and Schmidt (2001).
The parameters of the stochastic frontier and the model for the technical inefficiency effects are estimated simultaneously by maximum likelihood.

4.2.2 Battese and Coelli (1995)

A number of empirical studies (Pitt and Lee, 1981) have estimated stochastic frontiers and predicted efficiency levels regressing the predicted efficiencies upon specific variables. The two-stage estimation procedure has also long been recognized as one which is inconsistent in its assumptions regarding the independence of the inefficiency effects in the two estimation stages. The two-stage estimation procedure is unlikely to provide estimates which are as efficient as those that could be obtained using a single-stage estimation procedure. This issue was addressed by Kumbhakar, Ghosh and McGukin (1991) and Reifschneider and Stevenson (1991) who propose stochastic frontier models in which the inefficiency effects (u_i) are expressed as an explicit function of a vector of specific variables and a random error. Battese and Coelli (1995) propose a model which is equivalent to the (4) where u_{it} which are non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero of the $N^+(\mu_{it}, \sigma_u^2)$ distribution; where:

$$\mu_{it} = z_{it}\delta \qquad (8)$$

where z_{it} is a p×1 vector of variables (such as covariate or time variables) which may influence the efficiency of a rail terminal; and δ is an 1×p vector of parameters to be estimated.

4.2.3 True fixed effect

In this case of true fixed effect model, α_i represents the additional rail terminal specific effects and thus the unobservable heterogeneity of rail terminals. It is important to underline that application of fixed effects to the stochastic frontier model is a reinterpretation of the

linear regression model with fixed effects, not of the frontier model. Following Greene (2005), the "true" fixed effects model is specified as (4).
The model is estimated by maximum likelihood. Unlike the usual fixed effect specification, in which the fixed effects are interpreted as inefficiency, the fixed effects in Greene's model represent unobserved heterogeneity.

4.2.4 True random Effect

Greene's true random effects model is an extension of the Aigner *et al.* frontier model that includes an additional time-invariant random term to capture, in this case, rail terminal-specific heterogeneity. The model can be expressed:

$$y_{it} = \alpha_i + f(x'\beta) + v_{it} - u_{it} \qquad \alpha_i \sim N(0, \sigma_\alpha^2) \tag{9}$$

This model not only includes a rail terminal-level source of heterogeneity α_i, which is potentially correlated with the explanatory variables, but also allows for a time-varying inefficiency term.

5. Pooled Models

Another type of data set, which is similar to panel data, is pooled data. Pooled data also includes the observations of rail terminal for several time periods. The primary difference between panel data and pooled data is the independence of errors. Both of the data sets generating processes assume that the error terms are identically distributed: $u_{it} \sim d\ (\mu, \sigma_u^2)$ in the homoscedastic case. However, under pooled data generating processes, an independence assumption is added: $u_{it} \sim iid\ (\mu, \sigma_u^2)$. In particular, this independence does not change over time. So that u_{it} and u_{is} are independently distributed. This permits time varying inefficiency since u_{it} and u_{is} are independent realization of the inefficiency component of the random error.
The pooled models considered in this paper are: ALS (Aigner, Lovell and Schmidt, 1977) and Stevenson (1980). The sample is considered as a series of cross-sectional subsamples pooled together and these models can also be estimated time-varying efficiency.
All of these models and assumptions are summarized in Table 3.

Table 3 - Econometric specifications of the stochastic production frontier

	Specific Component α_i	Time varying Inefficiency u_{it}	Random noise v_{it}	Inefficiency estimate
ALS (77) (Pooled)	None	$u_{it} \sim N^+(0, \sigma_u^2)$	$v_{it} \sim N(0, \sigma_v^2)$	$E(u_{it} \vert \varepsilon_{it})$
Stevenson (80) (Pooled)	None	$u_{it} \sim N^+(\mu, \sigma_u^2)$	$v_{it} \sim N(\mu, \sigma_v^2)$	$E(u_{it} \vert \varepsilon_{it})$
B&C (92)	None	Truncated normal $u_i \sim N^+(\mu, \sigma_u^2)$ $u_{it} = \{\exp[-\eta(t-T)]\} u_i$	$v_{it} \sim N(0, \sigma_v^2)$	$E(u_{it} \vert \varepsilon_{it})$
BC (95)	None	Truncated normal $u_{it} \sim N^+(\mu_{it}, \sigma_u^2)$ $\mu_{it} = z_{it}\delta$	$v_1 it \sim N(0, \sigma_1 v^{\uparrow} 2)$	$E(u_{it} \vert \varepsilon_{it})$
Pitt and Lee (81)	Half Normal $\alpha_i \sim N^+(0, \sigma_\alpha^2)$	Half Normal $u_i \sim N^+(0, \sigma_u^2)$	$v_1 it \sim N(0, \sigma_1 v^{\uparrow} 2)$	$E(u_1 i \vert \varepsilon_{\lfloor} it)$
B&C (88)	None	Truncated normal $u_i \sim N^+(\mu, \sigma_u^2)$	$v_i \sim N(0, \sigma_v^2)$	$E(u_1 i \vert \varepsilon_{\lfloor} it)$
TFE	Fixed	Half Normal $u_{it} \sim N^+(0, \sigma_u^2)$	$v_{it} \sim N(0, \sigma_v^2)$	$E(u_{it} \vert \varepsilon_{it})$
TRE	$\alpha_i \sim N(0, \sigma_\alpha^2)$	Half Normal $u_{it} \sim N^+(0, \delta_v^2)$	$v_{it} \sim N(0, \delta_v^2)$	$E(u_{it} \vert \alpha_i + \varepsilon_{it})$

6. Main results

Table 4 shows the estimation results of the applied models from which the results of the models TFE and TRE are missing due to a non-convergence. We first fit the pooled and panel models to the data set and compare the results of these models from two aspects: the estimation of parameters and the estimation of the inefficiency, λ and γ, where $\lambda = \sigma_u / \sigma_v$ and $\gamma = \sigma^2_u / (\sigma^2_u + \sigma^2_v)$. In particular, the parameter γ lies on the interval [0,1].
If there is no inefficiency, the value of σ_u would be zero, thus the value of λ would be zero. Here, λ is expected to be significant different from zero, indicating the obvious inefficiency. The null hypothesis γ=0, implies that the technical inefficiency effects are not present in the model. The half-normal distribution is a special case of the truncated normal distribution, and implicitly involves the restriction $H_0 : \mu = 0$. The hypothesis that efficiency is invariant over time (i.e. η = 0) has been tested. These are tested through imposing restrictions on the model and using the generalized likelihood-ratio test statistic (λ) to determine the significance of the restriction. The generalized likelihood ratio statistic is defined by:

$$\lambda = -2ln\left\{\left[\frac{L(H_0)}{L(H_1)}\right]\right\} = -2\{ln[L(H_0)] - \ln[L(H_1)]\} \qquad (10)$$

where $L(H_0) =$ the value of the log likelihood function for the stochastic frontier estimated under null hypothesis and [($L(H_1$)] is the value of the log-likelihood function for stochastic production function under alternative hypotheses. In our case, the γ are all significant. Moreover, from Table 4 we can note that all parameters are significant at the 1% level, with the exception of the dummy variable "Interport" significant at 10% for the Pitt and Lee (81) and B&C (88) models and significant at the 5% level for the B&C (92) model.

When technical inefficiency is investigated, we can find that the B&C (95) and Stevenson (80) give the relatively large estimation of λ (20.1430) and (61.087) respectively. This result is also confirmed by the parameter γ whose value is close to one. A good result is given by Batttese and Coelli (92).

Table 4 - Estimation results

Parameter	Stevenson (80) Pooled	Pitt and Lee (81) Time-invariant	B&C (88) Time-invariant	B&C (92) Time-varying	B&C (95) Time-varying
α	5.9956*** (0.4909)	6.6099*** (0.8670)	6.6179*** (0.8986)	6.3136*** (0.8094)	5.9445*** (0.4921)
Year	-0.0956*** (0.0224)	-0.1170*** (0.0170)	-0.1170*** (0.0171)	-0.0524** (0.0256)	-0.0782*** (0.0277)
ln Employment (units)	-0.2887*** (0.0504)	-0.2331*** (0.0698)	-0.2326*** (0.0715)	-0.2386*** (0.0663)	-0.2908*** (0.0510)
ln Terminal area (square meters)	-0.5770*** (0.0475)	-0.6246*** (0.0857)	-0.6252*** (0.0877)	-0.6164*** (0.0803)	-0.5776*** (0.0479)
ln HHI	0.8702*** (0.0427)	0.8356*** (0.0334)	0.8359*** (0.0343)	0.8196*** (0.0332)	0.8734*** (0.0436)
Interport (yes=1 no=0)	0.3022*** (0.0877)	0.2678* (0.1518)	0.2676* (0.1526)	0.2523** (0.1309)	0.3013*** (0.0882)
η	-	-	-	-0.1211*** (0.03586)	
λ	61.087	2.4845	2.4490	3.8356	20.1430
γ	0.9997	0.8606	0,8570	0.9363	0,9975
σ_u^2	280.3883	0.5577	0.5413	1.2237	32,2044
σ_v^2	0.0751	0.0903	0.0903	0.0832	0,0793

***, **, * *indicates the significance at 1%, 5% and 10% level respectively.*

In table 5 pair wise rank order correlations for different models shows differences between the models in technical efficiency, we note that the highest correlation is between the B&C (95) and Stevenson (80) Models, while the lowest correlation is among B&C (92), Stevenson (80) and B&C (95).

Table 5 - Kendall's rank order correlations between of technical efficiency estimates for different models

	BC88	BC92	PittL~81	Steve~80	BC95
BC88	1.0000				
BC92	0.8660	1.0000			
PittLee81	0.9800	0.8507	1.0000		
Stevenson80	0.7239	0.6739	0.7101	1.0000	
BC95	0.7213	0.6994	0.7060	0.9341	1.0000

Due to the log-log transformation of input and output variables we can observe that the input elasticities to productivity index are statistically significant and with a similar magnitude across models. The coefficients have the negative sign with reference to employment and terminal size; this is because technological change is decreasing in the period as confirmed by the negative coefficient of the time trend year and evidently, adding more quantities of production factors such as labour and physical capacity, the rail productivity index tends to decrease. On the contrary the effects of the market power index and localisation inside an interport are positives. At the same levels of traffic these results seem to favour infrastructures with less unutilized capacity in contexts in which business agglomeration forces are active.

The efficiency scores for the time-invariant models and the time varying models are presented in Tables 5 and 6.

Table 6 - Time invariant efficiency scores for the rail terminal

Terminal	Pitt and Lee (81)	B&C (88)
Bari Ferruccio	0.7080	0.7117
Bologna	0.2312	0.2328
Brescia	0.3817	0.3840
Brindisi	0.6115	0.6148
Busto Arsizio	0.7076	0.7104
Candiolo	0.5237	0.5272
Catania Bicocca	0.4819	0.4845
Gallarate	0.7429	0.7467
Gela	0.9014	0.9030
Lamezia Terme	0.9186	0.9201
Leghorn Guasticce	0.8580	0.8611
Lugo	0.2848	0.2867
Maddaloni Marcianise	0.3023	0.3044
Marcianise	0.2201	0.2216
Melzo	0.9235	0.9246
Milan Certosa	0.4789	0.4813

Milan Segrate	0.5254	0.5282
Milan Smistamento	0.6873	0.6906
Mortara	0.6864	0.4157
Nola	0.4642	0.4673
Novara	0.8741	0.8762
Padua	0.7616	0.7651
Padua Scalo	0.6269	0.6301
Palermo Brancaccio	0.2012	0.2026
Parma/Castelguelfo	0.7982	0.8019
Pescara Porta Nuova	0.6290	0.6321
Piacenza	0.3008	0.3027
Pomezia-S. Palomba	0.7687	0.7725
Rho	0.8273	0.8311
Rivalta Scrivia	0.8161	0.8199
Rome Smistamento	0.5011	0.5040
Torino Orbassano	0.5238	0.5269
Trento	0.6053	0.6086
Verona	0.7216	0.7250

Table 7 - Average time varying efficiency scores for the rail terminal

Terminal	B&C (92)	B&C (95)
Bari Ferruccio	0.7486	0.7893
Bologna	0.2610	0.2937
Brescia	0.4089	0.5295
Brindisi	0.6272	0.7493
Busto Arsizio	0.7721	0.7785
Candiolo	0.5408	0.6554
Catania Bicocca	0.5184	0.6547
Gallarate	0.7784	0.7968
Gela	0.9157	0.8821
Lamezia Terme	0.9104	0.8896
Leghorn Guasticce	0.8837	0.8299
Lugo	0.3023	0.4130
Maddaloni Marcianise	0.3265	0.4041
Marcianise	0.2211	0.3873
Melzo	0.9412	0.8797
Milan Certosa	0.5223	0.6443
Milan Segrate	0.5689	0.6748

Milan Smistamento	0.7347	0.7852
Mortara	0.3829	0.4778
Nola	0.4985	0.5863
Novara	0.9122	0.8510
Padua	0.8201	0.7831
Padua Scalo	0.6565	0.7694
Palermo Brancaccio	0.1863	0.4020
Parma/Castelguelfo	0.8327	0.8129
Pescara Porta Nuova	0.6403	0.8038
Piacenza	0.3341	0.4089
Pomezia-S. Palomba	0.8035	0.8121
Rho	0.8172	0.8036
Rivalta Scrivia	0.8321	0.7946
Rome Smistamento	0.5166	0.6802
Torino Orbassano	0.5513	0.6764
Trento	0.6550	0.7094
Verona	0.7894	0.7728

All the models suggest the existence of negative technical change over time. The time varying models confirm that technical efficiency has decreased over time, in fact the η coefficient in Model 3 is significantly negative.

The rankings in Table 5 for time invariant models and in Table 6 for the time-varying models highlight the significant degree of efficiency over 0.7 of the rail terminals of Northern Italy, particularly specialized in cross-frontier rail traffic in the Alps, more especially with Central Europe (Germany, Austria, Switzerland and France). The Novara, Parma, Padua and Verona interports, set alongside the main lines of trans-European traffic which cross the Po Valley, perform a role of the highest order within the total balance of goods traffic passing between Northern Italy and the rest of Europe. Melzo, Rho, Gallarate and Busto Arsizio intermodal terminals not inside an interport structure achieve a very good level of efficiency. Leghorn and Rivalta intermodal terminals benefit from the maritime traffic of the Leghorn and Genoa ports. The only terminals included in this range of efficiency belonging to Central-Southern Italy are Pomezia and Bari. The terminals of Lamezia and Gela achieve a very high level of productivity because of their small dimensions and the few input resources used.

The negative pattern in technical efficiency might be due to the quasi-fixed nature of inputs related to the given installed capacity; a significantly high decrease in traffic in the years 2009-2010 might have determined for many terminals a situation of overcapacity which is captured in the applied models by a lower technical efficiency and its decay over time.

Generally, the results show that there is a great potential for efficiency improvements of over 50% among terminals, even though the rail cargo market in Italy has declined in recent years.

6.1 Time- varying Technical Efficiency

Figure 1 shows the Kernel density distribution of the technical efficiency estimates for the models Stevenson (80), B&C (92) and B&C (95), and figure 2 shows the first quartile, mean and third quartile scores per year for the same models. In particular, Battese and Coelli (95) and Stevenson (80) show the same empirical distribution, while in Battese and Coelli (92) it is different. The technical efficiency of model B&C (92) is decreasing (see negative η), while the model B&C (95) and Stevenson(80) show the same trend. Moreover, the spread of efficiency scores (inter-quartile range) is widest in B&C 92.

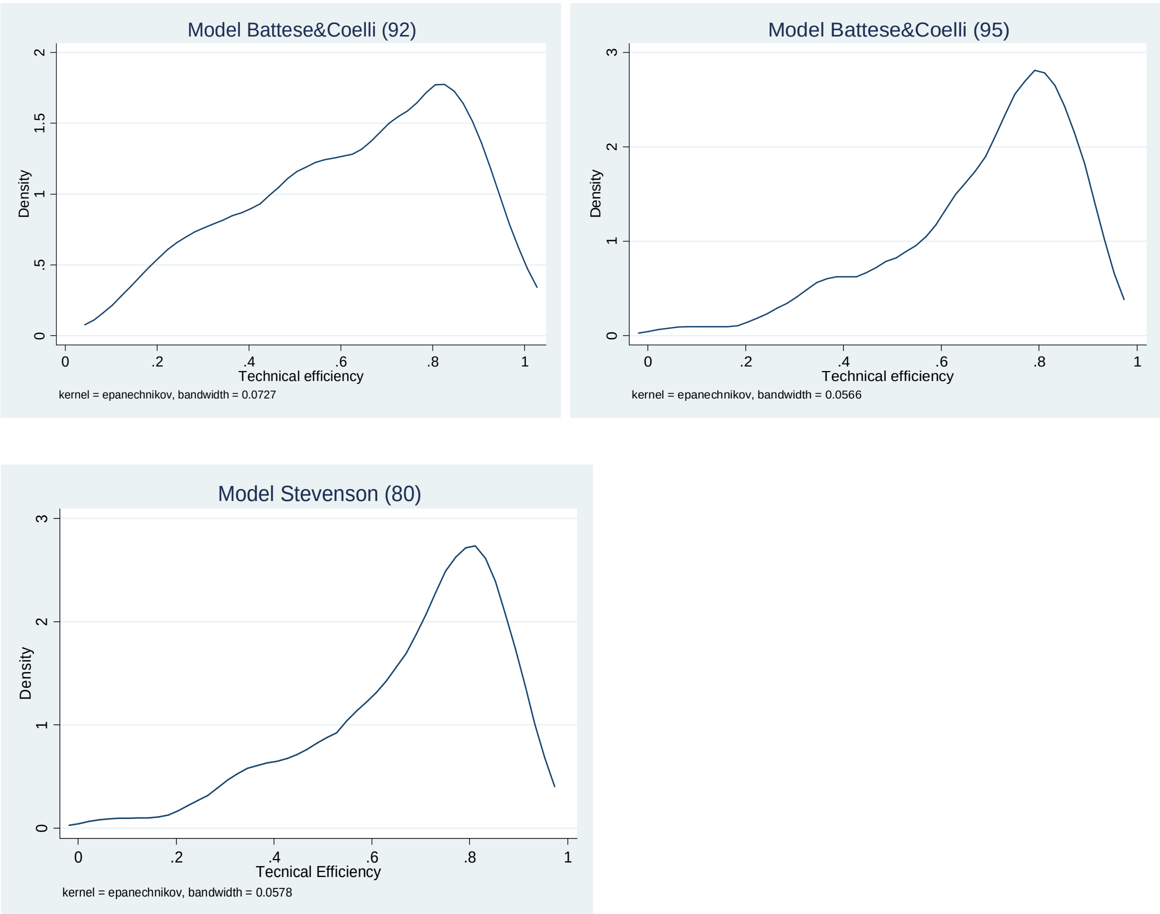

Figure 1 - Technical efficiency distribution of sample rail terminals for B&C (92), B&C(95) and Stevenson (80) models

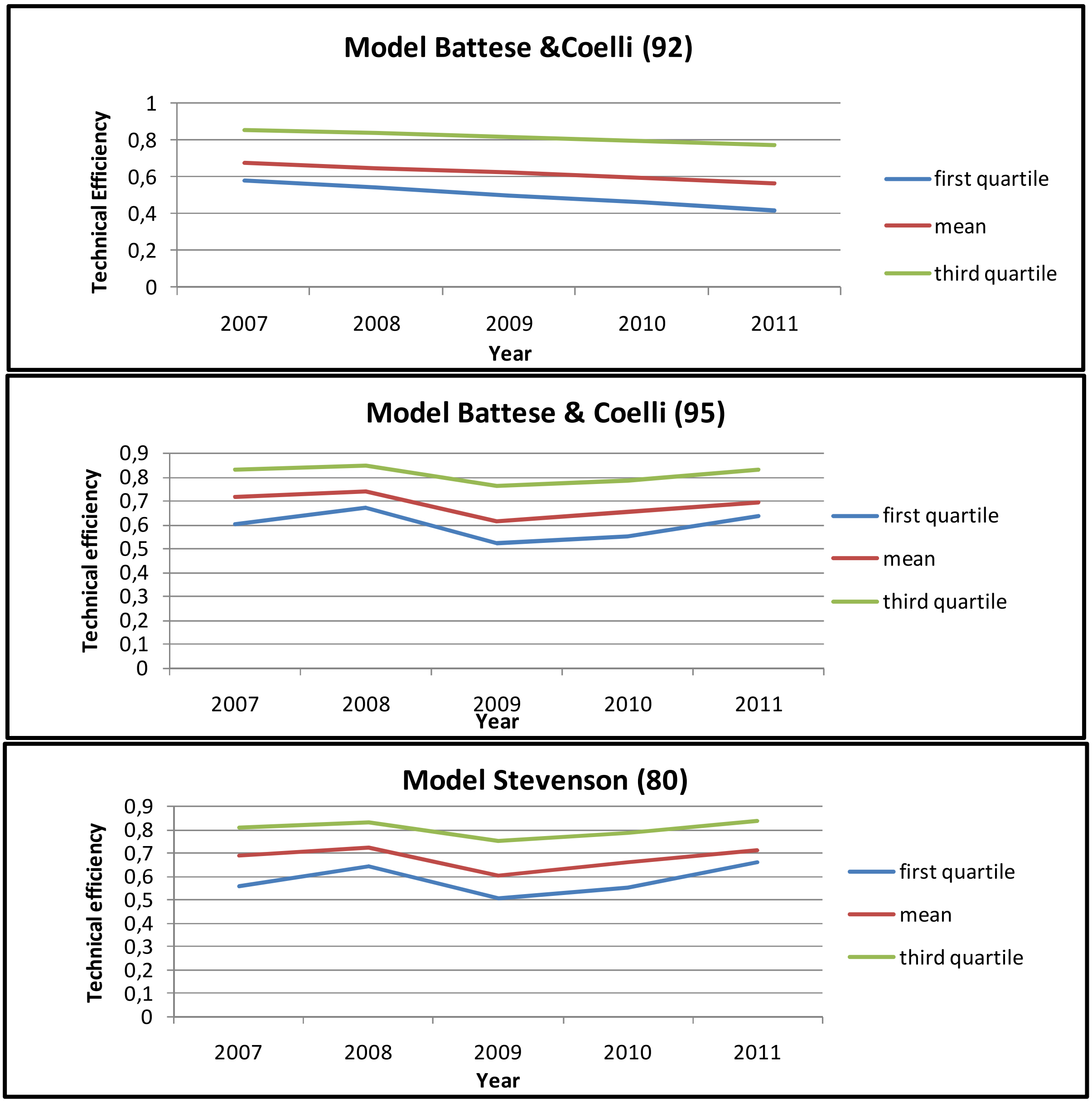

Figure 2 - The first quartile, mean and third quartile values of technical efficiency of sample rail terminals for B&C (92), B&C(95) and Stevenson (80) models

7. Conclusions

Italian rail-road intermodal transport is founded on a model that is diversified through the regions. In some cases the regions have followed the national policy based on the "interport" model promoted through the legislation which provided public contributions (Law 240/90), whereas in other regions there has been a greater development of "single" model of public or private property rail terminals.

This study focuses on productivity and efficiency in a sample of 34 Italian intermodal rail terminals observed over the period 2007-2011 utilizing an original panel dataset built by the

authors on several sources. The sample is representative of national intermodal rail-road and sea-rail traffic since it considers all the main Italian rail terminals. Eight different stochastic frontier models have been estimated assuming a Cobb-Douglas production function where the annual rail productivity index (RPI) of the terminals is assumed to be obtained by combining four inputs: labour, terminal area, market power and the localisation context. Particularly attention was paid to analysis of technological change in production output and technical efficiency levels over time, applying the most useful and suitable econometric models existing in literature.

Panel data frontier model estimation has been widely used to estimate technical efficiency. Yet the technical efficiency measures may be distorted by specification error. Our concern was not to rank the different models by some criterion of suitability of statistical reliability. Rather we sought to demonstrate the range of models available and differences between them in the assessment of efficiency. The variability of the results from same different models clearly demonstrates the difficulty in choosing of a model. No model can be held to be ‘correct’, and the efficiencies will always be a kind of unobserved or modeled effect. For the future, model choice in empirical research should not be based on ‘standard practice’, but on a reasoned choice. A good start point for deciding which estimator should be utilized is the quality of data and the choice of variables.

The results achieved by the application of stochastic frontier models confirm the high rates of inefficiency which characterize many Italian rail terminals, the average level of efficiency differs markedly among the various Italian regions and it is higher considering the time-varying models. The intermodal rail function has justified the majority of the investments made in this sector with regard to the greater environmental sustainability of rail transport, and the results obtained seem to reinforce even further the decisive condition of competitive advantage given by localization which serves internal basins of terrestrial exchange along the main lines of trans-European traffic.

Most of the rail terminals that are large in production scale are more likely to be associated with higher production quantitative scores but not always with higher productivity and efficiency scores.

Estimated models show a negative technological change over the period 2007-2011, as well as negative efficiency growth considering the severe fall in demand in the years 2009 and 2010. The negative pattern of efficiency over the sample period might be due to the as yet unclear evidence of the crisis in terms of supply reaction.

Research analyses regarding productivity and the capacity of Italian intermodal terminals to contribute towards improvement in the disequilibria which characterize the Italian transport system should regard the possibilities of recovering efficiency based on greater functional continuity with the nodal sources of international traffic, such as ports and cross-border traffic nodes along the Trans-European transport corridors.

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