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Labour inputs substitution during corporate restructuring: a translog model approach for US freight railroads

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After deregulation in 1980, competitive pressures forced the large US freight railroads to reduce costs and restructure, resulting in an economic renaissance of US railroad companies after years of poor financial conditions. The most striking restructuring measure receiving much attention was dramatic labour downsizing: until 2004 employment was reduced by 60%. But other overlooked measures are the significant restructuring of workforce composition and important changes in railroads' workplace organization practices and corporate culture. To better understand this successful occupational restructuring, I investigate labour inputs substitutional relationships by using a translog variable cost model. Labour is decomposed into six employee categories rather than traditional production-nonproduction breakdown to estimate inputs elasticities of substitution. The data investigated is a unique firm-level dataset on US freight Class I Railroads, covering a 22-year period, that allows this fine-grained analysis. I also document railroad workplace organization practices relating to results and reflecting changes in railroads corporate culture. I find strong substitutability between managerial positions and transportation employees, pointing to achievement of better command and control of operations; a high degree of complementarity between the most skilled employee categories and the strongest substitute relationship between transportation and maintenance of Ways&Structures groups.

Keywords: translog, labour restructuring, labour inputs substitution, workplace organization, panel data.

JEL Classification Codes: C33, G34, J21, J82, L 92

I. Introduction

Largely because of excessive regulation, by the 1970s US freight railroads were in extremely poor financial condition. Bankruptcies were common, service was poor, and railroads could not afford the costs of maintaining tracks and equipment. Deregulation returned the large US Class I Railroads to the competitive marketplace after nearly a century of tight government regulation. Since the passage of the 1980 Staggers Railroad Act, the primary regulatory reform, competitive pressures have stimulated crucial changes in the way that railroad companies think about their operations, markets and customers. Regulatory reform resulted in more aggressive railroad management and stimulated crucial changes in the railroad companies' culture (Gallamore 1997).

Competition forced the railroad firms to reduce costs. One of the most striking restructuring measures adopted by railroads was dramatic labour downsizing. Employment was reduced by 60% between 1981 and 2004. This downsizing affected every railroad employee category, but not in the same way. In fact, in addition to labour downsizing, the railroads also undertook significant restructuring in the composition of their workforce and implemented important changes in their organizational structures.[1] Moreover, this occupational restructuring helped to generate operational efficiencies and has significantly contributed to the economic renaissance of the US railroad companies.[2]

An important dimension in understanding this occupational restructuring is the nature of the substitution relationship between the employee categories prevalent during the period of occupational restructuring. Complementarities and substitutabilities between these employee categories are expected to largely explain the viability and success of the railroads' occupational restructuring.

Other authors have already shown that, since deregulation, there was a significant increase in railroad aggregate labour input flexibility: wage elasticities have become more elastic (e.g., Hsing and Mixon, 1995). After deregulation, there was an increase in the substitution possibilities and a greater flexibility, in general, in the use of inputs by railroads that was partly explained by the less favourable bargaining environment for the rail unions.[3] The 1980s represent a turning point in railroad union-industry relationships, with unions becoming more willing to adjust to the railroads' need to contain labour costs (Schwarz-Miller and Talley, 2002). Unions understood that increasing productivity was key to survival. With this change in climate, railroads were better able to realize the productivity enhancing benefits of

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[1] The effect of deregulation on US railroad employment has been extensively documented. See, for example, McFarland (1989), MacDonald and Cavalluzzo (1996) and Bitzan (1997). For empirical evidence on the effect of deregulation on railroad employee composition, see, for example, Schwarz-Miller and Talley (1996) and Bitzan (1997).

[2] See Friebel *et al.* (2008) for empirical evidence on the operational efficiencies that resulted from railroad employee composition restructuring.

[3] Several empirical studies have examined the influence of unionization on the ease of substitution of labour in industries other than railroads. For instance, for the US manufacturing industry, both Freeman and Medoff (1982) and Magnani and Prentice (2005) find that higher unionization is associated with less flexibility in the use of labour inputs.

technological progress from the introduction of labour-saving technologies.

The purpose of this article is to investigate in detail the substitutional relationships of the railroad employee categories during the post-deregulation period. For this purpose, I use a multi-input/output translog variable cost function. To properly account for the difference in skill levels, the analysis must segment the total labour force into the relevant employee categories. Usually, the literature on labour-labour substitution segments the total labour force into only two employee categories: production and nonproduction workers. To obtain a better understanding of the occupational restructuring process, this article goes beyond this approach by distinguish between six existing employee categories. The elasticities of substitution between labour inputs and the remaining railroad inputs are also examined. The examination of overall inputs substitution possibilities are expected to help to better explain the already cited operational efficiencies.

The data investigated are a unique firm-level dataset on US freight Class I Railroads covering a 22-year period, which allows for a fine-grained analysis. These data contain detailed information on firm-level operating costs and, most important, employment and wage information for six occupational categories. Each occupation requires different levels of formation or human capital; each employee category can therefore be considered to be associated with a particular skill level. Many other empirical studies have already emphasized that using firm-level datasets is always preferable to using industry-level datasets for the analysis of input elasticities (e.g., Magnani and Prentice, 2006).

It seems intuitively reasonable to expect that the complementarities and substitutabilities between different employee categories relate to particular workplace organizational practices. In effect, following deregulation, railroads incorporated changes into their workforces' practices, as reported by many of the railroads' top management teams. This article provides examples of the workplace organization practices within the railroad firms in the post-deregulation period that relate to the complementarities and substitutabilities found between different employee categories. Most of the introduced changes in workplace practices resulted from the railroad companies' shift to a more customer-oriented model after deregulation and their return to the competitive marketplace. Railroad top management teams identify these changes as improvements in the way that they organized their firms and as a source of operational efficiency.

To the best of my knowledge, no similar study has been conducted to date for this large and important industry, an industry that belongs to a sector that represents the fourth largest share of the total US labour force. The EU decided over a decade ago that railways should be privatized in all member countries. The large rail sector in the EU may learn from the US experience. It is important to understand the workings behind the successful occupational restructuring of the US railroads.

The primary findings indicate that there is strong substitutability between some nonproduction and production employee categories, namely, those with managerial positions and those within the transport group, indicating that the railroad companies have achieved better command and control of freight operations. I find a high degree of complementarity between the two most skilled employee categories, which relates to workplace practices, such as the widespread use of teamwork to improve communication at high levels of the organization. There is also a complementary relationship between the executive positions and the positions that are responsible for the maintenance of equipment, which is related to the refocus of railroad management on providing reliable service to their customers. The strongest substitute relationship found is between transport and maintenance of ways and structures groups. Finally, the results reveal that all of the labour occupations are substitutable for the equipment input, but not on an equal level. More precisely, the substitution relationship is weaker for the most skilled labour categories.[4]

The overall findings indicate the importance of going beyond the production/nonproduction duality when examining substitution possibilities between labour inputs and other inputs and when understanding the restructuring processes. A much richer picture can be obtained for the understanding of the workings of occupational restructuring.

II. Background

With the passage of the Interstate Commerce Act in 1887, freight railroads became the first US industry that was subject to comprehensive federal economic regulation. For the next 93 years, the federal government, mainly through the Interstate Commerce Commission, controlled wide areas of rail operations and management.

Regulation imposed lengthy merger proceedings and route abandonment hearings, lack of flexibility in rate setting and the prohibition of joint use of common track between two carriers leading to duplication of service, lack of innovation, loss of market share and high costs (Bitzan, 1997). 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 Act were that rail management, not government regulators, should run railroads. The reform allowed the

[4] Association of American Railroads (AAR) 2008.

railroads to establish their own routes, tailor their rates and services to market conditions, and differentiate rates on the basis of demand. The reform also permitted long-term service contracts between railroads and their customers and eased procedures for the abandonment and the sale of rail lines.

There is general agreement that US rail deregulation is a good example of how a policy shift can produce significant changes in the economic health of an industry. Most railroad experts agree that US deregulation was a major success after its introduction. Both companies and customers have benefited (see, for instance, Hilmola and Szekely, 2006, for a summary of US railway deregulation literature).

With competition, the railroads began to think about how to achieve a better match between their huge physical plants and huge workforces, on the one hand, and the available traffic, on the other hand (Gallamore, 1999).

The main effects of the reform were an increase in shipment density and size, the initiation of double-stack container train service, which was triggered by the allowance of long-term contracts between railroads and shippers, an increase in market concentration and the reinvestment of hundreds of billions of dollars in productive rail infrastructure and equipment.

For the workforce, there was dramatic labour downsizing; by 2004, employment had been reduced to a third of its size in 1981. This dramatic decrease is displayed in Fig. 1, which shows the evolution of total employment between 1978 and 2004. Employment was stable between 1978 and 1981, and then, right after the passage of the main deregulatory reform, it suffered dramatic downsizing. However, this downsizing did not affect all of the employee categories equally. This is shown in Fig. 2, which disaggregates the labour downsizing by occupational category.

Regarding employee compensation, it is difficult to accurately measure the impact of deregulation on the labour prices for the different employee categories. The corporate restructuring that followed deregulation involved diverse restructuring measures, including merging processes, abandoning unprofitable lines and using new labour-saving technologies (in particular, using double-stack containers, as already mentioned). Each of these measures may have affected the compensation for different employee categories differently. However, overall, the data suggest that deregulation benefitted all employee categories in terms of compensation, as can be observed in Fig. 3, which plots the evolution of real average annual compensation by occupational category. Real compensation for all employee categories suffered general decreases between 1978 and 1981 while, following deregulation, real compensation on average increased for all employee categories, although the degree of the increase varied depending on the employee category.[5] For instance, over the period from deregulation until 2004, the annual compensation for the most skilled categories (*Executives&Officials* and *Professional&Administrative*) increased by about 70%, yet for the other categories, it increased by about 50%.[6]

Fig. 4 shows the evolution of rail material, equipment and fuel prices[7] between 1978 and 2004. Prices for both material and equipment have been increasing overtime since 1978, while the price for fuel shows a fluctuating pattern.

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[5] For analyses on the effect of deregulation on earnings in other transport industries, see, for instance, Peoples (1996) for the trucking industry and Cremieux (1996) and Hirsch and Macpherson (2000) for the airline industry.

[6] If examining the period from 1981 to 2001 instead, the largest increase in real compensation is for *Train&Engine*, which is consistent with the results from the analysis by Bitzan (1997) on the impact of deregulation on earnings. As explained in his analysis, in many cases, the technological innovations that were put into use following deregulation allowed the engineers and conductors to perform the duties previously performed by brakemen and switchmen, while still performing their own duties. Thus, the large productivity gains realized by engineers and conductors relative to brakemen and switchmen suggest a much larger increase in earnings resulting from deregulation.

[7] Cost indices for material, equipment and fuel reported by the AAR to the Surface Transportation Board based on surveys of member railroads.

III. The Model

I use a variable cost model with the specification of Ivaldi and McCullough (2001) but with labour prices disaggregated into the six existing employee categories. The specification is therefore as follows:

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

where:

VC = annual operating variable cost,[8]

y = output, divided by:

y_B, y_G, y_V, y_I = car-miles[9] of bulk traffic (i.e., open hopper, closed hopper), general traffic (gondolas, box cars), intermodal traffic (trailers and containers on flat cars), and replacement ties installed in a given year (a measure of infrastructure output), [10]

w_L = vector of labour prices = ($w_{EXECOF}, w_{PROFADM}, w_{MAINW}, w_{MAINEQ}, w_{TRANSP}, w_{TRENG}$) = average annual compensation[11] of Executive&Official, Professional&Administrative, Maintenance of Way&Structures, Maintenance of Equipment&Stores, Transport group and Train&Engine positions,

w_E, w_F, w_M = rail equipment, fuel and material price index,

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8 Values deflated by producer price index base-1982.

9 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. 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.

10 On mature rail networks most infrastructure-related activity is aimed at maintaining the capacity of 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).

11 Values deflated by producer price index base-1982.

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

road = miles of road operated

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

• *Executive&Officials:* managerial positions

• *Professional&Administrative*: technical and clerical positions

• *Maintenance of Ways&Structures*

• *Maintenance of Equipment&Store*s

• *Train&Engine*: conductors, yard or road engineers and other people who physically operate the trains

• *Transport*, other than *Train&Engine*: people involved with on-line train operations except for engine and train crew personnel

The functional form used to estimate Equation 1 is a flexible multiproduct translog:

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

where VC represents variable costs, *w* is the 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 measures the degree of occupational dissimilarity between two periods of time,[12] 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.[13] These input shares are obtained by using Shepard's Lemma and are of the form:

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

where S_i is the share of variable cost allocated to input i, that is, $w_i x_i / VC = d \ln VC / d \ln w_i$. The share equations are estimated for all of the inputs except for one, to avoid perfect collinearity. The data are mean scaled so that, at the mean, the logarithm will be zero.[14]

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 prices.[15] This property 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

12 See Table 1 for a detailed description.

13 It yields more degrees of freedom and efficient parameter estimates without additional unrestricted coefficients.

14 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.

15 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.

Nelson, 1988).[16]

IV. Input Demand and Substitution Elasticities

The translog parameter estimates can be used to calculate elasticity values.[17]

The formulas for input demand, cross-price and (Allen) substitution elasticities for the translog cost function are as follows:

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

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

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

All of these measures are one-price-one-factor elasticities: both elasticities measure the responsiveness of input i to a 1 % change in the price of input j, with all other prices and output held constant. By construction, σ_{il} are symmetric, but not η_{il}, and σ_{il} must have the same sign. Inputs are substitutes if $\sigma_{il} >$ 0 and complements if $\sigma_{il} <$ 0.

To provide further insights into the substitution possibilities, Morishima elasticities of substitution are also calculated, which are an alternative to the above Allen Elasticities of Substitution. The Morishima elasticity is an exact measure of how the i, j input ratio responds to a change in w_j, which is a much more economically

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

[17] See the appendix for the demonstration.

relevant concept than the Allen elasticity (Chambers, 1988, p.96). The Morishima elasticity measures *relative* input adjustment to any single-factor price changes. Two inputs 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.[18]

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

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

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.

V. Data and Estimation Results

The sources for the data are the annual *Analysis of Class I Railroads* and the quarterly *Railroad Cost Indexes* published by the Association of American Railroads. The sample is an unbalanced panel of 22 Class I firms operating in the US between 1982 and 2004.[19] Variable definitions are given in Table 1, and summary statistics are given in Table 2.

The system estimated includes the cost equation (Equation 2), eight share equations (Equation 3), and four additional equations that represent instrumental variable regressions for the output variables y_B, y_G, y_V and y_I, to control for

[18] It is a measure of the ease of substitution and a sufficient statistic for assessing the effects of changes in prices on relative factor shares, whereas the Allen elasticity of substitution is not (see Blackorby and Russel, 1989).
[19] Firms are defined as the accounting entities presented in the *Analysis.*

endogeneity problems.[20] The instruments are selected input prices and exogenous variables, such as coal consumption and population, calculated for the territory served by each railroad per year.

The assumptions that are 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,[21] and autocorrelation is corrected by estimating autoregressive parameters for the cost equation and the share equations. To account for contemporaneous correlation, the system is simultaneously estimated using the FIML command from SAS for Windows, Release 9.1.

Basic regression results

The results are presented in Table 4. All of 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*),[22] and all but three are significant at conventional levels. The

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[20] As argued in Ivaldi and McCullough (2001), 'partial deregulation of the rail industry in 1980 meant that output levels and composition became strategic decisions not independent of firm characteristics'.

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

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

time trend suggests that the railroad operating variable costs have been declining at approximately 1.01 % per year. The effect of employee restructuring on costs is negative but not significant at conventional levels.

Regarding the output variables, the elasticity of costs with respect to *intermodal* type of traffic (0.0981) has the smallest significant positive value, which reflects the inherent efficiencies of intermodal type of traffic relative to the rest.

In terms of share biases effects (the measure of how input *i*'s expenditure share responds to an increase in output *j*, i.e., AB_{ij} terms coefficients), and in particular, the effects related to the different labour categories, the majority of the significant biases have a negative sign. Regarding *intermodal* type of output, *Professional& Administrative* is the only category that obtains a highly significant negative coefficient: increases in intermodal traffic result in decreases for the expenditure share of this employee category.

In contrast, increases in *infrastructure* type of output result in increases for maintenance employees and for *Train&Engine* expenditure shares. *Maintenance of Ways&Structures* labour shows the largest magnitude for this effect. The interference between operations and infrastructure activity may explain the result for the *Train& Engine* positions. Essentially, *Train&Engine* includes the people who physically operate the trains, such as conductors. The interference between operations and infrastructure activity may make the scheduling and repositioning of this portion 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 result could be explained by the nature of bulk operations. Bulk traffic usually moves in blocks of cars or unit

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coefficient.

trains.[23] 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. This simplification reduces the need for high capability of command and control, which could partially explain the decrease in the expenses for managerial positions. At the same time, this simplification does cause increases in the expenditure share for *Maintenance of Equipment&Stores* and *Train&Engine.*

Input demand and substitution elasticities results

Table 6 reports the estimated demand and the substitution elasticities for the six employee categories and for fuel, materials and equipment.

All of the own-price elasticities have the expected sign, i.e., input demand reacts negatively to an increase of own price. All of the coefficients are highly significant (1% level). Labour demand elasticities differ according to the employee category, as expected. Moreover, the results are consistent with those of Hamermesh (1987), indicating that own-price demand elasticities are lower for workers that embody higher-skill human capital: the low demand elasticities of *Executives& Officials* (-0.142) and *Professional&Administrative* (-0.354) contrast with the relatively larger values for the remaining employee categories. Those remaining employee categories have very similar demand elasticities. The *Transport* group shows the lowest own-price elasticity (-0.571).

Examining the results for the remainder of the inputs, *fuel* shows the least

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

elastic demand, with an own-price elasticity equal to -0.144, which is a plausible result for a transport industry, while *materials* shows the most elastic demand (-1.246).

One of the most important and interesting findings regarding the substitution elasticities is the high degree of substitutability between the *Transport* (production workers) and the *Executives&Officials* (nonproduction workers) groups. The elasticity of substitution for these two categories is 3.751, which is the largest positive value in the table and highly significant (1% level). This result suggests a better command and control of railroads network operations - railroads being able to substitute technology and managers for production workers - during the post-deregulation period.

The results indicate an equally high degree of substitutability between *Executives&Officials* and *materials.* The elasticity of substitution for these two categories is 2.657, significant at 5% level. *Executives&Officials* includes managers that directly supervise train and yard operations. This result suggests that more supervision effectively results in less wastage of material.

In contrast, there is a significant complementary relationship between *Executives&Officials* and *Maintenance of Equipment&Stores*, with an elasticity of substitution of -2.807 highly significant (1% level). This result suggests that the presence of more managerial positions is associated with an increased number of these specific maintenance occupations.

Another remarkable finding is the high degree of complementarity between what can be identified as the two most skilled employee categories, namely, *Executives & Officials* and *Professional&Administrative.* These two employee categories complement each other during the post-deregulation period.

The results indicate a very strong substitute relationship between the *Transport* and *Maintenance of Ways&Structures* groups. In fact, these two employee categories perform various similar jobs. Tables 7 and 8 provide 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 result indicates 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 it is to substitute the latter with the former.

Likewise, the results indicate that there is a substitute relationship between *Transport* and *Train&Engine,* though this substitute relationship is not as strong as it is for *Maintenance of Ways&Structures* and *Transport*. These groups do perform some similar tasks, but this list of overlapping tasks is smaller than it is in the preceding case.

Moreover, the signs of the substitution elasticities are different between the six employee categories and two of the three remaining inputs, namely, fuel and materials. For instance, the substitution elasticity between *materials* and *Executives &Officials* is 2.657 (i.e., strong substitute relationship), significant at 5% level, and 1.757 for *Maintenance of Equipment & Stores*, significant at 5% level, while it is -4.625 (i.e., strong complementary relationship) between *materials* and the *Transport* group, significant at 1% level. These results indicate that total labour does not form a consistent aggregate, which is consistent with the results from studies in industries other than railroads.[24] These results indicate the importance of disaggregating labour by relevant employee categories when studying the complementarities and substitutabilities of labour with other inputs.

Fuel obtains the only significant elasticity with *Train&Engine* employee category (0.795). There is a substitution relationship for these two categories. One possible explanation is that with higher energy prices more engineers are engaged, which search for and implement energy-saving measures.

Finally, an inspection of the *Equipment* column in Table 6 reveals that all of the labour occupations are substitutable for this input, but not equally: the substitution relationship is weaker for the most skilled categories. For example, the elasticity of substitution for *Professional&Administrative* is 0.745, yet it is much larger for *Transport,* 1.811.

VI. Related Workplace Organization Practices

The chart below summarizes the most relevant results regarding the substitution relationships and relates them to corporate strategies and particular workplace organization practices that were implemented by the railroads during the post-deregulation period, as reported by the railroads' top management teams:

Results	**Points to**	**Workplace Practices**

[24] See, for example, the analysis of the Australian iron and steel industry in Turnovsky and Donnelly, 1984, where labour is divided into administrative workers and production labour. They find that the various elasticities between administrative and production workers and the other inputs, namely, energy, materials and capital, usually have opposite signs (or are very different), while the elasticity between aggregate labour and these same inputs are always bound by these two former elasticities as some sort of average of the two.

Strong Substitutability Executive&Official and Transport Strong Substitutability Executive&Official and Material	Better command and control of operations	Teamwork between operations and sales/marketing enabling joint forecasting and planning
Strong Complementarity Executive&Official and Professional & Administrative	Work teams 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
Strong Complementarity Executive&Official and Maintenance Equipment&Store	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 indicates that railroad firms achieved better command and control of freight network operations. As already argued, this result suggests that the railroads have been able to substitute technology and managers for production workers.

This result may be related to the changes in the payment system for railroad managers after the regulatory reform. There is empirical evidence from railroad studies (e.g., Bitzan, 2004) that there was a stronger pay for performance relationship as a result of deregulation. Logically, pay for performance may increase work pressures for other transportation workers: the significance of pay for performance for rail management could result in the managers demanding enhanced efficiency from their workers. The provision of payment incentives may have then become an effective way to improve the monitoring of railroad employees by managers.

Better command and control has, to a large extent, been achieved because of initiatives aiming to improve the operational planning process. For example, the widespread use of teamwork between operations and sales/marketing when setting the annual planning cycle has allowed for a better match between operations and the transportation manpower requirements. As Dick Davidson, CEO of Union Pacific (UP) during the 1990s, 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 its forecast on locomotive and manpower requirements and so on. (Railway Age, February 2, 1992)

Likewise, the high degree of substitutability between *Executives&Officials* and *material* suggests that more supervision effectively results in less wastage of material; this result closely relates to the theory that there is better command and control of freight operations.

The strong complementary relationship between *Executives&Officials* and *Professional&Administrative* may be related to another important change in railroad company culture after deregulation: the widespread use of cross-functional teams in developing revised business processes and new information technology applications (Gallamore, 1999).

Again, after the enactment of regulatory reform, the railroads reshaped their way of thinking about their operations, markets and customers. The railroads found that mixing people from different departments or disciplines could allow them to better assemble information on customer requirements and broad railroad operational needs. *Executives&Officials* and *Professional&Administrative* are the two most likely categories to be involved in these team practices. The *Executives&Officials* category includes jobs that set broad policies and direct individual departments, and the *Professional&Administrative* category includes several supervisory, technical and inspector-type positions for different departments and sub-departments.

One example of initiative of this type was the creation of study teams that included representatives from positions belonging to *Professional&Administrative* (Finance, Marketing&Sales, Car Management, Operations) and *Executive&Officials* (Strategic Planning) to determine how to improve service reliability. These teams worked together to develop market-based operating plans that provided railroads a view into short- and long-term capacity needs. In essence, there was teamwork at the top of the railroad companies. In most cases, these teams responded to the need for better communication, a need which was seen in the railroad organizations that descended from the previously common hierarchical or militaristic organizational styles. Southern Pacific (SP), when talking about teamwork, said:

SP's top managers and labour officials now get together semiannually and frankly discuss company finances, traffic volume and anything else they want to discuss. (Powell, 1996)

Finally, the complementary relationship between *Executives&Officials* and *Maintenance of Equipment&Stores* may reflect the fact that railroad managers are focusing on the safety and service reliability standards that they can offer to their customers. This finding is consistent with the transition to a more customer-oriented corporate culture that was undoubtedly stimulated by the regulatory reform. Service reliability and safety improvement have been two of the most important improvement strategies adopted by rail management in the post-Staggers era, and both are aimed to achieve customer satisfaction. When railroad firms were asked about their priorities in the 1990s, the improvement of service reliability was one element that was recurrently mentioned. 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)*

With the increase in competition, railroad managers became aware of the increasing importance of employing sufficient maintenance of equipment personnel, enabling them to minimize the amount of time that machines were not in service (because of on-going repair work) and to prevent locomotive breakdowns.

The new emphasis on service reliability was motivated largely by the rise of Just-in-Time manufacturing operations, which drove companies to demand on-time delivery performance from their shippers. Manufacturers were reducing component inventories. Retailers, similarly, were holding smaller inventories of goods for sale, relying on their ability to get rapid response to their orders. There was little room and tolerance for service failures.

This situation is closely related to the railroads' safety standards concerns, as accidents disrupt operations and cause service failures, explaining why the improvement of safety records became another priority for railroad strategies. Regular maintenance checks are expected to prevent accidents and help decrease derailment frequency and freight damage.

Moreover, some railroad companies realized that locomotive breakdowns represented a significant share of their costs. UP executives noted this in the 1990s 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. (Railway Age, February 1, 1992)*

Lastly, apart from the organizational practices listed above, there were other organizational practices that took place at the same time that deserve to be mentioned. Some of these practices relate to the elasticities of substitution results. These practices also reflect significant changes in the railroads' corporate cultures.

Railroads established quality teams, or departments that were charged with helping the company to become more customer driven. These teams were dedicated to building customer satisfaction. One related initiative for some railroads was the establishment of Customer Service Centers, such as those created by CSX at the beginning of the 1990s and by SP in Denver.

Railroads reorganized their sales and marketing departments to be more customer oriented. For example, Burlington Northern Santa Fe Corp. (BNSF) formed four new marketing groups (agricultural products, coal, consumer products and industrial products) at the end of the 1990s. This new structure was intended to improve their ability to develop customised service packages that met their customers' transportation needs.

Railroads empowered employees by setting up cross-functional quality improvement teams (QIT) and made employee involvement their main objective. UP set up a QIT, and by 1992, about 11% to 12% of the UP workforce was involved. UP also started to use employee involvement teams and state-of-the-art training, adding peer trainers to help their employees become more productive. One example of a cross-functional quality improvement team is provided by SP, who created a cross-functional team of locomotive engineers, dispatchers, mechanical department personnel and conductors that created a new procedure for reporting locomotive mechanical problems. This procedure proved to be a vast improvement over the old procedure and, at the same time, ameliorated communication between employees from different departments and improved labour-management relationships.

Several railroad companies underwent changes in management, including the introduction of job rotations and new recruits. For instance, a chairman of SP said that, at the beginning of the 1990s, 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 (Railway Age, 1993). There were also reductions in the management ranks that were intended to increase the managers' responsiveness and accountability.

VII. Concluding Remarks

After deregulation, competitive pressures forced the railroad firms to reduce costs. One of the restructuring measures receiving much attention was dramatic labour downsizing. However, aside from the labour downsizing, railroads also undertook significant restructuring in the composition of their human resources and implemented important changes in their organizational structures. This human resources restructuring has generated operational efficiencies within the US railroad companies.

This article investigates the labour inputs substitutional relationships in this industry during the post-deregulation period to help better understand this successful human resources restructuring. It presents a translog cost model designed to estimate the complementarities and substitutabilities between the different employee categories.

Rather than separating the workforce into only two employee categories (production and nonproduction workers), as is standard practice in the literature on labour-labour substitution, this article goes beyond this approach by distinguishing between six different employee categories to obtain a better understanding of the substitution and complementary labour relationships. The elasticities of substitution between labour inputs, as well as between labour and other inputs, are estimated to provide insight into the overall substitution possibilities in railroads.

For this purpose, this article uses a unique dataset from the US Class I Railroads. This dataset has two advantages: the data are firm-level, and it has very detailed information on the workforce composition that enables labour to be divided into six different employee categories beyond the traditional production/nonproduction categorization.

In addition, this analysis provides examples of related workplace organizational practices within railroad firms during the post-deregulation period. Most of these practices are reported by railroad top management teams as a source of operational efficiencies.

The primary findings of this analysis are, first, the strong substitutability between some nonproduction and production employee categories, namely, between those categories with managerial positions and the transport group, pointing to the achievement of better command and control of freight operations Second, there is a high degree of complementarity between the two most skilled employee categories, which relates to workplace practices such as the widespread use of teamwork to improve communication at the higher levels of the organization. There is also a complementary relationship between executive positions and positions involved in the maintenance of equipment, which is connected to the refocus of railroad management on providing reliable service to their customers. The *Transport* and the *Maintenance of Ways&Structures* groups showed the strongest substitute relationship. Finally, the results reveal that all the labour 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 the lowest own-price demand elasticities are those of the most skilled employee categories, which is consistent with Hamermesh (1983); increases in intermodal type of traffic result in significant decreases in the Professional&Administrative expenditure share, and the substitution elasticities between the six different labour inputs and two of the three remaining inputs have different signs, indicating that total labour does not form a consistent aggregate.

Most of the workplace organization practices documented here resulted from the shift of railroad companies toward a more customer-oriented model after deregulation. A return to the competitive marketplace forced the railroads to emphasize service quality, with service reliability becoming a crucial element in their business. This shift is connected to the increased importance of agility and speed in responding to customer needs, a primary concern of other industries in the service sector.[25]

My overall findings indicate the importance of going beyond the traditional production/nonproduction duality when examining substitution possibilities between inputs and when examining corporate restructuring to gain a better understanding of corporate restructuring processes.

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

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Appendix

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:

$$d \ln x_i = d \ln\left(\frac{\partial C}{\partial p_i}\right)$$

$$= \frac{1}{C_i} d\left(\frac{\partial C}{\partial p_i}\right)$$

$$= \frac{1}{C_i} \sum_{k=1}^{N} \frac{\partial}{\partial p_k}\left(\frac{\partial C}{\partial p_i}\right) dp_k$$

$$= \frac{1}{C_i} \sum_{k=1}^{N} \frac{\partial^2 C}{\partial p_i \partial p_k} dp_k$$

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:

$$d \ln x_i = \frac{1}{C_i} \frac{\partial^2 C}{\partial p_i \partial p_j} dp_j$$

$$= \frac{1}{C_i} \frac{\partial^2 C}{\partial p_i \partial p_j} p_j d \ln p_j$$

$$= \frac{1}{C_i} C_{ij} p_j d \ln p_j$$

And from here we get:

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

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

$$\sigma_{ij} \equiv \frac{1}{S_j} \eta_{ij}$$

$$= \frac{C}{p_j x_j} \frac{p_j C_{ij}}{C_i}$$

$$= \frac{C C_{ij}}{C_i C_j}$$

Elasticities of substitution with a translog cost function

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

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

$$C_{ij} \equiv \frac{\partial^2 C}{\partial p_i \partial p_j} = \partial \left(\frac{C}{p_i} S_i \right) / \partial p_j$$

$$= \frac{C_j}{p_i} S_i + \frac{C}{p_i} \frac{\partial S_i}{\partial p_j}$$

$$= \frac{p_j x_j}{p_i p_j} S_i + \frac{C}{p_i} \frac{1}{p_j} \frac{\partial S_i}{\partial \ln p_j}$$

$$= \frac{C}{p_i p_j} \left(\frac{p_j x_j}{C} S_i + AA_{ij} \right)$$

$$= \frac{C}{p_i p_j} (S_i S_j + AA_{ij})$$

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

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

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:

$$C_{ii} \equiv \frac{\partial^2 C}{\partial p_i^2} = \partial\left(\frac{C}{p_i} S_i\right) / \partial p_i$$

$$= \frac{C_i}{p_i} S_i - \frac{C}{p_i^2} S_i + \frac{C}{p_i} \frac{\partial S_i}{\partial p_i}$$

$$= \frac{p_i x_i}{p_i^2} S_i - \frac{C}{p_i^2} S_i + \frac{C}{p_i^2} \frac{\partial S_i}{\partial \ln p_i}$$

$$= \frac{C}{p_i^2}\left(\frac{p_i x_i}{C} S_i - S_i + AA_{ii}\right)$$

$$= \frac{C}{p_i^2}\left(S_i^2 - S_i + AA_{ii}\right)$$

and then:

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

Table 1. Variable definitions

Variable	Description
Variable cost (VC)	Operating variable costs: labour + material + fuel + equipment expenditures
OUTPUT	
Bulk (y_B)	Total car-miles 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 (w_{EXECOF})	$82 (deflated by producer price index base-1982) average annual compensation Executives&Officials
Professional&Administrative ($w_{PROFADM}$)	$82 av. an. comp. Professional&Administrative
Maintenance of Way&Structures (w_{MAINW})	$82 av. an. comp. Maintenance of Way&Structures
Maintenance of Equipment&Stores (w_{MAINEQ})	$82 av. an. comp. Maintenance of Equipment&Stores
Transport, other than Train&Engine (w_{TRANSP})	$82 av. an. comp. tranportation positions
Train&Engine (w_{TRENG})	$82 av. an. comp. Train&Engine
Fuel (w_F)	$82 rail fuel price index
Material (w_M)	$82 rail material and other input price index
Equipment (w_E)	$82 rail equipment price index
QUASI-FIXED INPUT & 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
Labour price (w_L)	$82 rail labour price index
Occupational restructuring	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	SD	Min	Max
Variable cost (*VC*)	\$82 (000)	1628 803	1 518 733	74351	6 759 155
Executives&Officials share (S_{EXECOF})	%	0.034	0.011	0.013	0.078
Professional&Administrative share ($S_{PROFADM}$)	%	0.063	0.024	0.020	0.172
Maintenance Way&Structures share (S_{MAINW})	%	0.072	0.014	0.040	0.124
Maintenance Equipment&Stores share (S_{MAINEQ})	%	0.065	0.016	0.031	0.113
Transport share (S_{TRANSP})	%	0.024	0.008	0.009	0.053
Train&Engine share (S_{TRENG})	%	0.160	0.023	0.083	0.227
Fuel share (S_F)	%	0.096	0.029	0.034	0.187
Material share (S_M)	%	0.099	0.034	0.035	0.274
Equipment share (S_E)	%	0.389	0.081	0.148	0.637
Bulk (y_B)	Car-miles (000)	639 026	725 709	16 576	3 951 606
General freight (y_G)	Car-miles (000)	933 540	1 015 678	32 868	6 208 521
Intermodal (y_v)	Car-miles (000)	309 382	344 664	3789	1 511 890
Infrastructure (y_I)	Ties (000)	1142	1032	27	4664
Executives&Officials price (w_{EXECOF})	\$82	57 266	11 753	34 418	99 147
Professional&Administrative price ($w_{PROFADM}$)	\$82	33 773	4895	21 715	51 207
Maintenance Way&Structures price (w_{MAINW})	\$82	31 131	3976	17 781	40 835
Maintenance Equipment&Stores price (w_{MAINEQ})	\$82	31 651	3730	19 212	45 995
Transport price (w_{TRANSP})	\$82	36 203	5913	23 086	61 541
Train&Engineering price (w_{TRENG})	\$82	45 696	9073	22 567	84 949
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	34 946
Time trend *(time)*	Years	9	6.3	0	22
restructuring	index	0.003	0.005	0.00002	0.052
Coal consumption	Tons (000)	300 760	172 846	9990	676 587
Population	Persons (000)	74 718	47 185	4631	173 769
Labour price (w_L)	Index	150.120	33.228	100	224.940

Table 3. US Class I Railroads 1982-2004

Railroad (Abbreviation)	Years observed	Railroad (Abbreviation)	Years observed
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
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
Ln(y_B)	7.5634	0.1863	0.8679	0.9813
Ln(y_G)	7.3819	0.1840	0.6542	0.9786
Ln(y_V)	19.143	0.2963	0.8265	0.9589
Ln(y_I)	27.287	0.3538	1.5357	0.9181

Notes: Number of observations: 272

Table 5. Parameter estimates

Parameter	Variable	Estimate	SE	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 Ways&Structures price* (w_{MAINW})	0.0693	0.0040	17.12
A4	*Maintenace of Equipment&Store price* (w_{MAINEQ})	0.0500	0.0076	6.59
A5	*Transport 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
AA18	$w_{EXECOF}*w_M$	0.0055	0.0045	1.22
AA19	$w_{EXECOF}*w_E$	-0.0015		*
AA23	$w_{PROFADM}*w_{MAINW}$	-0.0056	0.0044	-1.28
AA24	$w_{PROFADM}*w_{MAINEQ}$	-0.0024	0.0041	-0.57
AA25	$w_{PROFADM}*w_{TRANSP}$	-0.0035	0.0028	-1.25

Notes: * Indicates parameter determined by input price homogeneity restrictions

Table 5 (continued)

Parameter	Variable	Estimate	SE	T-Ratio
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
AB23	$w_{\text{PROFADM}}*y_{\text{V}}$	-0.0036	0.0016	-2.20
AB24	$w_{\text{PROFADM}}*y_{\text{I}}$	0.0011	0.0014	0.78

Notes: * Indicates parameter determined by input price homogeneity restrictions

Table 5 (continued)

Parameter	Variable	Estimate	SE	T-Ratio
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
AB43	w_{MAINEQ}*y_V	0.0003	0.0015	0.22
AB44	w_{MAINEQ}*y_I	0.0030	0.0013	2.23
AB41	w_{MAINEQ}*y_B	0.0040	0.0024	1.69
AB42	w_{MAINEQ}*y_G	-0.0056	0.0024	-2.33

Notes: * Indicates parameter determined by input price homogeneity restrictions

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

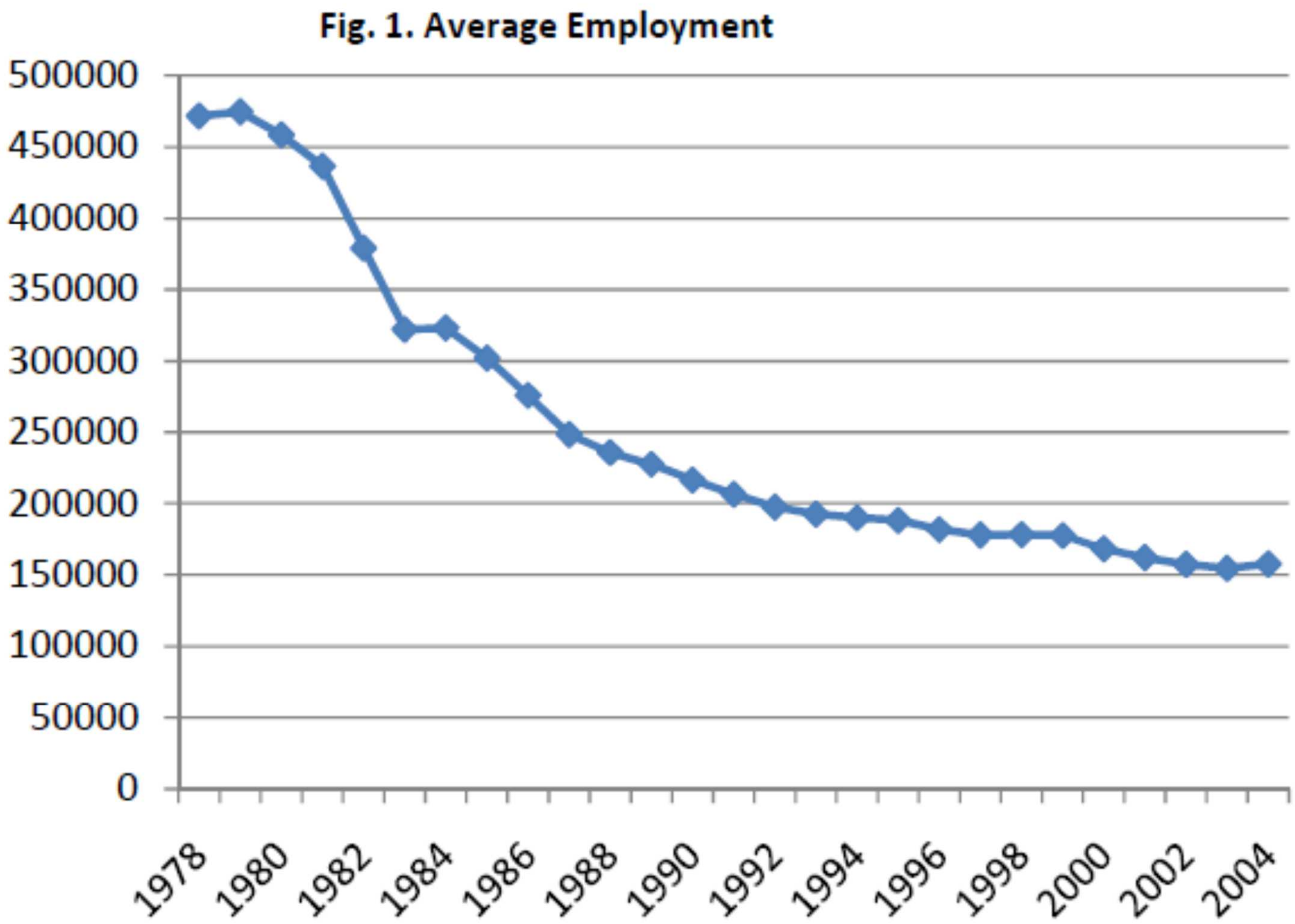
	Exec.& Officials	Profess.& Admin.	Main. Way&Struct.	Main.Equip.& Store	Transport	Train&Engine	Fuel	Material	Equipment
Exec.&Officials	-	-0.151***	-0.025	-0.094***	0.126***	-0.003	-0.008	0.089**	0.030*
		(0.037)	(0.029)	(0.030)	(0.051)	(0.016)	(0.016)	(0.045)	(0.018)
Profess.&Admin.	-0.279***	-	-0.016	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

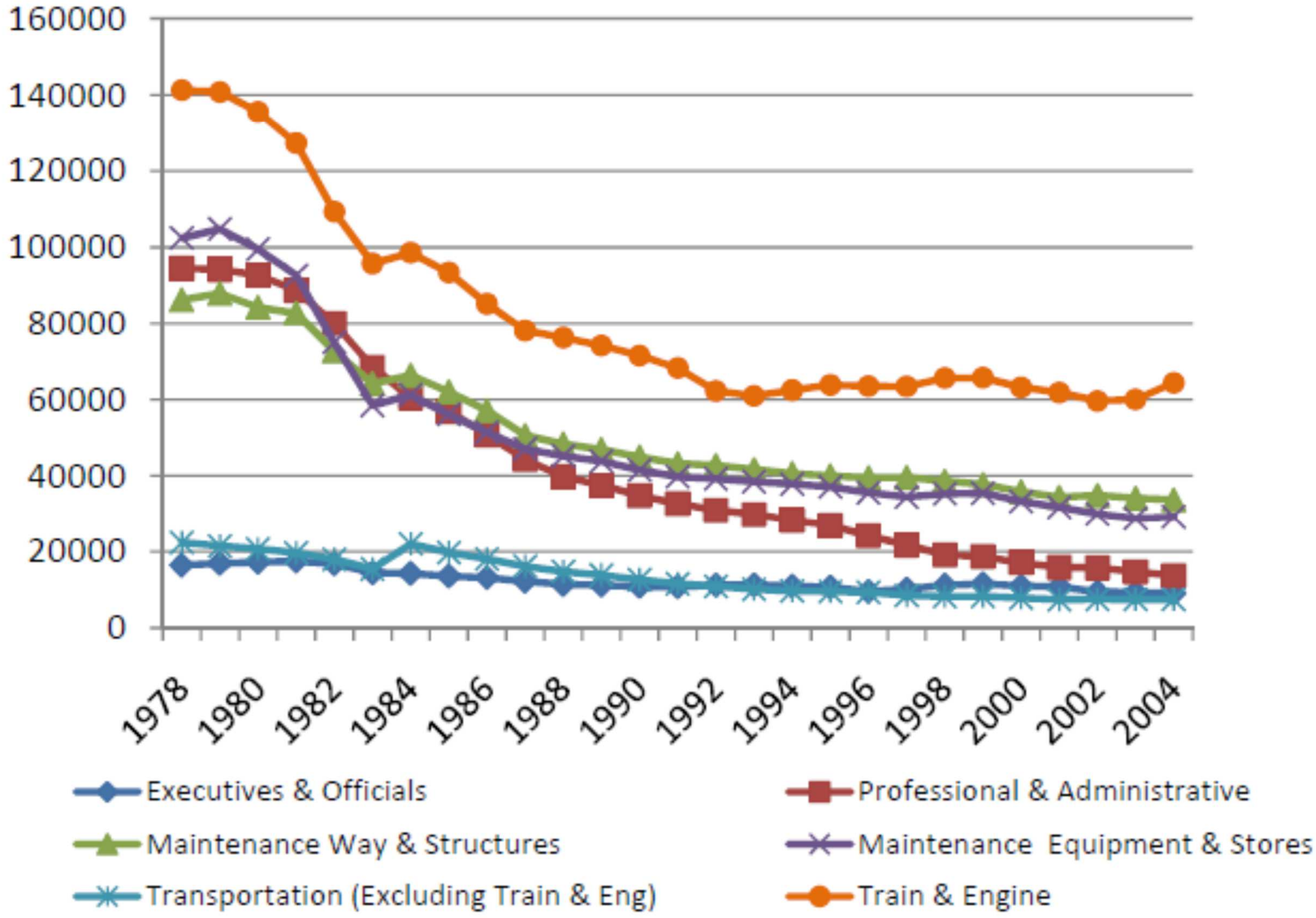
	Exec.& Officials	Profess.& Admin.	Main. Way&Struct.	Main.Equip.& Store	Transport	Train&Engine	Fuel	Material	Equipment
Exec.&Officials	-	-0.009	0.116*	0.047	0.268***	0.139**	0.133**	0.231***	0.172***
		(0.067)	(0.062)	(0.062)	(0.078)	(0.060)	(0.058)	(0.076)	0.065
Profess.&Admin.	0.075	-	0.337**	0.380***	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.



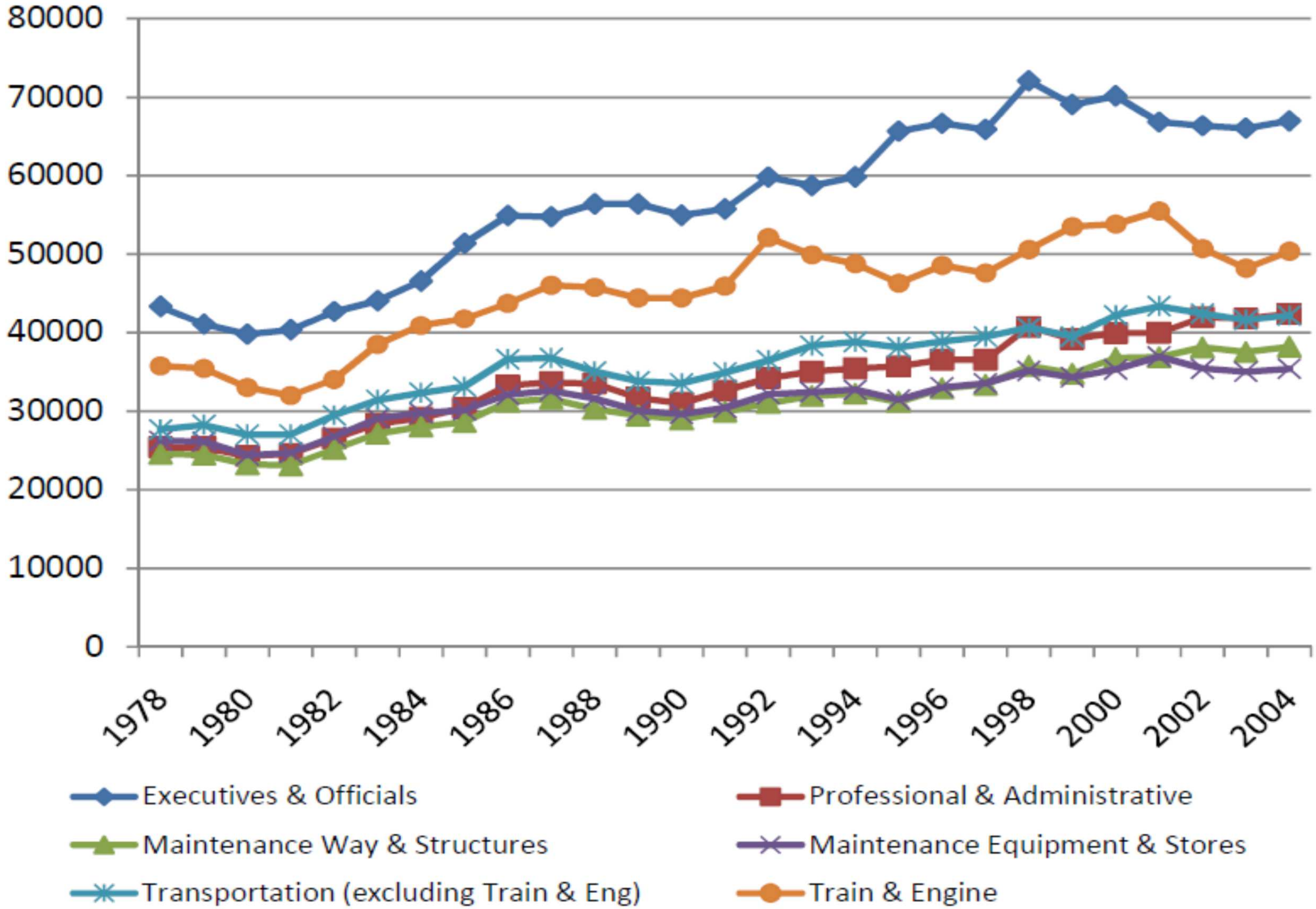
Source: Analysis of Class I Railroads published by the Association of American Railroads.

Fig. 2. Employment by Category



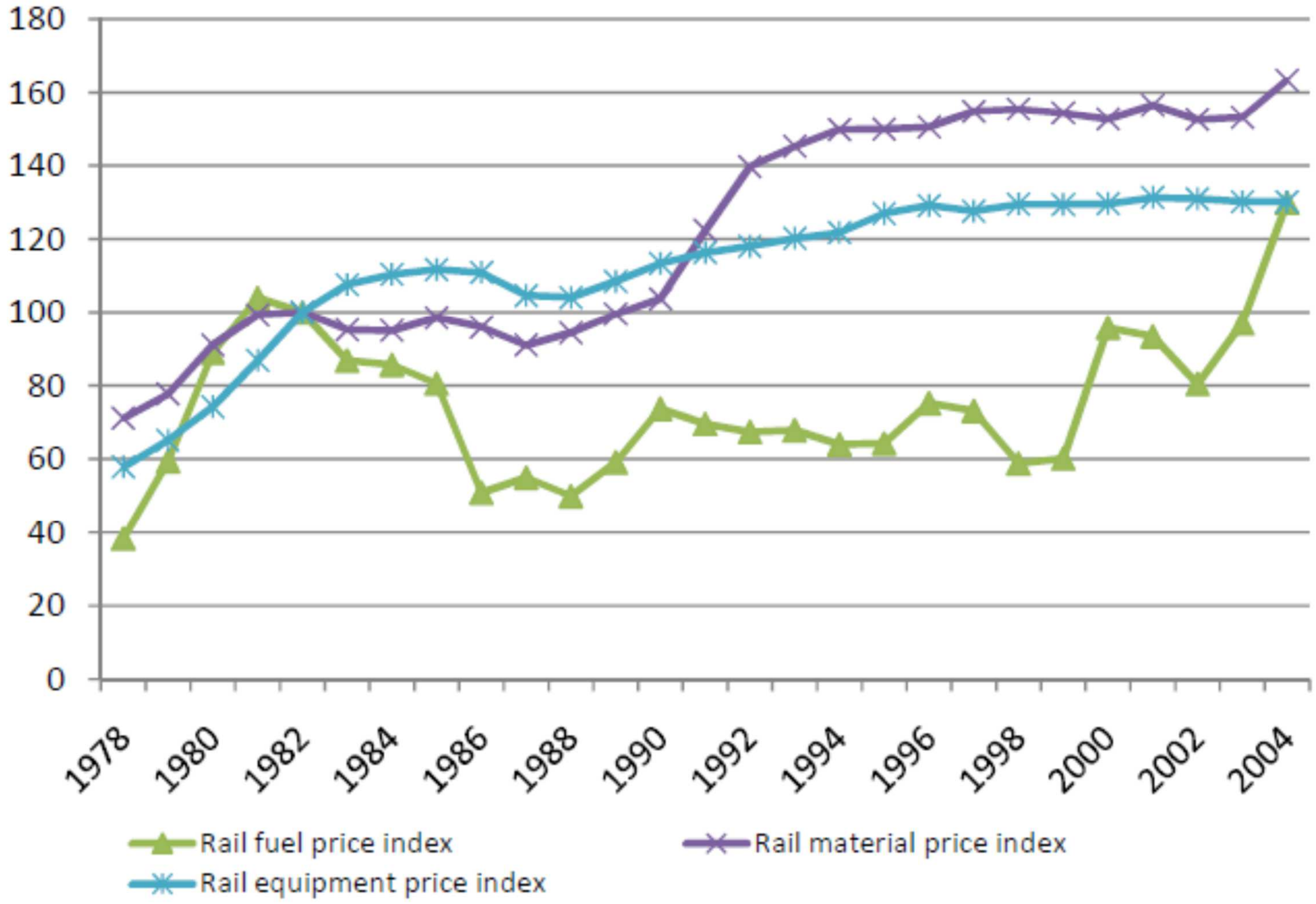
Source: Analysis of Class I Railroads published by the Association of American Railroads.

Fig. 3. Real Average Annual Compensation by Category (base 1982)



Source: Analysis of Class I Railroads published by the Association of American Railroads.

Fig. 4. Material, Equipment and Fuel Prices (index base 1982)



Source: Analysis of Class I Railroads published by the Association of American Railroads.