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Outsourcing, Imports and Labour Demand*

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Abstract

This paper examines the effects of purchased services and imported intermediate materials on the labour demand for different skills in German manufacturing sectors. We derive and estimate a factor demand system based on the generalised Box-Cox cost function nesting both the normalised quadratic and the translog functional form. We find that the impacts of output and capital growth are more important in explaining the demand for heterogeneous labour than substitution effects between labour and non-labour inputs. Similarly, the increasing use of both imported materials and purchased services is a consequence of output growth rather than input substitution.

Keywords: Outsourcing of services; intermediate imports; heterogeneous labour; Box–Cox cost function

JEL classification: *J*23; *O*33

I. Introduction

There is growing evidence that the last 30 years have witnessed a dramatic change in the way goods are manufactured and services are provided. During this period, increasing amounts of purchased services, imported materials, skilled labour and capital have been used in production. Conversely, firms have begun to replace relatively unskilled workers with other inputs. One explanation for the simultaneous decline in the number of unskilled workers and the strong increase in purchased services in manufacturing is the common practice of outsourcing of services. Anecdotal evidence suggests that numerous workers now employed in low-skilled service occupations, such as cleaners, telemarketers or truck drivers, were previously employed by manufacturing firms. Another common explanation is that rising imports of intermediate material inputs have contributed to the dramatic decline in

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the employment share of unskilled labour. These observations have raised concerns about the consequences and the driving forces of outsourcing and imports.

This paper examines the impact of purchased services and imported inputs on the demand for heterogeneous labour. We analyse the production technology in more detail than in previous studies by distinguishing between seven variable input factors: three types of labour and four components of intermediate materials. As in Morrison-Paul and Siegel (2001), we study the impact of an increase in the quantity of purchased services and imports of intermediate inputs on the demand for heterogeneous labour, where purchased services are used as an indicator of outsourcing. In contrast to the Morrison-Paul and Siegel, we also investigate the determinants of demand for intermediate imports and purchased services. Furthermore, we are able to assess the total impact of outsourcing and imports on labour demand, which is composed of a quantity (or scale) and a price effect (see Section II).

There are several theoretical and empirical studies on the effects of intermediate imports on heterogeneous labour; see Aghion, Caroli and Garcia-Peñalosa (1999) for a recent overview. Feenstra and Hanson (1999) investigate the impact of international outsourcing on the relative wage of non-production labour based on 450 U.S. manufacturing industries. They define international outsourcing as imported intermediate inputs purchased from the same two-digit industry. They find that outsourcing can account for at least 15 percent of the increase in the relative wage of non-production workers. Our study is based on German data. In Germany, wages of different skill levels have grown at the same rate of about 4.5 percent per year. Therefore, we focus on the impact of purchased services on the demand for heterogeneous labour rather than on the impact of purchased services on relative wages. For Germany, Steiner and Mohr (1998) find that the shift in demand towards skilled labour is more pronounced in import-intensive industries than in other industries. However, this effect is rather weak. According to Fitzenberger (1999), who uses two-digit German manufacturing data, the shift in demand away from unskilled labour is mainly a result of technological change rather than a consequence of increasing international trade.

Despite the growing demand for purchased services in manufacturing, the links between labour demand, the demand for purchased services and the determinants of the demand for such services have been widely ignored in the literature. To our knowledge, this is the first German study that investigates the effects of the increasing demand for purchased services on the demand for different types of labour. Using four-digit U.S. manufacturing industry data, Morrison-Paul and Siegel (2001) address this issue and estimate a factor demand system for four different educational levels. They find that the cost share of purchased services appears to have a relatively small negative impact on the demand for labour across all skill levels. Trade measured as the ratio of imports to output has a similarly negative impact on the demand for less educated labour. However, this effect is much weaker than the impact of technological change.

The layout of the paper is as follows. In Sections II and III we introduce the theoretical and empirical models. Section IV presents the data and documents some stylised facts. Section V contains the empirical results and Section VI concludes.

II. The Impact of Quantities and Prices

Let $x = (x'_L, x'_M)' \in \mathbb{R}_+^{S_L} \times \mathbb{R}_+^{S_M}$ denote a vector of variable inputs and $p = (p'_L, p'_M)' \in \mathbb{R}_+^{S_L} \times \mathbb{R}_+^{S_M}$ the corresponding vector of prices. These inputs are combined in production, with some fixed goods $z \in \mathbb{R}_+^{S_z}$, including the level of capital and output. The relationship $f(x_L, x_M, z) = 0$ characterises the technical production constraints. Vectors x and p are both split into two subvectors. We are thus able to distinguish labour inputs x_L from intermediate material inputs x_M. Let the set χ_L be composed of all indices corresponding to labour inputs, and χ_M be the set of all intermediate material input indices (thus, the cardinality of χ_L and χ_M is S_L and S_M, respectively).

The restricted cost function is defined as:

$$\begin{aligned} \tilde{c}(p_L, x_M, z) &= \min_{x_L}\{p'_L x_L : f(x_L, x_M, z) = 0\} \\ &= p'_L \tilde{x}_L(p_L, x_M, z). \end{aligned}$$

The relationship between restricted and unrestricted cost functions is well known:

$$\begin{aligned} c^*(p_L, p_M, z) &= \min_{x_L, x_M}\{p'_L x_L + p'_M x_M : f(x_L, x_M, z) = 0\} \\ &= \min_{x_M}\{\tilde{c}(p_L, x_M, z) + p'_M x_M\} \\ &= p'_L x^*_L(p_L, p_M, z) + p'_M x^*_M(p_L, p_M, z), \end{aligned}$$

where

$$x^*_L(p_L, p_M, z) = \tilde{x}_L(p_L, x^*_M(p_L, p_M, z), z) \tag{1}$$

denotes the unrestricted labour demands.

This framework is useful for identifying the impact of x_M, including purchased services and intermediate imports, on the restricted labour demand functions $\tilde{x}_L$. When estimating this impact, Morrison-Paul and Siegel (2001) rely on the restricted demands $\tilde{x}_L$ to derive the effects of purchased services and imports $\partial\tilde{x}_i/\partial x_j(x_j/\tilde{x}_i)$, with $i \in \chi_L$ and $j \in \chi_M$. These effects can also be recovered from the unrestricted demand functions x_L^*. Indeed, from the relationship between restricted and unrestricted demands (1), it follows that:[1]

$$\frac{\partial x_L^*}{\partial p_M'} = \frac{\partial \tilde{x}_L}{\partial x_M'} \frac{\partial x_M^*}{\partial p_M'}$$

$$\Leftrightarrow \frac{\partial \tilde{x}_L}{\partial x_M'} = \frac{\partial x_L^*}{\partial p_M'} \left[\frac{\partial x_M^*}{\partial p_M'}\right]^{-1}. \tag{2}$$

That is, $\partial\tilde{x}_L/\partial x_M'$ can be calculated from the unrestricted demand functions x^*.

It is easy to show that—once expressed in terms of elasticities—equation (2) becomes

$$\varepsilon(x_L^*, p_M') = \varepsilon(\tilde{x}_L, x_M')\varepsilon(x_M^*, p_M')$$

$$\Leftrightarrow \varepsilon(\tilde{x}_L, x_M') = \varepsilon(x_L^*, p_M')[\varepsilon(x_M^*, p_M')]^{-1}, \tag{3}$$

where the matrix $\varepsilon(x_L^*, p_M')$ has

$$\varepsilon(x_i^*, p_j) \equiv \frac{\partial x_i^*}{\partial p_j} \frac{p_j}{x_i^*} \tag{4}$$

as entries, with $i \in \chi_L$ and $j \in \chi_M$. The elasticity matrices $\varepsilon(\tilde{x}_L, x_M')$ and $\varepsilon(x_M^*, p_M')$ are defined accordingly.

From the first line of (3), we can see that even though the impact of x_M on restricted labour demands $\tilde{x}_L$ may be important, the impact of input prices p_M on unrestricted labour demands x_L^* can be limited if the own-price reactions of material inputs (reflected by the matrix $\varepsilon(x_M^*, p_M')$) are small.

III. A Variant of the Box–Cox Cost Function

The vector of variable inputs is defined as $x = (x_h, x_s, x_u, x_d, x_e, x_m, x_o)'$ and the corresponding input price vector as $p = (p_h, p_s, p_u, p_d, p_e, p_m, p_o)'$,

[1] We assume that the matrix $\partial x_M^*/\partial p_M'$ is regular. See Chambers (1988) for a discussion of duality relationships in production analysis.

where the denomination of the variables is summarised in Table 1. We consider three categories of labour inputs and split intermediate materials into four components: (i) domestic non-energy intermediate materials, x_d; (ii) energy, x_e; (iii) imported intermediate materials, x_m; and (iv) purchased services, x_o. The vector $z = (z_k, z_y, t)'$ contains the level of production, z_y, the net capital stock at constant prices, z_k, and a time trend t. The vectors x_L and x_M, introduced in Section II, are identified as $x_L = (x_h, x_s, x_u)'$ and $x_M = (x_d, x_e, x_m, x_o)'$, with each vector comprising labour inputs and material input components, respectively.

Since empirical estimates of elasticities are shown to be sensitive to the choice of the functional form, we formulate a variant of a Box–Cox cost function that has the advantage of nesting some of the usual specifications. The Box–Cox cost function was initially proposed by Berndt and Khaled (1979). We extend their formulation in order to nest the normalised quadratic and the translog functional form; see Koebel, Falk and Laisney (2000) for details. As the variables may differ across observations, p, x and z are now supplemented by the subscripts n and t denoting industry and time, respectively. The total variable costs are denoted by c and correspond to the total wage bill plus materials expenditures. The Box–Cox transformations are given by

Table 1. *Denominations of the variables*

Labour inputs (number of workers, full-time equivalent) x_L	
x_h	high-skilled labour (workers with a university or polytechnical degree)
x_s	medium-skilled labour (workers with a certificate from the dual vocational training system plus foremen and technicians)
x_u	low-skilled or unskilled workers (excluding apprentices)
Material input components (all in constant prices) x_M	
x_d	domestic non-energy intermediate materials (excluding purchased services)
x_e	energy (including imported energy)
x_m	imported intermediate materials (excluding purchased services and energy)
x_o	purchased services (including imports of purchased services)
Fixed characteristics z	
z_k	net capital stock in constant prices
z_y	gross output in constant prices
t	time trend
Input prices (normalised to 1 in 1978) p	
p_h	gross annual labour costs per high-skilled worker
p_s	gross annual labour costs per medium-skilled worker
p_u	gross annual labour costs per unskilled worker
p_d	price index domestic non-energy intermediate materials
p_e	price index energy
p_m	price index imported intermediate materials
p_o	price index purchased services

$$Z_{jnt} = \begin{cases} \dfrac{z_{jnt}^{\gamma_1} - 1}{\gamma_1} & \text{for } \gamma_1 \neq 0, \\ \ln z_{jnt} & \text{for } \gamma_1 = 0 \end{cases}, \quad j = k, y, \tag{5}$$

$$P_{jnt} = \begin{cases} \dfrac{(p_{jnt}/(\theta_n' p_{nt}))^{\gamma_1} - 1}{\gamma_1} & \text{for } \gamma_1 \neq 0 \\ \ln(p_{jnt}/(\theta_n' p_{nt})) & \text{for } \gamma_1 = 0 \end{cases}, \quad j = h, s, u, d, e, m, o. \tag{6}$$

Note that in (5), the transformation is not applied to the time trend but only to z_k and z_y. The specification of the cost function is

$$c(p_{nt}, z_{nt}; \alpha_n) = \begin{cases} p_{nt}'\bar{x}_{n1}(\gamma_2 C(P_{nt}, Z_{nt}; \alpha_{0n}) + 1)^{1/\gamma_2} & \text{for } \gamma_2 \neq 0 \\ p_{nt}'\bar{x}_{n1} \exp(C(P_{nt}, Z_{nt}; \alpha_{0n})) & \text{for } \gamma_2 = 0 \end{cases}, \tag{7}$$

where

$$C(P_{nt}, Z_{nt}; \alpha_{0n}) = \alpha_{Cn} + P_{nt}'A_{pn} + Z_{nt}'A_z + \tfrac{1}{2}P_{nt}'A_{pp}P_{nt} + P_{nt}'A_{pz}Z_{nt} + \tfrac{1}{2}Z_{nt}'A_{zz}Z_{nt}. \tag{8}$$

The technological parameters to be estimated are gathered in the vector $\alpha_n = (\alpha_{0n}', \gamma_1, \gamma_2)'$, where α_{0n} comprises all free parameters of α_{Cn}, A_{pn}, A_z, A_{pp}, A_{pz} and A_{zz}. Note that the subscript n characterises parameters that are industry-specific. To account for heterogeneous technologies, we introduce some industry-specific parameters α_{Cn} and A_{pn}. As in the case of functional specifications, which can hardly be justified in economic terms, it is difficult to find a rationale for homogeneous technologies across sectors that are as different as the chemical and automotive industries, for example. Thus, we also allow the parameters α_{0n} and γ_1, γ_2 to vary across broadly defined groups of industries. In particular, we distinguish between durable goods and non-durable goods industries.

The parameters γ_1 and γ_2 merit special attention since they capture the way in which the variables p_{jnt}, z_{jnt} and c_{nt} are modified by the Box–Cox transformation. Both the translog and the normalised quadratic functional forms are nested within the generalised Box–Cox specification and are obtained as special cases, for $\gamma_1 \to 0$, $\gamma_2 \to 0$ and for $\gamma_1 = 1$, $\gamma_2 = 1$, respectively. Some restrictions are placed on the parameters α_{0n} so that the cost function is symmetric in p_{nt} and z_{nt} and the number of parameters is parsimonious; see Koebel *et al.* (2000).

The optimal demand functions x^* are obtained from c by applying

Shephard's lemma and are used to form the input–output coefficients x^*_{nt}/z_{ynt} considered in our regression:

$$x_{nt}/z_{ynt} = x^*(p_{nt}, z_{nt}, \alpha_n)/z_{ynt} + \nu_{nt}, \tag{9}$$

where $x^*(p_{nt}, z_{nt}, \alpha_n) = \partial c^*/\partial p_{nt}$ and ν_{nt} denotes a residual vector that is uncorrelated with the explanatory variables, has zero conditional mean and a constant variance matrix. The main reason why we consider input–output coefficients x_{nt}/z_{ynt} instead of the demand levels x_{nt} as explanatory variables is that the assumption of homoscedastic residuals appears more plausible for the former specification than for the latter. The system of seven factor demands is estimated using non-linear *SUR* on panel data.

The terms $p'_{nt}\bar{x}_{n1}$ and $\theta'_n p_{nt}$ are introduced in (7) to guarantee that the cost function is linearly homogeneous in prices. Diewert and Wales (1987) show that there are many possibilities for defining θ_n and that the flexibility of the specifications above does not depend on choosing θ_n in a particular way. The parameters θ_n are usually defined as a function of some x_{nt} and c_{nt}, which can lead to endogeneity problems, because in this case the same variables occur on both the LHS and RHS of (9). To avoid this, we specify

$$\theta_n = \frac{\dfrac{1}{N-1}\sum_{i \neq n} x_{i1}}{\dfrac{1}{N-1}\sum_{i \neq n} c_{i1}} \equiv \frac{\bar{x}_{n1}}{\bar{c}_{n1}},$$

so that $\theta'_n p_{nt}$ corresponds to a variant of a Laspeyres price index for total variable costs, normalised to 1 in 1978 (at which $t = 1$).

The main hypothesis we want to investigate is whether it is easier to substitute unskilled labour for both purchased services and imported materials than it is to substitute highly skilled labour for purchased services and imported materials. The substitution effect indicates that a firm will use more of an input whose relative price has decreased. Different impacts of capital accumulation, output growth and time may be further explanations for the shift towards skilled labour and away from unskilled labour. Finally, higher output and time elasticities for both purchased services and imported materials compared to other input factors may also explain the increasing demand for both purchased services and intermediate materials in manufacturing.

IV. Data and Stylised Facts

The data used in this study are publicly available from government agencies. The German Federal Statistical Office publishes data on gross output and materials, in both constant and nominal prices; the net capital stock is calculated by the perpetual inventory method. National accounts data are supplemented by different components of intermediate materials drawn from input–output tables, broken down into 58 product groups. Separate input–output tables are available for imported materials. All input–output tables are deflated using two-digit input price deflators. In order to preserve enough degrees of freedom, we aggregated the 58 types of intermediate materials available for each industry into four main categories (see the Appendix for further details). The German Federal Employment Office provides data on employment at different skill levels. The corresponding data on earnings are from the Institute for Employment Research (*IABS Beschäftigtenstichprobe*).[2]

Table 2 reports summary statistics on the average annual change in inputs and output for 26 industries over the period 1978–1990. Purchased services have been the fastest growing input factor in West German manufacturing, followed by high-skilled labour and imported intermediate materials. During the period 1978–1990, purchased services in constant prices increased by 4.1 percent per year (unweighted mean based on 26 industries). In 1990, West German manufacturing firms devoted, on average, 17 percent of their gross output to purchased services. Most of the rise in such services as a factor of production in manufacturing can be attributed to the growing importance of purchased business services (e.g. temporary personnel supply services, consulting, accounting) representing 45 percent of total purchased

Table 2. *Average annual changes in input quantities and factor prices*[a]

% change in quantities	Mean	S.D.	Min.	Max.
High-skilled labour, x_h	3.6	2.2	−1.0	8.3
Medium-skilled labour, x_s	0.4	1.8	−3.9	4.2
Unskilled labour, x_u	−2.9	2.0	−8.7	0.8
Domestic materials, x_d	1.1	1.7	−2.6	5.3
Energy, x_e	1.2	2.1	−3.0	6.0
Imported materials, x_i	3.5	2.7	0.2	11.1
Purchased services, x_o	4.1	1.7	1.0	7.6
Net capital stock, z_k	0.2	2.3	−4.2	4.6
Output, z_y	1.5	1.8	−1.9	6.5

[a]Average annual growth rate for 26 industries over the period 1978–1990.

[2]For further details on the construction of labour inputs and wages, see the Appendix and Falk and Koebel (2001).

services in 1990 compared to 35 percent in 1978.[3] At the individual industry, level, light industries (textiles, leather and wearing apparel), paper, wood and electronic products have a higher than average share of purchased services in total output. Furthermore, all industries show a rise in their demand for purchased services; the largest increase, with growth rates of 6 percent or more, can be found in machinery, vehicles, electronic products, publishing and printing, paper and plastics. Similar increases can be observed in other industrialised countries. In U.S. manufacturing, Fixler and Siegel (1999) report an increase in the share of purchased services in total costs from 10.1 percent in 1979 to 12.8 percent in 1988; see also Raa and Wolff (2001).

There has also been a strong increase in the demand for imports of intermediate materials (3.5 percent per year), particularly in plastics, followed by automotive, paper and electronic products. In contrast to imported materials, domestic materials in constant prices have grown more gradually over time.

Turning to the input factor prices described in Table 3, we note that prices of the four material components grew at a lower rate than the wages of the different types of workers. Within intermediate materials, imported materials and domestic materials show the slowest price increase. The increase in the price of intermediate imports of about 2.2 percent is smaller than the increase in the price of domestic non-energy materials of about 2.5 percent. The finding that the price of imported inputs increased less than the price of domestic inputs is consistent with Diehl (1999). This difference is highest in

Table 3. *Average annual changes in input prices*[a]

% change in prices	Mean	S.D.	Min.	Max.
High-skilled labour, p_h	4.6	0.2	4.0	5.1
Medium-skilled labour, p_s	4.4	0.4	3.5	5.2
Unskilled labour, p_u	4.6	0.3	4.0	5.3
Domestic materials, p_d	2.5	0.7	−0.1	3.4
Energy, p_e	2.9	0.2	2.4	3.3
Imported materials, p_m	2.2	0.7	0.2	3.2
Purchased services, p_o	2.8	0.2	2.4	3.0

[a] Average annual growth rate for 26 industries over the period 1978–1990.

[3] The strong increase in the number of workers in personnel supply services in Germany coincides with the rising demand for purchased business services as an input of production in manufacturing. During the period 1978–1990, the number of workers in temporary personnel supply services increased by 12.9 percent per year, which is the highest employment growth rate among all business service industries.

light industries (leather, textiles and clothing), where it comprises about one percentage point per year or 10 percent during the period 1978–1990. The wage structure has not changed very much over the period 1978–1990; see also Fitzenberger (1999).

V. Empirical Results

The system (9) of seven equations was estimated using non-linear *SUR*. The pooled model consists of 50 free parameters plus 7×26 parameters for industry dummies that have to be estimated on the basis of $26 \times 9 \times 7$ observations. To control for heterogeneity across industries, we allowed the coefficients to vary across broadly defined groups of industries. First, we split the 26 industries into (i) durable goods industries (13 industries, among them metal products, machinery, transport equipment, electrical machinery) and (ii) non-durable goods industries (13 industries, among them food, chemical products, etc.). Second, we considered the alternative split sample based on the skill intensity of production and distinguished between skill-intensive and non-skill-intensive industries. The split sample based on the distinction between durable goods and non-durable goods yields the highest likelihood value. Furthermore, a likelihood ratio test was conducted to test whether the parameters of the cost functions are identical across the two subsamples (with the exception of the industry-specific parameters α_{Cn} and A_{pn}). The null hypothesis that the parameters are equal across the subsamples is rejected in all cases.[4] Therefore, we rely on the more disaggregated model that accounts for heterogeneity between durable goods and non-durable goods industries in the remainder of this section.

Table 4 contains the estimates of the Box–Cox parameters γ_1 and γ_2 for the pooled and split sample factor demand model. We find that the Box–Cox (BC) parameters γ_1 and γ_2 are either significantly different from zero or significantly different from one in all cases. A likelihood ratio test suggests that the parameters γ_1 and γ_2 are jointly significantly different from zero and from one, indicating that both the translog (TL) and the normalised quadratic (NQ) functional forms are rejected.

A comparison of the own-price elasticities across the different functional forms shows that the Box–Cox functional form also outperforms the other functional forms regarding the number of significantly negative own-price elasticities. Although the number of negative own-price elasticities ranges

[4]The LR test is calculated as 2 (3,115.9 + 3,280.8 − 6,133.1) = 527.2 where the log-likelihood value based on pooled data is 6,133.1 and the two remaining log-likelihood values are obtained from split sample regressions. Under the null hypothesis, this test statistic is chi-squared distributed with 50 degrees of freedom. The LR test value is considerably higher than both the 1 and 5 percent threshold critical values of about 67.5 and 76.1, respectively.

Table 4. *Estimates of the Box–Cox parameter*

	Split sample				Pooled sample		
	BC		NQ	TL	BC	NQ	TL
γ_1	0.474 (0.035)	0.764 (0.036)	1	0	0.724 (0.035)	1	0
γ_2	0.198 (0.027)	0.154 (0.032)	1	0	0.253 (0.035)	1	0
Log-*L*	3,115.9	3,280.8	6,162.6	6,298.9	6,133.1	5,926.8	6,038.9

Note: The parameters γ_1 and γ_2 capture the way variables p_{jnt}, z_{jnt} and c_{nt} are modified by the Box–Cox transformation. Standard errors in parentheses.

between six based on the BC and five or less based on the other two functional forms, the empirical results exhibit some regularity with respect to the specification: none of the cross-price elasticities between labour and non-labour inputs exhibits a sign reversal, except for some of the cross-price elasticities between highly skilled workers and non-labour inputs. The own-wage elasticity of highly skilled workers, in absolute terms, is rather large. However, the result is also sensitive to the choice of the functional form. The remaining cross-price elasticities are robust across different functional forms, although the NQ tends to underestimate the size of the price elasticities, in absolute values, compared to both the TL and the BC. Output, time and capital elasticities are also quite similar across the three functional forms. We find little evidence of serial correlation. Unreported results show that the Durbin–Watson statistics (panel-data adjusted) are close to two for the material input equations and between 1.23 and 1.54 for the three labour demand equations.[5]

As statistical tests reject the NQ and the TL against the BC, our interpretation of elasticities is based mainly on the BC functional form. Table 5 shows both own-price and cross-price elasticities as well as the corresponding *t*-values for seven input demands based on the BC functional form and on the split sample results due to the distinction between durable goods and non-durable goods industries. Elasticities are computed for each industry and are evaluated for 1990 data. This gives us 49 price elasticities for each of the 26 industries. We only report the median of the distribution of each elasticity across industries and the *t*-values indicating the significance level of the median.

We find no evidence that unskilled labour can be substituted for either imported materials or purchased services. In contrast, we find a significant

[5] The Durbin–Watson test is applied to equispaced data.

Table 5. *Price elasticities of factor demand based on split sample results*[a]

$\varepsilon(x_i^*, p_j)$	p_h	p_s	p_u	p_d	p_e	p_m	p_o
x_h^*	**−0.828**	0.232	−0.202	0.615	−0.285	−0.081	0.404
	(−4.67)	(0.48)	(−1.24)	(2.95)	(−7.68)	(−0.84)	(1.20)
x_s^*	0.015	**−0.392**	0.179	0.012	−0.095	−0.093	0.076
	(0.74)	**(−3.81)**	(0.91)	(0.08)	(−5.26)	(−1.99)	(0.43)
x_u^*	−0.036	0.353	**−0.421**	−0.241	0.043	−0.192	−0.048
	(−1.28)	(0.85)	**(−2.35)**	(−2.09)	(0.78)	(−0.94)	(−0.31)
x_d^*	0.024	0.008	−0.076	**−0.228**	−0.116	0.138	0.056
	(4.74)	(0.08)	(−2.33)	**(−2.16)**	(−7.00)	(4.14)	(0.68)
x_e^*	−0.110	−0.183	0.066	−0.243	**0.248**	0.410	0.347
	(−2.65)	(−4.66)	(0.73)	(−0.49)	**(0.86)**	(1.78)	(2.84)
x_m^*	−0.007	−0.122	−0.145	0.323	0.112	**−0.174**	−0.123
	(−1.32)	(−1.39)	(−2.96)	(2.54)	(2.98)	**(−1.84)**	(−1.25)
x_o^*	0.027	0.103	−0.063	0.080	0.090	−0.102	**−0.754**
	(2.04)	(0.82)	(−0.41)	(0.62)	(1.37)	(−1.37)	**(−4.46)**

[a]Median elasticities across industries for the year 1990; *t*-value of the actual median in parentheses.

complementarity relationship between unskilled labour and domestic materials ($\varepsilon(x_u^*, p_d) = -0.24$). This indicates that an increase in the price of domestic materials will lower the demand for unskilled workers. This empirical result on the relationship of no substitutability between less skilled labour and imported materials is contrary to the findings of Tombazos (1999) for the U.S. One reason for these different results may be the small share of German imports from newly industrialised countries (NICs) in the Far East.[6] Between 1976 and 1985, the value of German imports from these countries as a share of total German imports remained stable at around 2.3 percent.[7] Between 1986 and 2000, the share rose slightly to around 4 percent.[8] Conversely, in the U.S., the share of imports from these countries was 6 percent in 1975 and had already reached 7.4 percent in 1980; see Aw and Roberts (1985).

Highly skilled workers tend to be a substitute for purchased services. The median value of the distribution of the cross-price elasticities of high-skilled labour is 0.40 with respect to the price of purchased services. Whereas the median value is not significantly different from zero, many non-reported elasticities are significant (6 cross-price elasticities are significant at the 5 percent level and another 10 cross-price elasticities are significant at the 10

[6]The Asian NICs include Hong Kong, Taiwan, South Korea, Singapore and the Philippines; see Aw and Roberts (1985).

[7]The data are from the Statistical Office Germany, time series numbers 4024 and 2085.

[8]Even more importantly, the share of German imports from Central and Eastern Europe increased from 7 percent in 1991 to 13 percent in 2000.

percent level). Surprisingly, we find a significant substitutability relationship between highly skilled workers and domestic materials. There is also evidence of complementarity between medium-skilled workers and energy on the one hand, and high-skilled workers and energy on the other. Hence, raising energy prices will decrease the demand for both medium- and highly skilled workers. As expected, own-wage elasticities are significantly negative for all of the skill levels. The own-wage elasticities of unskilled workers and medium-skilled workers are -0.42 and -0.39, respectively. We find a positive but insignificant cross-price elasticity between medium-skilled and unskilled labour.[9]

There are some significant cross-price elasticities between the different material inputs. Significant pairwise substitutability relationships can be found between energy and imported materials and between imported materials and domestic materials. Note that domestic and imported material inputs are far from perfect substitute: $\varepsilon(x_d^*, p_m) = 0.14$. This means that changes in the import price have a small impact on the demand for domestic intermediate materials. Since either cross-price elasticities between different types of materials are quite small or relative input price movements between different types of materials are negligible, little of the shift in factor demand towards purchased services and imported materials can be explained by price effects.

A possible explanation as to why several price elasticities are insignificant is the small sample size. For comparison, we also calculated the elasticities of factor demand obtained from pooled data consisting of all 26 manufacturing industries.[10] As expected, the *t*-values, in absolute values, are somewhat larger in the pooled model. The positive cross-price elasticity either between medium-skilled labour and purchased services or between highly skilled workers and purchased services turns out to be significant at the 1 percent level. Similarly, the *t*-value of cross-price elasticity between unskilled workers and imported materials changes from -0.9 to -2.2. Furthermore, we find very few contradictions with respect to the sign of the estimated elasticities based on either pooled data or the split sample.

In order to allow for a comparison with earlier studies in which purchased services or imported materials are treated as fixed factors, we also report the scale elasticities of the restricted labour demand functions $\tilde{x}_L$ calculated using formula (3). Table 6 presents the scale elasticities of the three types of labour; their variance is calculated as explained in the Appendix. Whereas the upper panel contains the scale elasticities based on the more disaggre-

[9] Koebel *et al.* (2000) find some significant substitutability between highly skilled workers and medium-skilled workers and between medium-skilled workers and unskilled workers in a model where capital is treated as a flexible input.

[10] The elasticities based on the pooled model are available on request.

Table 6. *Scale elasticities of labour demands*[a]

$\varepsilon(\tilde{x}_i, x_j)$	x_d	x_e	x_m	x_o
		Split sample		
$\tilde{x}_h$	−2.191	−0.209	−0.694	−1.908
	(−0.64)	(−0.19)	(−0.42)	(−0.37)
$\tilde{x}_s$	−1.216	−0.053	−0.714	−0.556
	(−0.12)	(−0.01)	(−0.19)	(−0.70)
$\tilde{x}_u$	−1.838	−0.143	−0.199	−1.069
	(−0.75)	(−0.03)	(−0.26)	(−0.54)
		Pooled sample		
$\tilde{x}_h$	2.785	−0.406	2.067	−2.105
	(0.84)	(−0.34)	(0.13)	(−0.05)
$\tilde{x}_s$	−0.532	−0.082	−0.058	−0.928
	(−0.54)	(−0.05)	(−0.01)	(−0.61)
$\tilde{x}_u$	−3.942	−0.087	−2.553	−0.034
	(−1.07)	(−0.15)	(−2.50)	(−0.06)

[a] See Table 5.

gated model, the lower panel contains the results for the pooled model. Most scale elasticities have a negative sign but are not significantly different from zero. This indicates that the increasing use of purchased services as well as imported materials tends to reduce the demand for all skill levels, but the effects are not significantly different from zero. This finding is consistent with the results in Morrison-Paul and Siegel (2001) for U.S. manufacturing. As regards the estimates based on the pooled model, however, we find a significantly negative impact of imported materials on the demand for unskilled workers. This effect is not robust when we allow for heterogeneity across durable goods and non-durable goods industries.

The estimates of $\varepsilon(\tilde{x}_i, x_j)$ are not very precise and vary considerably across industries, no matter which split sample is considered. This is related to the fact that the estimated matrix $\varepsilon(x_M^*, p_M')$ in (3) is almost singular for some industries and therefore causes the estimates of $\varepsilon(\tilde{x}_L, x_M')$ to explode. It is somewhat comforting that the standard deviations also explode in these cases (see the equations in the Appendix). Whether the restricted elasticities could be estimated precisely from an unrestricted demand system would be an interesting question to address in further work.

Table 7 presents output and time elasticities as well as the impact of capital on factor demand. Output elasticities are significant at the 5 percent level in all cases except for the output elasticity of energy. Imported and domestic materials as well as purchased services benefit more from output growth than the different skill types of labour. The output elasticities of the different skill levels range between 0.38 for medium-skilled workers and 0.53 for highly skilled workers, while the output elasticities of imported

Table 7. *Output, capital and time elasticities*[a]

$\varepsilon(\tilde{x}_i, z_j)$	z_y	z_k	t
x_h^*	0.525	0.491	0.041
	(7.23)	(5.03)	(8.95)
x_s^*	0.383	0.169	0.009
	(4.89)	(1.98)	(2.54)
x_u^*	0.432	0.117	−0.045
	(4.89)	(1.08)	(−6.49)
x_d^*	0.852	0.123	0.009
	(10.56)	(1.88)	(1.89)
x_e^*	0.051	0.997	0.027
	(0.46)	(6.41)	(3.38)
x_m^*	0.981	0.382	0.026
	(9.76)	(3.23)	(6.24)
x_o^*	0.704	0.059	0.023
	(9.51)	(0.50)	(6.52)

[a]See Table 5.

materials and purchased services are 0.98 and 0.70, respectively. Unreported results show that the scale elasticity, $\varepsilon(c^*, z_y)$, is about 0.74 for the split sample results and 0.69 for pooled data. This indicates the presence of increasing returns to scale, a finding that is consistent with Flaig and Rottmann (2001) and Koebel *et al*. (2000) using a similar data set.[11] The low output elasticities of labour demand can be interpreted as evidence of "jobless growth", indicating that output growth must be substantial in order to create jobs, given the negative effects of a wage increase and labour-saving technological change on unskilled labour.

Calculations for the time elasticities are given in the third column of Table 7. Given the effects of output, capital and input prices, unskilled labour decreases over time while the remaining inputs increase over time. The impact of capital on factor demand is positive in most cases, indicating that most input factors benefit from capital accumulation (see column 2 in Table 7). High-skilled labour benefits more from capital growth than all other input factors. In particular, the impact of capital on the different types of labour increases with the skill level ($\varepsilon(x_h^*, z_k) \geqslant \varepsilon(x_s^*, z_k) \geqslant \varepsilon(x_u^*, z_k)$) which is consistent with capital–skill complementarity.

[11]The relatively low output elasticities of different types of workers are partly due to the restricted cost function framework adopted here. Modelling the capital stock as a variable factor of production results in somewhat higher output elasticities; see Koebel *et al*. (2000).

VI. Conclusion

In West German manufacturing, the demand for both purchased services and imported intermediate inputs has been expanding more rapidly than gross output. This paper has offered three contributions to the economic analysis of these changes. First, we investigated the input substitution possibilities and the effects of output and capital on input demand more thoroughly than in previous studies. In particular, we analysed the impact and the determinants of purchased services and imported materials on the demand for heterogeneous labour. Second, we formulated a new variant of a Box–Cox cost function nesting both the normalised quadratic and the translog functional forms. Third, we distinguished between both the quantity and price effects of purchased services and imported materials.

We find that the effects of output and capital are more important in explaining the demand for heterogeneous labour than substitution effects between different types of labour with either purchased services or imported materials. Similarly, the increasing demand for both imported materials and purchased services is a consequence of output growth rather than of input substitution. Moreover, the empirical results highlight the importance of distinguishing between price and quantity effects of purchased services and imported materials. The quantity effect indicates that the increasing demand for purchased services and imported inputs tends to reduce the demand for all skill levels, but the effects are not significantly different from zero in most of the cases.

Appendix

Data Description

The primary source of the different components of intermediate materials is the German Federal Statistical Office. We used input–output Table 1.1 containing product-to-product tables of the value of commodity i used as an intermediate input by industry j (*Fachserie 18, Volkswirtschaftliche Gesamtrechung, Reihe 2, Input–Output Tabellen*). We also used input–output Table 1.3 containing the corresponding matrices for imported intermediate inputs. These data are available for the years 1978, 1980, 1982, 1984–1988, 1990.[12] For each industry, there are 58 types of intermediate inputs available as well as 58 types of imported material inputs. We regrouped them into four broadly defined groups:[13]

[12]The main reason for not using more recent data is that annual input–output tables for Germany for the 1990s based on NACE, Rev. 1 (Statistical Classification of Economic Activities in the European Union) will not be published until mid-2002.

[13]We do not disaggregate purchased services into imports of purchased services and domestic purchased services. For West German manufacturing, the share of imported purchased services in total intermediate materials was less than 1 percent in 1990.

(i) domestic non-energy intermediate materials (excluding purchased services), including 35 elementary intermediate inputs out of a total of 58;
(ii) energy (including imported energy), including 7 elementary intermediate inputs out of a total of 58;
(iii) services (including imported services), including 16 elementary intermediate inputs out of a total of 58;
(iv) imported non-energy intermediate materials (excluding purchased services).

This aggregation yields the total expenditures for each of the four types of intermediate inputs. In order to obtain the corresponding input–output tables in constant prices, each of the 58 types of intermediate materials was deflated by the respective price index (producer price indices for domestic outputs supplied to intermediate demand, available from the German Statistical Office). Input–output Table 1.3 was deflated using price indices of imported materials taken from *Preisindizes für die Ein- und Ausfuhr* (*Fachserie 17, Reihe 8*, various issues). Intermediate materials in constant prices for the four aggregate intermediate inputs were calculated by adding up the corresponding elementary inputs expressed in constant prices. Then, the corresponding aggregate input prices for the four components of intermediate materials were obtained by dividing the nominal values by the corresponding values in constant prices. This gives the price indices p_{dnt}, p_{ent}, p_{mnt} and p_{ont}. Finally, we adjusted the data from the input–output tables for the small difference in national accounts data.

An important caveat concerns the use of the official prices of service industries as deflators for purchased services. Griliches (1992) points out the difficulty in measuring prices of services, particularly due to the rapid change in the quality of services. Obviously, the increase in the output price of purchased services may be explained to some extent by changes in the quality of purchased services (business services, telecommunication services) rather than by inflationary price changes. If we have overestimated the prices of purchased services, then we must have underestimated their level in constant prices, which suggests that the growth in purchased services in constant prices would be higher than the growth according to official statistics.[14]

The nominal value and the value at constant prices of gross production, gross materials and the net capital stock were obtained from national accounts. Employment data were provided by the German Federal Employment Office. Labour was transformed into full-time equivalents. Data on gross earnings per full-time unskilled worker and medium-skilled worker were obtained from a 1 percent random sample from the German Social Security Accounts for the period 1975–1990. Earnings data for the highest skill group were taken from German Wage and Salary Statistics. Gross earnings per full-time worker were transformed into labour costs by adding the employer's contribution to social security.

[14]A further bias is introduced by the common practice, adopted by many statistical agencies, of using the consumer price index for deflating service output.

Calculation of the Standard Errors

The variance of the restricted elasticities can be obtained as follows. The "delta method" allows us to write $\text{vec}\,\varepsilon(\tilde{x}_L, x'_M)$, the $(S_L S_M \times 1)$ vector, stacking the elements of $\varepsilon(\tilde{x}_L, x'_M)$, in the neighbourhood of the true values $\varepsilon^0 \equiv \varepsilon(x^{0*}, p'_M)$ as:

$$\begin{aligned}\text{vec}\,\varepsilon(\tilde{x}_L, x'_M) &= g(\varepsilon(x^*, p'_M))\\ &\simeq g(\varepsilon^0) + \left.\frac{\partial g}{\partial\,\text{vec}'\,\varepsilon}\right|_{\varepsilon=\varepsilon^0} (\text{vec}\,\varepsilon(x^*, p'_M) - \text{vec}\,\varepsilon^0),\end{aligned}$$

where the $(S_L S_M \times 1)$ vector g is defined by

$$g(\varepsilon(x^*, p'_M)) = \text{vec}[\varepsilon(x^*_L, p'_M)[\varepsilon(x^*_M, p'_M)]^{-1}]. \quad \text{(A1)}$$

Thus, the variance of $\text{vec}\,\varepsilon(\tilde{x}_L, x'_M)$ is related to the variance of $\text{vec}\,\varepsilon(x^*, p'_M)$ by

$$\text{V}[\text{vec}\,\varepsilon(\tilde{x}_L, x'_M)] \simeq \left.\frac{\partial g}{\partial\,\text{vec}'\,\varepsilon}\right|_{\varepsilon=\varepsilon^0} \text{V}[\text{vec}\,\varepsilon(x^*, p'_M)] \left.\frac{\partial g'}{\partial\,\text{vec}\,\varepsilon}\right|_{\varepsilon=\varepsilon^0}.$$

As the matrix $\text{V}[\text{vec}\,\varepsilon(x^*, p'_M)]$ is obtained from the regression (9), it is now possible to calculate $\text{V}[\text{vec}\,\varepsilon(\tilde{x}_L, x'_M)]$ using the expression for $\partial g/\partial\,\text{vec}'\,\varepsilon$ given in (A2) and (A3) below. Note that only the elements on the main diagonal of $\text{V}[\text{vec}\,\varepsilon(\tilde{x}_L, x'_M)]$ are interesting for our purpose. From (A1) and the properties of the vec operator it follows that

$$\begin{aligned}g(\varepsilon(x^*, p'_M)) &= ([\varepsilon(x^*_M, p'_M)']^{-1} \otimes I_L)\text{vec}\,\varepsilon(x^*_L, p'_M)\\ &= (I_M \otimes \varepsilon(x^*_L, p'_M))\text{vec}[[\varepsilon(x^*_M, p'_M)]]^{-1},\end{aligned}$$

where I_L denotes the $(S_L \times S_L)$ identity matrix. From the first equality, we obtain that

$$\frac{\partial g}{\partial\,\text{vec}'\,\varepsilon(x^*_L, p'_M)} = ([\varepsilon(x^*_M, p'_M)']^{-1} \otimes I_L), \quad \text{(A2)}$$

and from the second equality that

$$\frac{\partial g}{\partial\,\text{vec}'\,\varepsilon(x^*_M, p'_M)} = -(I_M \otimes \varepsilon(x^*_L, p'_M))([\varepsilon(x^*_M, p'_M)']^{-1} \otimes [\varepsilon(x^*_M, p'_M)]^{-1}). \quad \text{(A3)}$$

Finally, $\partial g/\text{vec}'\,\varepsilon(x^*, p'_M)$ is obtained by juxtaposing $\partial g/\text{vec}'\,\varepsilon(x^*_L, p'_M)$ and $\partial g/\text{vec}'\,\varepsilon(x^*_M, p'_M)$.

The dimensions of the matrices involved in this Appendix are shown in Table A1.

Table A1. *Some matrices and their dimensions*

Matrix	Dimension
g	$S_L S_M \times 1$
$\varepsilon(x^*, p'_M)$ and ε^0	$(S_L + S_M) \times S_M$
$\text{vec}\, \varepsilon(x^*, p'_M)$	$(S_L + S_M) S_M \times 1$
$\partial g / \partial\, \text{vec}'\, \varepsilon(x^*_L, p'_M)$	$S_L S_M \times S_L S_M$
$\partial g / \partial\, \text{vec}'\, \varepsilon(x^*_M, p'_M)$	$S_L S_M \times S_M S_M$
$\partial g / \partial\, \text{vec}'\, \varepsilon(x^*, p'_M)$	$S_L S_M \times (S_L + S_M) S_M$
$\text{V}[\text{vec}\, \varepsilon(\tilde{x}_L, p'_M)]$	$S_L S_M \times S_L S_M$
$\text{V}[\text{vec}\, \varepsilon(x^*, p'_M)]$	$(S_L + S_M) S_M \times (S_L + S_M) S_M$

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