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The German Motor Vehicle Industry: Costs and Crisis

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ABSTRACT

During the late 1980s and 1990s, Japanese expertise with their flexible and efficient motor vehicle manufacturing system posed a substantial challenge to the German automobile industry. The German industry, renowned for its high quality, struggled to maintain its competitiveness in the new environment. This research investigates cost characteristics of the German motor vehicle industry, using a translog cost function to examine economies of scale, relationships among the input pairs, and other issues involving the industry between 1975 and 2007. The findings include that German automobile production still has available economies of scale at its maximum output level; that the input pairs of capital and labor, capital and insourced intermediate goods as well as labor and insourced intermediate goods are complements, while the other input pairs are substitutes. However, not all of these input relationships are statistically significant. The industry has increased its use of imported (outsourced) inputs, and labor demand has become more sensitive to its own price as well as that of outsourced inputs. The results also suggest that the recent restructuring of the industry has been successful in increasing its international competitiveness.

I. Introduction

The motor vehicle industry has been a major mainstay of the Germany economy, so when it faces difficulties it has the potential to significantly impact the country. In 2008, employment in the motor vehicle and parts industry (herstellung von Kraftwagen und Kraftwagenteilen) accounted for about 7.2% of employment in German manufacturing.[1] That same year, the industry accounted for about 25.1% of total manufacturing exports, down slightly from 2007, when the comparable figure was 26.9%.[2] According to Jürgens (2004, p. 412), "The auto industry has a higher share of employment and of turnover in the manufacturing sector in Germany than in any other auto-producing country, and this share has increased since the 1980s." Jürgens (2004, p. 412) also states that the auto industry in Germany has performed far better with respect to growth rates, employment, and exports than in any other industrial country post-World War II. In 2008, the German auto industry produced 6,045,730 motor vehicles, ranking fourth among the major world producers of such vehicles. Moreover, Germany ranked third among the world automobile producers with an output of 5,532,030 automobiles [Associazione Nazionale Filiera Industria Automobilistica (ANFIA), 2009, pp. 68-70]. According to the ANFIA data, Germany also ranked third in vehicle exports with 4,256,742 vehicles, behind Japan with 6,727,091 and France with 4,322,191. South Korea, Spain, and Mexico ranked fourth, fifth, and sixth, respectively (ANFIA, 2009, pp. 83-84).[3]

During the 1970s and at least most of the 1980s, the German manufacturing system was considered to be characterized by a superior way of organizing production, more flexible than the mass production systems with standardized products. This German system, known as

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[1]Statistisches Bundesamt, *Statistisches Jahrbuch 2009*, 2009, pp. 82, 93.

[2]Statistisches Bundesamt, 2009, pp. 470, 474.

[3]Also see Leoncini and Montresor (2001) for a discussion of the German motor vehicle performance in the export market. In 2008, Germany ranked ahead of France in automobile exports, with 3,906,589 cars compared with 3,736,921 for France (ANFIA, 2009, pp. 83-84).

diversified quality production or DQP, was centered around a particular type of craft organization based on the concept of *Beruf*, or specific skills. It was based on specialized vocational and apprenticeship training, workplace codetermination, and collective bargaining. As a result, it was viewed as being able to produce higher quality products than the mass production methods used extensively in the United States, for example. During the 1980s, the German motor vehicle manufacturers generally used a manufacturing system with some of the DQP characteristics to produce diversified products that were aimed for non-price competitive sectors of the market, and their management and production arrangements were considered a role model for the rest of Germany. Still, most of the German auto makers, including the luxury manufacturers, also had some models that were produced in higher volumes that resulted in most of their profits (Herrigel and Sabel, 1999; and Jürgens, 2004, pp. 411, 414).

However, in the late 1980s and 1990s, this formerly highly regarded system came under attack as the Japanese became proficient with their even more flexible and efficient manufacturing system. This new source of international competition particularly impacted the German auto industry, which had been renowned for its production of very high quality vehicles. The Japanese, moreover, were also achieving production of high quality cars at lower unit costs. During 1992-1994, employment in the German auto industry fell dramatically, by nearly twenty percent from 824,324 in 1991 to 692,036 in 1994, and Volkswagen adopted a 28.8 hour work week. In 1993, Volkswagen apparently had a breakeven level of output that was greater than its capacity (Jürgens, 2004, pp. 415-516). Nevertheless, while the auto industry struggled for ways to become more competitive, slowing product diversification was not one of them during this period. During the 1980s, there were between 140 and 180 different models of German cars. By 2000, that number had increased to 260. Outsourcing, increased foreign production, and modularization were strategies increasingly adopted by the German auto industry (Jürgens, 2004, 418-419).

Still, between 1996 and 1999, the German auto industry had annual labor productivity growth of only 1.5% compared with the French auto industry's nearly 15%. Reasons given for the less favorable German performance included the French adopting lean manufacturing systems and reducing overhead, design simplification and other measures to cut materials and purchasing costs, and no change in outsourcing on the part of the French industry. In the case of the German industry, increased outsourcing resulted in greater coordination requirements that did not allow for labor force reductions (McKinsey Global Institute, 2002, pp. 10-16).

While its labor productivity growth did not match that of the French, Jürgens (2004, pp. 421-422) argues that the efforts of the German auto industry to restructure their operations and increase product quality and diversification were successful.[4] Using strategic international outsourcing to create value chains that made optimal use of low and high cost locations, highly skilled workers in diversified quality production, and innovative activities in the areas of product technologies and concepts apparently has enabled the German industry to once again thrive in spite of its relatively high level of labor costs. Between 1977 and 2007, gross output (in current euros) increased by 580%, exports by about 760%, while labor costs increased by 188%. Employment in the industry, however, increased by less than 38%. On the other hand, intermediate goods used by the industry increased by a multiple of about 7.64 over this period, including an increase in domestic intermediate goods of 6.84 times and an increase in imported goods of 10.78 times. These data indicate that output in nominal terms grew much more quickly

[4] See Springer (1999) for a discussion of the reorganization of the workplace from the mid-1980s onward and Pries (2002) for another view of the changes in the German auto industry during the 1990s.

than labor costs over this period, but intermediate goods costs, especially for outsourced goods, grew more rapidly than output. Thus, motor vehicle firms were using more intermediate goods relative to labor in 2007 than in 1977. Over this same period, output increased in terms of constant euros by a factor of 2.51.[5]

The authors have not found much recent econometric work regarding the German auto industry other than the Leoncini and Montresor (2001) paper cited earlier. One detailed study using data from 1970-84 by Fuss and Waverman (1992, see esp. pp. 213-231) compared productivity in the German, Japanese, Canadian, and U. S. auto industries. Their study indicated that German auto makers began the 1970s as the lowest-cost and most efficient manufacturers. However, Germany lost this position over the next decade as a result of higher input prices and a decline in technical efficiency compared with the Japanese. They did find evidence of economies of scale at the mean levels of output for the auto makers of all four countries (Fuss and Waverman, 1992, p. 121-122).

In this paper we revisit costs and the economies of scale issue in light of more recent data and the production changes that have taken place in the German motor vehicle industry since the mid-1970s. We also explore the relationships among the various inputs, separated into domestic capital, labor, domestic (insourced) intermediate products and foreign (outsourced) products, including how they have changed over the past three decades. We employ a set of dummy variables in an effort to gain some insight regarding the effects on industry costs from (1) German reunification, (2) the establishment of the euro, (3) a major crisis in the auto industry in the 1990s, and (4) the restructuring that took place in the industry during the latter part of the study period. Because of its flexible functional form, we use a translog cost function, briefly

[5]Statistisches Bundesamt, 1980, pp. 99, 161-162, 245, and 472; and Statistisches

discussed below, to facilitate the study. Firm-specific panel data would be preferable in such a study, but only aggregate industry data were available to us. Nevertheless, we believe that some interesting insights, though tentative, can be gained from these industry-level data.

II. The Translog Cost Function

The production technology of the automobile industry is assumed to be representable by an implicit transformation function:

$$\vartheta(Y,K,L,D,F,T) = 0, \qquad (1)$$

where Y is real output, K is capital, L is labor, D is insourced (domestically produced) intermediate goods, F is outsourced (imported) intermediate goods, and T represents time-related components, including technological change. If the transformation function in (1) has a strictly convex input structure, there exists a unique cost function

$$TC = f(Y,P_K,P_L,P_D,P_F,T), \qquad (2)$$

where P_K is the price of capital, P_L is the price of labor, P_D is the price of insourced (domestic) intermediate goods, and P_F is the price of outsourced (imported) intermediate goods.

The exact cost function specified in (2) can be approximated with the translog cost function

$$\ln (TC) = \alpha_0 + \alpha_T T + \alpha_Y \ln Y + (1/2)\delta_{YY} (\ln Y)^2 + \sum_i \beta_i \ln P_i \qquad (3)$$

$$+ 1/2 \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \rho_{Yi} \ln Y \ln P_i$$

$$+ \sum_i \gamma_{iT} T \ln P_i + 1/2\, \gamma_{TT} T^2,$$

where *i, j* = *K, L, D*, and *F*.[6] The parameters of the translog cost function (3) can be estimated

Bundesamt, 2009, pp. 93, 372-373, 474, and 514.

[6]Technically, the estimation of this cost function requires that input markets be

indirectly by estimating the coefficients of the cost share equations, S_i, where

$$S_i = \$_i + D_{Yi} \ln Y + \underset{j}{3} (_{ij} \ln P_j + (_{iT} T, \qquad (4)$$

and *i,j = K, L, D, F*.

The minimum requirements for the cost function to describe a "well-behaved" technology are that it be (1) linearly homogeneous in input prices, (2) positive and monotonically increasing in input prices and output, and (3) concave in input prices. The restrictions imposed on the parameters by the requirement that the cost function be linearly homogeneous in factor prices allow the translog cost function and share equations to be written so that only twenty parameters must be estimated. The additional assumption of homotheticity requires that the D_{Yi} terms equal zero, and the more restrictive assumption of homogeneity requires that $*_{YY}$ also equal zero. Only three of the factor share equations are linearly independent since their sum must be equal to unity, so $S_F = 1 - S_L - S_K - S_D$.[7]

The model to be estimated, therefore, consists of the three factor share equations, S_K, S_L and S_D, and the translog cost function. Separate stochastic error terms, assumed to reflect errors in optimizing behavior, are implicitly added to these equations.

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perfectly competitive. While the input markets relevant to this study are not exactly perfectly competitive, administered or negotiated prices which result in essentially fixed prices from an individual firm point of view can perform a similar role for estimation purposes. Extensive government involvement in the economy and labor union influence through collective bargaining procedures have resulted in characteristics of perfect competition in that certain prices appear fixed from an individual firm point of view. See, for example, Addison, *et. al.* (2001); Hein and Truger (2006, esp. pp. 8, 12, and 27; and 2005, p. 4); Knoppik and Beissinger (2003); and Möller (2010).

[7]For a more thorough discussion of the translog cost function see (Truett and Truett, 2007), (Greene, 2000, pp. 640-644); (Kohli, 1991); and (Brown, Caves, and Christensen, 1979).

We used data from 1975-2007.[8] Several dummy variables were added to reflect changes in the aggregate economy as well as in the industry. Dummy 1 was equal to 1 from 1991 onward, after the unification of the former West Germany and East Germany. Dummy 2 was equal to 1 from 2002 through 2007, after the implementation of the euro currency on January 1, 2002. Dummy 3 was 1 between 1992 and 1994 during the major crisis of the auto industry in the 1990s, and Dummy 4 was 1 between 1995-1998 to reflect a major restructuring period in the German motor vehicle industry. The final version of the model contained only neutral technological change (time trend) variables since some of the regularity conditions were violated when the input-related time trend variables were included. The cost function and share equations

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[8]The following data were used in estimating the total cost function. The price of labor was given by the average hourly earnings in euros in the road vehicle manufacturing industry [*Durchschnittliche Wochenarbeitszeiten und Bruttoverdienste der Arbeiter und Arbeiterinnen im Produzierenden Gewerbe: Bruttostundenverdienste* (*insgesamt*)]. The data were for *Straßenfahrzeugbau* until 1991, after which they were for *Fahrzeugbau*. The data series utilized for the price of capital was given by the government bond yield. The price of imports was given by *Index der Einfuhrpreise: Kraftwagen und Kraftwagenteile*. The price of domestic (insourced) intermediate goods was given by *Index de Erzeugerpreise gewerblicher Produkte (Inlandsabsatz: Erzeugnisse der Vorleistungsgüterproduzenten*. The data for nominal output (*Bruttoproduktionswert: Kraftwagen und Kraftwagenteilen*) and the producer price index of the gross output (*index der Erzeugerpreise gewerblicher Produkte*: *Kraftwagen und Kraftwagenteile*) were used to calculate the real value of output. All price indices utilized 2000 as the base year. Wages paid to labor was given by *Personalkosten*. Total intermediate goods costs were calculated as the sum of *Materialverbrauch, Einsatz an Handelsware, Kosten für Lohnarbeiten* (*ingesamt*); *Kosten für sonstige ind./handw. Dienstleistungen; and Sonstige Kosten*. Foreign (outsourced) intermediate goods were given by *Einfuhr nach Güterabteilungen des Güterverzeichnisses für Produktionsstatistiken: Kraftwagen und Kraftwagenteile*. Domestic (insourced) intermediate goods were then calculated as total intermediate goods less outsourced intermediate goods. Total capital cost was calculated as *Nettowertschöpfung zu Faktorkosten* less *(Personalkosten*) plus (*Mieten und Pachten* and *Abschreibungen auf Sachanlagen*). All of the nominal data were in millions of euros. Total cost was equal to wages plus capital costs plus intermediate goods costs. Data utilized prior to 1991 were for West Germany (Früheres Bundesgebiet), while that for 1991 and later years were for the unified Germany (Deutschland). The data sources, Statistisches Bundesamt, *Statistisches Jahrbuch Für die Bundesrepublik Deutschland*, and the International Monetary Fund, *International Financial Statistics Yearbook*, are listed in the bibliography. All price variables, real output, and total cost were normalized using 1975 as the base year.

were estimated using the Zellner-efficient method (Zellner, 1963).

III. Empirical Results

The estimated coefficients of the cost function are shown in Table 1.[9] Most of these estimated values are not important in and of themselves, but they are used to calculate the direct and cross price elasticities for the inputs. The coefficients of the terms containing output variables are important, however, because as a group they allow us to obtain an estimate of the cost elasticity (Christensen and Green, 1976, p. 662; and Tybout and Westbrook, 1995, p. 61):

$$E_C = \partial \ln TC / \partial \ln Y = \alpha_Y + \alpha_{YY} \ln Y + \sum_i \gamma_{iY} \ln P_i .$$

The estimated cost elasticity calculated at the minimum output level and the mean input prices was 1.67 and significantly greater than one. At the mean output level and the price means, the cost elasticity was .90, but not significantly less than one at the 10% level of significance. However, at the maximum output level and the price means, the cost elasticity was .33, and was

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[9] The monotonicity and regularity conditions were satisfied at all of the sample points for this version of the model.

The conventional single-equation Durbin-Watson statistic for the total cost equation for the model with the homogeneity restrictions imposed was 2.59, a value that was in the inconclusive range at the 5% level of significance. See Durbin (1957), Malinvaud (1970, p. 509), and Berndt and Christensen (1973, p. 95) for a discussion of utilizing the Durbin-Watson statistic to check for serial correlation in the case of simultaneous equations.

A Lagrange multiplier test for serial correlation was also done on the total cost equation using lagged values of the error term ranging from one to nine periods (see Godfrey, 1988, pp. 112-117; and Greene, 2000, pp. 540-541). The null hypothesis of $\rho = 0$ could not be rejected at the 5 percent level of significance.

The Regression Specification Error Test (RESET, Maddala, 1992, p. 478) was also performed on the total cost equation using terms involving the dependent variable estimates up to the fourth power. This procedure also did not indicate model misspecification at the 5% level of significance.

significantly less than one at the 0.5% level of significance. A value of the cost elasticity, E_C, less than one indicates economies of scale, since total cost is increasing more slowly than output. A cost elasticity equal to one is consistent with constant returns to scale, since total cost and output are rising by the same proportion. These rather unusual results, consistent with diseconomies of scale at lower levels of output and economies of scale at higher output levels likely directly reflect the response of the German auto manufacturers to market pressures.[10] As explained earlier and particularly in the 1990s, German motor vehicle manufacturers transformed their production processes from operations relying to a large extent on highly skilled workers and relatively low volumes of comparatively expensive vehicles to the production of more vehicles designed for the mass market. So it would seem reasonable that as the volume of the automotive industry grew, the production process changed to one of embracing more of the mass production techniques for some models, resulting in scale economies that were not available with previous technologies.[11]

In an unpublished paper, Dankbaar (2004, pp. 5-6) argues that until the mid-1980s, Volkswagen was a high-volume manufacturer that focused on scale economies. After 1985, however, Volkswagen embarked on a strategy of product differentiation and economies of scope, as contrasted with one strictly based on economies of scale. That observation would be

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[10]In earlier research, using Mexican panel data, Tybout and Westbrook (1995) found evidence of economies of scale that decreased as plant size increased in the transportation industry. Truett and Truett found evidence of scale economies in the South African motor vehicle industry (Truett and Truett, 2006), Italian automotive industry (Truett and Truett, 2003), and the Australian automobile industry (Truett and Truett, 1996). Truett and Truett (2007) found evidence to suggest scale economies at lower output levels for the French automotive industry, but diseconomies at mean and maximum output levels.

[11]Nguyen and Reznek (1990) found that in some cases their data were consistent with the hypothesis that larger firms were operating in a range where economies of scale were larger than for smaller firms.

consistent with the proliferation of models that took place during that period. However, he (Dankbaar, 2004, p. 4) also states that "almost all the specialists have been absorbed by volume manufacturers, or they are trying to become volume manufacturers themselves."

With respect to the dummy variables, the estimated coefficient of Dummy 1, reflecting the unification of Germany in 1991, was significantly less than zero at nearly the 5% level of significance. This result suggests that the unification with East Germany resulted in somewhat lower costs for the motor vehicle industry, perhaps because of initially lower wage rates in East Germany.[12] The coefficient of Dummy 4 was also significantly less than zero at almost the 5% level, consistent with the restructuring process in the motor vehicle industry successfully lowering costs. The estimated coefficient of Dummy 2 was negative, but only significantly less than zero at about the 20% significance level. This result suggests that the implementation of the common currency may have put more pressure on the motor vehicle industry to reduce unit costs, but its statistical significance is ambiguous. The estimated coefficient of Dummy 3 was positive, indicating that total costs were higher for a given output level during the 1992-1994 auto industry crisis. However, the coefficient was significant at only about the 12% level. Still, this finding may be related to rigidities in the German labor market and fixed capital costs during that time period.

The estimated direct price elasticities of demand are reported in Table A1.[13] All of these

[12] Uhlig (2006, p. 384) states that both wages and productivity are lower and unemployment is still higher in the former East Germany than in West Germany, with the result that migration is still continuing to the former West Germany. Snower and Merkl (2006, p. 375) argue that the East German wage rate was raised too rapidly after unification, causing a dramatic increase in unemployment.

[13] The cross price elasticities of demand ($E_{ij} = \partial \ln X_i / \partial \ln P_j$) can be expressed in terms of the cost shares and the estimated parameters of the model as

estimates are negative, as one would expect. However, the estimated values of the direct price elasticity of demand for domestic (insourced) intermediate goods, E_{DD}, is quite low. Using a bootstrap procedure (Eakin, *et. al*., 1990; and Kerkvliet and McMullen, 1997), we found that the mean estimated direct price elasticities of demand for labor and foreign intermediate goods, E_{LL} and E_{FF}, were significantly less than zero at the 0.5% level of significance. E_{KK} was significantly less than zero at about the 8% significance level, while E_{DD} was significantly less than zero at only about the 18% level.[14] These results suggest that the quantity demanded of domestic intermediate goods was not very sensitive to their price, perhaps because other inputs were generally not considered to be close substitutes for them.

The cross price elasticity of demand estimates are given in Table A2. These results suggest that capital and labor, capital and insourced intermediate goods, and labor and domestic intermediate goods have a complementary relationship, while capital and outsourced (imported) intermediate goods, labor and outsourced intermediate goods, and domestic and imported intermediate goods were substitutes. Using the bootstrap procedure, we found that the mean

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$$E_{ij} = S_j + \frac{X_{ij}}{S_i} .$$

The general formula for the direct price elasticity of demand for input *i* in terms of the parameters of this model is

$$E_i = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i} .$$

[14]While the quantity demanded of labor may be highly responsive to its price, Knoppik and Beissinger (2003) found a high degree of downward nominal wage rate rigidity in the

estimates of E_{LF} and E_{FL} were significantly greater than zero at the 0.5% significance level, and the relationship is especially strong in the case of the responsiveness of labor demand to a change in foreign input prices. The values for E_{DF} and E_{FD} were significant at the 5% level. Thus, it appears that outsourced intermediate goods were substitutes for both domestic labor and insourced intermediate goods. However, the mean estimated values of E_{KF} and E_{FK} were significantly positive at only about the 23% level of significance.

The evidence for the complementary relationships between the input pairs was in general less statistically significant. The values for E_{KL} and E_{LK} were significantly less than zero at only the 17% and 18% significance levels, respectively. The mean estimated values for E_{LD} and E_{DL} were significantly less than zero at only the 19% and 20% levels, respectively, while those for E_{KD} and E_{DK} were not significant at any reasonable level. While the input pairs of labor and capital and labor and domestic intermediate goods may be complements, at most the relationship in each case is one of weak complementarity. This finding may have resulted from a situation where domestic capital and labor and labor and insourced intermediate goods are primarily complements, but are also substitutes in some cases. Depending on the exact input pairs involved, domestic intermediate goods and capital may have both complementary and substitute relationships as well, with the result that the estimated cross price elasticities were not significantly different from zero.

We also used the bootstrap procedure to see if there were statistically significant changes in the estimated elasticity coefficients over time, between the first period (1975) and the last period (2007). The direct price elasticity of demand for labor decreased (*increased* in absolute value) significantly at the 0.5% level, consistent with the hypothesis that the quantity demanded of labor

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German labor market.

was becoming more responsive to market pressures. The value of E_{FF} increased (*decreased* in absolute value) significantly at the 11% level, giving some support to the hypothesis that the quantity demanded of imported intermediate products was less sensitive to their own price in 2007 than in 1975. The estimated direct price elasticities for capital and domestic intermediate goods did not change significantly at any reasonable significance levels.

The behavior of the cross price elasticities of demand for labor and outsourced intermediate goods was interesting. The value of E_{LF}, which shows the impact on the demand for labor of a change in the price of foreign inputs, increased significantly over time at the 0.5% significance level. This result suggests that the demand for labor became more sensitive to changes in the prices of outsourced inputs over the study period. On the other hand, the value of E_{FL}, indicating the impact of a change in the price of labor on the demand for foreign inputs, *decreased* significantly over time at about the 5% significance level. This finding is consistent with the demand for outsourced inputs becoming less sensitive to changes in the price of labor. This result is also consistent with the finding discussed above that the absolute value of E_{FF} decreased over time. It suggests that the quantity demanded of foreign inputs in the German production of motor vehicles has become less sensitive to the prices of both labor and the foreign inputs themselves. This finding may be related to that of the McKinsey Global Institute (2002, pp. 10-16) that increased reliance on imports resulted in coordination problems that did not allow as great a reduction in labor as had been anticipated. If the McKinsey Global Institute report is correct with respect to imports and labor, then it would be reasonable for business firms to be a bit more hesitant in substituting foreign inputs for domestic, even when the price of the foreign inputs fell. Nevertheless, the demand for domestic labor has apparently become more sensitive to the prices of outsourced inputs. These two results that may appear to be somewhat contradictory may be explained by the fact that the share of labor in total cost decreased over that time period from nearly 32% to about 16% of total cost. On the other hand, the cost share of outsourced inputs increased from about 13% to nearly 22%. Given the elasticity formulas, these two facts would help to explain the behavior of the two elasticity coefficients over time (see footnote 11). Clearly, German auto makers were using a greater proportion of imported inputs in 2007 than in 1975.

The estimated value of E_{LD} decreased significantly over time (the complementary relationship between labor and insourced intermediate goods became stronger) at the 5% significance level. This result suggests that the quantity demanded of labor is becoming more sensitive to domestic intermediate input price changes. Moreover, it is consistent with the finding regarding the behavior of the direct price elasticity of demand for labor, E_{LL}, and would be consistent with the hypothesis that the demand for labor has become more sensitive to price changes, whether its own or that of related inputs. Over time, the cost share of domestic intermediate goods rose somewhat, from a little over 51% to about 57%, a change that was not nearly as substantial in percentage terms as that for outsourced (imported) inputs.

The value of E_{FK} decreased significantly at the 15% level. Since imported intermediate goods and capital were (at most) weak substitutes, this result is also consistent with the above findings indicating that the quantity demanded of foreign goods in relative or percentage terms has become less sensitive to the prices of other inputs as well as its own price. However, once again, this finding may at least partially reflect the fact that the cost share of the outsourced inputs increased substantially over the study period. Finally, the values of E_{DF} and E_{KF} increased significantly only at the 17 and 21 percent significance levels, respectively. The values of the cross price elasticities for all other input pairs did not change significantly at any reasonable significance levels over the study period.

IV. Summary and Conclusions

The findings of this study are rather intriguing. First, it appears that the German motor vehicle industry is now operating in an output range of economies of scale, while at lower output levels it experienced diseconomies of scale. At least two factors may be responsible for this result. On the one hand, the number of models of German vehicles has substantially increased over time, so that the opportunities for further economies of scale may have arisen. In addition, the German motor vehicle industry reorganized its production processes in the latter part of the 1990s in an effort to become more efficient and obtain some of the cost advantages of mass production techniques. A future, more detailed study which followed particular models over time could help in the understanding of the phenomena at work with respect to output and cost. These data, however, are not available to the authors at the present time.

All of the estimated direct price elasticities of demand for the inputs were negative, although the mean estimated values for E_{DD} were not significantly less than zero at the 10% significance level. The value of E_{LL} increased in absolute value over time, while that of E_{FF} decreased. These findings are consistent with other results suggesting that the demand for labor was becoming more responsive to price changes, while the opposite was true for the demand for foreign inputs.

The results were consistent with the hypothesis that capital and labor, capital and domestic intermediate goods, and labor and domestic intermediate goods had a complementary relationship, while the other input pairs were substitutes. However, only the mean estimates of E_{LF}, E_{FL}, E_{DF}, and E_{FD} were significantly different from zero at standard significance levels. The findings with respect to the complementary relationships may reflect the relatively highly specialized nature of some of the inputs, especially the domestic inputs, in the German motor vehicle production processes. Still, particular pairs of these same inputs may also be substitutes in certain cases, resulting in the finding that none of the complementary relationships were significant at the mean estimated values.

The results with respect to E_{LF}, which increased significantly over time (substitutes relationship became stronger), and E_{LD}, which decreased significantly (complementary relationship became stronger), are consistent with the demand for German auto workers becoming more sensitive to intermediate input prices, both domestic and foreign. The behavior of E_{LL} over time, discussed above, also supports this conclusion of some increasing flexibility in the market for German auto workers, as does the decline in the cost share of labor. However, the estimated value of E_{FL} apparently decreased over time, consistent with the finding that E_{FF} decreased in absolute value, and indicating that the demand for imported inputs has become less sensitive to input price changes. These results may reflect the finding of the McKinsey Global Institute discussed above regarding imported inputs and coordination issues as well as the fact that the cost share of imported inputs has increased by nearly 70% over time (from 13% to nearly 22%).

The findings with respect to the dummy variables suggest that German unification resulted in lower costs for the industry as did the restructuring of the industry in the second half of the 1990s. The advent of the euro may also have increased competitive pressures on the industry, but the evidence is weak that its effect was significant. The estimated coefficient for Dummy 3 suggested (at the 12% significance level) that the auto industry crises between 1992 and 1994 resulted in higher costs.

The finding that the labor market is becoming more price sensitive may enhance the competitiveness of the German motor vehicle industry as it competes in the global market place. However, the coordination difficulties that it has apparently had with outsourced inputs may present a problem if international competitive pressures make imported intermediate products significantly less costly than domestic inputs. The declining sensitivity over time of the quantity demanded of imported inputs to their own price as well as the price of labor may reflect these coordination issues as well as the fact that imported inputs now represent a substantially larger share of total cost.

Spatz and Nunnenkamp (2002) argue that low-skilled and labor-intensive links of the motor vehicle value chain are likely to be most at risk from competitive pressures from developing countries such as those in Southern and Central Europe, South East Asia, and Latin America. The authors state that while human capital intensity increased from 1982-2002, the relative wage rate of low-skilled workers decreased, a development that helped Germany cope with global competition and maintain its position among the world's top motor vehicle manufacturers. Dankbaar (2004, p.7) applauds the German car manufacturers' strategy of emphasizing scope over scale and product innovation over productivity.

The findings of this research suggest that the German motor vehicle industry has increased in competitiveness with respect to cost in the international marketplace and also has the opportunity to take advantage of additional scale economies. However, we are not aware of research that suggests that at the present time the industry can compete globally solely on a cost basis. It follows, therefore, that the reputation of German automobiles for quality and other characteristics important to consumers will continue to be a critical element in the future success of the industry in the global economy.

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Table A1 Direct Price Elasticities

Year	E_{KK}	E_{LL}	E_{DD}	E_{FF}
1975	-0.853	-1.105	-0.106	-4.262
1976	-0.854	-1.125	-0.105	-4.540
1977	-0.855	-1.163	-0.103	-4.482
1978	-0.856	-1.164	-0.103	-4.384
1979	-0.856	-1.243	-0.101	-3.792
1980	-0.857	-1.289	-0.101	-3.467
1981	-0.857	-1.343	-0.100	-3.230
1982	-0.857	-1.332	-0.098	-3.396
1983	-0.857	-1.312	-0.097	-3.614
1985	-0.856	-1.339	-0.090	-3.832
1986	-0.857	-1.274	-0.096	-3.977
1987	-0.857	-1.272	-0.098	-3.806
1988	-0.857	-1.290	-0.099	-3.584
1989	-0.857	-1.349	-0.098	-3.313
1990	-0.856	-1.415	-0.100	-2.893
1991	-0.856	-1.438	-0.099	-2.888
1992	-0.856	-1.406	-0.101	-2.894
1993	-0.856	-1.336	-0.104	-2.869
1994	-0.856	-1.390	-0.105	-2.632
1995	-0.855	-1.422	-0.104	-2.594
1996	-0.855	-1.424	-0.104	-2.589
1997	-0.854	-1.446	-0.101	-2.671
1998	-0.853	-1.458	-0.096	-2.867
1999	-0.853	-1.496	-0.096	-2.758
2000	-0.851	-1.590	-0.093	-2.655
2001	-0.850	-1.600	-0.089	-2.758
2002	-0.850	-1.595	-0.089	-2.772
2003	-0.847	-1.610	-0.086	-2.785
2004	-0.844	-1.668	-0.084	-2.729
2005	-0.840	-1.681	-0.077	-2.855
2006	-0.837	-1.765	-0.073	-2.784
2007	-0.833	-1.863	-0.069	-2.729

Table A2 German Motor Vehicle Industry Cross Price Elasticities

Year	E_{KL}	E_{LK}	E_{KD}	E_{DK}	E_{KF}	E_{FK}
1975	-0.075	-0.020	-0.118	-0.024	1.046	0.759
1976	-0.094	-0.025	-0.113	-0.021	1.060	0.810
1977	-0.137	-0.036	-0.132	-0.022	1.124	0.794
1978	-0.141	-0.037	-0.139	-0.023	1.135	0.774
1979	-0.197	-0.053	-0.164	-0.026	1.217	0.657
1980	-0.236	-0.064	-0.194	-0.029	1.286	0.593
1981	-0.269	-0.076	-0.211	-0.030	1.338	0.547
1982	-0.279	-0.076	-0.220	-0.030	1.356	0.576
1983	-0.271	-0.072	-0.212	-0.029	1.340	0.616
1985	-0.313	-0.081	-0.234	-0.029	1.403	0.653
1986	-0.254	-0.065	-0.201	-0.027	1.312	0.686
1987	-0.248	-0.064	-0.203	-0.028	1.307	0.654
1988	-0.261	-0.068	-0.217	-0.030	1.335	0.611
1989	-0.301	-0.081	-0.241	-0.032	1.398	0.558
1990	-0.324	-0.093	-0.260	-0.035	1.441	0.481
1991	-0.337	-0.098	-0.264	-0.034	1.458	0.479
1992	-0.325	-0.092	-0.266	-0.036	1.447	0.481
1993	-0.307	-0.080	-0.291	-0.041	1.454	0.476
1994	-0.344	-0.092	-0.326	-0.044	1.526	0.431
1995	-0.376	-0.100	-0.350	-0.045	1.581	0.422
1996	-0.372	-0.100	-0.345	-0.045	1.572	0.421
1997	-0.398	-0.106	-0.356	-0.043	1.609	0.434
1998	-0.423	-0.110	-0.363	-0.041	1.640	0.467
1999	-0.449	-0.119	-0.385	-0.042	1.687	0.446
2000	-0.503	-0.140	-0.418	-0.042	1.771	0.425
2001	-0.521	-0.143	-0.427	-0.041	1.798	0.442
2002	-0.515	-0.142	-0.420	-0.041	1.785	0.445
2003	-0.558	-0.148	-0.469	-0.042	1.874	0.444
2004	-0.609	-0.162	-0.516	-0.044	1.969	0.432
2005	-0.670	-0.168	-0.579	-0.044	2.089	0.451
2006	-0.718	-0.187	-0.617	-0.045	2.172	0.436
2007	-0.766	-0.210	-0.654	-0.045	2.253	0.425

Table A2 Con't. Cross Price Elasticities

Year	E_{LD}	E_{DL}	E_{LF}	E_{FL}	E_{DF}	E_{FD}
1975	0.007	0.006	1.118	3.056	0.124	0.447
1976	0.016	0.011	1.135	3.263	0.115	0.467
1977	0.013	0.008	1.186	3.203	0.117	0.486
1978	0.010	0.007	1.191	3.126	0.120	0.484
1979	-0.028	-0.016	1.324	2.641	0.143	0.494
1980	-0.056	-0.030	1.409	2.377	0.160	0.497
1981	-0.089	-0.045	1.508	2.182	0.175	0.501
1982	-0.072	-0.036	1.480	2.310	0.164	0.510
1983	-0.052	-0.027	1.437	2.482	0.152	0.516
1985	-0.048	-0.023	1.468	2.640	0.141	0.539
1986	-0.023	-0.012	1.362	2.772	0.135	0.520
1987	-0.030	-0.016	1.366	2.641	0.143	0.511
1988	-0.046	-0.025	1.405	2.466	0.153	0.507
1989	-0.082	-0.040	1.512	2.243	0.169	0.512
1990	-0.141	-0.066	1.649	1.913	0.201	0.500
1991	-0.151	-0.068	1.687	1.903	0.201	0.506
1992	-0.136	-0.064	1.634	1.916	0.201	0.498
1993	-0.109	-0.058	1.524	1.918	0.203	0.476
1994	-0.152	-0.077	1.634	1.730	0.226	0.471
1995	-0.168	-0.081	1.690	1.694	0.230	0.477
1996	-0.170	-0.082	1.694	1.690	0.231	0.477
1997	-0.170	-0.077	1.722	1.743	0.222	0.494
1998	-0.155	-0.066	1.723	1.882	0.203	0.518
1999	-0.183	-0.075	1.799	1.794	0.213	0.518
2000	-0.244	-0.089	1.974	1.700	0.224	0.530
2001	-0.238	-0.083	1.982	1.772	0.213	0.544
2002	-0.234	-0.083	1.972	1.783	0.212	0.544
2003	-0.239	-0.082	1.997	1.790	0.211	0.551
2004	-0.278	-0.089	2.107	1.739	0.216	0.559
2005	-0.271	-0.083	2.120	1.828	0.204	0.576
2006	-0.333	-0.093	2.286	1.763	0.211	0.585
2007	-0.407	-0.102	2.479	1.710	0.216	0.594

Table 1 Estimates of Motor Vehicle Industry Model Parameters (t Values)

α_{0}	0.047
	(1.458)*
α_{Y}	1.705)
	(24.186)****
α_{YY}	-0.849
	(-6.045)****
β_{K}	0.090
	(9.471)****
β_{L}	0.339
	(38.017)****
β_{D}	0.447
	(37.922)****
γ_{KK}	0.005
	(0.206)
γ_{LL}	-0.151
	(-4.139)****
γ_{DD}	0.200
	(2.690)***
γ_{KL}	-0.037
	(-2.091)**
γ_{KD}	-0.051
	(-1.539)*
γ_{LD}	-0.149
	(-5.731)****
γ_{KY}	-0.010
	(-0.330)
γ_{LY}	-0.080
	(-2.784)****
γ_{DY}	0.118
	(-5.731)****
α_{T}	-0.023
	(4.704)****
α_{TT}	0.001
	(4.423)****
DUMMY1	-0.023
	(-1.625)*
DUMMY2	-0.011
	(-0.852)
DUMMY3	0.164
	(1.196)
DUMMY4	-0.023
	(-1.696)*

*Significant at the 10% significance level.
**Significant at the 5% significance level.
***Significant at the 1% significance level.
****Significant at the 0.5% significance level.