The measurement of labour productivity in wholesaling *

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Labour productivity is often discussed in economic literature, yet productivity studies in wholesaling are rare. On the whole, wholesaling is a neglected area of research in contrast with its important position in the distribution channel. Our analysis of labour productivity in wholesaling makes use of a labour–cost relationship – originally developed for retailing – to study differences in labour productivity across wholesale business types. For this purpose, averaged data are used of 61 German wholesale types for the 7-year period, 1979 through 1985. The labour–output relationship is estimated applying a pooled, an error-component and a variable-intercept model. Also, heteroskedasticity is considered.

We find that economies of scale with respect to labour are present due to the occurrence of threshold labour. Moreover, labour quality, inventory turnover rate, mode of operation and position in the distribution channel significantly affect labour productivity. Regarding the models used for estimation, the variable-intercept model performs slightly better than the error component model.

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1. Introduction

Traditionally, researchers in the wholesale area emphasize the impopularity of wholesaling as a subject of scientific research. Although the necessity of wholesaling as an independent means of distributing merchandise is already recognized by Adam Smith (1981, Book II, Chap. V), theoretical development in this area is inert to a proverb. [1] There are several reasons for this slack attitude towards scientific research of wholesale phenomena. One reason may be the consideration of wholesaling as a dying branche rapidly becoming obsolete (cf. Lopata, 1969; Beckman and Engle, 1949). Another reason is the deep-rooted suspicion against the intervention of wholesalers in the distribution channel: "for of all middlemen considered parasitic, the wholesaler is the most accused" (Bartels, 1962, p. 147). A final reason may be the suspicion among people working in the wholesale area against the usefulness and possible success of quantitative techniques, especially in matters of interfirm diagnostics and industry dynamics.

In this paper, a theoretical framework is constructed to study labour productivity in the wholesale trade. It is our aim to establish the impact on labour productivity of sales volume (scale), position in the distribution channel and other characteristics to be described below. To achieve this purpose we

[1] A pathbreaking contribution is made by Beckman and Engle (1949; first edition, 1926) who describe wholesaling in relation to economic theory. Empirical analyses are rarely found in wholesaling. Two noteworthy exceptions are Bucklin (1972) and Martin (1984), who deal with structure and profitability of U.S. wholesale trade.

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describe the meaning of production in terms of wholesaling and discuss several empirical indicators of wholesale production. We use the fact that the value of wholesale production can be measured by value added to derive a relationship between employment and wholesale production. The relationship is then used to study differences in labour productivity across German wholesale business types.

Our empirical analysis of labour productivity is inspired by analogous research in the retail area. This inspiration is justified by the similarity in nature of the production process of wholesaling and retailing. Firstly, in both areas production consists of providing a service capacity "to be used at the discretion of customers" (Nooteboom, 1982, p. 163). There is no physical product that can be stocked or resold. Secondly, as in retailing, the service capacity in wholesaling consists of various dimensions, such as assortment, price level, reliability, delivery time, payment facilities, flexibility in case of claims and returns, frequency of deliveries, repair and maintenance services, promotional activities, etc. However, an important difference between wholesaling and retailing remains with respect to mode of operation: wholesalers usually do not maintain selling area to serve their customers. Instead, much effort in wholesaling is concerned with order acquisition, handling inventories, transport and administration.

In retailing, the absence of a physical product and the stochastic nature of customer arrivals have led to the construction of a non-homogeneous, linear labour cost relationship, which is firmly based in queuing theory (see Nooteboom 1980, 1982, 1987; Frenk, Thurik and Bout, 1989). At present, we use the labour–cost relationship to study labour productivity in the German wholesale trade. We are particularly interested in the influence on labour productivity of scale, quality of labour, inventory turnover rate, mode of operation and position of the wholesale business type in the distribution channel. Other variables of interest, like composition of the labour force, competitive situation on buyer and seller markets and possible delays in the adjustments of actual to desired labour volume are left for future research. [2]

The data consist of averaged information on 61 German wholesale business types for the period 1979 to 1985. [3] Error-component and variable-intercept models are employed to estimate the effects and to reduce possible bias resulting from neglected variables. In addition, we evaluate the occurrence of heteroskedasticity: the variance of the disturbance term may not be equal for all wholesale types and years. Consideration of heteroskedasticity is another refinement in the determination of direction and extent of the unknown effects.

The outline of the paper is as follows. Section 2 presents our view on the nature of wholesale production. Section 3 contains an empirical illustration of labour productivity in the German wholesale trade. The model used to study labour productivity is developed in Section 4. The estimation techniques are briefly discussed in Section 5 and the estimation results are presented in Section 6. Section 7 concludes the paper.

2. The nature of wholesale production

Wholesalers appear at all stages in the distribution process matching almost all types of sellers and buyers and trading all kinds of merchandise. Activities of wholesalers are only rarely noticed, despite their important role in society. Unlike in manufacturing, production in wholesaling is a rather obscure

[2] From various studies in the retail area addressing similar notions, we mention Nooteboom (1983), Thurik (1984), Thurik and Vollebregt (1984), Thurik and Kleijweg (1986) and Thurik (1986).

[3] A wholesale business type is defined as a group of merchant wholesalers trading a similar type of merchandise.

event in the sense that there is a lot of activities going on, but there is no tangible product. The same holds true for production in retailing, but at least retailers assume a visible part in everyday life. In this section we describe the nature of wholesale production to shed light on the societal role of wholesaling. Moreover, we discuss the choice of an indicator of wholesale output.

Among others, Van de Woestijne (1966) summarizes the wholesale production process as order transformation. Wholesalers transform conditions under which suppliers are willing to sell into conditions under which customers are willing to buy. Basically, supply and demand conditions differ with respect to time, place, quality and quantity. Differences in these four dimensions are solved by numerous wholesale activities, like inventory holding, market coverage, transport, assembling, breaking bulk, cleaning, sorting, repacking, performing customer services, providing a convenient assortment and offering credit [4] (see, e.g., Rosenbloom, 1987; Van den Berg et al., 1984; Batzer and Greipl, 1975; Nieschlag et al., 1976). The product of wholesaling is the result of this transformation process, namely the *availability* of services and commodities throughout time and place, in varying qualities and quantities. However, unlike in manufacturing where a clear distinction between production and marketing process usually occurs, the product in wholesaling is only recognized as output once the transformation process is concluded with a transaction. The transformation process and the selling process are inseparable. The buyer directly participates in determining the output of the transformation process, as Fletcher and Snee (1985) note.

[4] These activities are not reserved to wholesalers alone. In many cases, they are carried out by manufacturers or customers as well. Wholesalers are characterized by their position in the distribution channel and not by their activities.

It is difficult to find a suitable measure of the wholesale product, since the societal function of wholesaling includes a wide variety of tasks. For an indicator of wholesale output to be acceptable, it should vary with the diversity and intensity of wholesale activities performed as well as with the volume of merchandise sold. [5] The *physical volume* of merchandise sold is quite a natural empirical indicator of the wholesale product in productivity analyses concerning individual wholesalers trading similar goods and performing similar tasks. Its usefulness becomes less apparent when the variety in tasks and the heterogeneity of the commodity assortment increase. The volume of merchandise can only be used in analyses on averaged data when transformed into some sort of product equivalent which is comparable across wholesale types. Another type of indicators often used in empirical research is the class of *monetary measures*. Monetary indicators are appropriate when either seen as society's valuation of the wholesale product or as a special case of weighing the commodity assortment, whereby prices act as weighting factors. Three obvious candidates are total sales, purchasing value and value added. The introduction of a price component makes the monetary indicator less desirable, since it becomes receptive to all kinds of market and regulatory characteristics. Furthermore, in case of elastic demand, interactions between price and volume of services may frustrate the ability of monetary indicators to adequately measure wholesale output.

The selection of an indicator is mainly based on purpose of the analysis and quality of the data. For performance comparisons across wholesale business types we prefer an indicator based on value added for two reasons. Firstly, there is an intuitive close relationship between value added and the trans-

[5] An interesting discussion on choice of output measure is found in Hall, Knapp and Winsten (1961).

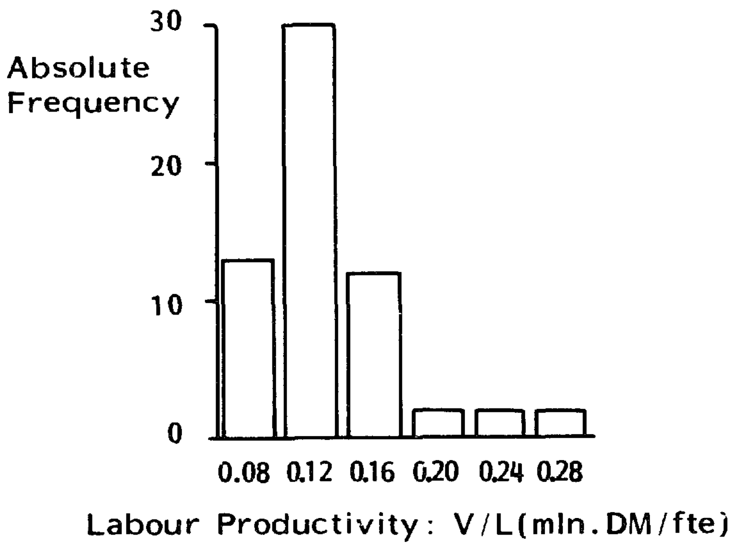

Fig. 1. Distribution of labour productivity for 61 German wholesale business types, 1985.

formation point of view on wholesale production. Wholesale production bridges the gap between supply and demand whereas value added does so regarding the valuation of merchandise at the supply and demand side. Secondly, total sales and purchases are inadequate as indicators of wholesale output in view of the data we use. Within wholesale business types considerable variation is present regarding the depth of tasks performed by different types of wholesalers (cf. Hall, Knapp and Winsten, 1961, p. 47). Across wholesale business types, differences occur with respect to scarcity of the merchandise and cummulated efforts of economic agents handling the goods before the wholesaler does.

3. Labour productivity in the German wholesale trade

Our empirical analysis is concerned with performance comparisons across wholesale business types. For this purpose we make use of averaged data on 61 German wholesale business types for the period 1979–1985. Details about sources and numerical characteristics of the data are found in appendix A. [6] Fig. 1 shows the distribution of labour productivity in our dataset for 1985.

At least two things can be derived from this chart. Firstly, average labour productivity is about 0.12×10^6 DMarks_{1985} ($\approx 0.04 \times 10^6$ $\text{US\$}_{1985}$) per employee, which is a considerable amount compared to retailing: 0.09×10^6 DMarks_{1985} per employee; and manufacturing: 0.10×10^6 DMarks_{1985} (Statistisches Bundesamt Wiesbaden, pp. 115, 226). Secondly, labour productivity differs widely with values ranging from 0.06×10^6 DMarks_{1985} to 0.24×10^6 DMarks_{1985} per employee. Low values for labour productivity are found in wholesaling in farm machinery and agricultural implements; installation requirements for gaz, water and electric; and lacker, paint and wallpaper; whereas wholesaling in coal and oilproducts are characterized by a high labour productivity.

Fig. 2 shows a plot of labour volume, measured in full-time equivalents, against value

[6] The data used in the analysis are available on a $5\frac{1}{4}''$ diskette, which can be obtained from the authors upon request.

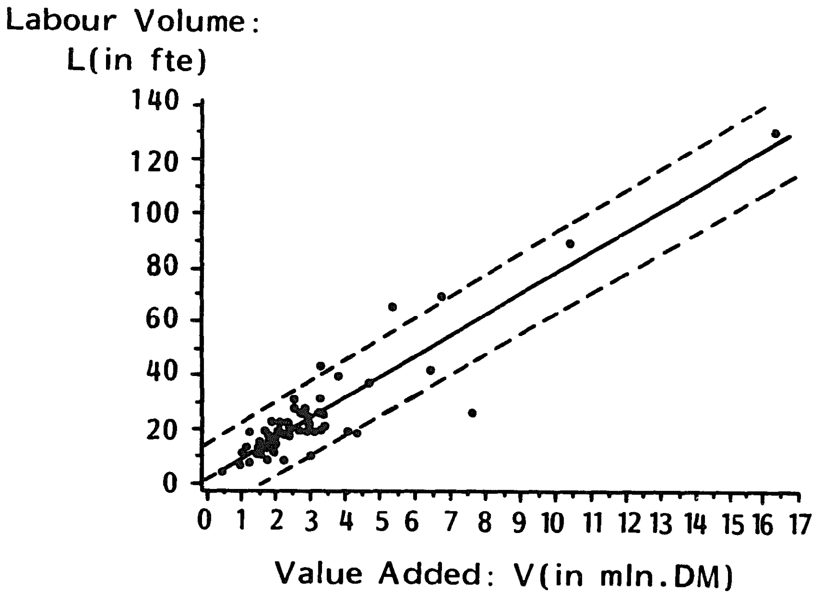

Fig. 2. Plot of labour volume vs. value added for 61 German wholesale business types, 1985.
Note: the solid line in Fig. 2 represents the regression line:

$$L = \underset{(1.72)}{-0.11} + \underset{(0.55)}{9.56}\ V \quad \left(R^2 = 0.83,\ N_{\text{obs}} = 61\right).$$

The dashed lines mark the 95% confidence limits for mean predicted values. For the entire period 1979–1985, this regression amounts to

$$L = \underset{(0.96)}{6.07} + \underset{(0.28)}{73.0}\ V \quad \left(R^2 = 0.61,\ N_{\text{obs}} = 426\right).$$

added for the year 1985. The pattern suggests a linear relationship between labour and wholesale output. In the next section, a model is developed to describe the labour–output relationship and to explain differences in labour productivity across wholesale business types.

4. The model

The framework for studying labour productivity derives from the linear labour–cost relationship developed by Nooteboom (1980, 1982):

$$L = \alpha + \bar{\beta} q, \tag{1}$$

with:

L : labour volume, measured in full-time equivalents,
q : volume of wholesale output.

Labour employed consists of threshold labour, α, which is the minimum amount of employees necessary to operate a wholesale establishment, and an amount of labour, which varies with the volume of wholesale services, $\bar{\beta} q$. Linear labour–cost relationships are consistently found for retail outlets belonging to the same shoptype (for references, see footnote 2). They are also found at higher levels of aggregation if appropriate allowance is made for product differences (Nooteboom, 1983; Thurik and Vollebregt, 1984; Thurik, 1986). Two problems have to be solved before model (1) can be used to study labour productivity at the level of wholesale business types. Firstly, the theoretical variable *wholesale product* has to be replaced by an empirical indicator of wholesale output. Secondly, the specification has to be corrected for differences in quality of labour and service package across wholesale business types.

One solution concerning the measurement of wholesale output is to approximate q directly by some monetary measure, preferably value added. However, interactions between price and volume of wholesale services make any kind of monetary measure a highly dubious indicator of wholesale output. We solve this problem by applying a concept proposed by White (1976). When value added is interpreted as valuation of the wholesale product, it can be assumed to be composed of the volume of wholesale output, q, and an implicit price for wholesale services, p_q:

$$V = p_q \cdot q, \tag{2}$$

with:

V : value added, measured as the difference between annual sales and purchasing value,

p_q : implicit price of the wholesale product, q.

The interactions between the implicit price, p_q, and the volume of wholesale services, q, are characterized by a loglinear relationship: [7]

$$q = \gamma p_q^{\delta}. \tag{3}$$

The price elasticity, δ, is not restricted to be negative, since q represents volume as well as diversity of the wholesale product. Yet, we expect that the more wholesale output is corrected for heterogeneities, the more accurately price elasticity is estimated.

Solving equation (3) for price p_q, substituting the result in equation (2) and solving for q gives

$$q = \gamma^{1/(1+\delta)} V^{\delta/(1+\delta)}, \tag{4}$$

which is substituted in model (1):

$$L = \alpha + \beta V^{\nu}, \tag{5}$$

where

$$\nu = \delta/(1+\delta) \quad \text{and} \quad \beta = \bar{\beta}\gamma^{1/(1+\delta)}.$$

In case of wholesalers trading the same type of merchandise and performing similar tasks, equation (5) can be used to estimate the unknown parameters α, β, and ν. But in general – and especially when comparing wholesale business types – heterogeneities occur with respect to quality of the labour force and service package provided. The scale independent labour intensity, β, is adjusted to take differences in labour requirements into account. Value added is corrected for differences in service package, which are assumed to depend on the position in the distribution channel [8]

$$\beta = \beta_0 W^{\beta_1} T^{\beta_2} S^{\beta_3},$$

$$V = \left(b_1 + \sum_{i=2}^{6} \beta_{4i} b_i\right) Q - \lambda\left(s_1 + \sum_{j=2}^{5} \beta_{5j} s_j\right) I, \tag{6}$$

with

Q : annual sales value in 10^6 DMarks_{1979},

I : purchasing value in 10^6 DMarks_{1979},

b_i : percentage of sales through channel i ($i = 1, 2, \dots, 6$),

s_j : percentage of purchases from channel j ($j = 1, 2, \dots, 5$),

W : average wage costs per employee,

T : average yearly turnover rate of inventories,

S : average share of sales from stock,

W, T, S are divided by their yearly sample average.

The extension is based on several considerations: [9]

[7] A deterministic loglinear specification is chosen to keep the derivation analytically tractable.

[8] In addition, heterogeneities may have an autonomous impact on demand for wholesale services (through eq. 3). Such an excercise is left for future research.

[9] Our labour relationship does not take into account differences in capital stock. The main reason is the absence of suitable data. This is not considered to be a serious shortcomming. *Within* wholesale business types, large changes in the labour/capital ratio are not expected, because the service-oriented production process leaves little room for substitution effects. Moreover, the results do not indicate the presence of a separate time effects. The establishment of such an autonomous time effect could be interpreted as the embodiment of technological progress over time. *Across* business types, differences in capital intensity are assumed to be accounted for by the particular structure of the models used to handle panel data: specific wholesale type characteristics are accounted for by either a stochastic or a fixed effect.

Labour quality, W

Defined as average wage costs per employee. The impact of wage rate on labour employed is two-fold. Firstly, a higher wage rate corresponds to higher labour quality, staff and personnel are more qualified, which increases labour productivity. Secondly, higher labour costs stimulate a more efficient use of labour (Nooteboom, 1980; Thurik, 1984). We expect $\beta_1 < 0$.

Inventory turnover rate, T

Measured by the ratio of purchasing value to average yearly stock level. A relatively high inventory turnover rate makes more efficient management of the physical distribution process necessary, which results in higher labour productivity: $\beta_2 < 0$.

Mode of operation, S

Measured by the share of supply from stock in total sales. Wholesale operations are roughly divided into deliveries directly from seller to buyer, supply from stock, and agency and brokerage. A relatively high share of supply from stock implies that relatively labour intensive inventory handlings occur in addition to transport and go-between. We therefore expect a relatively low labour productivity: $\beta_3 > 0$.

Buyer and seller categories, b_i and s_j

Approximated by the share of sales to buyer type i in total sales and the share of purchases from seller type j in total purchases, respectively. (See Table 1 for descriptions of b_i and s_j.) The parameters β_{4i} and β_{5j} represent the impact on labour productivity of different buyer and seller categories in relation to manufacturing (acting as buyer and seller respectively). The parameter λ measures the ratio of two effects, namely purchases from and sales to manufacturers, β_{51}/β_{41}. When the distribution process involves much personal attention, providing a wide assortment and offering a wide variety of additional services, labour intensity will be relatively high. For instance, a high share of sales to professional users – like physicians, dentists and artisans – often involves repeated personal negotiations, extensive maintenance services and quick deliveries. As a result, labour productivity will be relatively low. Similarly, a high share of purchases from agricultural sellers may involve a relatively small assortment providing possibilities for efficient management of the distribution process. A relatively high labour productivity is expected.

5. Estimation of the labour–output relationship

The data are pooled to determine direction and extent of explanatory variables. Pooling has certain advantages over using either time series or cross-section information: the strong increase in sample points reduces multicollinearity among explanatory variables, offers increased possibilities of identifying economic models and reduces omitted variables bias

Table 1
Buyer and seller categories, b_j and s_j

Buyer categories		Seller categories	
b_1	% sales to manufacturing	s_1	% purchases from manufacturing
b_2	% sales to wholesaling	s_2	% purchases from wholesaling
b_3	% sales to retailing	s_3	% purchases from agriculture
b_4	% sales to other prof. users	s_4	% purchases from other suppliers
b_5	% sales to private users	s_5	% import
b_6	% export		

(see, e.g., Hsiao, 1986). Below we summarize three models used to estimate the extended labour–output relationship, which is given as

$$L = \alpha + \beta_0 W^{\beta_1} T^{\beta_2} S^{\beta_3} \times \left(\left(b_1 + \sum_{i=2}^{6} \beta_{5i} b_i \right) Q - \lambda \left(s_1 + \sum_{j=2}^{5} \beta_{6j} s_j \right) I \right)^{\nu} + \varepsilon, \tag{7}$$

with ε_{it} the disturbance term for wholesale type i $(i = 1, 2, \ldots, N)$ at year t $(t = 1, 2, \ldots, T)$. Indices for wholesale types and years are left out to simplify notation.

(1) The straightforward *pooled model* (PM). The disturbances, ε_{it}, are assumed to be normally, identically and independently distributed: $\varepsilon_{it} \sim \mathrm{N}(0, \sigma_\varepsilon^2)$.

(2) An *error-component model* (EC). In the EC-model, the disturbance term, ε_{it}, is assumed to be composed of a business type effect μ_i, a time effect λ_t and a remaining effect ν_{it}:

$$\varepsilon_{it} = \mu_i + \lambda_t + \nu_{it}.$$

The composing effects are independently (among themselves and among each other) and normally distributed, with $\mu_i \sim \mathrm{N}(0, \sigma_\mu^2)$, $\lambda_t \sim \mathrm{N}(0, \sigma_\lambda^2)$, and $\nu_{it} \sim \mathrm{N}(0, \sigma_\nu^2)$. A Likelihood Ratio test and a Lagrange Multiplier (LM) test proposed by Breusch and Pagan (1980) are used to examine the null hypothesis of no stochastic effects: $\sigma_\mu^2 = 0$ and $\sigma_\lambda^2 = 0$.

(3) The *variable-intercept model* (VI). For each wholesale business type i, the overall intercept α is replaced by a fixed, non-stochastic intercept α_i. The disturbance structure remains unchanged. A Likelihood Ratio (LR) test is considered to examine the null hypothesis that all intercepts are equal.

The three models are estimated by method of maximum likelihood. A description of the various likelihood functions can be found in Van Dalen, Koerts and Thurik (1989). From the vast amount of literature on panel estimation, we mention Amemiya (1971), Maddala (1971), Mundlak (1978), Nerlove (1971) and textbooks such as Judge et al. (1985) and Hsiao (1986).

An evaluation of the error-component and the variable-intercept model is a difficult matter and a choice for either one of them heavily depends on the quality of the data and the purpose of the analysis. For instance, the variable-intercept model is fairly easy to apply, but disadvantages are the considerable loss in degrees of freedom for large N and small T and the fact that the fixed intercepts rarely have a meaningful interpretation, yet take account of a large part of the variation between dependent and explanatory variables (cf. Wallace and Hussain, 1969; Maddala, 1971). On the other hand, application of the error-component procedure is more comprehensive, but if the distributive assumptions are correctly applied, interference concerns the entire wholesale sector (Mundlak, 1978). We follow Hausman (1978) in presenting estimation results for both the error-component and the variable-intercept model, because in our situation a choice for either model is arbitrary.

In addition to the three models, we evaluate the possibility of heteroskedastic disturbances by assuming a flexible variance structure $\sigma_{\varepsilon,it}^2 = h(z_{it}'\phi)$, where z_{it}' is a row vector of explanatory variables and ϕ a column vector of unknown parameters both of order s (cf. Breusch and Pagan, 1979). In particular, $s = 2$, $z_{it}^{(1)} = 1$, $z_{it}^{(2)}$ represents the scale variable $V_{it} - \min_{it} V_{it}$, and

$$\sigma_{\varepsilon,it}^2 = \exp\left(\phi_1 + \phi_2 z_{it}^{(2)}\right) = \sigma_0^2 \exp(2\sigma_1 z_{it}).$$

6. Estimation results

In Table 2, the estimation results are presented for the three models with and without heteroskedasticity.

Several conclusions can be drawn from the estimation results. The hypothesis that the error-component model is equal to the pooled model – $H_0: \rho = 0$ – is rejected. The outcomes of the LM-statistics (521.43 and 617.16, with and without heteroskedasticity, respectively) as well as the LR_1-statistics imply significance levels below 1%. Similarly, the hypothesis that there is no heteroskedasticity – $H_0: \sigma_1 = 0$ – is rejected given the outcomes of both the LR_2-statistics and the F-statistics.[10]

A choice between the error-component and the variable-intercept model is hard to make on formal, statistical grounds. First, the well-known Hausman (1978) test is applicable to linear models only. Second, the information criteria provided by Akaike (1973), AIC, and Schwarz (1978), SC, have conflicting implications in our situation. On the basis of AIC, the variable-intercept model is preferred, whereas SC results in choosing the error-component model. Third,[11] the J-test proposed by Davidson and MacKinnon (1981), shows preference for the variable-intercept model in case of homoskedasticity, but rejects both models in case of heteroskedasticity. Fourth, there is an intuitive argument in favour of the variable-intercept model. Inspection of the residuals from the error-component models reveals that labour volume is consistently over- or underestimated in time for more than 60% of all wholesale business types. The phenomenon does not occur in case of the variable-intercept models, which may indicate misspecification of the error-component model due to correlation between stochastic wholesale business type effects, μ_i, and explanatory variables.

The point estimates obtained with alternative estimation techniques differ considerably. However, there is accordance with respect to the direction of the estimates.

Scale, $\hat{\alpha}$

In the German wholesale trade, economies of scale are present as result of threshold labour, α. Whereas the minimum number of full-time workers equals about two in the pooled model, it varies from 5 to 7 in the case of the error-component and the variable-intercept model. This figure is relatively high as compared to outcomes for retailing (for references, see footnote 2), where threshold labour is equal to one or two depending on the opening hours of the shop and the number of independently operating departments. The assumption of a threshold labour equal for all wholesale business types apparently is too restrictive. More information is required to take account of differences in threshold labour.

(Price) elasticity, $\hat{\nu}$ (δ)

We find that $\hat{\nu}$ is higher than one in most cases which correspond with a negative price elasticity δ. In the variable-intercept model, $\hat{\nu}$ differs significantly from one implying a price elasticity equal to -5.17.

Labour quality, $\hat{\beta}_1$

The hypothesis that higher wage rates imply higher labour quality, thereby stimulating labour productivity, is confirmed. The estimate $\hat{\beta}_1$ is significantly lower than zero in all cases.

Turnover rate, $\hat{\beta}_2$

The inventory turnover rate has a positive influence on labour productivity, which confirms the hypothesis that a higher inventory

[10] Cf. Pagan and Hall (1983). The hypothesis $H_0: \sigma_1 = 0$ can also be tested by a linear regression of the squared residuals from the results obtained without heteroskedasticity against $z_{it}^{(1)}$ and $z_{it}^{(2)}$. The F-statistics for these regressions are 68.2 (PM), 54.1 (EC) and 56.5 (VI) implying significance levels below 1%.

[11] One referee suggested to estimate a convex combination of the error-component and the variable-intercept model. However, this would lead to identification problems. Instead, we apply Davidson and MacKinnon's J-test, which amounts to adding the fitted values of the error-component model to the variable-intercept model and testing its significance; and, vice versa, adding the fitted values of the variable-intercept model to the error-component model.

Table 2
Estimation results for the labour–output relationship equation (5) [a]

		No heteroskedasticity			Heteroskedasticity		
		PM	*EC*	*VI*	*PM*	*EC*	*VI*
α	Intercept [b]	−0.94	7.27	6.96	1.87	5.03	7.32
		(1.48)	(1.67)	(1.65)	(0.97)	(1.20)	(1.35)
β_0	Labour intensity	9.87	2.94	1.88	7.76	4.33	2.36
		(1.03)	(0.65)	(0.49)	(0.80)	(0.82)	(0.66)
ν	Elasticity	0.86	1.03	1.11	1.05	1.08	1.24
		(0.04)	(0.07)	(0.07)	(0.05)	(0.08)	(0.11)
β_1	Labour quality	−1.33	−1.18	−1.14	−1.36	−0.70	−0.79
		(0.11)	(0.13)	(0.12)	(0.12)	(0.14)	(0.16)
β_2	Turnover rate	−0.12	−0.36	−0.42	−0.08	−0.28	−0.56
		(0.03)	(0.08)	(0.09)	(0.03)	(0.06)	(0.09)
β_3	Mode of operation	0.38	0.68	0.72	0.40	0.52	0.73
		(0.06)	(0.11)	(0.11)	(0.06)	(0.09)	(0.12)
				Influence of sales to buyer category i with respect to manufacturing			
β_{42}	Wholesaling	0.89	0.78	0.72	0.92	0.94	0.57
		(0.02)	(0.09)	(0.14)	(0.02)	(0.05)	(0.08)
β_{43}	Retailing	0.95	1.00	1.20	0.92	0.97	0.93
		(0.01)	(0.05)	(0.09)	(0.01)	(0.03)	(0.04)
β_{44}	Other professional users	0.98	1.12	1.44	1.02	1.15	1.23
		(0.03)	(0.16)	(0.32)	(0.02)	(0.08)	(0.12)
β_{45}	Private users	0.31	−1.88	−3.91	0.79	0.24	−0.04
		(0.11)	(0.55)	(1.01)	(0.08)	(0.30)	(0.57)
β_{46}	Export	0.99	1.05	1.10	0.91	0.91	0.82
		(0.02)	(0.11)	(0.17)	(0.02)	(0.06)	(0.09)
				Influence of purchases from seller category j with respect to manufacturing			
λ	Ratio: β_{51}/β_{41}	0.87	0.66	0.53	0.89	0.80	0.58
		(0.02)	(0.07)	(0.10)	(0.01)	(0.05)	(0.07)
β_{52}	Wholesaling	0.98	0.80	0.80	1.00	1.03	1.13
		(0.02)	(0.14)	(0.28)	(0.02)	(0.07)	(0.19)
β_{53}	Agriculture	1.01	1.71	2.32	1.09	1.39	1.76
		(0.06)	(0.43)	(1.08)	(0.03)	(0.16)	(0.43)
β_{54}	Other sellers	1.02	0.75	1.64	1.03	1.09	2.05
		(0.04)	(0.31)	(0.75)	(0.03)	(0.16)	(0.47)
β_{55}	Import	1.16	1.50	1.86	1.11	1.25	1.58
		(0.02)	(0.15)	(0.36)	(0.02)	(0.07)	(0.17)
				Variance components			
σ_1	Heteroskedasticity	–	–	–	0.30	0.28	0.36
					(0.02)	(0.02)	(0.02)
σ_0	Standard deviation	5.24	6.71	2.21	2.12	2.69	0.72
		(0.18)	(0.54)	(0.08)	(0.13)	(0.26)	(0.05)
ρ	Share in wholesale type variance [c]	–	0.86	–	–	0.88	–
			(0.02)			(0.02)	

Table 2 (*continued*)

		No heteroskedasticity			Heteroskedasticity		
		PM	*EC*	*VI*	*PM*	*EC*	*VI*
		Diagnostics					
L	Log-Likelihood	−921.0	−716.7	−552.1	−834.6	−584.9	−435.7
LR_1	Likelihood ratio [d]	–	408.7	737.9	–	499.4	797.8
LR_2	Likelihood ratio [e]	–	–	–	172.9	263.5	232.8
AIC	Akaike's Information Criterion [f]	4.39	3.44	2.94	3.99	2.82	2.40
SC	Schwarz Criterion [g]	4.55	3.61	3.69	4.16	3.01	3.16
r^2	Squared correlation [h]	0.96	0.94	0.99	0.93	0.92	0.97
NT	Number of observations	427	427	427	427	427	427

[a] Asymptotic standard errors are given within parentheses.
[b] In case of the variable-intercept model: $\hat{\alpha} = \Sigma_i \hat{\alpha}_i$.
[c] The parameter ρ represents wholesale type specific variance as proportion of total variance: $\rho = \sigma_\mu^2/\sigma_\varepsilon^2$.
[d] *LR*-statistic based on comparison of likelihood values of *EC* and *VI* procedures with maximum likelihood (*ML*).
[e] *LR*-statistic based on comparison of the likelihood values of the estimation procedures with and without heteroskedasticity.
[f] Akaike's Information Criterion calculated as $(-2/NT)\hat{L} + 2K/NT$, where K is the number of estimated parameters.
[g] Schwarz Criterion calculated as $(-2/NT)\hat{L} + (K \ln NT)/NT$.
[h] Squared correlation coefficient between dependent variable, L, and the explained part of the model, $\hat{L}$.

turnover rate necessitates more efficient inventory management.

Mode of operation, $\hat{\beta}_3$

A high share of supply from stock has a negative effect on labour productivity, which is in accordance with the relatively labour intensive nature of this type of operations.

Sales to different buyers, $\hat{\beta}_{4i}$

Deliveries to professional users are more labour intensive than other deliveries. This is in accordance with our expectation that these deliveries often require personal negotiations for relatively small orders. Supplies to other wholesalers are less labour intensive, which may be caused by a shift of labour intensive activities, like inventory holding and sales contact, to the other wholesalers. The higher productivity resulting from sales to private users is rather puzzling. Explanations may be the absence of a delivery phase for otherwise intensive operations and the higher price paid for by private users. The impact of sales to retailers and export depend on the weight given to large scale wholesalers. If allowance is made for heteroskedasticity, we find these sales to be more productive than sales to manufacturers. The higher productivity comming from export may be explained by the relatively small assortment. In case of sales to retailers the intensive nature of handling many relatively small orders may be compensated by more efficient management of the distribution process.

Purchases from different sellers, $\hat{\beta}_{5j}$

Purchases from the seller categories – agriculture, import and other sellers – are less intensive than purchases from manufacturers. We assume that the main reason for the higher productivity is the relatively small assortment. In addition, importing goods often corresponds with sales to other wholesalers resulting in higher productivity. Purchases from other wholesalers are slightly more productive than purchases from manufacturers, which is consistent with our finding that sales to other wholesalers are more productive. Again, this finding depends on whether allowance is made for heteroskedasticity.

7. Final remarks

By proposing a combined methodological-empirical approach, we hope to stimulate theoretical development in the somewhat neglected area of wholesaling. A theoretical framework is constructed to study labour productivity at the aggregate level of wholesale business types and an empirical application using panel data is given for the German wholesale trade. Notwithstanding the shortcommings of the data, like the relatively short time series and limited in-depth business type information, the results of our analysis seem encouraging. Although the parameter estimates differ across alternative models, the signs of the effects hardly vary. Summarizing, we find that:

- economies of scale with respect to labour employed are present in the German wholesale trade,
- a higher quality of labour stimulates labour productivity,
- the inventory turnover rate emphasizes the relevance of efficient management of the distribution process which has a positive effect on productivity,
- a relatively high share of supply from stock results in higher productivity,
- different types of buyers and sellers have a different effect on labour productivity, and
- no systematic productivity growth is found in the period considered, 1979 through 1985.

The occurrence of heteroskedasticity does affect certain conclusions. For instance, export and sales to retailers as well as purchases from others wholesalers appear to be less labour intensive, if less weight is given to large scale wholesalers.

It is difficult to state a preference for either the error-component or the variable-intercept model on the basis of the estimation results. In analogy with the concept of pluriformity of theories advanced by Feyerabend (1963), we think it necessary to apply different estimation techniques to interpret certain relationships or empirical facts. The general consistency in the sign of the estimates, when applying different models, inspires confidence in the underlying hypotheses. However, the variable-intercept model is preferred to the error-component model in view of the residual pattern. The error-component model may be misspecified because of correlation between the stochastic wholesale business type effect and the explanatory variables.

The theoretical framework developed in this paper sheds light on labour productivity in wholesaling. Yet, it can be extended conceptually. The following variables are obvious candidates for inclusion in the model: part-time and family labour, average weekly working hours, degree of functional specialization within a wholesale business type and – if monthly or quarterly data are available – adjustment lags of actual to desired labour volume causing cyclical effects in labour productivity. Moreover, the relationship between volume and price of services can be extended taking additional explanatory variables into account, such as competition and regulation within a wholesale business type and the competitive situation on buyer and seller markets.

Appendix A. Data

The data used for estimating the models are available in publications from the German *Statistisches Bundesamt Wiesbaden.* [12]

[12] Statistisches Bundesamt Wiesbaden:
- Fachserie 6, Reihe 1.2: Wareneinkauf, Lagerbestand und Rohertrag im Grosshandel;
- Fachserie 6; Reihe 1.3: Warensortiment sowie Bezugs- und Absatzwege im Grosshandel;
- Fachserie 17, Reihe 6: Index der Grosshandelsverkaufspreise;

Verlag W. Kohlhammer GmbH: Stuttgart–Mainz.

Table A.1
Numerical characteristics of some variables [a]

		Min	Max	Mean	Standard deviation
L	Labour (in fte.)	4.236	130.900	25.978	19.322
Q	Sales (in 10^6 DM_{1979})	2.765	399.851	24.250	39.814
I	Purchases (in 10^6 DM_{1979})	1.871	382.589	21.525	38.162
W	Wage rate	0.744	1.625	1.000	0.159
T	Inventory turnover rate	0.167	9.876	1.000	1.124
S	Mode of operation	0.135	1.436	1.000	0.280
Share of sales to:					
b_1	Manufacturing	0.005	0.839	0.300	0.232
b_2	Wholesaling	0.022	0.478	0.143	0.097
b_3	Retailing	0.003	0.872	0.333	0.261
b_4	Other professional users	0.000	0.610	0.082	0.112
b_5	Private users	0.000	0.115	0.021	0.026
b_6	Export	0.001	0.375	0.122	0.091
Share of purchases from:					
s_1	Manufacturing	0.013	0.822	0.421	0.201
s_2	Other wholesalers	0.025	0.540	0.166	0.110
s_3	Agriculture	0.000	0.826	0.036	0.115
s_4	Other suppliers	0.003	0.478	0.059	0.070
s_5	Import	0.017	0.834	0.318	0.201

[a] Wage rate, inventory turnover rate and mode of operation are divided by their yearly sample average.

The information concerns 61 four-digit wholesale types covering the 7-year period 1979–1985.

Labour volume is constructed by adding the number of part-time workers for 0.6 to the number of full-timers. Our output measure is based on the contribution of a wholesale type to the national product: gross margin or value added. It is deflated by an index of the wholesale selling price. The wage rate is measured as average wage costs in 10^6 DMarks per employee. Inventory turnover rate is defined as the ratio of purchasing value of sales to average yearly inventories. Mode of operation is approximated by the supply from stock in relation to total sales. In Table A.1 some relevant numerical characteristics of the variables are presented.

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