Workplace Organization after Deregulation: Evidence from US Class I Railroads, 1982-2004 *

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Abstract

Following deregulation, the increase in intramodal competition forced railroads to reduce costs. One of the most striking restructuring measures was labor downsizing. Apart from this, railroads have also significantly restructured their human resources composition, and this has proven to generate operational efficiencies. To better understand and explain how these changes have been made, this paper presents a multi-input/output translog variable cost model with labor input divided by employee categories. This model enables us to estimate elasticities of substitution between these different employee categories and other inputs as well as cross- and own-price elasticities of labor demand for the post-deregulation period. I find that there is strong substitutability between some production and nonproduction employee categories, namely managerial positions and the transportation group, pointing to the achievement of better command and control of freight operations; a high degree of complementarity between the most skilled employee categories; I also find that the strongest substitute relationship is between the transportation and maintenance of ways&structures groups and that total labor does not form a consistent aggregate.

Keywords: matched worker/firm data,

JEL Classification Codes:

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1 Introduction

Deregulation returned US Class I Railroads to the competitive marketplace after nearly a century of tight government regulation. Since passage of the 1980 Staggers Railroad Act, the main regulatory reform, competitive pressures stimulated crucial changes in the way railroad companies thought about their operations, markets and customers. This resulted in more aggressive railroad managements and triggered changes in railroad corporate culture.

Competition forced railroad firms to reduce costs. As in virtually all transport sectors, labor costs represent a significant share of railroads production costs. This partially explains one of the most striking restructuring measures adopted by railroads: dramatic labor downsizing. Employment was reduced by 60% between 1981 and 2004. This rationalization of the labor force was possible thanks to, among other things, the abandonment of light density and unprofitable lines, merger procedures and the adoption of labor-saving technologies.[1]

Downsizing affected all railroad employee categories, but not in the same way. Overall, railroads undertook significant restructuring in the composition of their human resources and implemented important changes in their organizational forms. They got rid of an outdated century-old tradition of bureaucratic, hierarchical (or "militaristic") organizations in favour of a more aggressive, marketing-oriented type of management driven by the customers.

Railroad firms began to focus on customer satisfaction because they understood that, in this new deregulated environment, meeting customer service quality requirements was a prerequisite not only for profitable operation but also survival. The new customer-oriented strategies may explain some of the changes in organizational forms.

The purpose of this paper is to give some evidence of the post-deregulation labor strategies that significantly contributed to the economic renaissance of US railroad companies and to help better understand the way in which they were realized. To do so, given that these human resources reorganization strategies translate into specific relationships of complementarity and substitutability between different labor factors, I study them by estimating the elasticities of substitution between different US Class I employee categories. I make use of examples on organizational strategies carried out by railroad firms to illustrate results.

I find strong substitutabilities between some production and nonproduction employee categories, namely executive positions and the transportation group, pointing to the

[1] See Schwarz-Miller and Talley (2002) for a complete survey on the topic.

achievement of better command and control of freight operations. I also find a high degree of complementarity between the most skilled employee categories, partially explained by the widespread use of teamwork at high levels of the organization aimed to improve communication. Additionally, there is a complementary relationship between executive positions and the maintenance of equipment positions, signalling that railroad management is refocusing on providing reliable service to their customers. Results further show that the strongest substitute relationship is between those members of the transportation group and those of the maintenance of ways&structures.

I also study the elasticities between labor factors and the rest of railroad production inputs. This is especially important if labor is demonstrated to be not separable from the rest of inputs.[2] Ignoring the rest of inputs would give biased estimates of labor-labor substitution.[3] Cross- and own-price elasticities for labor and the rest of inputs are also reported.

Results reveal that all labor occupations are substitutable for the equipment input, but not on an equal level. More precisely, the substitution relationship is less strong for the more skilled categories.

The obtained labor demand elasticities are consistent with the conclusion of Hamermesh (1987) that own-price demand elasticities are lower for workers that have more general human capital embodied and that increases in intermodal type of traffic result in significant decreases of professional&administrative expenditure shares. As well, I find differences in the signs of the substitution elasticities between the six labor inputs and two of the three remaining inputs, indicating that total labor does not form a consistent aggregate.

For this type of study one needs data sets that have detailed workforce information disaggregated according to relevant employee categories. In fact, usually the literature on labor-labor substitution separates the workforce into just two categories: production and nonproduction workers.[4] This paper goes beyond these studies in that I distinguish between six different employee categories, so that we can get richer information on the substitution and complementary labor relationships.

I investigate a comprehensive data set on US Class I railroads after deregulation. It contains detailed information on firm-level operating costs and, in particular, and most importantly, employment and wages information for six occupational categories: man-

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[2]That is, if the elasticities of substitution of the rest of inputs for various types of labor are not identical.

[3]Hamermesh and Grant (1979).

[4]See Hamermesh and Grant (1979) for a complete summary of the empirical literature on skill substitution.

agers&officials, professional&administrative, maintenance of equipment&stores, maintenance of ways&structures, transportation and train&engine. Each occupation requires different levels of formation or human capital; therefore, each employee category can be thought of as being attached to a particular skill level.

The model estimated is a multi-input/output translog variable cost function with the labor input divided into these different employee categories. The multi-output nature of the cost function enables us to also examine how a particular labor input expenditure share responds to an increase in a particular output. Furthermore, by dividing labor into different employee categories, I'm able to examine the appropriateness of considering the labor input as forming a consistent aggregate. To the best of my knowledge, no such a study has been conducted to date for this specific industry.

Section 2 describes the institutional background of deregulation. Section 3 presents the empirical cost model. Section 4 explains the elasticity concepts to be calculated. Section 5 describes the data and presents both the regressions and the elasticity results. Section 6 lists other relevant organizational structure changes. Section 7 concludes.

2 Background

With the passage of the Interstate Commerce Act in 1887, freight railroads became the first U.S. industry subject to comprehensive federal economic regulation. For the next 93 years, the federal government, mainly through the ICC (Interstate Commerce Commission, America's first independent regulatory agency), would control wide areas of rail operations and management.[5]

Regulation imposed lengthy merger proceedings and route abandonment hearings, lack of flexibility in rate setting, prohibition of joint use of common track between two carriers leading to duplication of service, lack of innovation, loss of market share and higher costs.[6] The combination of these elements explains the poor financial condition of the industry beginning in the early 1970s.

Congress passed the Staggers Rail Act in 1980, marking the beginning of the post-deregulation period for this industry. The basic principles of the Staggers Act were that rail management, not government regulators, should run railroads. The reform allowed railroads to establish their own routes, tailor their rates and services to market conditions, and differentiate rates on the basis of demand. It also permitted long-term service contracts between railroads and their customers, and eased procedures for the abandonment

[5] Association of American Railroads (2006).

[6] Railroad News (1998).

and sale of rail lines.

With competition, railroads began thinking hard how to achieve a better match between their huge physical plants and work forces on the one hand and available traffic on the other.[7]

The main effects of the reform were an increase in shipment density and shipment size, the initiation of double-stack container train service thanks to the allowance of long term contracts between railroads and shipping lines (because of the high level of strategic and financial commitment, including the substantial specialized capital required), an increase in market concentration (from 38 firms in 1978 to 7 in 2004) and reinvestment of hundreds of billions of dollars in productive rail infrastructure and equipment.

In reference to the work force, there was a dramatic labor restructuring, with employment reduced to a third of its 1981 size by 2004. Evidence for this is given by Figure 1, which shows the evolution of total employment between 1978 and 2004. However, downsizing didn't affect all the employee categories with the same intensity. This can be seen in Figure 2, which disaggregates the labor downsizing by occupational category.

3 The Model

The model used is a variable cost model. I use the specification of Ivaldi and McCullough (2001), but given that I want to study the complementarities and substitutabilities between the different labor inputs, labor prices are here disaggregated into the six existing employee categories. My specification is then the following:

$$VC = VC(y_B, y_G, y_V, y_I, w_L, w_E, w_F, w_M, haul, road) \tag{1}$$

where:

VC = annual operating variable cost,

y = output, divided by:

y_B = car-miles[8] of bulk traffic (i.e. open hopper, closed hopper),

y_G = car-miles of general traffic (gondolas, box cars),

[7] R. Gallamore (1999).

[8] Physical measure indicating the movement of a car a distance of one mile. Most studies use aggregate ton-miles as the unit of freight output. But this data is not available on a commodity-by-commodity basis. In contrast, there is annual data on car-miles by equipment type, and this is important because different car-types are involved in freight services that have different cost and demand characteristics. This means that using car-miles makes it possible to estimate costs in a way that is both technologically accurate and market-relevant. See Ivaldi and McCullough (2001) for a complete discussion on the advantages of using this measure.

y_V = car-miles of intermodal traffic (trailers and containers on flat cars),

y_I = replacement ties installed in a given year, a measure of infrastructure output,[9]

w_L = vector of labor prices,

$= (w_{\text{EXECOF}}, w_{\text{PROFADM}}, w_{\text{MAINW}}, w_{\text{MAINEQ}}, w_{\text{TRANSP}}, w_{\text{TRENG}})$,

where

w_{EXECOF} = average annual compensation of executive and official positions,

w_{PROFADM} = average annual compensation of professional and administrative positions,

w_{MAINW} = average annual compensation of maintenance of way and structures positions,

w_{MAINEQ} = average annual compensation of maintenance of equipment and stores positions,

w_{TRANSP} = average annual compensation of transportation positions, other than train and engine,

w_{TRENG} = average annual compensation of train and engine positions,

w_E = rail equipment price index,

w_F = rail fuel price index,

w_M = rail material and other inputs price index,

$haul$ = average length of haul covered by freight railroads from departure to destination,

$road$ = miles of road operated,

The Surface Transportation Board classifies and defines the mentioned six job titles as follows:

- *Executives&Officials:* managerial positions, including those of chief executives, corporate department heads and major sub-department heads, corporate executives and managers assisting department and sub-department heads, regional managers, chief division officers and managers directly supervising train and yard operations. In sum, these are jobs requiring administrative and managerial personnel, who set broad policies, exercise overall responsibility for execution of these policies, and direct individual departments or special phases of firms operations.

- *Professional&Administrative*: these are basically technical and clerical positions, including technical occupations requiring a high degree of training and/or supervising sub-professionals and technicians, technical occupations requiring a high degree

[9] On mature rail networks most infrastructure-related activity is aimed at maintaining the capacity of the existing network rather than expansion. The maintenance activity is viewed here as a variable output which imposes costs directly and which interacts directly with other outputs, Ivaldi and McCullough (2001) p.165.

of knowledge and/or skill, supervisors responsible for the administrative activity of a department, sub-department, office or region, sales and traffic representatives and agents, inspectors, instructors, clerical technicians and specialists, office machine and data equipment operators, secretaries, typists, general and other clerks, telephone operators and office attendants.

- *Maintenance of Way&Structures*: this category includes positions such as maintenance of way and structures supervisors and inspectors, bridge and building gang foremen, carpenters, ironworkers, painters, helpers, machine operators, gang foremen, communications workers, signalmen and signal maintainers.

- *Maintenance of Equipment&Stores*: this includes maintenance of equipment supervisors and general foremen, storekeepers, gang foremen, electrical workers, machinists, sheet metal workers, enginehouses laborers, equipment operators and general laborers.

- *Train&Engine*: these are conductors, yard or road engineers and other people who physically operate the trains, such as switchmen, brakemen and yard or road firemen.

- *Transportation*, other than train and engine: this category includes such personnel as station agents, flagmen, interlocking tower operators, and other people involved with on-line train operations except for engine and train crew personnel.

The functional form used to estimate (1) is a flexible multiproduct translog which can be written:

$$\begin{aligned}
\ln VC(y,w;t) \quad = \quad & A_0 + \sum_i A_i \ln w_i + \sum_j B_j \ln y_j + \sum_k C_k \ln t_k \\
& + \frac{1}{2}\sum_i \sum_l AA_{il} \ln w_i \ln w_l + \sum_i \sum_j AB_{ij} \ln w_i \ln y_j \\
& + \sum_i \sum_k AC_{ik} \ln w_i \ln t_k + \frac{1}{2}\sum_j \sum_m BB_{jm} \ln y_j \ln y_m \\
& + \sum_j \sum_k BC_{jk} \ln y_j \ln t_k + \frac{1}{2}\sum_k \sum_h CC_{kh} \ln t_k \ln t_h \qquad (2)
\end{aligned}$$

where VC represents variable costs, w is a set of input prices, y is the set of outputs, and t represents the quasi-fixed variables *road* and *haul*. Time and an occupational restructuring variable which basically measures the degree of occupational dissimilarity between two periods of time[10] are also included, both in level form. The efficiency of the estimation is improved by estimating variable cost and share equations for each input simultaneously: it yields more degrees of freedom and efficient parameter estimates without additional unrestricted coefficients. These factor shares are obtained by using the Shepard's Lemma, and are of the form

$$S_i = A_i + \sum_l AA_{il} \ln w_l + \sum_j AB_{ij} \ln y_j + \sum_k AC_{ik} \ln t_k \tag{3}$$

where S_i is the share of variable cost allocated to input i, that is, $w_i x_i / VC = d \ln VC / d \ln w_i$. Share equations are estimated for all inputs but one, to avoid perfect collinearity. The data is mean scaled so that, at the mean, the logarithm will be zero. This is convenient for the interpretation of estimation results, since the first order term parameter estimates will show the elasticity of costs with respect to those variables when all variables are at their sample means.

The cost function being twice differentiable, its Hessian matrix must satisfy the following symmetry restrictions: $AA_{il} = AA_{li}$, $BB_{jm} = BB_{mj}$, $CC_{kh} = CC_{hk}$. A well-defined dual cost function must also verify the property of linear homogeneity of degree 1 with respect to input factor prices. It ensures that the cost-minimizing bundle does not change if all prices are multiplied by the same positive scalar, and therefore, maintains the basic property that only the ratios of the inputs' prices affect the allocation of inputs. It is enforced by dividing the mean-scaled variable cost and i-1 mean scaled prices by the ith mean-scaled price, which is the input price from the share equation that is dropped (e.g. Daughety and Nelson, 1988).[11]

4 Factor Demand and Substitution Elasticities

The translog parameter estimates can be used to calculate elasticity values.[12]

The formulas of factor demand, cross-price and (Allen) substitution elasticities for the translog cost function are the following:

$$\eta_i = d \ln x_i / d \ln w_i \mid_{y,t=const, w_j=const\ \forall j \neq i} = S_i - 1 + (AA_{ii}/S_i)$$

[10] See Table 1 for a detailed description.

[11] This is equivalent to imposing a set of restrictions on the cost function parameters: $\sum_i A_i = 1, \sum_i A_{il} = \sum_l A_{il} = 0, \sum_i AB_{ij} = \sum_i AC_{ik} = 0$.

[12] Look at the appendix for the demonstration.

$$\eta_{il} = d\ln x_i / d\ln w_l \mid_{y,t=const, w_k=const\ \forall k\neq l} = (AA_{il} + S_i * S_l)/S_i$$

$$\sigma_{il} = \eta_{il}/S_l = (AA_{il}/S_i * S_l) + 1$$

All these measures are one-price-one-factor elasticities: that is, both elasticities measure the responsiveness of input i to a one percent change in the price of input j, with all other prices and output held constant. By construction, σ_{il} are symmetric, but not the η_{il}, and must have the same sign.

Factors are substitutes if $\sigma_{il} > 0$ (an increase in the price of input j will lead to an increase in the demand for input i), and complements if $\sigma_{il} < 0$ (an increase in the price of input j will lead to a decrease in the demand for input i).

I will concentrate on these elasticity measures for the results given that they give us information on the complement or substitution nature of the relationship between different factors, which is the main interest of this study. However, to provide further insights on substitution possibilities, Morishima elasticities of substitution are also calculated, which are an alternative to the above Allen Elasticities of Substitution. The Morishima elasticities measure the percentage change in the ratio of a pair of factors with respect to a change in the ratio of their respective prices. That is, they measure *relative* input adjustment to single-factor price changes. This means that two factors are substitutes (complements) if an increase in the price of one causes the quantity of the other to increase (decrease) *relative* to the quantity of the input whose price has changed. This is then a one-price-two-factor elasticity.[13]

The formula for the Morishima elasticity of substitution is the following:

$$\sigma_{il}^{M} = \eta_{il} - \eta_l$$

It can be seen that because η_l (factor demand elasticity) is always negative, two inputs that are Allen substitutes are also Morishima substitutes. However, the converse does not hold.

[13] It is a measure of the ease of substitution and a sufficient statistic for assessing the effects of changes in price ratios on relative factor shares, whereas the Allen elasticity of substitution is not (see Blackorby and Russel, 1989).

5 Data and Estimation Results

The sources for the data are the annual *Analysis of Class I Railroads* and quarterly *Railroad Cost Indexes* published by the Association of American Railroads. The sample is an unbalanced panel of 18 Class I firms operating in the U.S. between 1982-2004. Firms are defined as the accounting entities presented in the *Analysis.*

Variable definitions are given in table 1, and summary statistics are in table 2.

The system estimated includes the cost equation (equation (2)), eight share equations (equation (3)), and four additional equations representing instrumental variable regressions for the output variables y_B, y_G, y_V and y_I, to control for endogeneity problems.[14] The instruments are some input prices and exogenous variables such as coal consumption and population calculated for the territory served by each railroad per year.

The assumptions made on the error vectors of the system follow Berndt et al. (1993). The error term is decomposed into three components: a firm-specific error term to capture special network effects, an error that exhibits first-order autocorrelation within the cost equation and the eight share equations and an error that is contemporaneously correlated across the cost and share equations. To control for firm-specific effects, dummy variables are introduced into the cost equation,[15] and autocorrelation is corrected by estimating autorregressive parameters for the cost equation and the share equations. To account for contemporaneous correlation, the system is simultaneously estimated using the FIML command of SAS for Windows Release 9.1.

5.1 Basic Regression Results

Overall results of these regressions are presented in Table 4. All the left-hand side variables are well-explained. The adjusted R-squared for the variable cost equation is 0.9904 and the Durbin Watson statistic is 2.281.

The parameter estimates for the cost function (equation (2)) are presented in table 5. All of the first order terms have the expected signs (except for *infrastructure* type of output and *haul)* [16] and all but three are significant at conventional levels. The time trend suggest that railroad operating variable costs have been declining at approximately 1.01

[14] As argued in Ivaldi and McCullough, "partial deregulation of the rail industry in 1980 meant that output levels and composition became strategic decisions not independent of firm characteristics".

[15] Including them in the eight share equations as well would have significantly decreased the degrees of freedom in the analysis.

[16] However, in a preceding regression using data just from 1984, haul got a negative and significant coefficient.

percent per year. The effect of employee restructuring on costs appears to be negative, but it is not significant.

With regard to output variables, the elasticity of costs with respect to *intermodal* type of traffic (0.0981) gets the smallest significant value, reflecting the inherent efficiencies of this type of traffic relative to the rest.

In terms of share biases effects,[17] that is, AB_{ij} terms coefficients, and in particular, in what concerns the different labor categories, the majority of the significant biases are negative. *Professional&administrative* is the only category to get a highly significant negative coefficient for intermodal type of output: increases in intermodal traffic result in decreases in this employee category's expenditure share.

In contrast, increases in *infrastructure* type of output result in increases of maintenance employees and *train&engine* expenditure shares, with the largest magnitude for *maintenance of way&structures* labor, which is plausible. One explanation for the *train&engine* result might be the interference between operations and infrastructure activity. Recall that this category basically includes people who physically operate the trains, such as conductors. This interference might make the scheduling and repositioning of this part of the crew more complicated and cost-inefficient.

Increases in *bulk* type of traffic produce decreases in the expenditure shares of *executives&officials* and *professional&administrative.* This may be explained by the nature of bulk operations. Bulk traffic usually moves in blocks of cars or unit trains.[18] Unit train operations involve regular, trolley-like movements between origins and destinations. Thus, bulk freight operations typically involve less complicated routing and less switching requirements than other types of traffic. Then, the reduced need for high capabilities of command and control could partially explain the decrease in the expenses on managerial positions. On the contrary, it causes increases in the expenditure share for *maintenance of equipment&stores* and *train&engine.*

5.2 Factor Demand and Substitution Elasticities Results

Table 6 reports estimated demand and substitution elasticities for the six labor input categories and for fuel, materials and equipment. Degrees of significance for all the elasticity values are also reported.

All the own-price elasticities have the expected sign, i.e., input demand reacts negatively to an increase of own price.

[17] The measure of how input i's expenditure share responds to an increase in output j.

[18] They carry only a single commodity from a single source and to a single destination.

Concerning labor demand elasticities, I get different results for each of the categories, as expected. Moreover, the results are consistent with the conclusion of Hamermesh (1987) that own-price demand elasticities are lower for workers that have more general human capital embodied: thus, the low demand elasticities of *executives&officials* (-0.142) and *professional&administrative* (-0.354) contrast with the relatively larger values for the rest of employee categories. Those remaining categories get very close demand elasticities, with the lowest own-price elasticity for the *transport* group (-0.571).

As for the rest of inputs, *fuel* gets the least elastic demand, with an own–price elasticity equal to -0.144, result which seems plausible in a transport industry, while *materials* get the most elastic, with an elasticity equal to -1.246.

One interesting observation is the difference in the signs of the substitution elasticities between the six different labor inputs and two of the three remaining inputs, namely fuel and materials. For instance, the substitution elasticity between *executives&officials* and *materials* is 2.657 (i.e. strong substitute relationship) while it is -4.625 (i.e. strong complementary relationship) between *materials* and the *transport* group. This indicates that total labor does not form a consistent aggregate (other studies reached a similar conclusion. One example is the paper by Turnovsky and Donnelly for the Australian Iron and Steel Industry, where they divide labor into administrative workers and production labor)[19]. This result stresses the interest of disaggregating labor by employee categories when studying labor complementarities and substitutabilities with other inputs.

One of the most important and interesting findings of this research is the high degree of substitutability between the *transport* (production workers) and the *executives&officials* (nonproduction workers) groups. They get an elasticity of substitution equal to 3.751, the largest positive value in the table. Railroads have been substituting technology and managers for production workers in the post-deregulation period.

There is an equally high degree of substitutability between *executives&officials* and *materials*. Their elasticity of substitution is 2.657. Recall that this employee category includes managers directly supervising train and yard operations. The result then implies that more supervision effectively results in less wastage of material.

In contrast, there is significant complementary relationship between *executives&officials* and *maintenance of equipment&stores*. Thus, the presence of more managerial positions is associated with an increased number of these specific maintenance occupations.

[19] In particular, they find that the various elasticities between administrative and production workers and the other inputs, namely energy, material and capital, usually have opposite signs (or are very different), while the elasticity between aggregate labor and these same inputs are always bound by these two former elasticities as some sort of average of the two.

Another interesting finding is the high degree of complementarity between what can be considered the most skilled railroad employee categories, namely *executives&officials* and *professional&administrative.*

There is a very strong substitute relationship between the *transport* and *maintenance of ways&structures* groups. In fact, they perform various similar jobs. Tables 7 and 8 give more information on this relationship: the estimated cross-price elasticity of *transport* by *maintenance of ways&structures* (0.085) is smaller than that of *maintenance of ways&structures* by *transport* (0.251). Similarly, the Morishima elasticity of substitution for *maintenance of ways&structures* with respect to transport wage rate (0.655) is smaller than the elasticity of *transport* with respect to *maintenance of ways&structures* wage rate (0.899). This means that an increase (decrease) in the price of *maintenance of ways&structures* increases (decreases) the demand for *transport* relatively more than a similar increase in the price of *transport* affecting the demand for *maintenance of ways&structures.* Hence, it is easier to substitute the maintenance group with the transport occupation than the latter with the former.

There is also a substitute relationship between *transport* and *train&engineering,* though this not as strong. These groups do perform some similar tasks, but this list of tasks is smaller than that in the preceding case.

Concerning the rest of inputs, *fuel* gets the only significant elasticity with *train&engine* employee category (0.795). There is a substitution relationship. This seems a reasonable result as the increased presence of engineering positions might result in less wastage of energy.

Material has a substitute relationship with the *maintenance of equipment&stores* employee category. Their substitution elasticity is 1.757. This result suggests that with other things being equal the increased manpower devoted to these maintenance operations might result in less wastage of material. By contrast, there is a strong complementary relationship between *material* and *transport* group.

Finally, inspection of the *equipment* column in Table 6 reveals that all labor occupations are substitutable for this input, but not equally. In fact, the substitution relationship is less strong for the most skilled categories. For instance, the elasticity of substitution for *professional&administrative* is 0.745 while it is 1.811 for the *transport* group. However, *equipment* appears to be much more substitutable with *material,* with an elasticity of substitution equal to 3.267.

6 Implications

A summary of the main results on substitution elasticities that can be related to specific corporate strategies and particular workplace organization practises goes as follows:

Result	**Points to**	**Examples of Strategies**
Substitutability between executive&officials and transportation/material expenses	Better command and control of train operations	Teamwork between operations and sales/marketing making joint forecasting and planning
Complementarity between executive&officials and professional&administrative	Workteams at the top level of the organization	Cross-functional study teams to improve service reliability Teams working in market-based operating plans to set future capacity needs
Complementarity between executive&officials and maintenance of equipment&stores	Increased importance of service reliability	Maintenance programs to improve safety records (e.g. derailment frequency)

The high degree of substitutability between the *transport* and the *executives&officials* groups points to railroad firms achieving better command and control of freight network operations in the post-deregulation period. As argued before, railroads have been able to substitute technology and managers for production workers.

This may be related to the payment system for railroad managers and the changes that they have incurred after regulatory reform. More precisely, there are empirical studies, such as the one by Bitzan (2004) that find a stronger pay for performance relationship as a result of deregulation. Logically, this may create greater work pressures for other transportation workers. That is, the significance of pay for performance for rail management could result in managers demanding enhanced efficiency from those workers. The provision of payment incentives may have then become an effective way to improve monitoring of railroad employees by managers.

Better command and control has to a large extent been achieved thanks to initiatives aimed to improve the operating planning process. For instance, the widespread use of teamwork between operations and sales/marketing when setting the annual planning cycle have allowed for a better match between operations and transportation manpower requirements. As Dick Davidson, CEO of Union Pacific (UP) during the 90s, noted in explaining the key phases of UP's quality program in an interview:

> The second phase of the program centered around our planning efforts–such as how we go through our annual planning cycle, from the time Marketing puts a traffic forecast together to where Operating puts out its forecast on locomotive and manpower requirements and so on. (RailwayAge, February 2, 1992)

The equally high degree of substitutability between *executives&officials* and *materials,* implying that more supervision effectively results in less wastage of material, also closely relates to the idea of better command and control of freight operations.

The explanation for the high degree of complementarity between *executives&officials* and *professional&administrative,* the most skilled employee categories, may be given by another important change in railroad company culture since the Staggers Act of 1980: the widespread use of cross-functional teams in developing revised business processes and new information technology applications.[20]

Again, after the enactment of regulatory reform, railroads reshaped their way of thinking about their operations, markets and customers. They found that mixing people from different departments or disciplines would allow them to assemble information on customer requirements and broad railroad operational needs. And those two categories are the most susceptible to be involved in those team practises, given that the first category includes jobs setting broad policies and directing individual departments and the second includes several supervisory, technical and inspector-type positions for different departments and sub-departments.

For example, railroads created study teams that included representatives from positions belonging to *professional&administrative* (Finance, Marketing&Sales, Car Management, Operations) and *executive&officials* (Strategic Planning) to determine what could be done to make service more reliable. The same positions worked together to develop market-based operating plans that gave railroads a look at short and long-term capacity needs. There was teamwork at the top of railroad companies. In most of the cases, these

[20] R. Gallamore (1999).

teams responded to the need for better communication within those railroads organizations they had inherited from the already mentioned hierarchical or militaristic organizational styles previously common. Southern Pacific, when talking about its teamworks, stated:

> Southern Pacific's top managers and labor officials now get together semiannually and frankly discuss company finances, traffic volume and anything else they want to discuss. (The Journal for Quality and Participation, June 1, 1996)

Finally, the complementary relationship between *executives&officials* and *maintenance of equipment&stores* might reflect the fact that railroad managers are paying attention to the safety and service reliability standards they can offer their customers.

That is, this finding is consistent with the transition to a more customer-oriented corporate culture that was undoubtedly stimulated by the regulatory reform. One of the most important improvement strategies adopted by rail management in the post-Staggers era has been that of service reliability and safety improvement, aimed at achieving customer satisfaction. In fact, when railroad firms were asked about their priorities in the 90s, one element was recurrently mentioned: improvement of service reliability. Michael H. Walsh, former CEO at UP, said:

> Probably the key in today's business world, not only domestically but internationally, is service reliability. That basically is delivering the customer's shipment time after time-when you tell him you are going to deliver it. A customer deserves that performance from us, because if he does not get it, you can bet he will find another way to transport his goods. (Railway Age, February 1, 1990)

Railroad managers became aware that having enough maintenance of equipment personnel, enabling them to minimize the period of time in which machines are not in service (because of ongoing repair work) and prevent locomotive breakdowns, gained importance with the increase in competition.

The new emphasis on service reliability is motivated to a large extent by the rise of Just-in-Time manufacturing operations that drived companies to demand on-time delivery performance from shippers. Manufacturers are reducing component inventories. Retailers, similarly, are holding smaller inventories of goods for sale, relying on their ability to get rapid response to orders. This implies that there is little room or tolerance for service failures.

This closely relates to railroads safety standards concerns as accidents disrupt operations and cause service failures. This explains why the improvement of safety records has been another priority in railroad strategies. Regular maintenance checkings are expected to prevent accidents and help decrease derailment frequency and freight damage.

Moreover, some railroad companies realised that locomotive breakdowns represented a significant share of their costs. UP executives noted this in the 90s in reference to their quality program:

> In the analysis phase of the program we found that locomotive breakdowns were the second leading cause of failure cost in the company. We had only 86% of our locomotives ready to run at any one time. We now have it up to nearly 93%, which represents 175 locomotives now pulling trains instead of broken down.

Lastly, apart from the organizational practises listed above, there were others taking place at the same time and that deserve to be mentioned. Some of them relate to the results on elasticities of substitution. They also reflect significant changes in railroads' corporate cultures.

Railroads established quality teams or departments charged with helping the company become more customer-driven. They were dedicated to build customer satisfaction. One related initiative was the establishment of Customer Service Centers for some railroads, such as that created by CSX at the beginning of the 90s and another by SP in Denver.

They reorganized their sales and marketing departments to be more customer oriented. This was the case of Burlington Northern Santa Fe Corp., which formed four new marketing groups (agricultural products, coal, consumer products and industrial products) at the end of the 90s. This new structure was intended to make them better able to develop customized service packages to meet BNSF customers' transportation needs.

Railroads empowered employees by setting up quality improvement teams (QIT) that were cross-functional and made employee involvement their main objective. UP set up a QIT and by 1992, about 11% to 12% of UP workforce were involved. Union Pacific Corp. also started to use employee involvement teams as well as state-of-the-art training, adding peer trainers to help their employees become more productive. A cross-functional quality improvement example is provided by the Southern Pacific Lines' cross-functional team of locomotive engineers, dispatchers, mechanical department personnel and conductors that created a new procedure for reporting locomotive mechanical problems. It proved to be a vast improvement on the old procedure and, at the same time, ameliorated communication among employees from different departments and built better labor-management relations.

Several railroad companies underwent changes in management, including the introduction of job rotations and new recruits. For instance, a chairman of Southern Pacific said that, at the beginning of the 90s, a very high percentage of their senior officer staff was either newly installed in their position after rotation from another job in the company or completely new to the company. [21]There were also reductions in the management ranks intended to increase managers responsiveness and accountability.

7 Concluding Remarks

By using firm-level panel data from US Class I Railroads, this paper presents a translog cost model designed to estimate the complementarities and substitutabilities between different railroad employee categories for the post-deregulation period.

The main objective is to give some evidence of the post-deregulation labor strategies that significantly contributed to the economic renaissance of US railroad companies and to help better understand the way in which they were realized. This is done by making use of examples on Ial strategies carried out by railroad firms.

I estimate the elasticities of substitution between labor factors and also with the rest of inputs. Cross- and own-price elasticities of labor factors and the rest of production inputs are also reported.

The main findings from this research are the strong substitutability between some production and nonproduction employee categories, namely those with managerial positions and the transportation group, pointing to the achievement of better command and control of freight operations; I find a high degree of complementarity between the most skilled employee categories, partially explained by the widespread use of teamwork to improve communication at high levels of the organization. There is also a complementary relationship between executive positions and the maintenance of equipment position, signalling that railroad management has refocused on providing reliable service to their customers. The strongest substitute relationship is that between the transportation and maintenance of ways&structures groups. Finally, results reveal that all labor occupations are substitutable for the equipment input, but not on an equal level. More precisely, the substitution relationship is less strong for the most skilled categories.

Other results are that own-price demand elasticities are lower for workers that embody more general human capital; this is consistent with the results from Hamermesh (1983); increases in intermodal type of traffic result in significant decreases of professional&administrative expenditure share and the obtained differences in the signs of the

[21]Railway Age (January 1993).

substitution elasticities between the six different labor inputs and two of the three remaining inputs, indicating that total labor does not form a consistent aggregate.

Most of the labor strategies studied here resulted from the more customer-oriented character of railroad companies after deregulation. A return to the competitive marketplace forced railroads to place much greater emphasis on service quality, with service reliability being a crucial element. This relates to the increased importance of agility and speed in responding to customer needs, a main concern of other industries in the service sector.[22]

In this research, I concentrate on the post-deregulation period. It would be very interesting to examine the existence of changes in the elasticities of substitution between the different employee categories and the rest of inputs, both in terms of sign and magnitude, by comparing their values for the period under regulation and after deregulation. One would expect to observe an increase in the substitution possibilities and greater flexibility, in general, in the use of factors by railroads after deregulation. The less favorable bargaining environment for rail unions probably had some influence.[23] In fact, the 1980s appeared to represent a turning point in railroad union-industry relations, with unions more willing to adjust to railroads need to contain labor costs.[24]

Unfortunately, there is a lack of availability of data for the years previous to deregulation.

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[22] In a survey published on the topic by McKinsey, executives from nine of ten industries stated that agility was either "extremely" or "very" important to business performance, while 86 percent said the same about speed. McKinsey Global Survey (2006).

[23] There are empirical studies on the influence of unionization in the ease of substitution between labor and other factors of production. For instance, Freeman and Medoff (1982) find that higher unionization in US manufacturing industry is associated with less flexibility in the use of labor inputs. Magnani and Prentice (2005) find that lower unionization is associated with greater flexibility in the use of labor inputs but less reported flexibility in the use of other non-labor inputs.

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TABLE 1
Variable Definitions

Variable	Description
Variable cost (VC)	Operating variable costs: labor + material + fuel + equipment expenditures
OUTPUT	
Bulk (y_B)	Total car-miles (loaded + empty) of open and covered hoppers cars
General freight (y_G)	Total car-miles of regular and refrigerated box cars, gondolas, tanks, autorack and all other
Intermodal (y_V)	Total car-miles of trailers and containers on flat cars
Infrastructure (y_I)	Ties laid in replacement
INPUT PRICES	
Executives & officials price (w_{EXECOF})	\$82 average annual compensation of executive and official positions per firm
Professional & administrative price ($w_{PROFADM}$)	\$82 average annual compensation of professional and administrative positions per firm
Maintenance of way & structures price (w_{MAINW})	\$82 average annual compensation of maintenance of way and structures positions per firm
Maintenance of equipment & stores price (w_{MAINEQ})	\$82 average annual compensation of maintenance of equipment and stores positions per firm
Transportation, other than train & engine (w_{TRANSP})	\$82 average annual compensation of tranportation positions, other than train & engine, per firm
Train & engine price (w_{TRENG})	\$82 average annual compensation of train and engineering positions per firm
Fuel price (w_F)	\$82 rail fuel price index
Material price (w_M)	\$82 rail material and other input price index
Equipment price (w_E)	\$82 rail equipment price index
QUASI-FIXED INPUT AND TECHNOLOGY	
Average haul *(haul)*	Average length of haul covered by freight railroads from departure to destination
Miles of road *(road)*	Miles of road operated
Time trend *(time)*	Time trend = year-1982
OTHER	
Coal consumption	Coal consumed in the firm-served states
Population	Population of firm served states
Labor price (w_L)	\$82 rail labor price index
Occupational reestructuring	index of occupational dissimilarity between t-1 and t: measure of the degree to which the occupational structure shifts over time , $1 - (\sum_i m_{ij1} m_{ij2}) \ / \ \left[\sum_i (m_{ij1})^2 \sum_i (m_{ij2})^2\right]^{1/2}$,where m_{ijt} is share of occupation i in firm j at period t

TABLE 2
Summary Statistics 1982-2004

Variable	Unit	Mean	StdDev	Min	Max
Variable cost (VC)	\$82 (000)	1628803	1518733	74351	6759155
Executives & officials share (S_{EXECOF})	Percent	0.034	0.011	0.013	0.078
Professional & administrative share (S_{PROFADM})	Percent	0.063	0.024	0.020	0.172
Maintenance of way & structures share (S_{MAINW})	Percent	0.072	0.014	0.040	0.124
Maintenance of equipment & stores share (S_{MAINEQ})	Percent	0.065	0.016	0.031	0.113
Transportation other than train & engine share (S_{TRANSP})	Percent	0.024	0.008	0.009	0.053
Train & engine share (S_{TRENG})	Percent	0.160	0.023	0.083	0.227
Fuel share (S_{F})	Percent	0.096	0.029	0.034	0.187
Material share (S_{M})	Percent	0.099	0.034	0.035	0.274
Equipment share (S_{E})	Percent	0.389	0.081	0.148	0.637
Bulk (y_{B})	Car-miles (000)	639026	725709	16576	3951606
General freight (y_{G})	Car-miles (000)	933540	1015678	32868	6208521
Intermodal (y_{v})	Car-miles (000)	309382	344664	3789	1511890
Infrastructure (y_{I})	Ties (000)	1142	1032	27	4664
Executives & officials price (w_{EXECOF})	\$82	57266	11753	34418	99147
Professional & administrative price (w_{PROFADM})	\$82	33773	4895	21715	51207
Maintenance of way & structures price (w_{MAINW})	\$82	31131	3976	17781	40835
Maintenance of equipment & stores price (w_{MAINEQ})	\$82	31651	3730	19212	45995
Transport group price (w_{TRANSP})	\$82	36203	5913	23086	61541
Train & engineering price (w_{TRENG})	\$82	45696	9073	22567	84949
Fuel price (w_{F})	Index	73.29	17.03	49.58	129.84
Material price (w_{M})	Index	116.23	21.72	91.04	163.34
Equipment price (w_{E})	Index	116.31	10.03	100	132.1
Average haul *(haul)*	Miles	484	220.68	175	1230
Miles of road *(road)*	Miles	9622	8225	442	34946
Time trend *(time)*	Years	9	6.3	0	22
restructuring	index	0.003	0.005	0.00002	0.052
Coal consumption	Tons (000)	300760	172846	9990	676587
Population	Persons (000)	74718	47185	4631	173769
Labor price (w_{L})	Index	150.120	33.228	100	224.940

TABLE 3
US Class I Railroads 1982-2004

Railroad (Abbreviation)	Years observed in the data	Railroad (Abbreviation)	Years observed in the data
Atkinson, Topeka & Santa Fe (ATSF)	1982-1995	Kansas City Southern (KCS)	1982-2004
Burlington Northern (BN)	1982-1995	Milwaukee (MILW)	1982-1984
Burlington Northern & Santa Fe (BNSF)	1996-2004	Missouri-Kansas-Texas (MKT)	1982-1987
Baltimore & Ohio (B&O)	1982-1983	Missouri Pacific (MP)	1982-1985
Chicago Northwestern (CNW)	1982-1994	Norkfolk Southern Corporation (NSC)	1986-2004
Consolidated Rail Corporation (CRC)	1982-1998	Seaboard Coastline (SCL)	1982-1985
CSX Corporation (CSX)	1986-2004	SOO line (SOO)	1982-2004
Denver, Rio Grande Western (DRGW)	1982-1993	Southern Pacific (SP)	1982-1996
Florida East Coast (FEC)	1982-1991	Southern Railway (SRS)	1982-1985
Grand Trunk Western (GTW)	1982-2001	Union Pacific (UP)	1982-1996
Illinois Central Gulf (ICG)	1982-2001	Union Pacific Southern Pacific (UPSP)	1997-2004

TABLE 4
Nonlinear FIML Summary

Equation	SSE	Root MSE	Durbin Watson	Adjusted R-Square
$\mathrm{Ln}(VC)$	2.2659	0.1159	2.2881	0.9904
S_{EXECOF}	0.0053	0.0047	2.0659	0.8112
S_{PROFADM}	0.0140	0.0076	2.249	0.8882
S_{MAINW}	0.0129	0.0073	2.2478	0.7125
S_{MAINEQ}	0.0117	0.0069	2.2603	0.7936
S_{TRANSP}	0.0026	0.0033	2.2449	0.7987
S_{TRENG}	0.0507	0.0145	2.5234	0.6166
S_{F}	0.0328	0.0117	2.4543	0.8270
S_{M}	0.1054	0.0209	1.5603	0.5393
$\mathrm{Ln}(\mathrm{y}_{\mathrm{B}})$	7.5634	0.1863	0.8679	0.9813
$\mathrm{Ln}(\mathrm{y}_{\mathrm{G}})$	7.3819	0.1840	0.6542	0.9786
$\mathrm{Ln}(\mathrm{y}_{\mathrm{V}})$	19.143	0.2963	0.8265	0.9589
$\mathrm{Ln}(\mathrm{y}_{\mathrm{I}})$	27.287	0.3538	1.5357	0.9181

Note: Number of observations: 272

TABLE 5
Parameter Estimates

Parameter	Variable	Estimate	Std Error	T-Ratio
A0	*constant*	0.6719	0.1461	4.60
T0	*time*	-0.0101	0.0034	-2.94
R0	*restructuring*	-0.001	0.0026	-0.39
A1	*executives & officials price* (w_{EXECOF})	0.0331	0.0072	4.58
A2	*professional & administrative price* (w_{PROFADM})	0.2420	0.0693	3.49
A3	*maintenace of way & structures price* (w_{MAINW})	0.0693	0.0040	17.12
A4	*maintenace of way & structures price* (w_{MAINEQ})	0.0500	0.0076	6.59
A5	*transportation other than train & engine price* (w_{TRANSP})	0.0187	0.0024	7.70
A6	*train & engine price* (w_{TRENG})	0.1714	0.0129	13.29
A7	*fuel price* (w_{F})	0.0327	0.0336	0.97
A8	*material price* (w_{M})	0.0872	0.0027	32.18
A9	*equipment price* (w_{E})	0.2956		*
B1	*bulk* (y_{B})	0.1053	0.0490	2.15
B2	*general freight* (y_{G})	0.2250	0.0513	4.39
B3	*intermodal* (y_{V})	0.0981	0.0318	3.09
B4	*infrastructure* (y_{I})	-0.0025	0.0274	-0.09
C1	*road*	0.3297	0.0545	6.05
C2	*haul*	0.0574	0.0313	1.83
AA11	w_{EXECOF}*w_{EXECOF}	0.0277	0.0019	14.34
AA22	w_{PROFADM}*w_{PROFADM}	0.0362	0.0064	5.71
AA33	w_{MAINW}*w_{MAINW}	0.0200	0.0057	3.54
AA44	w_{MAINEQ}*w_{MAINEQ}	0.0201	0.0058	3.44
AA55	w_{TRENG}*w_{TRENG}	0.0098	0.0026	3.77
AA66	w_{TRANSP}*w_{TRANSP}	0.0303	0.0070	4.29
AA77	w_{F}*w_{F}	0.0732	0.0041	17.76
AA88	w_{M}*w_{M}	-0.0340	0.0182	-1.87
AA99	w_{E}*w_{E}			*
AA12	w_{EXECOF}*w_{PROFADM}	-0.0115	0.0023	-4.93
AA13	w_{EXECOF}*w_{MAINW}	-0.0043	0.0021	-2.05
AA14	w_{EXECOF}*w_{MAINEQ}	-0.0083	0.0019	-4.31
AA15	w_{EXECOF}*w_{TRANSP}	0.0022	0.0013	1.80
AA16	w_{EXECOF}*w_{TRENG}	-0.0059	0.0025	-2.32
AA17	w_{EXECOF}*w_{F}	-0.0041	0.0015	-2.71

* Indicates parameter determined by input price homogeneity restrictions

TABLE 5 (continued)

Parameter	Variable	Estimate	Std Error	T-Ratio
AA18	$w_{\text{EXECOF}} * w_{\text{M}}$	0.0055	0.0045	1.22
AA19	$w_{\text{EXECOF}} * w_{\text{E}}$	-0.0015		*
AA23	$w_{\text{PROFADM}} * w_{\text{MAINW}}$	-0.0056	0.0044	-1.28
AA24	$w_{\text{PROFADM}} * w_{\text{MAINEQ}}$	-0.0024	0.0041	-0.57
AA25	$w_{\text{PROFADM}} * w_{\text{TRANSP}}$	-0.0035	0.0028	-1.25
AA26	$w_{\text{PROFADM}} * w_{\text{TRENG}}$	-0.0070	0.0039	-1.79
AA27	$w_{\text{PROFADM}} * w_{\text{F}}$	-0.0026	0.0023	-1.16
AA28	$w_{\text{PROFADM}} * w_{\text{M}}$	0.0024	0.0065	0.37
AA29	$w_{\text{PROFADM}} * w_{\text{E}}$	-0.0062		*
AA34	$w_{\text{MAINW}} * w_{\text{MAINEQ}}$	-0.0030	0.0042	-0.71
AA35	$w_{\text{MAINW}} * w_{\text{TRANSP}}$	0.0043	0.0027	1.59
AA36	$w_{\text{MAINW}} * w_{\text{TRENG}}$	-0.0042	0.0037	-1.13
AA37	$w_{\text{MAINW}} * w_{\text{F}}$	-0.0066	0.0021	-3.09
AA38	$w_{\text{MAINW}} * w_{\text{M}}$	-0.0139	0.0056	-2.46
AA39	$w_{\text{MAINW}} * w_{\text{E}}$	0.0131		*
AA45	$w_{\text{MAINEQ}} * w_{\text{TRANSP}}$	-0.0058	0.0030	-1.92
AA46	$w_{\text{MAINEQ}} * w_{\text{TRENG}}$	-0.0029	0.0035	-0.82
AA47	$w_{\text{MAINEQ}} * w_{\text{F}}$	-0.0046	0.0020	-2.32
AA48	$w_{\text{MAINEQ}} * w_{\text{M}}$	0.0049	0.0056	0.86
AA49	$w_{\text{MAINEQ}} * w_{\text{E}}$	0.0020		*
AA56	$w_{\text{TRANSP}} * w_{\text{TRENG}}$	6.318E-6	0.0021	0.00
AA57	$w_{\text{TRANSP}} * w_{\text{F}}$	-0.0013	0.0011	-1.22
AA58	$w_{\text{TRANSP}} * w_{\text{M}}$	-0.0014	0.0033	-4.12
AA59	$w_{\text{TRANSP}} * w_{\text{E}}$	0.0077		*
AA67	$w_{\text{TRENG}} * w_{\text{F}}$	-0.0031	0.0038	-0.83
AA68	$w_{\text{TRENG}} * w_{\text{M}}$	-0.0233	0.0080	-2.93
AA69	$w_{\text{TRENG}} * w_{\text{E}}$	0.0160		*
AA78	$w_{\text{F}} * w_{\text{M}}$	-0.0151	0.0062	-2.45
AA79	$w_{\text{F}} * w_{\text{E}}$	-0.0357		*
AA89	$w_{\text{M}} * w_{\text{E}}$	0.0870		*
AB11	$w_{\text{EXECOF}} * y_{\text{B}}$	-0.0054	0.0017	-3.05
AB12	$w_{\text{EXECOF}} * y_{\text{G}}$	0.0011	0.0018	0.62
AB13	$w_{\text{EXECOF}} * y_{\text{V}}$	-0.0016	0.0011	-1.45
AB14	$w_{\text{EXECOF}} * y_{\text{I}}$	0.0011	0.0009	1.16
AB21	$w_{\text{PROFADM}} * y_{\text{B}}$	-0.0048	0.0027	1.80
AB22	$w_{\text{PROFADM}} * y_{\text{G}}$	-0.0066	0.0027	-2.42

* Indicates parameter determined by input price homogeneity restrictions

TABLE 5 (continued)

Parameter	Variable	Estimate	Std Error	T-Ratio
AB23	$w_{PROFADM}*y_V$	-0.0036	0.0016	-2.20
AB24	$w_{PROFADM}*y_I$	0.0011	0.0014	0.78
AB31	$w_{MAINW}*y_B$	0.0043	0.0026	1.60
AB32	$w_{MAINW}*y_G$	-0.0087	0.0027	-3.21
AB33	$w_{MAINW}*y_V$	-0.0018	0.0017	-1.04
AB34	$w_{MAINW}*y_I$	0.0075	0.0015	5.00
AB41	$w_{MAINEQ}*y_B$	0.0040	0.0024	1.69
AB42	$w_{MAINEQ}*y_G$	-0.0056	0.0024	-2.33
AB43	$w_{MAINEQ}*y_V$	0.0003	0.0015	0.22
AB44	$w_{MAINEQ}*y_I$	0.0030	0.0013	2.23
AB51	$w_{TRANSP}*y_B$	-0.0003	0.0013	-0.24
AB52	$w_{TRANSP}*y_G$	-0.0018	0.0013	-1.37
AB53	$w_{TRANSP}*y_V$	0.0002	0.0008	0.20
AB54	$w_{TRANSP}*y_I$	0.0009	0.0007	1.37
AB61	$w_{TRENG}*y_B$	0.0143	0.0053	2.68
AB62	$w_{TRENG}*y_G$	-0.0119	0.0054	-2.20
AB63	$w_{TRENG}*y_V$	0.0020	0.0034	0.58
AB64	$w_{TRENG}*y_I$	0.0047	0.0029	1.64
AB71	w_F*y_B	0.0147	0.0044	3.36
AB72	w_F*y_G	0.0010	0.0044	0.22
AB73	w_F*y_V	0.0053	0.0026	2.02
AB74	w_F*y_I	-0.0002	0.0022	-0.09
AB81	w_M*y_B	0.0238	0.0053	4.51
AB82	w_F*y_G	-0.0243	0.0053	-4.59
AB83	w_F*y_V	0.0102	0.0033	3.14
AB84	w_F*y_I	-0.0201	0.0054	-3.71
AB91	w_E*y_B	-0.0506		*
AB92	w_E*y_G	0.0568		*
AB93	w_E*y_V	-0.0110		*
AB94	w_E*y_I	0.0020		*
BB11	y_B*y_B	0.0410	0.0513	0.80
BB22	y_G*y_G	-0.0083	0.0889	-0.09
BB33	y_V*y_V	0.0558	0.0247	2.25
BB44	y_I*y_I	0.0004	0.0195	0.02
BB12	y_B*y_G	0.0278	0.0522	0.53

* Indicates parameter determined by input price homogeneity restrictions

TABLE 5 (continued)

Parameter	Variable	Estimate	Std Error	T-Ratio
BB13	y_B*y_V	-0.0138	0.0250	-0.55
BB14	y_B*y_I	-0.0280	0.0214	-1.31
BB23	y_G*y_V	-0.0501	0.0325	-1.54
BB24	y_G*y_I	0.0094	0.0269	0.35
BB34	y_V*y_I	0.0233	0.0173	1.34
CC11	*road*road*	0.0890	0.0468	1.90
RHOVC	*VC equation*	0.7430	0.0292	25.48
RHOEX	S_{EXECOF} *equation*	0.9585	0.0204	46.96
RHOPROF	$S_{PROFADM}$ *equation*	1.0116	0.0047	213.76
RHOMAINW	S_{MAINW} *equation*	0.8830	0.0246	35.85
RHOMAINEQ	S_{MAINEQ} *equation*	0.9330	0.0166	56.05
RHOTRANSP	S_{TRANSP} *equation*	0.9003	0.0240	37.56
RHOTRENG	S_{TRENG} *equation*	0.9291	0.0251	37.00
RHOWF	w_F *equation*	0.9968	0.0086	115.59
RHOWM	w_M *equation*	0.4255	0.0411	10.36

TABLE 6
Estimated Demand and Substitution Elasticities

	Exec.&Officials	Profess.&Admin.	Main.Way&Struct.	Main.Equip.&Store	Transport	Train&Engine	Fuel	Material	Equipment
Exec.&Officials	-0.142***	-4.495***	-0.757	-2.807***	3.751***	-0.094	-0.251	2.657**	0.883*
	(0.057)	(1.114)	(0.859)	(0.884)	(1.530)	(0.472)	(0.462)	(1.358)	(0.526)
Profess.&Admin.		-0.354***	-0.265	0.416	-1.322	0.302	0.559	1.392	0.745*
		(0.102)	(0.987)	(1.020)	(1.853)	(0.389)	(0.380)	(1.058)	(0.431)
Main.Way&Struct.			-0.649***	0.363	3.492**	0.636**	0.041	-0.963	1.471***
			(0.079)	(0.903)	(1.565)	(0.321)	(0.310)	(0.798)	(0.356)
Main.Equip.&Store				-0.626***	-2.666	0.723**	0.262	1.757**	1.078***
				(0.090)	(1.906)	(0.338)	(0.317)	(0.878)	(0.389)
Transport					-0.571***	1.002**	0.427	-4.625***	1.811***
					(0.107)	(0.534)	(0.468)	(1.364)	(0.523)
Train&Engine						-0.650***	0.795***	-0.480	1.257***
						(0.044)	(0.245)	(0.504)	(0.266)
Fuel							-0.144***	-0.587	0.046
							(0.043)	(0.648)	(0.341)
Material								-1.246***	3.267***
								(0.184)	(0.687)
Equipment									-0.823***
									(0.158)

Notes: Elasticities are computed at the mean of actual cost shares.
*** significant at the 1% level, ** 5% level, * 10% level.

TABLE 7
Estimated Cross-Price Elasticities

	Exec.&Officials	Profess.&Admin.	Main.Way&Struct.	Main.Equip.&Store	Transport	Train&Eng.	Fuel	Material	Equipment
Exec.&Officials	-	-0.151***	-0.025	-0.094***	0.126***	-0.003	-0.008	0.089**	0.030*
		(0.037)	(0.029)	(0.030)	(0.051)	(0.016)	(0.016)	(0.045)	(0.018)
Profess.&Admin.	-0.279***	-	-0.016	0.026	-0.082	0.019	0.035	0.086	0.046*
	(0.069)		(0.061)	(0.063)	(0.115)	(0.024)	(0.024)	(0.066)	(0.027)
Main.Way&Struct.	-0.054	-0.019	-	0.026	0.251**	0.046**	0.003	-0.069	0.106***
	(0.062)	(0.071)		(0.065)	(0.112)	(0.023)	(0.022)	(0.057)	(0.026)
Main.Equip.&Store	-0.182***	0.027	0.024	-	-0.173	0.047**	0.017	0.114**	0.070***
	(0.057)	(0.066)	(0.059)		(0.124)	(0.022)	(0.020)	(0.057)	(0.025)
Transport	0.091***	-0.032	0.085**	-0.065	-	0.024*	0.010	-0.112***	0.044***
	(0.037)	(0.045)	(0.038)	(0.046)		(0.013)	(0.011)	(0.033)	(0.013)
Train&Engine	-0.015	0.048	0.102**	0.115**	0.160*	-	0.127***	-0.077	0.201***
	(0.075)	(0.062)	(0.051)	(0.054)	(0.085)		(0.039)	(0.080)	(0.043)
Fuel	-0.024	0.054	0.004	0.025	0.041	0.077***	-	-0.057	0.004
	(0.044)	(0.036)	(0.030)	(0.031)	(0.045)	(0.024)		(0.062)	(0.033)
Material	0.262**	0.137	-0.094	0.173**	-0.456***	-0.047	-0.058	-	0.322***
	(0.133)	(0.104)	(0.079)	(0.086)	(0.134)	(0.050)	(0.064)		(0.068)
Equipment	0.343*	0.290*	0.572***	0.419***	0.705***	0.489***	0.018	1.271***	-
	(0.204)	(0.167)	(0.139)	(0.151)	(0.203)	(0.103)	(0.133)	(0.267)	

Notes: Each element in the table is the elasticity of demand for the input in the column with respect to a price change of the input in the row.
Elasticities are computed at the mean of actual cost shares.
*** significant at the 1% level, ** 5% level, * 10% level.

TABLE 8
Estimated Morishima Elasticities of Substitution

	Exec.&Officials	Profess.&Admin.	Main.Way&Struct.	Main.Equip.&Store	Transport	Train&Eng.	Fuel	Material	Equipment
Exec.&Officials	-	-0.009	0.116*	0.047	0.268***	0.139**	0.133**	0.231***	0.172***
		(0.067)	(0.062)	(0.062)	(0.078)	(0.060)	(0.058)	(0.076)	0.065
Profess.&Admin.	0.075	-	0.337**	0.380***	0.272	0.372***	0.388***	0.440***	0.400***
	(0.134)		(0.136)	(0.134)	(0.177)	(0.108)	(0.100)	(0.125)	0.110
Main.Way&Struct.	0.595***	0.630***	-	0.675***	0.900***	0.695***	0.652***	0.580***	0.755***
	(0.090)	(0.125)		(0.110)	(0.142)	(0.080)	(0.081)	(0.097)	0.092
Main.Equip.&Store	0.444***	0.653***	0.650***	-	0.453***	0.673***	0.643***	0.740***	0.696***
	(0.102)	(0.124)	(0.118)		(0.177)	(0.096)	(0.091)	(0.100)	0.101
Transport	0.662***	0.539***	0.656***	0.506***	-	0.595***	0.582***	0.459***	0.615***
	(0.114)	(0.128)	(0.118)	(0.132)		(0.107)	(0.108)	(0.115)	0.109
Train&Engine	0.636***	0.700***	0.752***	0.766***	0.811***	-	0.777***	0.574***	0.851***
	(0.083)	(0.074)	(0.057)	(0.063)	(0.085)		(0.054)	(0.094)	0.078
Fuel	0.119**	0.197***	0.147***	0.169***	0.185***	0.220***	-	0.087	0.148**
	(0.056)	(0.050)	(0.047)	(0.047)	(0.060)	(0.041)		(0.077)	0.070
Material	1.508***	1.383***	1.151***	1.419***	0.790***	1.199***	1.188***	-	1.568***
	(0.234)	(0.218)	(0.192)	(0.183)	(0.230)	(0.193)	(0.196)		0.238
Equipment	1.166***	1.112***	1.395***	1.242***	1.527***	1.311***	0.840***	2.093***	-
	0.316	0.288	0.274	0.290	0.311	0.242	0.252	0.392	

Notes: Each element in the table is the elasticity of demand for the input in the column with respect to a price change of the input in the row.
Elasticities are computed at the mean of actual cost shares.
*** significant at the 1% level, ** 5% level, * 10% level.

1 Elasticities of Substitution and the Cost Function

From the Shephard's Lemma, if we know the cost function, we can calculate the optimal demand of factors thanks to the relationship:

$$x_i = \frac{\partial C}{\partial p_i} \equiv C_i$$

And it is from here that we get:

$$\begin{aligned}
d\ln x_i &= d\ln\left(\frac{\partial C}{\partial p_i}\right) \\
&= \frac{1}{C_i} d\left(\frac{\partial C}{\partial p_i}\right) \\
&= \frac{1}{C_i}\sum_{k=1}^{N} \frac{\partial}{\partial p_k}\left(\frac{\partial C}{\partial p_i}\right) dp_k \\
&= \frac{1}{C_i}\sum_{k=1}^{N} \frac{\partial^2 C}{\partial p_i \partial p_k} dp_k
\end{aligned}$$

But as all the prices are constant except for p$_j$,we have that dp$_k = 0$ $\forall k \neq j$. Then, the above relation becomes:

$$\begin{aligned}
d\ln x_i &= \frac{1}{C_i}\frac{\partial^2 C}{\partial p_i \partial p_j} dp_j \\
&= \frac{1}{C_i}\frac{\partial^2 C}{\partial p_i \partial p_j} p_j d\ln p_j \\
&= \frac{1}{C_i} C_{ij} p_j d\ln p_j
\end{aligned}$$

And from here we get:

$$\eta_{ij} = \frac{d\ln x_i}{d\ln p_j} \mid_{y=const, p_k=const\ \forall k\neq j} = \frac{p_j C_{ij}}{C_{ij}}$$

We can then calculate the Allen substitution elasticity, σ_{ij},

$$\begin{aligned}
\sigma_{ij} &\equiv \frac{1}{S_j}\eta_{ij} \\
&= \frac{C}{p_j x_j}\frac{p_j C_{ij}}{C_i} \\
&= \frac{C C_{ij}}{C_i C_j}
\end{aligned}$$

1.1 Elasticities of Substitution with a Translog Cost Function

We can apply the formulas above to a translog cost function. We have:

$$\begin{aligned}
C_i &\equiv \frac{\partial C}{\partial p_i} = \frac{C}{p_i}\frac{\partial \ln C}{\partial \ln p_i} = \frac{C}{p_i}\frac{p_i x_i}{C} = \frac{C}{p_i}S_i \\
C_{ij} &\equiv \frac{\partial^2 C}{\partial p_i \partial p_j} = \partial\left(\frac{C}{p_i}S_i\right)/\partial p_j \\
&= \frac{C_j}{p_i}S_i + \frac{C}{p_i}\frac{\partial S_i}{\partial p_j} \\
&= \frac{p_j x_j}{p_i p_j}S_i + \frac{C}{p_i}\frac{1}{p_j}\frac{\partial S_i}{\partial \ln p_j} \\
&= \frac{C}{p_i p_j}\left(\frac{p_j x_j}{C}S_i + AA_{ij}\right) \\
&= \frac{C}{p_i p_j}(S_i S_j + AA_{ij})
\end{aligned}$$

And by using this we obtain the expression for the cross-price elasticity:

$$\begin{aligned}
\eta_{ij} &= \frac{p_j C_{ij}}{C_{ij}} = p_j \frac{C}{p_i p_j}(S_i S_j + AA_{ij})\frac{p_i}{C}\frac{1}{S_i} \\
&= \frac{AA_{ij} + S_i S_j}{S_i}
\end{aligned}$$

and for the Allen elasticity of substitution:

$$\sigma_{ij} \equiv \frac{1}{S_j}\eta_{ij} = \frac{AA_{ij} + S_i S_j}{S_i S_j}$$

Similarly, we have:

$$\begin{aligned}
C_{ii} &\equiv \frac{\partial^2 C}{\partial p_i^2} = \partial\left(\frac{C}{p_i}S_i\right)/\partial p_i \\
&= \frac{C_i}{p_i}S_i - \frac{C}{p_i^2}S_i + \frac{C}{p_i}\frac{\partial S_i}{\partial p_i} \\
&= \frac{p_i x_i}{p_i^2}S_i - \frac{C}{p_i^2}S_i + \frac{C}{p_i^2}\frac{\partial S_i}{\partial \ln p_i} \\
&= \frac{C}{p_i^2}\left(\frac{p_i x_i}{C}S_i - S_i + AA_{ii}\right) \\
&= \frac{C}{p_i^2}\left(S_i^2 - S_i + AA_{ii}\right)
\end{aligned}$$

and then:

$$\eta_{ii} = \frac{p_j C_{ii}}{C_i} = \frac{AA_{ii} + S_i^2 - S_i}{S_i} = \frac{AA_{ii} + S_i(S_i - 1)}{S_i}$$

FIGURE 1: Average Employment

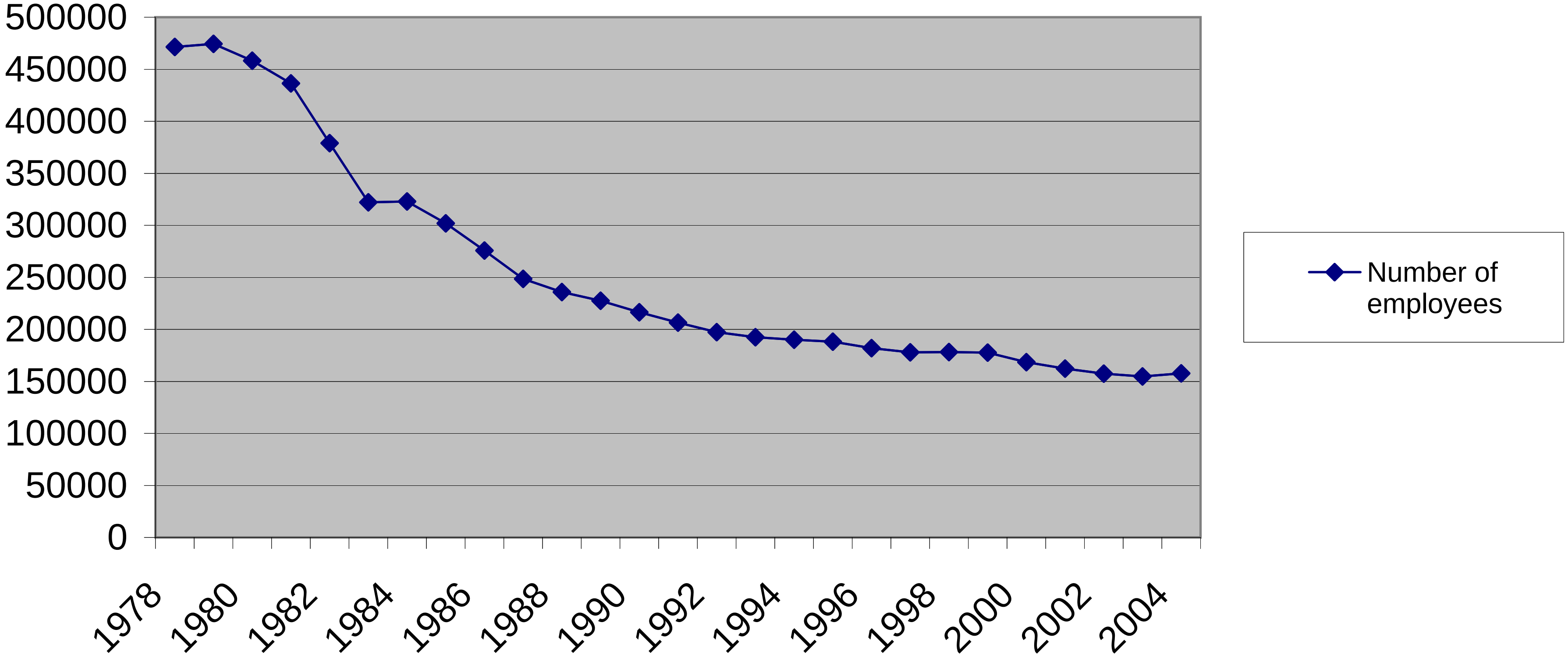

FIGURE 2: Employment by Category