ECONOMETRIC ANALYSIS OF HIGHWAY CONSTRUCTION TECHNOLOGY

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1. INTRODUCTION

Economic analyses of highway construction, its production structure and productivity, have been rare because of the complexity of the industry's production process. In recent years the efficiency demands for government actions have stimulated a large interest in economic studies of regulated industries and also of road construction.

Most studies have relied on scant aggregate data and assumed, a priori, economies of scale to be constant. Walters (1), Meyer, Kain, and Wohl (2) and particularly Keeler and Small (3) have considered the highway construction technology, but only Keeler and Small allowed for economies of scale with a Cobb-Douglas type mathematical form of the cost function.

In the present paper the translog cost function is used. It was introduced to econometric literature by Christensen, Jorgenson, and Lau in the 1970's and since then used in many fields of economic analysis. Spady and Friedlaender (4) and Wang Chiang and Friedlaender (5) have used it to analyse the production structure and economies of scale and scope in the US regulated trucking industry; Tauchen, Fravel, and Gilbert (6) to evaluate the economies of scale in intercity bus industry; Berechman (7) to study the production process of urban bus transit; and Talvitie and Bäckström (8) to analyse the production process of nationwide bus transit.

After defining the functional form (in chapter II) and the data (chapter III), this paper tests for separability of the cost function (chapter IV), analyzes output aggregation possibilities (chapter V), evaluates the elasticities of substitution (chapter VI) and price elasticities between factors of production (chapter VII), tests for economies of scale and scope (chapter VIII), analyzes general differencies between regions and the nature of technical change (chapter IX), and concludes with policy implications (chapter X).

Finland Highway and Waterways Administration (TVH), the source of the data in the study, is a typical state highway agency and consists of the Central Administration and of 13 Highway Regions. The Central Administration issues guidelines, prepares policies, develops standards and handles negotiations and interface with the Ministry of Transportation and the Parliament. The Regions execute the program and policies.

2. TRANSLOG COST FUNCTION

Translog cost function is a flexible mathematical form which offers a second order approximation to an unknown production function. It is called flexible bacause it places very few a priori restrictions on the underlying production technology and because it characterizes all the relevant properties of neoclassical production theory: economies of scale, factor substitution and tehnological change.

For highway construction the cost function has the following general form:

$$\text{Total costs} = f(P,Y,M,T,D)$$

where P represents the vector of factor prices, Y the vector of output, M the vector of management variables, T stands for trend, and agency dummy variables D are included to represent region specific factors.

In the general translog form the above model becomes:

$$(1) \quad \ln C(\ln P_i, \ln Y_j, \ln M_k, \ln T, D_i) = a_0 + \Sigma a_i \ln P_i + \Sigma b_j \ln Y_j + \Sigma c_k \ln M_k + 1/2(\Sigma\Sigma d_{ij} \ln P_i \ln P_j + \Sigma\Sigma e_{ij} \ln Y_i \ln Y_j + \Sigma\Sigma f_{kl} \ln M_k \ln M_l) + \Sigma\Sigma g_{ij} \ln P_i \ln Y_j + \Sigma\Sigma h_{ik} \ln P_i \ln M_k + \Sigma\Sigma m_{jk} \ln Y_j \ln M_k + n_T \ln T + 1/2 n_{TT} (\ln T)^2 + \Sigma p_{iT} \ln P_i \ln T + \Sigma s_i D_i + \epsilon.$$

The symmetry conditions ($d_{ij}=d_{ji}$, $e_{ij}=e_{ji}$ and $f_{kl}=f_{lk}$), and the homogeneity restrictions ($\Sigma a_i=1$, $\Sigma_j d_{ij}= \Sigma_j g_{ij}= \Sigma_k h_{ik}=\Sigma p_{iT}=0$ $\forall i$) are imposed.

Input cost share equations are obtained by Shephard's lemma:

$$S_i = \frac{X_i p_i}{C} = \frac{\delta C}{\delta p_i}\frac{p_i}{C} = \frac{\delta \ln C}{\delta \ln p_i} \qquad (X_i = \text{quantity of input } i)$$

$$(2) \quad S_i = a_i + \tfrac{1}{2}\Sigma d_{ij} \ln P_j + \Sigma g_{ij} \ln Y_j + \Sigma h_{ik} \ln M_k + p_{iT} \ln T.$$

3. THE DATA

The data consist of the regions' annual time series data from 1978 to 1987 and of over 100 recently completed highway projects with project duration from 1-4 years.

Since road construction can be viewed as acquiring, moving, disposing, and treating materials, the volume of this work, measured in m^3, is defined as output. In order to test for a multiproduct production process, four separate classes according to the road width (<6.5m, 7-8.5m, >9m and "other") are specified to reflect the possibility of four different production technologies.

The output class labeled "other" includes small "lump sum" projects for improving traffic safety, bicycle or walk ways, minor road side or rest area projects and the like.The input prices include wages, capital service, haulage, and material.

There are three management variables over which the highway agency, or management of a project, is considered to have control. The effects on costs of **speed of construction**, measured as cubic meters per number of projects in a given year, and of the **percentage of contract work** both give valuable information of past decisions and to future planning. The amount of **own fixed manpower** is defined as the third management variable, which, in the short run, is often beyond the management's control. Several other variables were tried.

The cross-section and time-series data are pooled together for estimation, using Zellner's seemingly unrelated regressions. The cost function is estimated jointly with cost share equations less one.

4. HYPOTHESIS TESTING

Hypothesis testing is a central part of model development. The translog mathematical form is a flexible tool because it allows the testing of several different underlying production technologies, from a non-homothetic and non-joint technology to the classical Cobb-Douglas functional form, in addition to the conventional tests of input substitution, economies of scale and scope, separability and the nature of technical change.

In most econometric studies data availibility makes disaggregation of variables impossible. A necessary condition for variable aggregation is separability of the elements within the aggregate from those outside of it. In other words, separability implies that marginal rates of transformation between pairs of factors to be aggregated are independent of the levels of factors outside that group, or mathematically:

$$\frac{\delta MRT_{ij}}{\delta x_k} = 0, \text{ where } MRT_{ij} = \frac{\delta C/\delta x_i}{\delta C/\delta x_j}.$$

Separability makes multiphase estimation possible and thus allows the handling of several variables. Separability is also a necessary condition for decentralization and delegation of decision making.

For derivation and proofs of the parameter restrictions for approximative separability in the translog function see e.g. Denny and Fuss (9).

4.1 Separability tests

The hypothesis testing was commenced by the sufficient conditions, i.e. the strong separability tests, and if these are rejected, continued with the tests for weak separability.

The analysis of highway construction technology was begun by studying whether input prices were strongly separable from management variables, which imply the following parameter restrictions to the cost equation (1):

$$h_{ik} = 0 \quad \forall i,k.$$

The hypothesis was accepted ($F(11,252)=0.565 < F^*=1.80$). The result implies that the share equations are independent of the management variables and vice versa, as the condition can be written alternatively as $h_{ik}=\delta S_i/\delta \ln M_k=0$. In practice this means that e.g. the speed of construction has no effect on the marginal rates of substitution between inputs, or that the substitution possibilities between factors of production are independent of the speed of construction, the percentage of contract work, or the amount of fixed manpower.

The next step was to test for strong separability between input prices and outputs. The parameter restrictions are:

$$g_{ij} = 0 \quad \forall i,j.$$

The hypothesis was accepted ($F(10,252)=0.234 < F^*=1.83$).

At this stage the cost function can be written in the general form: $\ln C = f(\ln Y_j, \ln M_k) + g(\ln P_i)$. The production process of highway construction is thus homothetic, i.e. the growth path of production is a ray through origin and the cost share equations are independent of the level of outputs:

$$g_{ij}=\delta S_i x \qquad x/\delta \ln Y_j=0.$$

Homotheticity implies also that scale economies are a function of the output levels and management variables only. Scale economies do not depend on the relative changes in input quantities or prices. From the highway agency's point of view, the result is not a good one because decisions of the level of outputs are often beyond the agency's control.

As to strong separability between outputs and management, the cost function can be written: $\ln C = f(\ln Y_j) + g(\ln M_k) + h(\ln P_i)$ which implies the following additional restrictions:

$$m_{jk} = 0 \quad \forall j,k.$$

This hypothesis was rejected ($F(12,252)=5.06 > F_*=1.80$) as was the equivalent hypothesis of weak separability ($F(5,252)=3.92 > F_*=2.21$). The latter hypothesis has the following general functional form: $\ln C = f(G(\ln Y_j), \ln M_k) + h(\ln P_i)$ and the parameter restrictions are:

$$m_{ik}b_j = m_{jk}b_i \quad i,j = \text{output pairs}$$
$$m_{ik}e_{sj} = m_{jk}e_{si} \quad i,j \neq s.$$

The results imply that in road construction, decisions made on the speed of construction, percentage of contract work and the amount of fixed manpower are related to the level of output. These two factors should be optimized simultaneously, possibly in the highway agency's regional office.

Thus far the maintained hypothesis is of the form: $\ln C = f(\ln Y_j, \ln M_k) + g(\ln P_i)$. In other words, input prices are strongly separable from both outputs and management but outputs are neither strongly nor weakly separable from management. This also means that a consistent input aggragate can be formed but outputs cannot be aggregated into a whole.

4.2 Partial aggregation tests

It is possible, however, that two or more outputs are partially separable from management. Two or more outputs can have a common production technology and they can form a consistent output aggregate. In theory outputs could be aggregated in several ways but in practice there are only a few intuitively and technically relevant possibilities.

The testing was commenced by studying if width classes 2 and 3 (7-8.5m and >9m) or 1 and 4 (<6.5m and other) could be aggregated by a translog index of the form: $\ln Y_{ij} = \Sigma b_j \ln Y_j + \Sigma\Sigma d_{ij} \ln Y_i \ln Y_j$ (where $i,j = 2,3$ or $1,4$). If either one of these tests is accepted, one more class is added.

The conditions for partial strong separability are:

$m_{rk} = 0$ and $e_{rj} = 0$ (where r = 2,3 or 1,4, r=j)

and for weak separability:

$$m_{ik}b_j = m_{jk}b_i \quad (i,j = \text{output pairs})$$
$$m_{ik}e_{sj} = m_{jk}e_{si} \quad (s \neq i,j)$$
$$e_{is}b_j = e_{sj}b_j.$$

Every aggregation possibility of outputs was rejected. This implies that outputs cannot be aggregated in a consistent way and that an efficiency analysis based on cost differentials should take the output proportions into account. The highway agency can be viewed as a multi-product firm, where decisions about the construction program and volume, the amount of own labor, and the speed of construction should be done jointly, and rather by the regional than the central management.

4.3 Maintained hypothesis

In the maintained hypothesis input prices are strongly separable from outputs and management variables but outputs are not separable from management. The cost function is reduced to the form:

$$(3) \quad \ln C = a_0 + \Sigma a_i \ln P_i + \Sigma b_j \ln Y_j + \Sigma c_k \ln M_k + \tfrac{1}{2}(\Sigma\Sigma d_{ij} \ln P_i \ln P_j + \Sigma\Sigma e_{ij} \ln Y_i \ln Y_j + \Sigma\Sigma f_{kl} \ln M_k \ln M_l) + \Sigma\Sigma m_{jk} \ln Y_j \ln M_k.$$

With respect to factor share equations, the maintained hypothesis implies that the input cost shares depend only on the prices of other inputs but not on output levels or management variables:

$$S_i = a_i + \Sigma d_{ij} \ln P_j.$$

This means in practice that decisions concerning outputs and management can be done in the highway agency independently of the input market. It would be the concern of the Central Administration to ensure competitiveness and free entry in the market for factors of production.

The results and conclusions of the next chapters are evaluated using the maintained hypothesis.

4.4 Elasticities of substitution

The elasticity of substitution is a measure to analyze the dependencies among and of substitution between input factors. The higher the elasticity, assuming positive input quantities, the greater the interchangeability is. In the present four factor model, the Allen partial elasticities substitution, σ_{ij}, are calculated from:

$$\sigma_{ij} = \frac{a_{ij} + S_i S_j}{S_i S_j}$$

where S_i is the factor share derived by Shephard's lemma. If $\sigma_{ij}>0$, the inputs are substitutes, if $\sigma_{ij}<0$, they are complementary and if $\sigma_{ij}=0$, they are used in fixed proportions in the production process. The results for TVH are shown in Table 1.

Table 1: Elasticities of substitution

Parameter	Value	S.D.
$\sigma12$	0.72	0.024
$\sigma13$	0.65	0.047
$\sigma14$	0.84	0.024
$\sigma23$	0.84	0.016
$\sigma24$	0.66	0.072
$\sigma34$	0.54	0.058

1=labor
2=capital
3=haulage
4=material
S.D.=standard deviation

All inputs in road construction are substitutes as every σ_{ij} is positive. The ease of substitution is relatively small. It reaches the minimum value between haulage and material (σ_{34}), and the maximum between labor and material (σ_{14}) and between capital and haulage (σ_{23}).

The elasticities of substitution are, however, significantly different from zero, which implies that the inputs are not used in fixed quantities in the production process. The elasticities are also statistically different from one. The results imply that a production structure of Leontief type is not prevailing in highway construction and that a Cobb-Douglas production function is not sufficient to reflect road construction technology.

4.5 Price elasticities

The price elasticity Eij of an input tells how a 1% change in the price of input i affects the demand for input j:

$$E^i_j = \frac{dX_j/X_j}{dP_i/P_i} = \frac{\delta \ln X_j}{\delta \ln P_i}.$$

Allen (10) has shown that the price elasticity E_{ij} can be calculated as the product of elasticity of substitution and cost share: $E_{ij} = S_j \sigma_{ij}$. The price elasticities of road constuctions are in Table 2.

Table 2: Price elasticities E_{ij} (standard deviation)

	labor	capital	haulage	material
labor	-0.16 (0.009)	0.24 (0.024)	0.21 (0.027)	0.27 (0.024)
capital	0.19 (0.018)	-0.15 (0.009)	0.22 (0.017)	0.18 (0.029)
haulage	0.16 (0.031)	0.20 (0.030)	-0.13 (0.015)	0.14 (0.018)
material	0.13 (0.024)	0.11 (0.026)	0.09 (0.020)	-0.09 (0.016)

All inputs are normal products in road construction, i.e. their demand decreases as the price increases ($E_{ii}<0$). The elasticities are, however, relatively near zero, which implies that the input demand responds rather rigidly to price changes. The cross price elasticities are also rather small, which implies that the increase in demand for input j caused by a 1% price raise in input i is small.

5. ROLE OF MANAGEMENT

The impact a management has on costs was studied by calculating the elasticity of costs with respect to management variables: $m_k=\delta lnC/\delta lnM_k$. The results are in Table 3. The effect of the speed of construction on total costs is important: 1% increase in the speed would reduce costs in every agency being 0.28% on average. The product completion time and the annual number of projects should be reduced in every region.

The positive cost elasticity with respect to the share of contract work is against intuition because competition in the construction market is most likely to decrease total costs, ceteris paribus. It is possible that the variable acts as a proxy for a phenomenon that is not represented in the function or that it is strongly multi-collinear with another variable in the model. For example, as the share of contract work rises, the fixed manpower of an agency is not efficiently employed and as a consequence total agency costs do not decrease. On the other hand, the data indicate that as the volume of work has increased with time, total costs as well as the percentage of contract work have increased. Other studies done by the TVH indicate that competition is beneficial to the agency.

Table 3: Cost elasticities of management variables:

Region name	m1	m2	m3
Uusimaa	-0.21	0.55	-0.38
Turku	-0.32	0.35	1.63
Häme	-0.29	0.72	0.18
Kymi	-0.30	0.38	1.33
Mikkeli	-0.25	0.54	1.09
P-Karjala	-0.24	0.66	1.21
Kuopio	-0.35	0.68	1.02
K-Suomi	-0.20	0.59	0.50
Vaasa	-0.21	0.56	0.45
K-Pohjanmaa	-0.19	0.51	1.78
Oulu	-0.26	0.58	1.20
Kainuu	-0.38	0.71	1.03
Lappi	-0.40	0.56	0.45
Mean	-0.28	0.57	0.88
st.dev.	0.11	0.22	0.69

m1=speed of construction
m2=% of contract work
m3=no. of fixed manpower

An increase of 1% in the amount of fixed manpower raises total costs 0.88% on the average whereas the share of labor is about 35% of the costs. The elasticity of costs with respect to the fixed amount of labor is very elastic, it is inelastic only in one region. The negative elasticity in one region is most probably explained by the region's possibility to use "trust" prisoners at low pay instead of hiring from the labor market.

6. SPECIAL FEATURES OF HIGHWAY PRODUCTION

The practical purpose of this paper is to reveal some special features of road construction technology. Until now the index number calculations used for efficiency comparisons in the TVH assume constant returns of scale. And the possible (dis)economies of scale in highway construction have not been studied thus far.

6.1 Economies of scale

As in some other regulated industries, e.g. in trucking industry (Wang Chiang and Friedlaender (5)), it is most probable that highway construction does not exhibit constant returns to scale over the whole range of output levels. The knowledge whether or not there are economies of scale would have strong impacts on government's construction policy and the organization of a highway agency. With scale economies, big construction projects would be the most efficient and the speed of construction would have a crucial role in the highway agency's productivity. On the other hand, if the industry faces diseconomies of scale, the appropriate construction policy would imply small project size and slow construction phase.

From the translog cost function in equation (3), the measure of cost efficiency, the reciprocal of scale elasticity, is calculated by summing the elasticities of cost with respect to each output type i:

$$\mu = \Sigma\left[\frac{\delta C/C}{\delta y_i/y_i}\right] = \Sigma\left[\frac{\delta \ln C}{\delta \ln Y_i}\right]$$

$$= \Sigma(b_j + \Sigma e_{ij}\ln Y_i + \Sigma m_{jk}\ln M_k).$$

$\mu \leq \geq 1$ implies there are diminishing, constant, or increasing economies of scale. At the grand sample mean, the multiproduct cost elasticity is 0.65 indicating important economies of scale. The measure of scale elasticity seems to grow almost linearly with region's output volume: at 600,000 annual cubic meters μ=0.3 approximately, whereas for the biggest regions of 3,000,000 cubic meters μ approaches 0.7. The result indicates that there are far too many (construction) regions (in Finland) as every region is operating on a too low scale.

It is evident that road construction is not efficient on a small scale. The optimum "firm" size is about 4 million cubic meters, for smaller volumes marginal costs are less than average costs. This implies that 4-5 regions, instead of the actual 13, would be enough to share the 16 million cubic meters of road constructed annually in Finland, assuming the present product mix.

There are many reasons for economies of scale to be present in highway construction. The indivisibility of factors of production, especially of capital equipment but also of labor, causes problems up to a certain project size. Special machines are more efficient than more general ones. A wide road might be easier to construct per road width because more efficient machines require less labor input. Many small projects require much supervision work or time is spent travelling between projects.

It is, however, difficult for the agency to reach the optimal level of output (in Finland). As the cost function is homothetic, i.e. strongly separable in input prices and output levels, changes in input quantities or prices do not affect the economies of scale. It follows that it is impossible for the agency to reach the optimum if it cannot decide its level of outputs, the annual number of highway projects or the amount of (own fixed) labor force; and these all are regulated to some extent by the legislature. The number of highway regions in the country is also beyond the TVH's control.

Yet, in the long run, the only efficient means of action for the region management are the management variables. The model reveals that even a small decrease in the amount of labor increases the cost efficiency of the region both directly and indirectly via more effective use of labor in the production process.

Acceleration of project completion time means cost savings. In an other study (TVH (11)) it has been shown that a project could and should be constructed 30% more rapidly than is actually done. This would reduce total agency costs by 10-12 per cent annually. The results of this paper confirm this finding. These two factors, the amount of labor and the speed of construction, should be a part of the region's authority to decide. The Central Administration should concentrate its efforts to ensure competitiveness in the market for factors of production instead of detailed management of the production process.

6.2 Product specific economies of scale

It is also possible to evaluate the economies of scale of a single product. Baumol (12) and Baumol, Panzar, and Willig (13) have shown that it can be done by comparing the cost elasticity of product j ($\delta \ln C/\delta \ln Y_j$) with its cost share. The results for road construction are in Table 4.

Table 4: Product specific economies of scale

Width class	Scale
1 (<6.5m)	0.36
2 (7-8.5m)	0.27
3 (>9m)	0.09
4 (other)	0.02

The relatively most important product specific economies of scale come from the production of width classes 3 and 4. It may, however, not be possible nor reasonable to increase the volume of output of the fourth class, which consists of safety and small "lump sum" projects, in order to exploit the growing economies of scale. But increases in the volume of the third class, which includes a.o. motorways, is possible and should be taken into account already in the planning process. There are also growing economies of scale in the production of the first and second width classes. In the whole, the volume of work in every region and every output class is far from optimum as to the scale of operation.

Economies of scale tells what technological advantages (disadvantages) occur from increases in the scale of production. It shows what is the optimum firm size for given output mix, but it does not indicate what combination of outputs is the most efficient.

6.3 Economies of scope

Economies of scope is an other production specific factor that should influence the management's decision making. Scope economies measure the possible cost advantage associated with joint production of many products. In our four output model economies of scope exist if the cost function is subadditive (see Baumol (12) and Baumol, Panzar and Willig (13) for a more thorough discussion):

$$C(y_1,y_2,y_3,y_4) < C(y_1,0,0,0) + C(0,y_2,0,0) + C(0,0,y_3,0) + C(0,0,0,y_4).$$

The degree of economies of scope, SC, is calculated from:

$$SC = (C(y_1,0,0,0) + C(0,y_2,0,0) + C(0,0,y_3,0) + C(0,0,0,y_4) - C(y_1,y_2,y_3,y_4)) / C(y_1,y_2,y_3,y_4).$$

If $SC<0$ the most efficient way of production would imply specialization in only one output type of the four road width classes. On the other hand, if $SC>0$ joint production is more efficient than specialization.

The measure of the degree of scope economies for TVH is -0.41 on the average. This indicates that joint production costs more than specialization to the production of one output. In other words, the cost function is not subadditive but $\Sigma C(Y_i) < C(y) = C(\Sigma Y_i)$. One reason for this surprising result is that the regions' actual product mixes and the annual number of projects are stipulated by the legislature. As the actual combination of outputs is not the result of an optimization procedure but the sum of projects approved by the legislature, the specialities of the production process have not influenced the combination of outputs.

The product-specific economies of scope associated with output type i, SC_i is given by

$$SC_i = \frac{C(Y_i,0) + C(0,Y_{N-1}) - C(Y)}{C(Y)},$$

where Y_i represents output type i and Y_{N-1} the set of outputs other than i. If $SC_i<0$, it is more efficient to produce output type i independently and the remaining in combination than to produce all output types together.

At the TVH grand sample mean the degree of product-specific economies of scope for output types 1 (<6.5m) and 3 (>9m) is zero. It is equivalently efficient to produce these width classes jointly or independently. On the contrary, specialization is profitable in the production of output classes 2 (7-8.5m) and 4 (others), SC_i being -0.35 and -0.41, respectively.

According to the region management, the product specific diseconomies of scope are most probably due to specialization of the labor force. A working group, constructing several two lane highway projects or specializating in safety projects, learns all the skills needed to do that work well. But the group does not get the experience to construct motorways and associated ramps (< 6.5m) as efficiently because the technology is different and changes rapidly. The results are important to regional management as they point toward the need for a flexible labor policy and for continuous training of labor.

7. REGION DUMMIES AND TREND

The purpose of the TVH cost function is to analyze the general characteristics of the production process of road construction. The translog index, derived from it, can be used in comparative evaluation of cost efficiency of the highway regions or of technological change in time. Region-specific differencies can also be evaluated in a general way using dummy variables, and the trend parameter gives a general idea of the technological change.

7.1 Region dummies

The 13 district-specific dummies were statistically significant as a group although most of the parameter specific t-tests showed that the value of the parameter was very probably zero. This means that there are only 2-3 regions that are significantly different from the reference region. As a whole it can be said that the geological, geographical, educational or other such factors are not relevant for the cost differencies between regions. The highway regions are relatively similar, and it is the differencies in output mix and level, in factor prices, and in management variables that explain the differencies in total costs.

7.2 Trend

It was a priori assumed that the trend variable is strongly separable from outputs and management variables. In translog cost function the second order terms of input prices and the trend measure the possible bias in technological change. Technological change is said to be input i saving (using) if the cost share of input i decreases (increases) with time. In the TVH cost function the bias in technological change is obtained by taking the derivative of a factor share equation with respect to the trend: $p_{iT} = \delta S_i / \delta \ln T$.

The results imply that the change in road construction technology has been biased. It has been labor saving (p_{1T}= -0.017) and capital using (p_{2T}=0.011), and haulage saving (p_{3T}=-0.02) and material using (p_{4T}=0.03). On the other hand there has been no pure technological change in highway construction but the value of the trend parameter alone is statistically insignificant.

8. CONCLUSIONS

The translog cost model suits well for the analysis of the highway construction technology: the R_2 is 0.98. The model gave new valuable information about road construction. For instance, the existence and importance of economies of scale was established, and the substitution possibilities of factors of production were shown to be relatively small. The TVH turned out to be a multi-product firm with a homothetic production process, i.e. independent of changes in the quantities of factors of production. Specialization in the construction process offers advantages as there are diseconomies of scope in the production of the most common road width class of 7-8.5m and of the "lump sum" category.

The results have several policy implications. From the agency's point of view, the results tell that an efficient cost structure is achieved by increasing the volume of output per highway region - by redefining the regions - and by operating with the management variables, i.e. by increasing the speed of construction, and by decreasing the amount of own labor force. The Central Administration should ensure the competitivenes of the factor markets and free entry to the market for contract offers, and decrease the rigidity of the labor market by encouraging movement of labor from one region to another.

Economies of scale and advantagess of specialization make the number of regions and the organizational structure in general an important issue in an Highway Administration. Larger region size enables efficient utilization of production factors, minimizes the harm from indivisibility of labor and capital and allows full advantages of specialization. Bigger project size is likely to induce contractors to innovate and develop the production methods. Finally, the results suggest that the traditional line organization could be less efficient than an organization where responsibilities are delegated to that level where management decisions can be still be made comprehensively. This means that program, project timing, labor and other resource, and agency personnel competence issues must be considered together.

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