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FIRM AND TIME VARYING TECHNICAL AND ALLOCATIVE EFFICIENCY: AN APPLICATION FOR PORT CARGO HANDLING FIRMS

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Abstract

In this paper we present an econometric model to calculate firm and time-varying indexes of technical and allocative inefficiency following both the parametric and the error component approach. To achieve these aims, we estimate a system of equations for a translog input distance function and cost shares equations. In order to illustrate the methodology we present an application for cargo handling in ports using a panel data obtained from firms operating at the port of Las Palmas in Spain. This sector is a multi-output and regulated sector so the estimation of an input distance function is especially useful for our aims.

Key words

Technical and Allocative Efficiency, Distance Function System, Spanish Ports Terminals.

In the last decade several models have been proposed to estimate firm and time-varying technical efficiency. These models could be grouped depending on the approach chosen to model the inefficiency. On one hand there are those which model technical inefficiency through an error component (see, for example, Kumbhakar (1990), Battesse and Coelli (1992), Battesse and Coelli (1995), Heshmati and Kumbhakar (1994), Heshmati *et al*. (1995) or Cuesta (2000)). These models involve the cost of making particular distributional assumptions for the one-side error term associated with technical efficiency. On the other hand, there are those which models technical inefficiency through the intercept of the function (see, for example, Cornwell *et al.* (1990); Lee and Schmidt (1993) or Atkinson and Primont (2002). In this way these model avoid making particular distributional assumptions. In this paper, we can get technical efficiency indexes, which may vary through time as well as across firms following this second approach.

With regard to allocative efficiency, Atkinson and Cornwell (1994) present two methods that permit the calculation of allocative inefficiency: the parametric approach and the error component approach. Färe and Grosskopf (1990) and Atkinson and Primont (2002) demonstrate that replacing the usual cost frontier with an input distance function can overcome the main drawbacks of the parametric approach by obtaining firm and time indexes of allocative efficiency. With regard to the second approach, the advantages of the distance function are developed in Rodríguez-Álvarez *et al.* (2004) which have dealt with the hypothesis in which the allocative efficiency is time-invariant and only varies across firms.

In this paper we extend the analysis in the case in which the efficiency is firm and time-varying in both approaches. Besides, we can calculate firm and time-varying technical efficiency and, separately, a measure of technical change. To do this, we present a distance system that is comprised of an input distance function and the share cost equations associated.

To illustrate our methodology we apply it to a panel data using a sample of cargo handling firms in Spanish ports. Although there are cases where several firms share a port terminal, in our case each cargo handling firm operates exclusively its own terminal in a consessional basis. The terminals analyzed are typical medium size port terminals. Terminal prices are subjects price caps, which are seldom binding but employment is highly regulated. This is not an unusual situation around the world.

A number of papers have been tracking the efficiency changes brought by reforms for the port infrastructure as surveyed by Estache *et al*. (2002). This is the first paper dealing with the efficiency of port terminals (private firms). In spite of the importance of this activity for the regulation of the sector, little is known in practice about the economics of this service.

The paper is organized as follows. Section 1 provides an overview of port terminals and their regulation in Spain. In Section 2 the model is presented. Section 3 concerns itself with the econometric model. The data are described and the results are presented in the Section 4. The final section contains brief concluding comments.

1. Port Terminals and their Regulation in Spain

Economic activities within a port are multiple and heterogeneous. Among them, cargo handling has been one of the most affected by technological changes on one hand and by competition among ports on the other. The importance of this activity is evident when one realizes that it means from 70% to 90% vessel's bill of load (De Rus *et al.*, 1994). Cargo handling services are usually performed in port terminals.

Technological changes have increased the relative importance of specific terminals within the port areas (e.g. multi-purpose[2], containers, liquid and solid bulk). Terminal facilities have now become heavily capital intensive and, depending on port size, more specialized as well, playing a key role in the choice of port by shippers. The role of the port terminals within the logistic systems makes them key actors of the port industry, playing a central role in the increasing competition within the sector.

In addition, the private sector has become increasingly interested in this type of activities. This has shifted the focus of the design of the competitive strategy of port authorities from the port as a whole to the terminals, making them the most important elements within the port industry. As pointed out by Heaver (1995), this change of focus is the main element to explain the increase of competition within the sector.

In the production of cargo handling services the following groups of factors are required: basic infrastructure, superstructure, machines and mobile equipment, and labor. Labor in a port can be classified grossly in two groups: workers directly involved in cargo handling operations (stevedores or port workers) and those who are not (mostly administrative and maintenance personnel). Traditionally the former group has been strongly regulated, although changes have taken place during the last decade, or so, worldwide.

The cargo handling service is usually viewed as one that has to be provided directly by the public sector or by private firms through concession contracts. The regulation of the Spanish port system is based upon a scheme that allows the combination of public property of the port infrastructure (docks, land, and so on) with private property of the superstructure (warehouses, cranes, and so on). The public authority determines the conditions under which the private initiative can operate by fixing maximum prices, length and characteristics of concessions, and other conditions (for more details see Tovar *et al*., 2004).

The stevedores or port workers working in Spanish port terminals are divided in two categories: those who are on the payroll (ordinary employment -LC) and those who are not (special employment -LE). These latter can be recruited on a provisional basis by any company to work 6-hour shifts. Regulation drives the level and composition of port labor (including the choice between LE and LC) for each terminal.

The possibility of contracting port workers for specific operations (LE) provides the stevedoring companies[3] with some flexibility since it allows them to adjust employment to the traffic levels of the terminal. However, this flexibility has its limits since under the current legislation, the operators do not have total freedom to decide how and to what extent to use each type of worker.[4]The stevedoring companies have:

- The obligation to perform at least 25% of its activities (in tons) with port workers on their payroll (LC).
- The obligation to use at least one LE port worker in each shift.
- A global limit on the number of operations they can perform with LC workers of 22 6-hours shifts per month; once they have reached that level, they are required to rely on LE workers.

2. Modelling firm and time-varying technical and allocative efficiency

To calculate firm and time-varying technical and allocative efficiency we propose an empirical model which consists of an input distance function and the associated input cost share equations:

$$\ln 1 = \ln D(y_{pt}, x_{pt}, K_{pt}, DT) + v_{pt} + u_{pt} \tag{1}$$

$$\frac{x_{ipt} w_{ipt}}{C_{pt}} = \frac{\partial \ln D\left(y_{pt}, x_{pt}, K_{pt}, DT\right)}{\partial \ln x_{ipt}} + v_{ipt} + A_{ipt} \tag{2}$$

where $D(y_{pt},x_{pt},K_{pt}, DT)$ is the short-run input distance function; y is an output vector, x is a variable input vector, K is a quasi-fixed input, DT is a time year dummy to control for neutral technical change, p denotes port terminal and t time. The error components v_{pt} and v_{ipt} represent statistical noise, and are assumed to be distributed as multivariate normal with zero mean.

2.1 Measuring Technical Efficiency

The error component $u_{pt} \geq 0$ in (1) represents the magnitude of technical efficiency (TE). We follow Cornwell *et al.* (1990) which specify a model which allows us to estimate time-varying technical efficiency levels for individual firms, without making strong distributional assumptions for technical inefficiency or random noise. Thus, if the constant in (1) is B_0, then it is possible to write:

$$\beta_{pt} = B_0 + u_{pt} = \beta_{pa} D_p + \beta_{pb} D_p t + \beta_{pc} D_p t^2 \quad (3)$$

Where D_p is a dummy variable for the port terminal p and β_{pa} ; β_{pb} ; β_{pc} are parameters to be estimated for this port terminal and t is a time trend. However, there is an interpretation problem because there is no easy way to empirically distinguish in (3) between technical inefficiency or technical change (for example, there is contradictory interpretations in Cornwell *et al.* (1990) or Good *et al.* (1995)).

To solve this problem, and following Heshmati and Kumbhakar (1995) and Heshmati, Kumbhakar and Hjalmarsson (1995) we have included in (1), the time dummy (*DT*). In this way, by including a time variable among the regressors, it would be possible to resolve the interpretation problem in the Cornwell *et al.* (1990) specification, since the time variable is associated with technical change and the error component (3) is associated with technical efficiency, which is allowed to vary across producers and through time (for details, see for example Lovell, 1996).

In this sense, the β_{pa} capture time-invariant TE whereas β_{pb} and β_{pc} capture time-varying TE. Thus, each producer has its own intercept (β_{pt}), which is allowed to vary quadratically through time at producer-specific rates. The TE of a port terminal in a time period is obtained from the estimated intercepts as $TE_{pt} = exp(-u_{pt})$ where $u_{pt} = \beta_{pt} - min(\beta_{pt})$. The efficiency index constructed in this way, ranges from 0 to 1. Thus, in each period at least one port terminal is estimated to be 100% technically efficient (with value 1), although the identity of the most technically efficient port terminal can vary through time.

2.2 Measuring Allocative Efficiency

To calculate allocative efficiency two econometric approaches are available (Atkinson and Cornwell, 1994): a) an error components approach, and b) a parametric approach

a) The Error Components Approach

In this approach we model allocative inefficiency through an error component. Thus in (2) the error components $A_{ipt} >=< 0$, i=1,…,n, represent allocative inefficiency, here represented by the difference between actual and stochastic shadow input cost shares from (2) (for more details see Rodríguez-Álvarez and Lovell, 2004). Moreover, if A_{ipt} is positive, the input i is being over-utilised with regard other inputs and viceversa.

In our case it is possible to specify allocative inefficiency for the input i as:

$$A_{ipt} = \alpha_{ipa} D_p + \alpha_{ipb} D_p t + \alpha_{ipc} D_p t^2 \tag{4}$$

Where D_p is a dummy variable for the port terminal p and α_{ipa} ; α_{ipb} ; α_{ipc} are parameters to be estimated for this port terminal and for the input i and t is a time trend. The α_{ipa} capture time-invariant allocative inefficiency whereas α_{ipb} and α_{ipc} capture time-varying allocative inefficiency.

b) The Parametric Approach

After estimation of the system (1) – (2), shadow price ratios are determined from the dual of Shephard Lemma as

$$\frac{\dfrac{\partial \mathrm{D}(y,x,K,DT)}{\partial \mathrm{x}_{\mathrm{i}}}}{\dfrac{\partial \mathrm{D}(y,x,K,DT)}{\partial \mathrm{x}_{\mathrm{j}}}} = \frac{\mathrm{w}_{\mathrm{i}}^{\mathrm{s}}}{\mathrm{w}_{\mathrm{j}}^{\mathrm{s}}}. \tag{5}$$

Where w^s is the shadow prices vector. If the allocative efficiency assumption is satisfied, these shadow price ratios coincide with market price ratios. However if expense preference behaviour causes allocative inefficiency, the two price ratios differ. To study such deviations, a relationship between the shadow prices (obtained through the distance function) and the market input prices is introduced by means of a parametric price corrections

$$w_i^s = k_i w_i \tag{6}$$

Dividing (6) by the corresponding expression for input j we obtain

$$\frac{w_i^s}{w_j^s} = k_{ij}\,\frac{w_i}{w_j}\,, \qquad (7)$$

where $k_{ij} = k_i/k_j$. From (7) the degree to which shadow price ratios differ from market price ratios is calculated. If $k_{ij} = 1$, there is allocative efficiency; while if $k_{ij} > (<)\ 1$, input i is under-utilised (over-utilised) relative to input j.

If we have a panel data, it is possible to obtain, for each pair of inputs, producer and time specific allocative efficiency indices k_{ij}. Thus, with both proposed approaches (the error component and the parametric approach) we can get time and firm varying indices of allocative efficiency. Moreover, it is important to distinguish between these two measures of allocative inefficiency (the parametric approach and the error components approach). In the error components approach, the a_{ipt}s represent the systematic allocative inefficiency *for each input*. In the parametric approach the k_{ij}s indicate the allocative inefficiency *for each pair of inputs*. Moreover, in the error components approach, behind the a_{ipt}s lies the assumption of an *additive* relationship between w_i and w_i^s. In the parametric approach a *multiplicative* relationship between w_i and w_i^s is specified, yielding the coefficients k_{ij} as indexes of allocative inefficiency.

But it is also important to emphasise the *relationship* that exists between the two approaches. If persistent inefficiency exists (that is, if the a_{ipt}s have mean values significantly different from zero), their inclusion is necessary if the estimated parameters, and consequently the estimated k_{ij}s, are to be unbiased. This implies that the inclusion of the parameters a_i in the empirical model is *indispensable* in order to obtain unbiased estimates of the k_{ij}s.

3. Econometric Specification

We now consider how to estimate the system (1) – (2). To do this, we have chosen a flexible functional form, a translog short run multiproduct input distance function which is specified as:

$$\ln 1 = B_0 + \sum_{r=1}^{m} \alpha_r \ln y_{rpt} + \frac{1}{2}\sum_{r=1}^{m}\sum_{s=1}^{m} \alpha_{rs} \ln y_{rpt} \ln y_{spt} + \sum_{i=1}^{n} \beta_i \ln x_{ipt} + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln x_{ipt} \ln x_{jpt} +$$

$$\xi_f \ln K_{pt} + \xi_{ff} \frac{1}{2} \ln K_{pt}^2 + \sum_{i=1}^{n} \xi_{fi} \ln K_{pt} \ln x_{ipt} + \sum_{r=1}^{m} \xi_{fr} \ln K_{pt} \ln y_{rpt} + \sum_{i=1}^{n}\sum_{r=1}^{m} \rho_{ri} \ln y_{rpt} \ln x_{ipt} +$$

$$\sum_{T=1}^{T} \gamma_T DT + u_{pt} + v_{pt} \tag{8}$$

$$\frac{x_{ipt} w_{ipt}}{C_{pt}} = \beta_i + \sum_{j=1}^{n} \beta_{ij} \ln x_{jpt} + \sum_{r=1}^{m} \rho_{ri} \ln y_{rpt} + \xi_{fi} \ln K_{pt} + A_{ipt} + v_{ipt} \tag{9}$$

where y = (y_1,…,y_m) is an output vector, x = (x_1,…,x_n) is a variable input vector, K is a quasi-fixed input, DT is a time dummy for year T, p denotes ports terminal; t denotes months and v_{pt}, v_{ipt}, u_{pt} and A_{ipt} are disturbance terms which have been already defined. Homogeneity of degree +1 of the input distance function in variable inputs is enforced by imposing the restrictions $\sum_{i=1}^{n} \beta_i = 1$, $\sum_{j=1}^{n} \beta_{ij} = 0$, $\sum_{i=1}^{n} \rho_{ri} = 0$ ($\forall$ r=1,…m), $\sum_{i=1}^{n} \xi_{fi} = 0$. We also impose the symmetry conditions $\alpha_{rs} = \alpha_{sr}$, $\beta_{ij} = \beta_{ji}$, $\xi_{fi} = \xi_{if}$, $\xi_{fr} = \xi_{rf}$, $\rho_{ri} = \rho_{ir}$.

The estimation of this equation system provides the suitable empirical context to calculate the technical and allocative efficiency by means the methodology proposed above.

4. Data and results

4.1 Data description

The sample consists of three multipurpose port terminals operating within the port area of La Luz and Las Palmas located in the Canary Islands (Spain). We have monthly data from 1992 through 1997 for Terminal one (T.1), from 1991 through 1999 for Terminal 2 (T.2), and from 1992 through 1998 for Terminal 3 (T.3). The final panel data set consists of 264 observations.).

Although the terminals deal mainly with containers, they also operate roll-on/roll-off cargo (ro-ro) as well as general break-bulk cargo, so we distinguish three outputs measured on total tons: containers (CONT), ro-ro cargo (ROD) and general break-bulk cargo (MG).

The input variables are: port workers[5]: ordinary (LC) and special[6] (LE); non-port workers[6] (NP), capital (GK), intermediate consumption (GI). We also consider a quasi-fixed input: total area (K).

The information available regarding the amount of work used is expressed in number of men per month for non-port workers and in number of shifts per month for port workers. A shift is a 6-hour work schedule. The total monthly labor expense for the terminals is calculated as the sum of the cost of such type of work.

Capital covers all the components of tangible assets of the company —i.e. buildings, machines, etc. The monthly cost results from the addition of the accounting depreciation for the period plus the return on the active capital of the period[8].

With regard to area, the terminals under analysis may make use of an area that has been granted under concession, which may be increased by provisionally renting —upon prior request— additional area from the port authority. The addition of both types of areas is called total area and the area used is measured in monthly square meters.

Lastly, the rest of the productive factors used by the company and that have not been included in any of the three preceding categories, such as office supplies, water, electricity, and the like, have been denominated under intermediate consumption. The monthly expense results from the aggregation of the rest of the current expenses other than depreciation, personnel expenses and payment for area, after the pertinent corrections in a manner such that the resulting monthly expense truly reflects consumption and not accountancy.

The total monthly production expenses for the terminals result from the aggregation of expenses of all the productive factors defined above. Table 1 shows the monthly values obtained for the entire sample and for each of the three terminals, both in terms of the defined inputs and outputs as well as the total expense incurred during service provision[9]. It is worth stressing that data was gathered directly from the firms files and that all the details were discussed with executives when necessary, particularly for the monthly assignment of expenses. Data is described in detail in Tovar de la Fé (2002).

(INSERT TABLE 1)

Out of the three products, general break-bulk cargo ("general cargo") represents an average of 9.9% of the total tons moved monthly, containers represent an 87.4% and ro-ro a 2.7%. On the other hand, labour costs account for an average of 53% of the monthly expense for the entire sample. Total area represents 13%, capital amounts to 8% and intermediate consumption reaches 26%. Within personnel, non-port workers account for 21% of personnel expense, while ordinary workers and special workers represent 36% and 43% respectively. The figures per company reveal similar patterns.

Moreover, the analysis of the information contained in Table 1 leads to a first approximation of the size of companies. Thus, taking into consideration the aggregated product volume, the largest company is T.3., followed by T.1 and by T.2. in the last position. On the other hand, where the variable used as size indicator is the total monthly production expense (mean value), even though T.3. is still found in the first place, the other two companies, T.1 and T.2. interchange positions. This result is due to monthly expenses do not vary monotonically with total production. This makes the different output composition a likely explanation for cost differentials, if factor prices were similar for the three companies. For example, the only explanation for the expense of T2 larger than those of T1 would be the difference in the traffic mix, particularly the larger volume of general cargo. This already suggests higher marginal costs for general cargo, which reinforces the need for a multipoutput analysis. (Jara-Díaz *et al*. (2005)).

4.2. Results

We have estimated the system (8)-(9) by means of iterative seemingly unrelated regressions (ITSUR), which is invariant to the omitted share equation. In Table 2, 3 and 4 we present the estimates values from the input distance system estimated. The variables have been divided by the geometric mean. Therefore, the first order coefficients can be interpreted as elasticities.

In Table 2 we can see the estimated parameters. It can be seen that all first order parameters are statistically significant and have the correct sign except the quasi-fixed input total area (K). This could be due to the terminals are growing so they are making important investments at the end or the period which are higher than it is needed in that moments. Terminal port infrastructures and superstructure must be built with determined minimum dimensions, so it is not possible to enlarge a terminal port in a continuous way. Finally, at the sample mean, the regularity conditions are satisfied: it is non-decreasing and quasi-concave in inputs and decreasing in outputs.

(INSERT TABLES 2 AND 3)

4.2.1 Technical efficiency

In Table 3 we present the coefficients estimated from which it is possible to obtain technical efficiency index (u_{pt}) following Section 2.1. These indexes have been represented in Figure 1 (following Cornwell *et al*. (1990) approach). The temporal pattern of technical efficiency for the three terminals shows that T.3 is the most efficient one for almost the whole period, when its technical efficiency score begin to getting worse. This occurs, more or less, when T.3 was moving from one place to another, bigger on, inside of port area. This change of size requires a huge investment which probably drives this result. Remember that T3 is the largest company so it seems to exit a relationship between size and efficiency The other two terminals, T.2 and T.1 present declining technical efficiency score in the first years and increasing in the latter, especially T.2 which substitutes for T.3 at the end of the period.

Others technical efficiency score are show in Figure 2. These are calculated considering the best observation as the reference technology. The Figure 2 tells us a similar story. In terms of technical efficiency trend T.3 shows a general decline (with the exception of the few firsts periods), T.2 presents a similar, but softer, pattern than in a figure 1. Lastly, T.1 shows a general decline in technical efficiency.

4.2.2 Allocative efficiency: Error Components Approach

On the other hand, estimated coefficients and asymptotic standard errors for AE parameters (A_{ipt} components) following the error component approach are shown in Table 4. Remember that A_{ipt} represent the systematic allocative inefficiency *for each input*.

The results of the estimation of the firm specific temporal pattern of allocative inefficiencies following the error components approach are reported in Figures 3 and 4 for the three terminals with respect to ordinary and special port workers (LC and LE) respectively.

Both factors are over-utilized, but it is interesting to note that the two graphs represent the inverse image of each other. Their joint analysis shows that each terminal has a preferred adjustment factor. It is LC for T.1 ad T.2 while it is LE for T.3. This would suggest that firms are operating with allocative efficiency with respect to one factor and with inefficiency with respect to the other factor.

This behavior is best understood by considering the relevance of regulation. Indeed, it is useful to remember that regulation drives the level and composition of port labor (including the choice between LE and LC) for each terminal. Regulation impedes the labor adjustments for both types of workers jointly. This is why they end up trying to maintain one degree of freedom and may tend to focus on adjustments in one of the workers categories at the time. Figures 3 and 4, indeed, show clearly that the employment policies of T.1 and T.2 differ from those followed by T.3.

Finally, as we can see from Figure 5, 6 and 7 the three terminals are allocatively inefficient in the use of the others three factors consider: Non port workers (NP) is under-utilized and intermediate consumption (GI) and capital (GK) are over-utilized, but the orders of magnitude are quite small in GI and GK. In the case of capital this probably simply reflect the difficulty of adjusting capital perfectly in a situation of growth as has been the case for the terminals during the period of analysis.

4.2.3 Allocative efficiency: Parametric Approach

In the parametric approach we get firm and time specific measures of AE for each pair of inputs. However, in order to conserve space we have reported only their values evaluated at the sample mean in Table 5[10] which have been estimated from equations (5) and (7).

Remember that k_{ij}<1 means that the ratio of the shadow prices of input i to that input j is lower than the corresponding ratio of actual prices. The analysis of the average estimated values for the k_{ij} reinforced the conclusions of the previous paragraphs and shows that LC is over-utilized relative to all the other inputs. Moreover, the coefficient k_{ij} which links LE and GK with the rest of the production factors other than LC are not statistically significant. The only exception is NP where both coefficients indicate under-use of NP with respect to LC and GK.

With respect to labor, the result may reflect the labor specific regulatory environment which impedes needed adjustments by the operators. As for capital, it may useful to point out that the levels of inefficiency are probably due to the impossibility of full adjustment as a result of indivisibility. Terminal port infrastructures and superstructure must be built with determined minimum dimensions[11].

The figures per company reveal similar patterns as we can see from Figure 8 in the appendix.

4.2.4 Technical Change

The coefficients of the time year dummies show the effect on the distance function of unobserved variables which, when evolving over time, affect all firms equally. We can check how these time effects affect the distance function from one year to another through the following expression:

$$TC_{T+1,T} = \gamma_{T+1} + \gamma_{T} \qquad (10)$$

A positive (negative) value for TC indicates an upward (downward) shift in the distance function (see Färe and Grosskopf, 1995). This measure is usually associated with technological change. The indices obtained from expression (10) are presented in Table 6.

From 1993 until 1997, the indices have a negative sign, which indicates that time has had a negative influence on firm activity. However, it can be observed that from this year these indices have evolved favorably, especially in the last period (1998-1999) where the coefficient is positive

CONCLUSIONS

In this paper we have presented an approach which allows us to estimate time-varying efficiency levels for individual firms without invoking strong distributional assumptions for inefficiency or random noise. Using a panel of Spanish ports, we have applied this methodology to a frontier input distance system. In this way, the operations of cargo handling firms in ports is analysed by means of the estimation of a multioutput input distance function using monthly data on firms located at the Las Palmas port in Spain.

Both size and traffic mix are first shown to be sufficiently diverse as to allow for a reliable estimation of a representative flexible (translog) function that permitted the calculation of firm and time-variant indexes of technical and allocative inefficiency within a framework consistent with a regulated and multiproduct sector, which further add to the contribution of the paper to the literature.

Implementing our approach with typical medium size port terminals data we highlight two main conclusions. The first one is that it seems to be a relationships between firms size and technical efficiency. The second one is that, our result respect to allocative efficiency suggest that the port labor specific regulatory environment impedes needed adjustments by the operators. Remember that labour means an average of 53% of the monthly expense and within personnel, port workers mean 80%. This figures revealed that regulation is being important in raising costs.

NOTES:

[1]A multiple-purpose (MP) terminal is designed to serve heterogeneous traffic, including non-containerized and containerized cargo. It can be transformed into a specialized one (e.g. containers only) by changing equipment.

[2] These are firms who are allowed to handling cargo. In our case the three terminal are also stevedoring companies, conversely they could not handling cargo by they own but contracting an stevedoring company.

[3]A collective agreement is an three-way agreement between the the State Stevedoring Association, the port workers and the stevedoring companies

[4]Port Workers are who handle cargo.

[5]This can be recruited on a provisional basis by any company to work 6-hour shifts.

[6]Administratives, executives, maintenance and control personnel, among others

[7]This rate of return evidences the compensation earned by risk-free capital, which is made up of bank interest plus a risk premium. It have been considered that for the period under analysis the return for both concepts amounts to 8% per annum. The price of capital is the quotient of the cost of capital divided by the active capital of the period (net fixed assets under exploitation for a given period t.)

[8]All monetary variables have been deflacted.

[9] Firm and time-specific results are available from the authors on request.

[10] It is not possible to enlarge a terminal port in a continuous way.

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TABLES

TABLE 1: Monthly Average Input, Output And Expense Values Get For The Entire Sample And For Each Terminal.

				Terminals					
		SAMPLE		T.1		T.2		T.3	
VARIABLE	**UNIT**	**MEAN**	**S.E.**	**MEAN**	**S.E.**	**MEAN**	**S.E.**	**MEAN**	**S.E.**
OUTPUTS									
CONT	1000 TON	59.2	41.57	53.1	9.72	33.5	7.45	97.4	54.36
MG	1000 TON	5.6	6.35	0.6	0.78	9.9	7.39	4.4	3.12
ROD	1000 TON	2.1	2.36	1.0	0.71	0.8	0.86	4.7	2.49
INPUTS									
LC	number of shifts per month	336.4	206.13	344.0	140.28	251.0	49.90	439.8	306.94
LE	number of shifts per month	339.4	161.40	207.5	93.11	400.4	193.44	374.0	75.70
NP	number of men per month	22.3	12.45	13.8	1.48	17.7	2.26	35.5	14.72
GI	1000 PTAS deflated	24,534.2	8445.04	21,961.4	5,485.22	20,573.2	3,556.72	31,832.1	10192.23
GK	1000 PTAS deflated	12,985.4	7728.52	6,063.2	429.87	11,043.0	3,939.85	21,416.1	7119.51
K	M^2	61,484.4	11758.16	63,971.8	7,892.25	57,530.6	2,597.86	64,435.8	18481.79
EXPENDITURE									
GLC	1000 PTAS deflated	17,964.1	8563.95	13,113.6	6,826.70	14,463.6	3,592.70	26,622.4	7979.02
GLE	1000 PTAS deflated	21,447.9	12515.12	18,759.9	6,911.54	20,738.9	9,453.66	24,663.6	17967.74
GNP	1000 PTAS deflated	10,410.9	4445.34	6,675.4	935.40	8,901.0	823.27	15,554.1	4376.25

TABLE 2: Distance System Estimated

Variable	Coefficient	Standard Error	t-Statistic	Variable	Coefficient	Standard Error	t-Statistic
L(CONT)	-0,2216	0,0289	-7,6478 **	**L(ROD).L(GK)**	0,0002	0,0001	1,3515
L(MG)	-0,0102	0,0043	-2,3474 **	**L(ROD).L(NP)**	-0,0001	0,0002	-0,9292
L(ROD)	-0,0137	0,0049	-2,7953 **	**L(LC).L(LC)**	0,0094	0,0105	0,8928
L(LC)	0,0505	0,0231	2,1871 **	**L(LC).L(NP)**	-0,0080	0,0035	-2,2556 **
L(LE)	0,1536	0,0187	8,1828 **	**L(LC).L(LE)**	0,0475	0,0097	4,8550 **
L(GI)	0,1625	0,0363	4,4773 **	**L(LC).L(GK)**	-0,0164	0,0028	-5,7865 **
L(K)	-0,2979	0,1075	-2,7698 **	**L(LC).L(GI)**	-0,0325	0,0040	-8,0850 **
L(GK)	0,0778	0,0325	2,3892 **	**L(LC).L(K)**	0,0199	0,0299	0,6642
L(NP)	0,5553	0,0414	13,4016 **	**L(LE).L(LE)**	0,0451	0,0159	3,5864 **
L(CONT).L(CONT)	-0,2015	0,0513	-3,9234 **	**L(LE).L(NP)**	-0,0112	0,0028	-3,9112 **
L(CONT).L(MG)	0,0073	0,0053	1,3717	**L(LE).L(GK)**	-0,0283	0,0024	-11,7313 **
L(CONT).L(ROD)	-0,0037	0,0034	-1,0943	**L(LE).L(GI)**	-0,0531	0,0041	-12,9357 **
L(CONT).L(LC)	-0,0193	0,0115	-1,6763 *	**L(LE).L(K)**	0,0748	0,0279	2,6755 **
L(CONT).L(LE)	0,0318	0,0142	2,2260 **	**L(GI).L(GI)**	0,1714	0,0036	46,9350 **
L(CONT).L(GI)	0,0010	0,0057	0,1808	**L(GI).L(NP)**	-0,0405	0,0030	-13,3161 **
L(CONT).L(K)	-0,3954	0,1644	-2,4045 **	**L(GI).L(GK)**	-0,0452	0,0024	-18,5634 **
L(CONT).L(GK)	-0,0078	0,0036	-2,1473 **	**L(GI).L(K)**	-0,0166	0,0123	-1,3461
L(CONT).L(NP)	-0,0057	0,0048	-1,1872	**L(K).L(K)**	-0,0389	0,5654	-0,0688
L(MG).L(MG)	-0,0010	0,0005	-1,8809 *	**L(K).L(GK)**	-0,0376	0,0083	-4,5322 **
L(MG).L(ROD)	-0,0000	0,0002	-0,0502	**L(K).L(NP)**	-0,0400	0,0080	-5,0236 **
L(MG).L(LC)	-0,0006	0,0009	-0,6563	**L(GK).L(GK)**	0,1034	0,0025	39,9988 **
L(MG).L(LE)	0,0004	0,0009	0,4456	**L(GK).L(NP)**	-0,0134	0,0023	-5,8078 **
L(MG).L(GI)	0,0007	0,0004	1,7288 *	**L(NP).L(NP)**	0,0733	0,0040	18,2330 **
L(MG).L(K)	-0,0304	0,0270	-1,1224	D_{T92}	0,0175	0,0247	0,7088
L(MG).L(GK)	0,0001	0,0002	0,8142	D_{T93}	0,0420	0,0475	0,8835
L(MG).L(NP)	-0,0006	0,0007	-0,9326	D_{T94}	0,0128	0,0582	0,2196
L(ROD).L(ROD)	-0,0021	0,0004	-4,6394 **	D_{T95}	0,0116	0,0666	0,1754
L(ROD).L(LC)	-0,0030	0,0008	-3,3630 **	D_{T96}	-0,0750	0,0738	-1,0160
L(ROD).L(LE)	0,0025	0,0009	2,6793 **	D_{T97}	-0,1189	0,0821	-1,4486
L(ROD).L(GI)	0,0004	0,0003	1,1881	D_{T98}	-0,1128	0,0915	-1,2325
L(ROD).L(K)	0,0505	0,0419	1,2050	D_{T99}	-0,0256	0,1039	-0,2472

* statistically significant at 10%
** statistically significant at 5%

TABLE 2: Distance System Estimated (Cont.)

TABLE 2 (Cont.)

Equation	Mean	R^2	Std. Error of Regression
Input distance function	--	--	0.0577
Ordinary worker share equation	0.2075	0.7410	0.0392
Special worker share equation	0.2461	0.8349	0.0395
Intermediate consumption share equation	0.2854	0.8990	0.0155
Capital share equation	01422	0.9651	0.0101
Non port worker share equation	0.1186	0.7721	0.0101

TABLE 3: β_{pt} Components (from Equation 3)

Parameters	Coefficients	Standard Error	t-statistic
β_{1A}	0,159941	0,078047	2,049290**
β_{1B}	0,000651	0,003996	0,162924
β_{1C}	0,000066	0,000037	1,793460*
β_{2A}	-0,134641	0,030852	-4,364070**
β_{2B}	0,008407	0,002469	3,405080**
β_{2C}	-0,000069	0,000022	-3,138940**
β_{3A}	-0,033355	0,078092	-0,427119
β_{3B}	-0,014350	0,004150	-3,457850**
β_{3C}	0,000191	0,000038	5,074150**

TABLE 4: A_{ipt} Components (from Equation 4)

Parameters	Coefficients	Standard Error	t-Statistic
α_{LC1A}	0,40593	0,04407	9,20993 **
α_{LC1B}	-0,00747	0,00175	-4,24704 **
α_{LC1C}	0,00004	0,00001	2,49251 **
α_{LC2A}	0,29493	0,03167	9,31045 **
α_{LC2B}	-0,00545	0,00058	-9,28886 **
α_{LC2C}	0,00003	0,00000	7,08032 **
α_{LC3A}	0,18591	0,03957	4,69835 **
α_{LC3B}	0,00126	0,00134	0,93461
α_{LC3C}	-0,00001	0,00001	-1,11926
α_{LE1A}	-0,19536	0,04448	-4,39217 **
α_{LE1B}	0,01137	0,00184	6,16482 **
α_{LE1C}	-0,00008	0,00001	-5,32444 **
α_{LE2A}	-0,01374	0,02560	-0,53665
α_{LE2B}	0,00496	0,00078	6,34155 **
α_{LE2C}	-0,00003	0,00000	-5,31448 **
α_{LE3A}	0,06135	0,03272	1,87487 *
α_{LE3B}	-0,00145	0,00100	-1,44446
α_{LE3C}	0,00001	0,00001	1,39342
α_{GI1A}	0,15668	0,03752	4,17539 **
α_{GI1B}	-0,00222	0,00055	-4,00701 **
α_{GI1C}	0,00002	0,00000	4,38919 **
α_{GI2A}	0,12033	0,03686	3,26461 **
α_{GI2B}	0,00007	0,00025	0,28905
α_{GI2C}	0,00000	0,00000	0,44014
α_{GI3A}	0,09818	0,03989	2,46107 **
α_{GI3B}	0,00095	0,00051	1,85248 *
α_{GI3C}	-0,00001	0,00001	-1,60063
α_{NP1A}	-0,44170	0,04121	-10,7165 **
α_{NP1B}	-0,00049	0,00045	-1,09709
α_{NP1C}	0,00001	0,00000	1,80670 *
α_{NP2A}	-0,45220	0,04241	-10,66180 **
α_{NP2B}	0,00042	0,00014	2,91068 **
α_{NP2C}	-0,00001	0,00001	-1,63180
α_{NP3A}	-0,39332	0,04236	-9,28417 **
α_{NP3B}	-0,00163	0,00045	-3,60950 **
α_{NP3C}	0,00001	0,00001	3,61833 **

TABLE 5: Average values for Coefficients k_{ij}

Coefficients	Mean[a]	t-Statistic
$k_{\text{Ordinary Worker, Special Worker}}$ $k_{LC,LE}$	0.3929	3.5135 **
$k_{\text{Ordinary Worker, Intermediate Consumption}}$ $k_{LC,GI}$	0.4249	2.5035 **
$k_{\text{Ordinary Worker, Capital}}$ $k_{LC,GK}$	0.4697	1.6714 *
$k_{\text{Ordinary Worker, Non Port Worker}}$ $k_{LC,NP}$	0.0527	39.2502 **
$k_{\text{Special Worker, Intermediate Consumption}}$ $k_{LE,GI}$	1.0813	0.2524
$k_{\text{Special Worker, Capital}}$ $k_{LE,GK}$	1.1953	0.3754
$k_{\text{Special Worker, Non Port Worker}}$ $k_{LE,NP}$	0.1343	52.4705 **
$k_{\text{Intermediate Consumption, Capital}}$ $k_{GI,GK}$	1.1053	0.1815
$k_{\text{Intermediate Consumption, Non Port Worker}}$ $k_{GI,NP}$	0.1242	31.5706 **
$k_{\text{Capital, Non Port Worker}}$ $k_{GK,NP}$	0.1123	18.8735 **

[a] Evaluated at the means of the data using parameter estimates of (8)-(9).

Note: We have tested the significance of the indices using the Wald test.

* statistically significant different from one at 10% level

** statistically significant different from one at 5% level

TABLE 6: Time Effects

Period	TC[a]	t-Statistic
1991-1992	0.0175	0.7088
1992-1993	0.0245	0.8252
1993-1994	-0.0292	-1.6602 *
1994-1995	-0.0011	-0.0645
1995-1996	-0.0867	-4.4513 **
1996-1997	-0.0439	-1.8896 *
1997-1998	0.0061	0.2014
1998-1999	0.0871	2.4701 **

[a] Evaluated at the means of the data using parameter estimates of (8)-(9).
Note: We have tested the significance of the indices using the Wald test.
* statistically significant at 10%
** statistically significant at 5%

FIGURES

Figure 1: Temporal Pattern of Technical Efficiency for the three Terminals

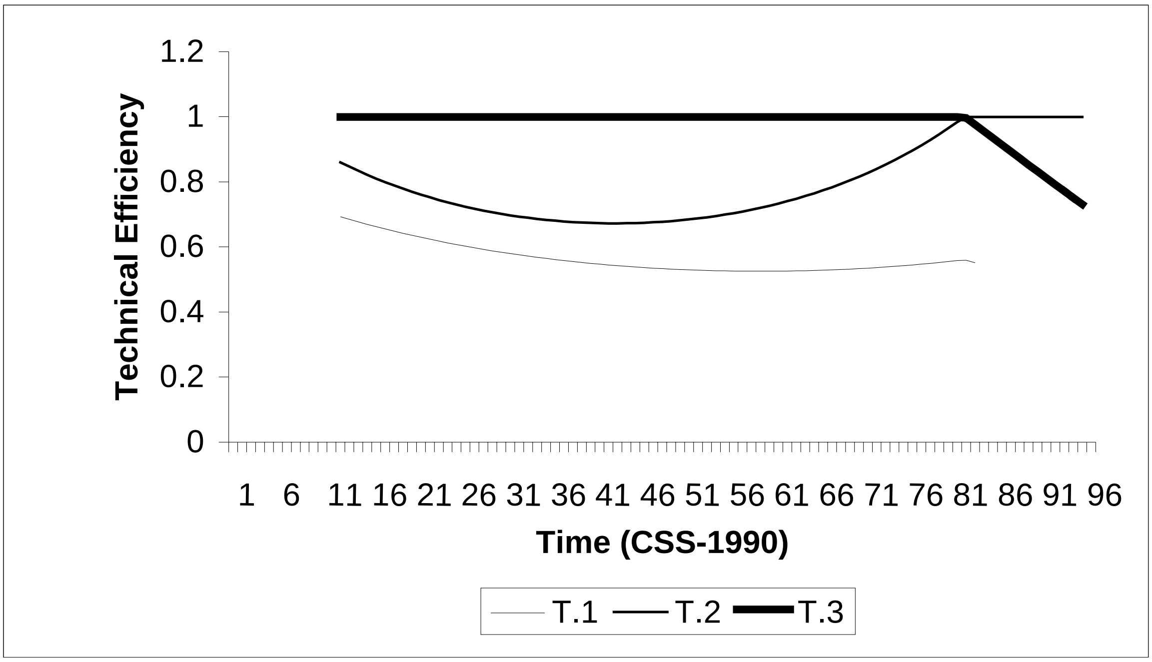


Figure 2: Technical efficiency score considering the best observation as the reference technology

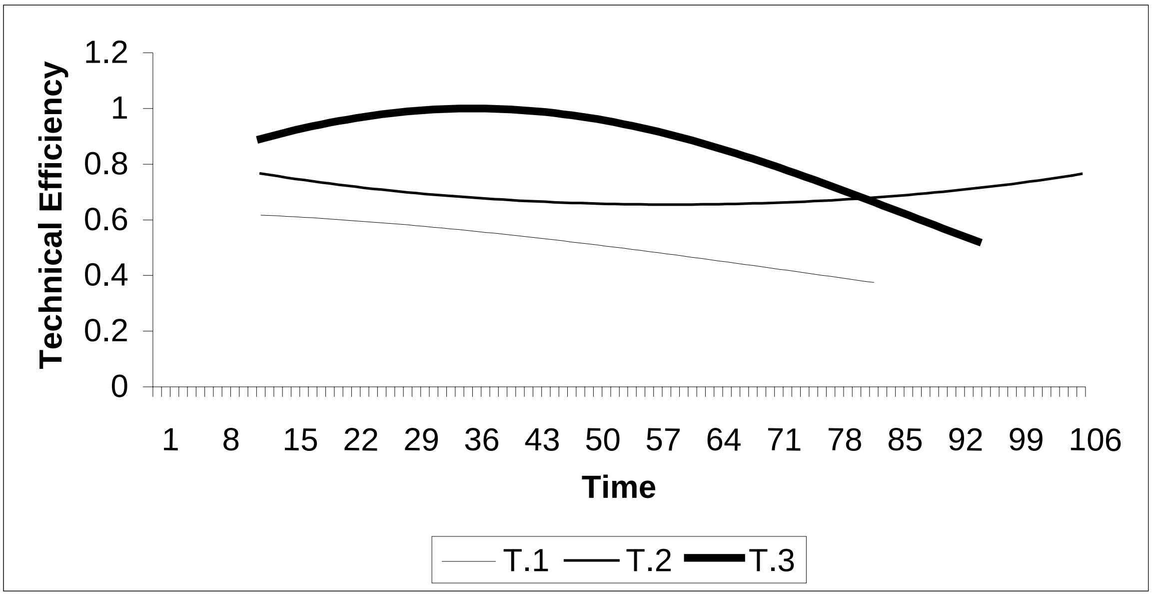


Figure 3: Firm Specific Temporal Pattern of Allocative Inefficiencies for LC (Error Components Approach)

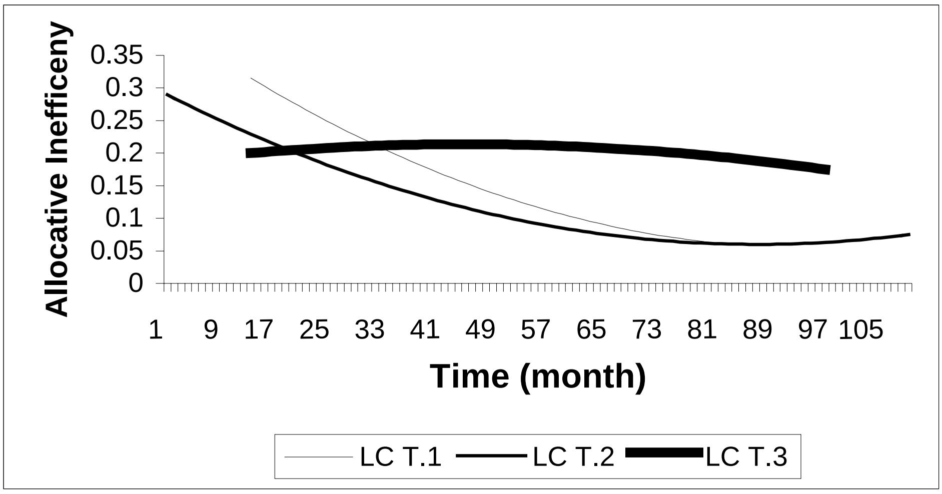


Figure 4: Firm Specific Temporal Pattern of Allocative Inefficiencies for LE (Error Components Approach)

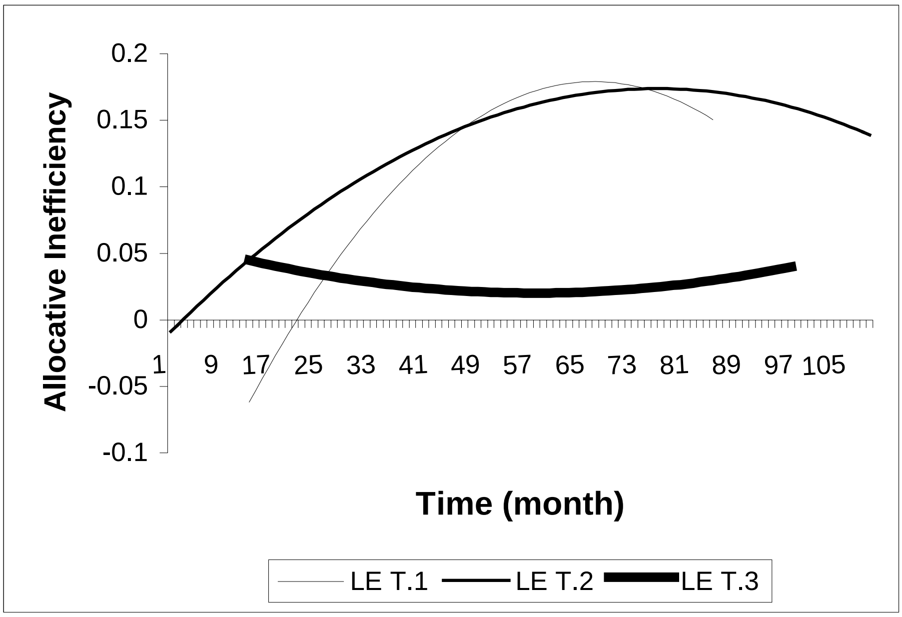


Figure 5:Firm Specific Temporal Pattern of Allocative Inefficiencies for NP (Error Components Approach)

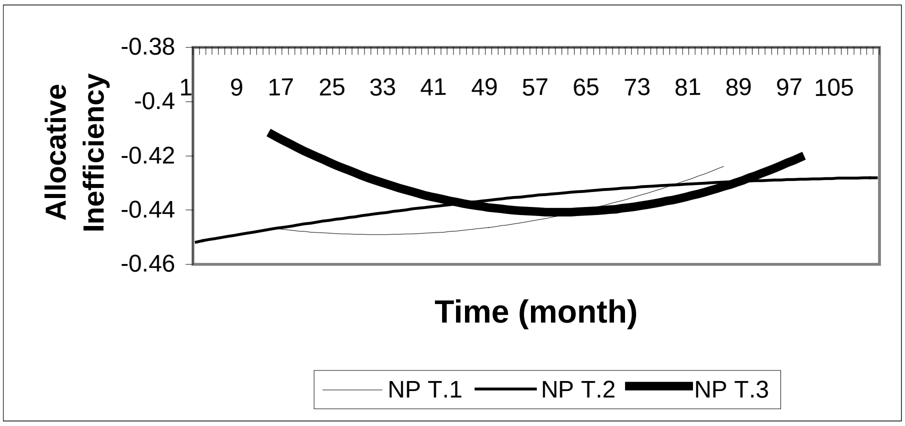


Figure 6: Firm Specific Temporal Pattern of Allocative Inefficiencies for GI (Error Components Approach)

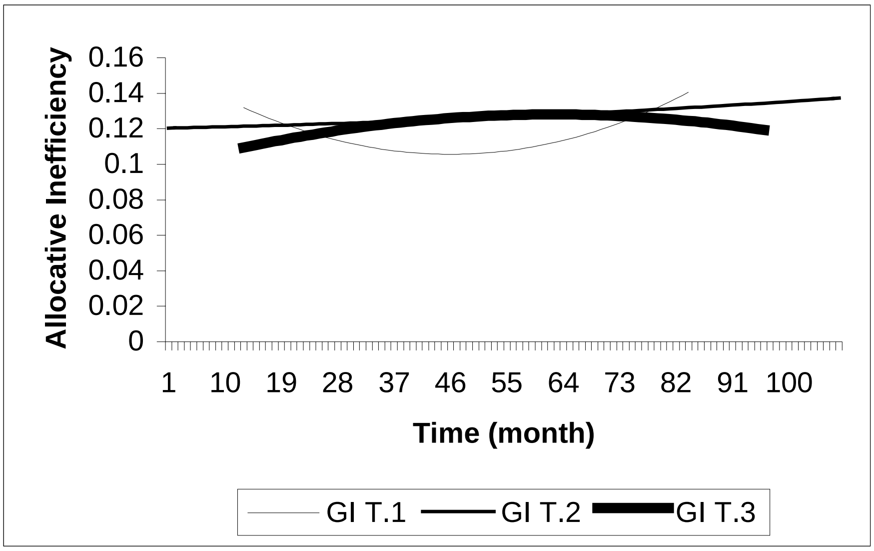


Figure 7: Firm Specific Temporal Pattern of Allocative Inefficiencies for GK (Error Components Approach)

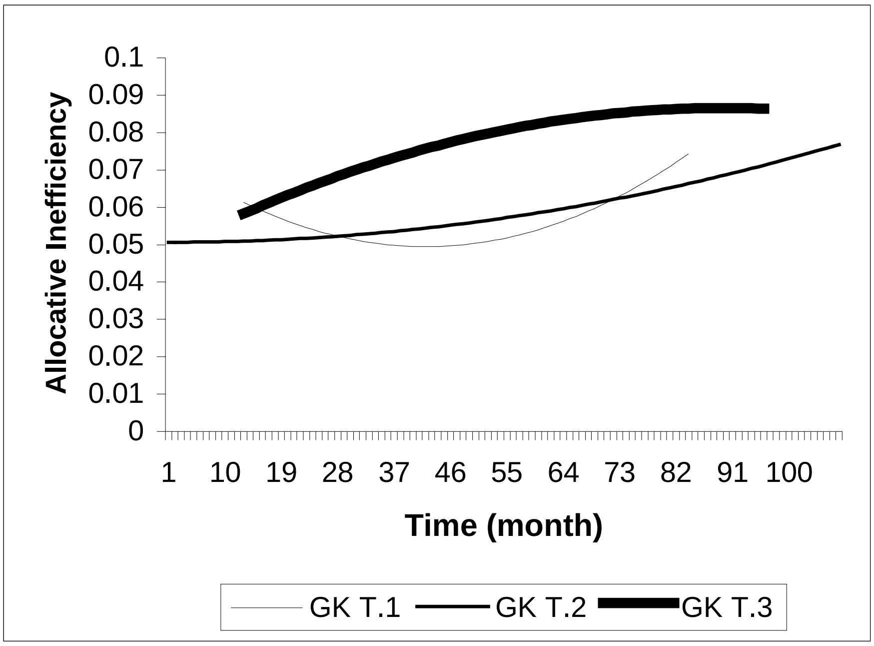
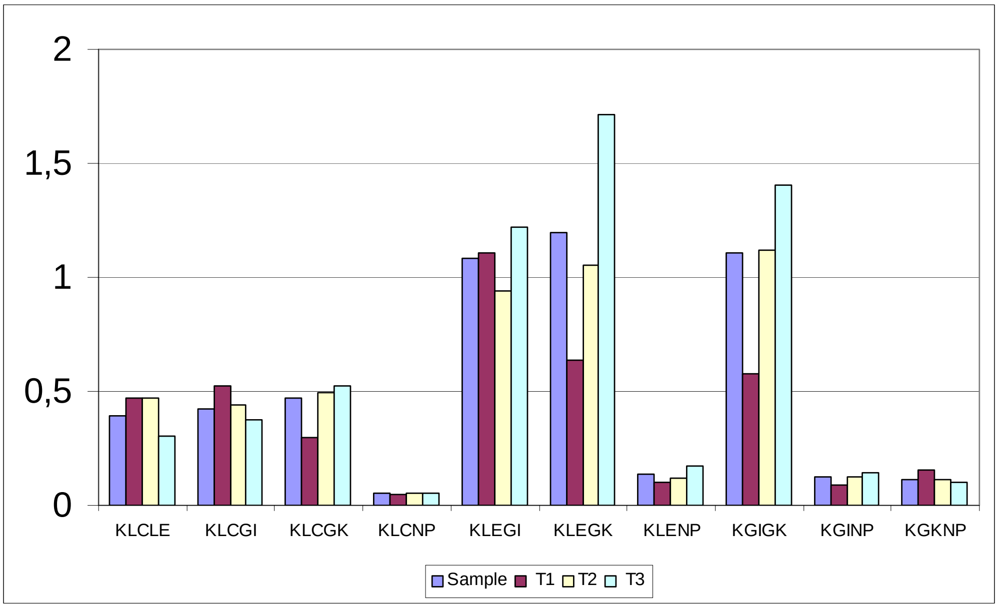


Figure 8: Average Firm Allocative Inefficiencies for each pair of inputs (Parametric Approach)



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