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Gokhan H. Akay
Mutlu Yuksel

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Gokhan H. Akay
Trinity University

Mutlu Yuksel
IZA

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IZA

P.O. Box 7240
53072 Bonn
Germany

Phone: +49-228-3894-0
Fax: +49-228-3894-180
E-mail: iza@iza.org

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ABSTRACT

Capital-Skill Complementarity: Evidence from Manufacturing Industries in Ghana*

Using U.S. manufacturing data, Griliches (1969) found evidence suggesting that capital equipment was more substitutable for unskilled than skilled labor. Griliches formulated this finding as the capital-skill complementarity hypothesis. The purpose of this study is to determine whether the capital-skill complementarity framework holds for Ghana manufacturing plants in industry and aggregate level. We use an unbalanced panel of plant-level data for manufacturing firms in Ghana during the 1991 and 1997 in four industries (food-bakery, textiles-garments, wood-furniture and metal-machinery). Our findings suggest that capital-skill complimentarity holds in aggregate level and wood-furniture sector in Ghana. However, we reject the capital-skill complementarity hypothesis for food-bakery, textile-garment and metal-machinery sectors.

JEL Classification: J30, O55

Keywords: capital-skill complementarity, elasticity of substitution, translog cost function

Corresponding author:

Mutlu Yuksel
IZA
P.O. Box 7240
D-53072 Bonn
Germany
E-mail: yuksel@iza.org

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1. Introduction

The increase in wage and income inequality in developed and developing countries in recent decades have drawn attention to the role of trade in explaining this wage disparity. There are two major hypotheses proposed to explain these structural changes. One strand of literature investigates the standard Hecksher-Ohlin model of trade. These studies conclude that trade liberalization decreases the wage differential between skilled and unskilled labor in developing countries while increasing the wage disparity in developed countries. Therefore, the expansion of trade in labor-intensive goods has put downward pressure on unskilled wages in traded sector (Wood, 1994; Lawrence and Slaughter, 1993; Sachs and Schatz, 1994). Another well-known explanation is the skill biased technological change (Autor, Katz and Krueger, 1998). Capital accumulation caused by trade liberalization increases the wage differential in developing countries. When technological change is skill biased, the relative demand for skilled labor expands as the level of technology increases. The skill biased technical change can be studied using the capital-skill complementary hypothesis. That is, if capital and skilled labor are complements, capital accumulation will exacerbate the wage disparity between skilled and unskilled workers.

Capital-skill complementary hypothesis, formalized first by Griliches (1969), stems from the fact that skilled labor could be a better complement to capital than unskilled labor. Therefore, due to the capital-skill complementarity in production, capital growth increases the marginal product of skilled labor, while decreasing the marginal product of unskilled labor. As a consequence, this process generates the dynamics of wage inequality in the most of the developed countries, where the existence of capital-skill complementary hypothesis is well documented (Griffin, 1992; Bergstrom and Panas, 1992; Krusell et al. 1998)

On the other hand, very limited number of studies examine whether capital-skill hypothesis holds for developing countries. Zhou, 2001 provides evidence suggesting that capital-skill hypothesis holds in developing countries. Mazumdar and Agnoli (2004) for Peru and Yasar and Paul (2008) for Turkey provide further evidence supporting capital-skill complementary. However, less is known whether capital-skill hypothesis also holds for less developed parts of world with little capital endowment. Indeed, Goldin and Katz (1998) pointed out that capital-skill relation may differ across countries, industries and time periods.

This paper investigates the skill-capital complementarity in Ghana. We extend the previous research on elasticities estimation through implementing translog cost function. We also add to the previous literature through using uniquely diverse and disaggregated firm-level data for the time period of 1991 -1997 in Ghana. Our estimation strategy incorporates panel data estimation techniques. We find evidence for capital-skill complementary in wood-furniture in Ghana. Our elasticity of substitution estimates show that unskilled labor, skilled labor and capital are substitutes for one another for aggregated manufacturing industries and individual sectors.

The existence of capital-skill complementarity hypothesis is vital for developing countries for two reasons. First, if there is capital-skill complementarities, capital accumulation may explain a larger fraction of demand increase for skilled labor in the developing country. The second reason is related to trade liberalization. Openness may stimulate investment in the country since an important portion of equipment in the developing country has to be imported rather than being produced by country's own technology. Thus, if capital-skill complementary hypothesis holds, trade may increase the relative demand for skilled labor through this process as well. Indeed, Teal (1997) provides evidence suggesting that the real wages in Ghana decreased substantially during the last twenty years. On the other hand, Bigsten et al. (1997) show that the median values of investment to value-added and capital, are less than 1 percent in the Ghanaian manufacturing sector. The channel underlying these findings may be low investment rates in Ghanaian manufacturing sector. That is, rates of investment are very limited to allow the real capital stock to grow. Another important conclusion proposed by Lall et al. (1994) suggests that "R&D effort in Ghana relevant to manufacturing industry is minuscule, well below the critical mass needed to make a significant contribution to the absorption, adaption or creation of technology". This may be responsible for the technical regress in Ghana.

The remainder of the paper is structured as follows. Section 2 presents the empirical model. Section 3 discusses the data and descriptive statistics. Section 4 describes the econometric methodology and presents empirical results. Section 5 concludes.

2. Empirical Model

In order to estimate the extend of capital-skill complementarity; one requires a functional form that is general enough to hold different elasticities of substitution. We use translog cost function suggested by Christensen et al. (1973).

For three inputs of production: capital, skilled labor and unskilled labor the translog cost function is stated by (1):

(1) $Ln\ C = \alpha_0 + \alpha_K\ Ln\ P_K + \alpha_S\ Ln\ P_S + \alpha_U\ Ln\ P_U + 1/2\ \gamma_{KK}\ Ln\ P_K\ LnP_K + 1/2\ \gamma_{KS} Ln\ P_K\ LnP_S + 1/2\ \gamma_{KU} Ln\ P_K\ LnP_U + 1/2\ \gamma_{SK} Ln\ P_S LnP_K + 1/2\ \gamma_{SS}\ LnP_S\ LnP_S + 1/2\ \gamma_{SU} Ln\ P_s LnP_u + 1/2\ \gamma_{UK} Ln\ P_U LnP_K + 1/2\ \gamma_{US} Ln\ P_U LnP_S + 1/2\ \gamma_{UU} Ln\ P_U LnP_U + \alpha_Y\ LnY + 1/2\ \gamma_{YY}\ (LnY)^2 + \gamma_{KY} LnP_K\ LnY + \gamma_{SY}\ LnP_S\ LnY + \gamma_{UY} LnP_U LnY$

where C represents total production cost, Y is total output, and P_K, P_S and P_U are the price of capital, skill labor and unskilled labor, respectively.

According to Shephard`s Lemma, the optimal cost minimizing demand for an input can be derived through differentiation of the cost function with respect to its price. In case of the translog cost function, this equals to the cost share of input j, S_j .

(2) $\partial Ln\ C / \partial Ln\ Pj = Pj/C\ \ \partial C/\partial Pj = PjVj/C = Sj.$

Vj measures the quantity of input j. Monotonicity of the partial derivatives require the LHS of (2) to be positive. For the inputs of capital, skilled and unskilled labor, differentiation of (1) with respect to ln Pj yields the following equations:

(3) $S_K = \alpha_K + \gamma_{KK}\ Ln\ P_K + \gamma_{KS} Ln\ P_S + \gamma_{KU} Ln\ P_U + \gamma_{KY}\ LnY$

(4) $S_S = \alpha_S + \gamma_{KS} Ln\ P_K + \gamma_{SS}\ LnP_S + \gamma_{SU} LnP_u + \gamma_{SY} LnY$

(5) $S_U = \alpha_U + \gamma_{KU}\ Ln\ P_K + \gamma_{SU} LnP_S + \gamma_{UU}\ Ln\ P_U + \gamma_{UY} LnY$

Therefore, the system of cost share equations for the three inputs is presented by (3), where the cost shares must sum up to one. The equality of cross derivatives is assured through the imposition of the following symmetry criteria:

(6) $\gamma_{KS} = \gamma_{SK}$ $\quad \gamma_{KU} = \gamma_{UK}$ $\quad \gamma_{SU} = \gamma_{US}$

As the cost-shares sum up to one, only two of the three equations are independent. Linear homogeneity is imposed through the following conditions:

(7) $\alpha_K + \alpha_S + \alpha_U = 1$,

(8) $\gamma_{KK}+\gamma_{KS}+\gamma_{KU}=0$, $\gamma_{SS}+\gamma_{SU}+\gamma_{SK}=0$, $\gamma_{UU}+\gamma_{UK}+\gamma_{US}=0$, $\gamma_{KY}+\gamma_{SY}+\gamma_{UY}=0$

Stochastic specification of the function is done through adding a random disturbance term to each cost-share equation. It is assumed that the vector of $\{\varepsilon_K, \varepsilon_S, \varepsilon_U\}$ is multivariate, normally distributed, with a mean vector of zero and with a constant covariance matrix. As the cost share equations sum up to one and only two of them are linearly independent, the sum of random errors adds up to zero for each observation. Due to these properties, the covariance matrix is singular and non-linear.

To overcome the problem of singularity, one of the three cost share equations from the system is dropped. Only two equations need to be directly estimated. The parameter estimates give the same result regardless of the choice of which equation is dropped. In a case, where the cost-share equation of capital is dropped, after the imposition of symmetry and constant returns to scale, the two equations estimated are:

(9) $S_S = \alpha_S + \gamma_{SK} \text{ Ln } (P_S/P_K) + \gamma_{SU} \text{ Ln } (P_S/P_U)$.

(10) $S_U = \alpha_U + \gamma_{SK} \text{ Ln } (P_K/P_U) + \gamma_{SS} \text{ Ln } (P_S/P_U)$.

From the estimated coefficients of the system of equations in (9) and (10), Allen-Uzawa elasticities of substitution can be derived through calculating:

(11) $\sigma_{ij} = (\gamma_{ij} + S_i S_j)/ (S_i S_j)$ and $\sigma_{ii} = (\gamma_{ii} + S_i^2 - S_i)/S_i^2 \quad i \neq j$

Where:

$\sigma_{ij} > 0 \rightarrow$ the factors are substitutes

$\sigma_{ij} < 0 \rightarrow$ the factors are complements

$\sigma_{ij} = 0 \rightarrow$ the factors have no relationship

Then the capital-skill complementarity hypothesis holds if $\sigma_{S,K} < \sigma_{U,K}$ suggesting that skilled labor and capital are better complements than unskilled worker and capital. Own- and cross-price elasticities of demand are calculated according to:

(12) $\varepsilon_{ij} = (\gamma_{ij} + S_i S_j)/ S_j$ and $\varepsilon_{ii} = (\gamma_{ii} + S_i^2 - S_i)/S_i$.

3. Data

The empirical analysis is conducted using unbalanced panel data gathered from Ghanaian manufacturing firms. These data are drawn from the Regional Programs for

Enterprise Development (RPED) data set provided by the Centre of Studies of African Economies (CSAE) at the University of Oxford. This dataset is assembled from seven annual surveys of Ghanaian manufacturing firms covering the period of 1991-1997. A total of 278 firms were sampled. The original sample of 200 firms, which were first surveyed in 1992, was drawn on a random basis from firms contained in the 1987 Census of Manufacturing Activities**.** Based on information gathered from these firms, a broadly representative panel data on the size distribution of firms across the major sectors of Ghana's manufacturing industry was constructed. The dataset provides a wide range of information that enables us to calculate the capital stock, value added, and employment of firms. Another clear advantage of our data is associated with attrition of the sample. If firms shut down over the study period for any reason, they were replaced with firms of the same size, sector, and location rendering the sample size of our data unchanged.

The annual surveys cover the four main manufacturing sectors, i.e., the largest in terms of manufacturing value added and employment. These sectors are food processing and bakery (food-bakery), textile and garments (textile-garment), wood products and furniture (wood-furniture), and metal products and machinery (metal-machinery). Firms in the sample are also classified by size (i.e., average number of employees) as micro (<5 employees), small (5-29 employees), medium (30-99 employees), and large (≥100 employees). In addition, our data includes information regarding major industrials towns of Ghana: Accra, Kumasi, Takoradi, and Cape Coast.

The annual surveys collected comprehensive information on each firm's ownership, production costs, profit, value added, investment, capital stock, wages, export level, and human capital used in production. In our data, a firm's output is given by the value of goods the firm produces. To make output comparable between years, a firm-specific price index (1991=100) is used to deflate output. The value added is calculated as difference between firm's output and raw material input and indirect costs, and it is also deflated in a firm-specific manner. Capital stock is defined as the capital (e.g., machines, tools, and other equipment) used by the firm to produce output, deflated and adjusted for depreciation and investment. The price of capital has been calculated as the ratio of pre-tax profits to the value of capital stocks where the pre-tax profit is calculated from the data on value-added and costs (Teal, 1997). Total employment includes the owner/manager, full-time workers, and part-time workers but excludes seasonal workers. Wages comprise of both basic wages and allowances, and they are deflated by the Consumer Price Index for Ghana. Each firm was interviewed for the firm-level information. In addition, up to ten workers of the firm, representative of the occupation categories in the firm, were interviewed in each year. Based on these interviews, our data reports the number of employees in each occupation category at the firm level. In the data, unskilled workers are defined as workers in occupational classifications of maintenance, production, masters and apprentices. On the other hand, skilled workers are classified as those working in occupations such as management, administration, sales and supervisors. Table 1 presents the descriptive statistics for the distribution of factors of production within firms in our sample. Table 1 suggests that these firms have 80 workers on average, where the relative average wage of skilled worker is twice as much as the relative wage of unskilled worker. On the other hand, Table 1 points out that these firms have three times more capital than labor.

Table 2 presents the descriptive statistics for the characteristics of firms. Table 2 shows that more than half of the firms in our sample are located in Accra, the capital city of Ghana. Moreover, 70 percent of the firms are owned by private enterprises, while only 21 percent of them are owned by foreigners and multinational companies. Table 2 also suggests that firms in our data are relatively medium and large sized with workers more than 30 per firm.

Table 3 shows the average skilled and unskilled wages in all sectors. According the theoretical model discussed in the previous section, one may expect the wage inequality between skilled and unskilled labor to be larger in traded sectors (Wood, 1994) and in sectors with higher capital-labor share.

4. Estimation Strategy and Empirical Results

The complete system of cost share equation provides seemingly unrelated regressions (SUR) and is estimated by using Zellner's SUR method in panel data. Each equation in the system is assumed to be stochastic and the stochastic terms are additive and joint normal distribution. To address the problem of singularity, we drop one equation as explained in the empirical model section. Hence, the SUR parameter estimates will not be invariant to the deleted equation, using the iterative Zellner efficient method (ISUR), we obtain the neutral parameter estimates.

In order to compute Allen-Uzawa partial elasticities of substitution, the cost function (1) and share equations (9) and (10) are estimated simultaneously by Zellner's seemingly unrelated regressions (SUR) method employed in panel data. 10 parameters are estimated directly using (1) and 5 parameters are calculated using equations (7) and

(8). Due to the structure of panel data, we also incorporate the sector-specific effects in our model. In particular, 4 sectors, 3 locations, union, export, 4 firm sizes, 6 years indicators are included in the estimation of total cost function. Since we use six years time span, it is plausible to assume that the technology parameters can be estimated under the Hicks-Neutrality assumption. [2]

Concavity requires that the own price elasticities for factors are negative. Indeed, Table 7 reveals that this condition holds in our estimation. On the other hand, for monotonicity, the cost function must be non-decreasing in input prices, which requires the fitted shares be positive at each observation. Table 5 presents that the fitted shares are positive at all pairs and highly correlated with actual shares. The parameter estimates for the model satisfy all regularity conditions.

Allen-Uzawa partial elasticities of substitution are in Table 6. The elasticity of substitution estimates summarized in Tables 6 suggest that skilled workers, capital and unskilled workers are substitutes for one another for each individual sector and at aggregate level. We also find evidence suggesting relatively high degree of substitution between unskilled and skilled labor in Ghanaian manufacturing sector. One of the underlying mechanisms behind our findings could be technical regress experienced in Ghana. Technical regress generates an increasing demand for unskilled labor that substitutes for the capital stock. Therefore, due to the technical regress, the elasticity of substitution between capital and skilled labor is smaller than that of capital and unskilled labor in aggregated level and wood-furniture industry.

[2] Hicks-Neutrality assumption suggests that technology advances that are caused by external factors do not change the relative price between factors.

Our findings provide weak evidence suggesting that the capital-skill complementarities holds in aggregated manufacturing industries and wood-furniture sector. On the other hand, we find opposite results of capital-skill complementarities for food-bakery, textile-garment and metal-machinery industries. There is no evidence for skilled-capital complementarity in these sectors. One possible interpretation of this result is the decline of the real capital stock due to the low rate of investment in these industries. As a consequence, a decline in the real capital stocks deteriorates the relative price of skilled labor in these industries.

Table 7 reports the own and price elasticities for four industries in our sample. As summarized in Table 7, the own price elasticity of skilled labor is the highest among the inputs for all industries, suggesting that demand for skilled labor is more sensitive to changes in its price compared to other factors of production. The cross-price elasticities are important to understand how demand for skilled labor responds to changes in the price of unskilled labor or capital. Table 7 shows that the cross price elasticities are positive and less than one between all inputs. This result suggests that all inputs used in production are substitutes for each other. However, one should be cautious since the cross price elasticity estimates do not differ significantly from zero.

5. Conclusion

In this paper, we analyze the estimation of cost function along with associated cost share equations to estimate factor substitution and skill-capital complementarity. We use annual firm-level data on the manufacturing sector in Ghana during the period of 1991-1997. The translog cost function is estimated following ITSUR framework with the assumption of a fixed sector-specific effect for aggregated manufacturing industries and each individual sector in Ghana.

The existence of capital-skill complementarity hypothesis is essential for developing countries for two reasons. First, if there is capital-skill complementarities, capital accumulation may explain a larger fraction of the increase in the demand for skilled labor in the country. Another reason is related to trade liberalization. Openness may stimulate investment in developing countries since an important portion of equipment used in production has to be imported rather than produced within the country with its own technology. If capital-skill complementary hypothesis holds, then trade may exacerbate the relative demand for skilled workers through this process.

We find weak evidence suggesting that capital-skill complementary holds for aggregated manufacturing industries in Ghana. The analysis of each individual sector reveals that the skill-capital complementarity exists only for wood-furniture sectors. Moreover, we find that all pairs of factors are substitute for one another in all four manufacturing industries in Ghana. However, the elasticity estimates do not ultimately support the hypothesis suggesting that skilled workers and capital are complements in production for all manufacturing sectors for Ghana.

Capital-skill complementarity is important to understand the underlying mechanisms behind the upsurge in the relative wages of skilled workers in the recent decades. Our findings shed light on some of the potential consequences of trade on capital-skill complementarity. However, we believe that more research has to be conducted to further comprehend the effects of capital accumulation and trade on capital-skill complementary with longer data set.

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Table 1. Summary Statistics

VARIABLES	N	MEAN	STD
Real Average Skill Wage	505	689,594	461,635
Real Average Unskilled Wage	505	331,763	190,161
Value Added	1171	133	619
Capital	1133	512	2,630
Output	1171	362	1,420
Employment	1170	71.90	145.20
Value Added/ Employment	1170	1.02	2.27
Capital/ Employment	1132	3.09	8.24

Notes: All monetary values are in million Ghanaian cedis, deflated to 1991 values; 1 million cedis (1991) approximately equals 2500 USD.

Table 2: Firm characteristics in Ghana

Export	
Food-bakery	3.37
Wood	7.87
Furniture	4.87
Textile-garment	3.37
Metal-machinery	3.00
Location	
Accra	58.43
Kumasi	31.09
Cape Cost	3.75
Takoradi	6.74
Ownership	
State	8.61
Private Ghanaian	70.04
Foreign	21.35
Size	
Micro	15.73
Small	28.46
Medium	32.21
Large	23.60

Notes: Number of firms are 267in total. All numbers are in percentages.

Table 3: Average wages

Industry	Average Skilled Wage	Average Unskilled Wage	Relative Wage
Food-Bakery	761,549	364,677	2.09
Wood-Furniture	639,642	309,028	2.07
Textile-Garment	521,257	254,814	2.05
Metal-Machinery	752,632	331,763	2.27

Notes: All monetary values are in million Ghanaian cedis, deflated to 1991 values; 1 million cedis (1991) approximately equals 2500 USD.

Table 4: Translog Cost function Estimation Manufacturing Industries 1991-1997

Parameters	Food-Bakery	Wood-Furniture	Textile-Garment	Metal-Machinery	Aggregated
α_o	-5.859	1.858	-13.289	2.867	-1.781
	(4.598)	(3.891)	(7.411)	(4.546)	(2.290)
α_s	0.109	0.157	0.765	0.442	0.244
	(0.125)	(0.087)	(0.224)	(0.109)	(0.058)
α_u	-0.108	0.238	0.631	-0.135	0.261
	(0.123)	(0.135)	(0.318)	(0.131)	(0.079)
α_Y	1.677	0.551	1.507	0.474	0.745
	(0.404)	(0.403)	(0.828)	(0.458)	(0.229)
γ_{ss}	-0.004	-0.006	-0.007	-0.006	-0.003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
γ_{su}	0.026	0.025	0.011	0.024	0.019
	(0.005)	(0.004)	(0.006)	(0.003)	(0.002)
γ_{uu}	-0.003	-0.006	-0.004	0.004	-0.006
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
γ_{yy}	-0.012	0.018	0.009	0.021	0.017
	(0.009)	(0.010)	(0.026)	(0.012)	(0.006)
γ_{sy}	-0.015	-0.017	-0.039	-0.029	-0.017
	(0.006)	(0.005)	(0.013)	(0.005)	(0.003)
γ_{uy}	-0.006	-0.011	-0.027	0.003	-0.012
	(0.006)	(0.007)	(0.018)	(0.006)	(0.004)
α_k	0.673	0.605	-0.395	0.693	0.495
	(0.193)	(0.152)	(0.340)	(0.160)	(0.096)
γ_{sk}	-0.022	-0.019	-0.004	-0.018	-0.016
	(0.005)	(0.002)	(0.006)	(0.003)	(0.002)
γ_{uk}	-0.023	-0.019	-0.007	-0.028	-0.013
	(0.005)	(0.004)	(0.006)	(0.004)	(0.002)
γ_{kk}	0.045	0.038	0.011	0.036	0.029
	(0.007)	(0.005)	(0.008)	(0.005)	(0.003)
γ_{ky}	0.021	0.028	0.066	0.026	0.029
	(0.008)	(0.007)	(0.021)	(0.007)	(0.005)

Notes: Numbers in parenthesis are standard error. Time, location, size, ownership structure, union and export dummies ar in all regressions

Table 5: Cost Shares

Industry	N	Actual Ss	Actual Su	Actual Sk	Fitted Ss	Fitted Su	Fitted Sk
Food-Bakery	114	0.131	0.133	0.736	0.138	0.125	0.737
Wood-Furniture	138	0.122	0.356	0.522	0.122	0.366	0.512
Textile-Garment	59	0.141	0.266	0.593	0.133	0.255	0.612
Metal-Machinery	144	0.171	0.231	0.598	0.160	0.235	0.605
Aggregated	454	0.139	0.235	0.627	0.138	0.234	0.627

Notes: Actual shares are calculated by using the data. Fitted shares are estimated.

Table 6: Allen-Uzawa Elasticity of Substitution

Industry	σ_{SK}		σ_{UK}		σ_{US}	
	Actual	Fitted	Actual	Fitted	Actual	Fitted
Food-Bakery	0.772	0.784	0.765	0.750	2.492	2.507
Wood-Furniture	0.702	0.696	0.898	0.899	1.576	1.560
Textile-Garment	0.952	0.951	0.956	0.955	1.293	1.324
Metal-Machinery	0.824	0.814	0.797	0.803	1.608	1.638
Aggregated	0.816	0.816	0.912	0.912	1.584	1.587

Table 7: Cross Price and Own Elasticities

Industry		Cross Price Elasticities			Own Elasticities		
	N	ε_{SK}	ε_{SU}	ε_{UK}	ε_{KK}	ε_{SS}	ε_{UU}
Food-Bakery	114	0.103	0.346	0.094	-0.202	-0.891	-0.899
Wood-Furniture	138	0.085	0.190	0.329	-0.414	-0.927	-0.650
Textile-Garment	59	0.126	0.176	0.244	-0.370	-0.920	-0.761
Metal-Machinery	144	0.130	0.262	0.189	-0.335	-0.878	-0.748
Aggregated	454	0.113	0.219	0.214	-0.326	-0.884	-0.791