JOURNAL OF ECONOMIC DEVELOPMENT
Volume 36, Number 1, March 2011

KOREAN AUGMENTED PRODUCTION FUNCTION: THE ROLE OF SERVICES AND OTHER FACTORS IN KOREA'S ECONOMIC GROWTH OF INDUSTRIES

ELIAS SANIDAS AND HYERI PARK*

Seoul National University

It is well known that economic growth and services have a positive association. In particular, the more developed an economy is, the higher the share of the services sector. While most research has focused on service output, this study also examines services as input. Recently, the need for taking services a separate input in the production function has come to the fore. Therefore, the OECD productivity manual generalizes the KLEM model to KLEMS (capital-labor-energy-materials-services) model by including the services as an input. We use KLEMS data in this study. In addition, we augmented the standard production function with other variables such as the inventory to sales ratio, R&D to sales ratio, education expenditure to sales ratio, and the debt to sales ratio. The findings are encouraging and lead us to formulate some important conclusions; for example, after the 1998 Financial Crisis, the Korean economy has increased in efficiency and this is partly due to an increased importance of services as both output and input.

Keywords: Services, Manufacturing, Production Function, Korean Industries, Financial Crisis, Panel Data
JEL classification: C2, L1, L2, L6, L8

* We thank Changmo Ahn and other participants of the 9th Korea and the World Economy Conference (Incheon, 2010) where an earlier version of this paper was presented for useful comments. We are also grateful to Otgonbat Ishdagva for thoroughly making and checking Tables of results. We are in particular grateful to two anonymous referees for their valuable comments and suggestions. This research was partly supported through the corresponding author's grant from SNU, Department of Economics, hence gratefully acknowledged.

1. INTRODUCTION

In this paper we estimate within a rigorous econometric framework production functions for Korean industries and for total, manufacturing and services sectors. This econometric framework addresses in particular the issue of endogeneity and hence uses methods that include instrumental variables (like GMM models); also for robustness we estimate alternative models such as fixed effects with instruments. Our estimated production functions include the following innovations. First, we include services as inputs and outputs. Second, we include some important non-accounting variables that might explain total factor productivity in a direct way: organizational and financial efficiency, technology as in R&D, and human capital. These innovations are important and to the best of our knowledge, they have not been used in production function estimation before, at least for Korea.

It is well known that economic growth and services have a positive association. Especially, the more developed an economy is, the higher the share of the services sector is as a percentage of GDP. This increasing share constitutes an important structural change in the economy and has drawn considerable academic interest (the term "structural change" was coined by Kuznets, 1957). Basically, there are two main views about this topic. First, Fisher (1935) and Clark (1940) explained that this structural shift is demand driven and it is caused by the difference between income elasticities of demand for goods and services. Summers (1985) and Baumol (1985) showed that income per capita and the share of the services sector might have a positive relationship on a nominal basis but not on a real basis (PPP). In contrast, Schettkat and Yocarini (2006) said that the share of services in final demand increases on a constant price basis as well as on a current price basis as per capita income increases. Second, Baumol (1967) and Fuchs (1968) suggested that this structural change is based on the supply side. According to "Baumol's disease hypothesis", resources are moved from the high efficient sector to the low efficient sector. Therefore, the economy shifts to the services economy as resources move from manufacturing (high productivity) to the services sector (low productivity).

In addition, there is empirical research which examines the increasing part of services as % of GDP (the 'structural change'). Kuznets (1966, 1971) and Marshall and Wood (1995) empirically verified this structural change in advanced economies. Francois and Reinert (1996), Kongsamut *et al*. (1997) found that the share of services rises with the level of development in a cross-country study. There is a positive relationship between the level of per capita income and the intensity of use of services in the manufacturing sector. Guerrieri and Meliciani (2003) recognized that services procured by services provider companies are becoming important to manufacturing. The close relationship between manufacturing and services and a diversified production process raise the content of services inputs for manufactured goods. This is also confirmed if we observe, as Rask and Rask (1994) correctly emphasized, that services and in particular some of its categories such as financial and telecommunications services are important even in the initial stages of economic development; it is then that these services are mostly needed in manufacturing.

Although most research has focused on services output, the present study centers on services as an input by estimating a production function. The most commonly used production functions for dealing with issues of growth and productivity are Cobb-Douglas, constant elasticity of substitution (CES), and translogarithmic standard production functions which employ capital and labor as factor inputs. Sometimes, capital and labor are supplemented by land, materials or energy. In addition, empirical studies on production functions or productivity were performed mostly with a two-input framework prior to the 1980s. In this case, we cannot explicitly identify the role of services in the production process and economic growth. Studies undertaken in the 1980s and later, used the KLEM (capital-labor-energy-materials) production function framework in which the role of materials and energy could be additionally recognized, but the role of services still was not explicitly specified.

Recently, the need for considering services as a separate input in the production function has come to the fore. Therefore, the OECD productivity manual (OECD, 2001) generalizes the KLEM model to KLEMS (capital-labor-energy-materials-services) model by including a services input. Thus, the EU constructed the EUKLEMS database. Banga and Goldar (2004) analyze the contribution of services to output growth and productivity in Indian manufacturing using the KLEMS framework with data for 148 industries and for 18 years. Their analysis reveals that increased use of services had a positive effect on output growth in Indian manufacturing during the 1990s. Moreover, he constructed a multilateral total factor productivity index (MTFP) to study the impact of services inputs on manufacturing productivity. He found that the productivity growth estimated for the post-reforms period is over-stated when services are not considered.

There is some research on estimating the production function for Korean industries. Kim and Koo (1999) estimated an aggregate production function of manufacturing industries using panel data for 11 Korean regions covering the period of 1977-1992. This study investigated the relationship between infrastructure and technical efficiency. Kim *et al*. (2001) estimated a generalized production function. Using 330 companies' data of 9 manufacturing industries, they calculated the elasticity for each input factor and the TFP growth rate by industry. They also estimated the effect of various factors such as size of firms, returns to scale, and market share on TFP growth. Shin (2005) investigated the shape of the aggregate production function of Korea using the constant elasticity of substitution (CES) production function over the 1970-2004 time period. Chung *et al*. (2006) estimated a knowledge production function for 15 South Korean industry sectors using panel data of patents and research workers over a 21-year period between 1982 and 2002. Park and Ryu (2006) identified the returns to scale in the aggregate production functions of four East Asian countries (Korea, Hong Kong, Singapore, and Taiwan) based on maximum likelihood estimation.

Another issue in estimating a production function is the existence of unexplained part (residual). It is usually called the Solow residual or total factor productivity (TFP).

Total factor productivity includes technological (technical) knowledge (TK), organizational efficiency (OE)[1] and other factors (see below). Although many scholars have emphasized the importance of technological knowledge and some of organizational efficiency, there has been limited research about organizational efficiency in Korea. Therefore, this study will extend the research boundary to organizational efficiency included in production function. Sanidas (2005) conducted research about organizational efficiency for the USA and Japan cases. According to his research the inventory to sales ratio was used as a well justified proxy for just-in-time (JIT) which is a good representative of organizational efficiency.

This proxy has been used by many other researchers such as Nakamura and Nakamura (1989), Lieberman and Demeester (1999), Irvine (2003), Swamidass (2007), Dalton (2009), and so on. The basis for using this proxy is simple: when more sophisticated organizational process innovations, such as the lean production system and JIT, practices take place, there is a general reduction in waste by decreasing inventories, increasing quality and decreasing costs (see Sanidas, 2005; Callen *et al*., 2005; Chen *et al*., 2005; Capkun *et al*., 2009; and so on). More recently, Lim and Sanidas (2010) have provided similar but more rigorous evidence on the role of organizational efficiency in Korea on a firm or sectoral basis. They provided evidence that this OE has been taking place in Korea since the end of the 1980s and more intensively after the Financial Crisis of 1997/98. In particular, for the connection between JIT and the services sector, see Yoo (2001).

A recent[2] example of an augmented production function is that by Cainelli (2008). This author analyzes the impact of innovative activities and agglomeration effects on firm's productivity. He estimated an augmented Cobb-Douglas function to account for the impact of technological innovation and district-specific agglomeration effects on a firm's productivity growth. His empirical results show that belonging to an industrial district and making product innovations are key factors in the productivity growth of firms. Lopez (2009) examined the relationship between organizational efficiency (in particular, outsourcing) and productivity using an unbalanced panel of Spanish manufacturing firms. By developing and estimating a theoretical framework, he justified the addition of outsourcing measures to the specification of a "standard" production function. He found that outsourcing intensity has a positive effect on productivity, mainly for firms belonging to light manufacturing industries. Note that this outsourcing intensity is well linked with OE and JIT.

This study aims at indentifying the role of services in Korea's economic growth and the contribution of services to each sector using the KLEMS production function framework which includes capital, labor, intermediate inputs (energy, materials, and

[1] There is a substantial literature in OE; Sanidas (2005) and Lim and Sanidas (2010) are some of the most recent relevant references.

[2] An example of an extended production function for Korea can be found in Lee *et al*. (1994).

services) and other control variables such as organizational efficiency and technological knowledge. Thus, we can examine the role of services inputs separately. First, we look into the role of services inputs on Korean economic growth over time (1970-2005). Second, we examine how differently services input affects each sector (manufacturing and services) before and after the financial crisis. Third, although we do not directly use TFP as a dependent variable, we explain the Solow residual of TFP part by estimating the newly established KLEMS production data in which we also consider other variables in order to include the effect of restructuring efficiency of firms (the proxy used is the inventories to sales ratio), technological knowledge (the proxy used is R&D to sales ratio), human capital (the proxy used is education expenditure to sales ratio) and financial strength or conditions (the proxy used is the debt to sales ratio). We compare results between the models which include these factors and the models which do not. This analysis is valuable because the extra four factors we include in our models and input services were introduced, developed, or promoted remarkably during the 1980s and 1990s in Korea.

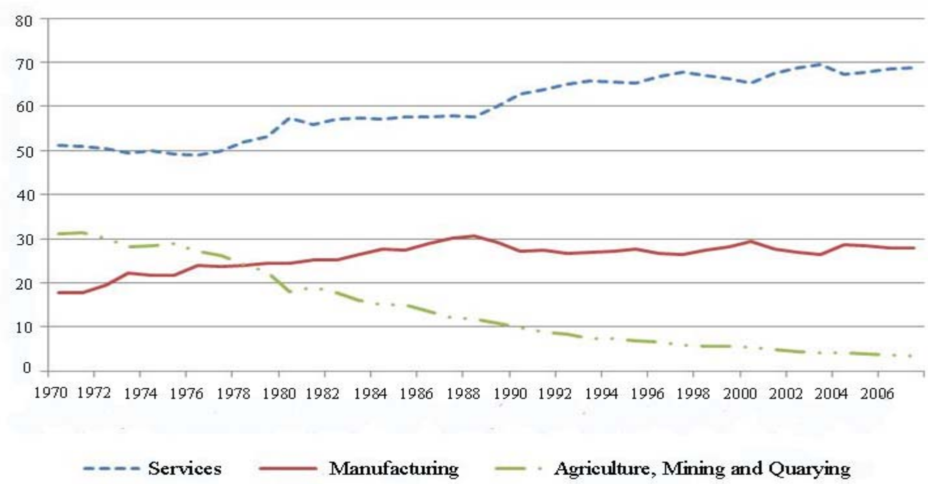
In Section 2 we briefly describe the role of services in Korea; in Section 3 we describe data and present our empirical findings; finally, in Section 4 we conclude with discussion and implications.

2. SERVICES IN KOREAN ECONOMY

2.1. The Role of Services as an Output in Korean Economy

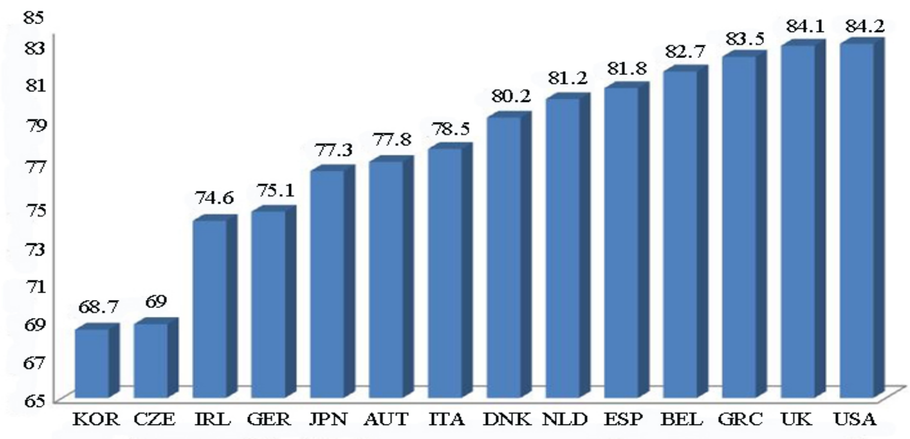
The share of services output as a percentage of GDP has steadily increased and it reached 68.7% in 2007. On the contrary, the share of agriculture, mining and quarrying outputs has decreased since the 1970s and recorded 3.3% in 2007, down from 31% in 1970 as Figure 1 shows. By the end of 1980s, shares of both manufacturing and services have increased. However, the share of services output has shown upward tendency and that of manufacturing has shown a steady tendency since the early 1990s. On the contrary, the sector of agriculture and mining has been continually decreasing.

Korea’s services share of 68.7% in 2007 is the lowest among OECD countries. According to Figure 2, the USA and UK have a very high services share of 84.2% and 84.1%, respectively. As already indicated, although Korea’s services industry has grown significantly, it still is the lowest percentage compared to other advanced countries as seen in Figure 2.



Source: EUKLEMS database (2009).

Figure 1. The Share of Services Output in Korean Economy's Nominal GDP (Unit: %)

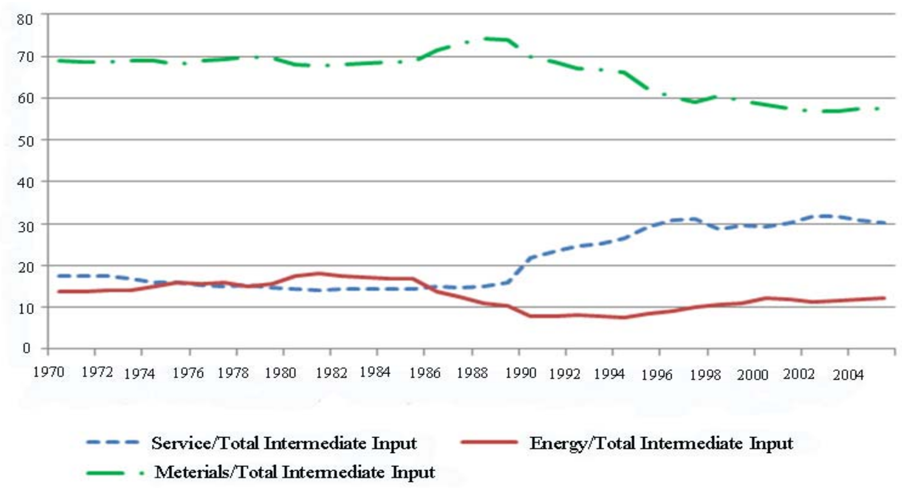


Source: EUKLEMS database (2009).

Figure 2. Share of Service Output in Nominal GDP (OECD Countries, 2007) (Unit: %)

2.2. The Role of Services as an Input in Korean Economy

Services play an important role not only as an output but also as an intermediate input. Further, its importance as an intermediate input, which also includes producer services (mainly sectors 19 and 20 in the Appendix) has increased recently. Figure 3 shows the share of each input[3] (services, energy, materials) out of total intermediate inputs in Korean economy. The share of the services input has increased drastically since the late 1980s when the share of services output started to increase. In other words, the increase of the services input is accompanied by the increase in services output. While the share of materials has decreased sharply since the end of the 1980s, the share of services inputs has increased remarkably since that time. The share of energy has decreased since the mid 1980s, but it has increased again since the mid 1990s. Therefore, it seems that the services input replaced materials. Of course, this might have happened only in some industries.



Note: Total intermediate inputs include materials, energy and services.
Source: EUKLEMS database (2008).

Figure 3. The Share of Services Inputs in Total Intermediate Inputs for All Industries (Unit: %)

As the competition among firms is deepened, the demand for professional services has increased to improve product competitiveness. Production supporting services, which were procured within the companies in the past, depend on outsourcing more recently due to increased trends in information, knowledge and specialization (Guerrieri and Meliciani, 2003). More precisely, the proportion of financial services and business

[3] Intermediate inputs are decomposed into energy, materials, and services inputs; we have identified coal and lignite, crude petroleum and natural gas, uranium and thorium ores, metal ores, coke, refined petroleum products and nuclear fuel, gas, water, and electricity commodities as energy inputs; both some primary commodities and manufacturing intermediate commodities as material inputs, and all remaining inputs are service inputs.

services has increased while that of wholesale and retail trade, accommodation, and restaurant and personal services has decreased (Kim *et al*., 2006). Financial services and business services (they correspond mainly to sectors 19 and 20 of KLEMS classification, see Appendix) are typical producer services which are usually used as an input. Therefore, this reflects that the importance of producer services as an input has been used more and more, in modern business. Note that when we refer to services inputs we mean all services inputs. This is because the data and our regressions do not differentiate between different types of services inputs.

Table 1. Contributions to Output Growth (Total Industry, Manufacturing, Services) (Unit: %)

Period	Output Growth (1)	Intermediate input (2)	Materials (3)	Energy (4)	**Services (5)**	Labor (6)	Capital (7)	TFP (8)
Total								
1971-1980	8.06	4.48	2.80	1.02	0.67 **(8.27)**	2.12	1.58	-0.13
1981-1990	10.69	6.26	4.31	0.66	1.29 **(12.09)**	1.58	1.04	1.81
1991-2000 (exl.1998)	8.31	4.73	2.38	0.75	1.60 **(19.23)**	1.11	0.93	1.55
2001-2005	4.66	3.12	1.73	0.36	1.02 **(21.99)**	0.69	0.44	0.41
Manufacturing								
1971-1980	8.74	6.56	4.50	1.59	0.46 **(5.32)**	0.34	0.88	0.96
1981-1990	12.69	9.63	7.45	1.14	1.03 **(8.12)**	0.79	0.80	1.47
1991-2000 (exl.1998)	8.66	6.44	4.06	1.24	1.15 **(13.22)**	0.15	0.63	1.44
2001-2005	5.15	4.18	2.94	0.42	0.82 **(16.02)**	0.07	0.34	0.56
Services								
1971-1980	8.40	3.11	1.60	0.60	0.91 **(10.81)**	3.75	2.23	-0.69
1981-1990	9.79	4.05	2.05	0.39	1.61 **(16.42)**	2.48	1.31	1.95
1991-2000 (exl.1998)	8.92	4.12	1.34	0.50	2.27 **(25.47)**	2.21	1.33	1.26
2001-2005	4.65	2.39	0.85	0.31	1.23 **(26.47)**	1.45	0.61	0.20

Notes: i) (2) is equal to (3)+(4)+(5). ii) (1) is equal to (2)+(6)+(7)+(8). iii) Numbers in parentheses are the respective contributions to gross output growth.

Source: Authors' calculation based on EUKLEMS data.

In Table 1, we can see the detailed movement of the contribution of each input to output growth over time (1970-2005). Also, the different role of services inputs for total industry, manufacturing and services is specified. In terms of proportion to total output growth, the contribution of the services input took up 8.27% in the 1970s and increased up to 21.99% in the 2000s. The contribution of the services input to services outputs was 10.8% in the 1970s and it increased up to 26.4% in the early 2000s while that of the services input to manufacturing sector recorded 5.32% in the 1970s and 16% in the 2000s. From this analysis, we deduct that the contribution of services inputs to services outputs is much bigger than that of services inputs to manufacturing. It shows that the role of a services input is becoming more important as Korea economy develops.

3. EMPIRICAL ANALYSIS

3.1. Data and Methodology

This empirical study uses the KLEMS Database[4] which has separate services input data. Moreover, it has long and continuous time series whereas the Bank of Korea's Input-Output Table is constructed every 5 years. Industry classification of KLEMS is based on NACE[5] which is compatible with ISIC[6]. Thus, we can easily match the KLEMS database with other international and Korean industrial data. This study also uses KISS VALUE (firm level data) which covers the period from 1980 to 2009 while the KLEMS Database (industry level data) covers the period from 1970 to 2005 (last year of availability, especially for the capital stock K). (See Table 2 for a summary of data sources). Variables that are related to organizational efficiency (inventories), technological knowledge (R&D), human capital (education and training expenditure), and financial conditions (debt) and sales are collected from the KISS VALUE database. Since the industry classification of KISS VALUE follows KSIC, we match all data to the KLEMS industry classification. Our analysis is conducted over 26 years (1980-2005) and 22[7] industries (see Appendix).

[4] KLEMS (or EUKLEMS since it has originated in the EU) is a well established database for the capital, labor, energy, materials and services (KLEMS) framework while the Input-Output table of the Bank of Korea does not classify intermediate goods into separate inputs (energy, materials, and services). However, within KLEMS there is no available data on a firm basis.

[5] NACE (nomenclature statistique des activités économiques dans la Communauté Européenne) is a European industry standard classification system consisting of a 6 digit code.

[6] ISIC (International Standard Industrial Classification) is a United Nations system for classifying economic data.

[7] Initially the KLEMS data contain 72 industries, but we reduce them to 24 according to KLEMS' correspondence between the 72-industry classification and the 24-industry classification. This re-classification is

Table 2. Data Coverage and Sources

Data	KLEMS (used only for *Y*, *K*, *L*, *E*, *M*, and *S*)	KISS VALUE (used only for independent variables)
Code	NACE	KSIC
Unit of Analysis	Industry	Company
Period Coverage	1970-2005	1980-2005
Industry Classification	Total: 24 industries Agriculture: 2 industries Manufacturing: 11 industries Services: 11 industries	Total: 22 industries (2 service sectors missing for some variables) Agriculture: 2 industries Manufacturing: 11 industries Services: 9 industries

Note: KISS Value data are re-classified according to the industrial classification of KLEMS, because KISS Value data are only recorded according to firms, hence the 22 industries were calculated by authors.

The econometric analysis of this study is based on the augmented Cobb-Douglas (Cainelli, 2008) function which includes organizational efficiency, technological knowledge and other factors. The inventories to sales ratio is used as a proxy for organizational efficiency. The R&D to sales ratio has been also been extensively used as a proxy for technological knowledge and innovations. Other control variables are the education expenditure to sales ratio and the debt to sales ratio. The general production function model used here is:

Y=F (*K*, *L*, *E*, *M*, *S*, *Organizational Efficiency*, *Technological Knowledge*, *edu*, *debt*, *unexplained*), (1)

where *Y*: gross output; *K*: capital stock; *L*: number of employees, or number of hours worked[8]; *E*: intermediate energy input; *M*: intermediate material input; *S*: intermediate services input; *Organizational Efficiency*: inventories to sales ratio; *Technological Knowledge*: R&D to sales ratio; *edu*: education expenditure to sales ratio; and *debt*: debt to sales ratio. All variables are in levels and in terms of logs and added up in a linear way, hence effectively we use the Cobb-Douglas function: this is the usual customary way of including variables in a production function[9].

This study uses the panel-data econometric models. First, fixed effects (FE) or random effects (RE) with or without instrumental variables (IV), then system GMM regressions are used. In subsequent sections and paragraphs more will be said for each

available on request.

[8] Hours worked is also included as an independent variable instead of number of employees. We obtained similar results (available on request).

[9] However, with system GMM modeling further below, we also use first differences in variables.

one of them in passing, but here we would like to emphasize that overall we could attach a hierarchy of ‘trust’ in these models. Thus, the FE (or RE) without IV are the lowest in the hierarchy, then up the ladder we put FE (or RE) with IV; and finally on top this ladder we can place the GMM models. The main reasons for this hierarchy are the presence or non-presence of endogeneity, the structure of lags and variables in levels or first differences. Only GMM has all three components in a comprehensive way. Nonetheless, for robustness, we present both FE with IV and GMM models in our analysis (and for further comparison sometimes we also show FE or RE without IV).

3.2. Regression Results

Tables 3, 4, and 5 summarize our results (for which the printouts and the relevant data base are available on request). The estimation results of our production functions for all industries and for the whole period (1980 to 2005), and only for FE or RE are shown in Table 3. Initially we estimated both FE and RE models but we only report the FE results in this paper (except once in Table 3 and once in Table 5) since both types of models sometimes yield overall similar results or the Hausman test indicated that FE models should be used as expected in these cases; or the RE model models yield wrong signs of coefficients. Furthermore note that we estimated the FE models without or with instrumental variables (this is possible with STATA); instrumental variables (or instruments) can often yield statistically better estimates (other researchers have used instrumental variables to account for endogeneity in their panel data regressions, see for example Basu *et al*., 2006). In Tables 3 and 4 we include mainly the FE models with instruments. The inclusion of the latter in FE estimation addresses the endogeneity issue for some variables (called instruments); this issue is more thoroughly addressed with GMM which offers more possibilities and options than the FE model does; GMM will be presented further below (for a good summary of these models as used in STATA see Cameron and Trivedi (2009); for a thorough treatment of them see Wooldridge, 2002).

There are three FE models presented in Table 3. Model 1 (columns 1, 2, 3, and 4 in Table 3) is the standard production model which has only accounting variables. Model 2 (columns 5, 6, and 7) is the augmented production function in which we are particularly interested. This model shows us the effect of the extra variables (organizational efficiency, technological knowledge, education expenditure ratio, debt ratio). To examine the results by industry, we use model 3 (columns 8 and 9).

Table 3. Fixed Effects (FE) Model with IV, Except as Indicated, for Whole Period (1980-2005)

	Type of Functions	Non-Augmented Production Function				Augmented Production Function				
	Type of Industries	All indus/s	All indus/s	Manuf/g	Services	All indus/s	Manuf/g	Services	All indus/s	All indus/s
	Dependent variable: ln*Y*	(1) FE	(2) FE.IV	(3) FE.IV	(4) FE.IV	(5) FE.IV	(6) FE.IV	(7) FE.IV	(8) FE.IV	(9) RE
	Variable: ln*E*	0.130***	0.146***	0.166***	0.226***	0.129***	0.180***	0.156*	**0.131*** **	**0.129*** **
	ln*M*	0.290***	0.259***	0.609***	0.206***	0.548***	0.534***	0.352***	**0.574*** **	**0.497*** **
	ln*S*	0.299***	0.294***	0.127***	0.216***	0.148***	0.147***	0.178***	**0.115** **	**0.206*** **
	ln*L*	0.123***	0.133***	0.135***	0.162***	0.144***	0.146***	0.121***	**0.152*** **	**0.138*** **
	ln*K*	0.139***	0.151***	0.043**	0.266***	0.072***	0.045*	0.234***	**0.072** **	**0.073*** **
	Economies of Scale	0.981	0.983	1.080	1.076	1.041	1.052	1.041	1.044	1.043
	L. ln*inventory*					-0.043***	-0.033*	0.004	**-0.061** **	**-0.001**
	ln*rd*					0.035**	0.018	0.037*	**0.057* **	**-0.006**
	ln*edu*					0.023***	0.026**	0.074***	**0.024*** **	**0.018*** **
	ln*debt*					-0.051***	-0.060**	-0.141***	**-0.068*** **	**-0.019** **
	constant	3.142***	3.230***	1.374***	1.938***	2.419***	2.118***	2.762***	**3.078*** **	**2.775*** **
Agri, fish &mining	Agriculture, hunting									
	Mining & quarrying								**0.509*** **	**0.338*** **
Manufac-tring	Food , beverages, tob								**-0.785*** **	**-0.562*** **
	Textiles, textile, leather & footwear								**-0.894*** **	**-0.813*** **
	Wood & cork								**-0.695*** **	**-0.635*** **
	Pulp, paper, paper, printing & publishing								**-0.799*** **	**-0.626*** **
	Chemical, rubber, plastics & fuel								**-0.835*** **	**-0.555*** **
	Other non-metallic								**-0.786*** **	**-0.652*** **
	Basic & fabric/metal								**-0.939*** **	**-0.638*** **
	Machinery, nec								**-0.859*** **	**-0.614*** **
	Electrical & opt/ equip								**-0.993*** **	**-0.597*** **
	Transport equipment								**-0.949*** **	**-0.557*** **

	Manuf/nec; recycling								**-0.753*** **	**-0.659*** **
Services	Elect, gas & water								**-0.178** **	**-0.090* **
	Construction								**-0.564*** **	**-0.487*** **
	Whole & retail trade								**-0.189** **	**-0.268*** **
	Hotels & restaurants								**-0.441*** **	**-0.664*** **
	Transport & storage & communication								**-0.625*** **	**-0.399*** **
	Financial intermed								**1.386*** **	**0.943*** **
	Real estate, renting & business activities								**-0.286*** **	**-0.157*** **
	Education								**-0.035**	**0.329*** **
	Other comm/services								**-0.452*** **	**-0.315*** **
Number of observations		572	550	275	225	452	267	163	**452**	**456**
Number of industries		22	22	11	9	22	11	9	**22**	**22**
R^2	Within	0.9650	0.9616	0.9969	0.9393	0.9756	0.9931	0.9597	**0.9877**	**0.9839**
	between	0.9180	0.9229	0.9943	0.7517	0.7596	0.9958	0.2033		**1.0000**
	Overall	0.9350	0.9362	0.9946	0.8283	0.8979	0.9943	0.8537		**0.9943**
legend: * p<0.1; ** p<0.05; *** p<0.01										

Notes: i) Ln stands for logarithm; *Y* for output, *E* for energy input, *M* for material input, *S* for services input, *L* for number of employees, *K* for capital stock, *inventory* for inventories to sales ratio, *rd* for R&D to sales ratio, *edu* for education expenditure to sales ratio, *debt* for debt to sales ratio. ii) For (2): Instrumented: ln*M* ln*S* ln*L* ln*K* ln*E*, **Instruments**: ln*LH* L.ln*E* L.ln*M* L.ln*S* L.ln*K*; For (3): Instr/ed: ln*M* ln*S* ln*L* ln*K* ln*E*, **Instruments**: ln*LH* hempe L.ln*E* L.ln*M* L.ln*S* L.ln*K* L.ln*L*; For (4): Instr/ed: ln*M* ln*S* ln*L* ln*K* ln*E*, **Instruments**: ln*LH* hempe L.ln*E* L.ln*M* L.ln*S* L.ln*K* L.ln*L*; For (5): Instr/ed: L.ln*inventory* ln*rd*, **Instruments**: ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* ln*debt* L.ln*L* L.ln*K* hempe L.ln*rd* L.ln*E* L.ln*S* L.ln*M* trd; For (6): Instr/ed: L.ln*inventory* ln*rd* ln*debt*; **Instruments**: ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* salse empe hempe trd L.ln*LH* L.ln*S* L.ln*E* L.ln*M* L.ln*rd* L.ln*K*; For (7): Instr/ed: ln*E* ln*debt*, **Instruments**: ln*M* ln*S* ln*L* ln*K* ln*education* L.ln*inventory* ln*rd* L.ln*K* empe L.ln*debt*; For (8): Instr/ed: L.ln*inventory* ln*rd*; **Instruments**: ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* ln*debt* indus_2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24 L.ln*LH* L.ln*K* hempe L.ln*rd* L.ln*S* L.ln*E*. iii) Hempe stands for total hours worked, empe for number of employees, trd for total R&D expenditure, indus (e.g., indus_2) for industry (e.g. industry no.2). iv) The *L* in front of a variable (e.g., L.ln*K*) means lag of 1 year for the variable ln*K*. v) The IV next to FE (as in FE.IV) stands for instrumental variables.

From the results shown in Table 3 we can draw several conclusions. First, we can indicate the negative coefficients for the inventory ratio and the debt ratio as expected (see Section 1). This means that, the lower inventory ratio (organizational or production efficiency proxy) and debt ratio (financial efficiency or strength proxy) an industry has, the more output it can achieve. A decreasing (as picked up by the negative coefficient) and low debt ratio indicates financial strength (Groppelli and Nikbakht, 2000). The other two extra factors, R&D ratio (technological knowledge) and education expenditure ratio have positive effects on outputs as expected. This is also verified with the GMM models as shown further below. Second, we observe that the coefficient of services input in Model 2 are smaller than that of services input in Model 1 (in the case of all industries sample). This brings out the possibility that the effect of services inputs is over-estimated with the standard production function; thus, the effect of services inputs decreases if we add these new variables. However, this conclusion is not so clearly confirmed with the GMM models as shown further below. In addition, this does not hold in the case of manufacturing although it still holds for the services sector[10].

Third, compared to the constant of Model 1 (non-augmented version), the constant of Model 2 (augmented version) is smaller; therefore, a part of unexplained residual in estimated Equation (1) might be identified by introducing the extra factors. This conclusion is also verified subsequently with other models such as GMM (see below). However, this conclusion does not hold when looking at the manufacturing and services sectors separately. Fourth, Table 3 also shows the individual industry effect (FE and RE are shown). Generally, the services industries have larger constants; this means that the effect of other factors (not explicitly added here) are crucial in services industries. Especially, it shows that the financial intermediation and education services are more affected by other factors not included here.

Fifth, when comparing the manufacturing and services sectors, for both augmented and non-augmented cases, the coefficients differ as follows: for services, the coefficients of inputs of services and capital are larger than those in manufacturing; the contrary holds for the coefficients of material and labor (although for the latter the situation is not very clear in the non-augmented model). We tend to accept these results as truly reflecting the two sectors (for instance, services are more services input oriented and so on). Also, the inventory ratio has a negative coefficient in manufacturing while it is not significant in services. This is reasonable because the services sector lags behind manufacturing in terms of organizational efficiency. On the other hand, the debt ratio

[10] The all-industries sample (22) includes Agriculture and Mining (number 1 and 2 in the list, see Appendix), whereas manufacturing excludes these two industries. Hence, at times it might not be possible to directly relate the three samples we use here (all industries, manufacturing, and services) in terms of coefficients. When we excluded these two primary industries from regressions, the results in terms of economies of scale for all industries were more in agreement with manufacturing and services (in a relative sense).

has a negative effect on outputs for both manufacturing and services sector. However, this ratio has probably less effect on manufacturing than that on services. R&D (technological knowledge) and education expenditure have consistently positive coefficients in all cases but they seem to be larger in services than manufacturing, probably because the services sector is "younger" than the manufacturing sector and hence R&D and education ratios are more crucial to this sector[11] (services). Lastly, the constant tends to be larger in the services than in the manufacturing regression. This means that the services sector is influenced by some other factors which are not specified yet in any study.

We now confirm the FE estimation result by using the system GMM approach, which takes into account the endogeneity problem of some or all variables. It also contains variables in both levels and first differences (hence the name of "system"), thus taking into account any inadequacies that variables only in levels might present (system GMM is often considered more adequate than simple first difference GMM as various researchers have suggested). In Table 4, GMM Model 1 shows the standard production function and GMM Model 3 shows the augmented production function for all industries and all years. Comparing Models 1 and 3, we can see that the differences are not substantial for the accounting variables. For Model 3 the inventories ratio and debt ratio have negative coefficients whereas the education expenditure ratio and R&D ratio have positive coefficients and they all are statistically significant, thus confirming the results of Table 3 for the FE estimations. In addition, the coefficients of the accounting variables material, etc, tend to agree with those of the results in Table 3 (with some small differences); whereas the coefficients of the extra variables (e.g., the inventory to sales ratio) are somehow smaller in GMM than in FE regressions but of the same sign in general (this might be due to the lag structures in GMM and that both levels and first differences are used in system GMM). In this Table 4 we also included versions of GMM which have labor in terms of hours worked (LH) (see columns 2 and 4) instead of number of employees (L) (see columns 1 and 3); the results are similar[12].

Table 4. GMM Estimation Results (All Industries) for Whole Period (1980-2005)

Type of Industries	All Industries				Manufacturing		Services
Type of Models	Non-Augmented		Augmented		Non-Aug	Augmented	Non-Aug
Dependent var: ln*Y*	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable: ln*E*	0.105***	0.147***	0.112***	0.113***	0.127***	0.161***	0.089**
ln*M*	0.290***	0.315***	0.355***	0.362***	0.532***	0.543***	0.322***

[11] However some readers might disagree with this conclusion, since it is known that manufacturing is in general R&D oriented; more research is needed in this respect.

[12] This similarity was observed in all models we estimated.

ln*S*	0.254***	0.298***	0.253***	0.255***	0.198***	0.194***	0.284***
ln*L* or ln*LH*	0.189***	0.166***	0.140***	0.154***	0.194***	0.113***	0.106
ln*K*	0.184***	0.064	0.158***	0.136***	0.024***	-0.032	0.197***
Economies of Scale	1.022	0.990	1.018	1.020	1.075	0.979	0.998
L.ln*inventory*			-0.011*	-0.019***		-0.061**	
ln*rd*			0.006*	0.012**		0.031	
ln*education*			0.013***	0.024***		0.039	
ln*debt*			-0.020***	-0.039*		-0.057*	
constant	2.984***	3.283***	2.644***	2.644***	2.113***	3.007***	2.482
Number of obs.	572	572	456	456	281	268	178
Number of industries	22	22	22	22	11	11	9
Arellano-Bond test for AR(2) in first differences	0.053	0.068	0.370	0.475	0.083	0.727	0.298
Hansen test of overid. restrictions	0.435	0.075	0.742	0.749	0.481	1.000	0.998

Notes: i) Ln stands for logarithm; *Y* for output, *E* for energy input, *M* for material input, *S* for services input, *L* for number of employees, *K* for capital stock, *inventory* for inventories to sales ratio, *rd* for R&D to sales ratio, *edu* for education expenditure to sales ratio, *debt* for debt to sales ratio. ii) *L* indicates labors employed and is used for (1), (3), (5), (6), (7). iii) *LH* indicates hours worked and is used for (2), (4). iv) For (1): **Instruments** for orthogonal deviations equation (i) Standard: FOD.(ln*E* ln*M* ln*S* ln*L* ln*K*), Instruments for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*L* ln*K*, GMM-type, DL(1 to 3).(ln*Y* L.ln*M* L.ln*S* L.ln*L* L.ln*K* ln*E*); For (2): **Instr/s** for orthogonal deviations equation (i) Standard: FOD.(ln*E* ln*M* ln*S* ln*LH*), DL(2 to 3).(ln*Y* ln*M* ln*S* ln*LH* ln*K*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*LH*, GMM-type; For (3): **Instr/s** for orthogonal deviations equation (i) Standard: FOD.(ln*E* ln*M* ln*S* ln*K* ln*rd* ln*education* ln*debt*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*K* ln*rd* ln*education* ln*debt*, GMM-type, DL(2 to 3).(ln*Y* L.ln*E* L.ln*M* L.ln*S* ln*L* L.ln*K* L.ln*inventory* ln*debt* ln*rd* ln*education*); For (4): **Instr/s** for orthogonal deviations equation (i) Standard FOD.(ln*E* ln*M* ln*S* ln*rd* ln*education*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd* ln*education*, GMM-type; For (5): **Instr/s** for orthogonal deviations equation (i) Standard FOD.(ln*E* ln*M* ln*S* ln*rd*), L2.(ln*Y* ln*E* ln*M* ln*S* ln*L* ln*K*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd*, GMM-type; For (6): **Instr/s** for orthogonal deviations equation (i) Standard FOD.(ln*E* ln*M* ln*S* ln*rd* ln*debt*), GMM-type, L2.(ln*Y* ln*E* ln*M* ln*S* ln*L* ln*K* L.ln*inventory* ln*rd* ln*education* ln*debt*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd* ln*debt*; For (7): **Instr/s** for orthogonal deviations equation (i) Standard FOD.(ln*E* ln*M* ln*S* ln*rd*), L2.(ln*Y* ln*E* ln*M* ln*S* ln*L* ln*K*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd*, GMM-type, DL.(ln*Y* ln*E* ln*M* ln*S* ln*L* ln*K*), GMM-type. v) Hempe stands for total hours worked, trd for total R&D expenditure. vi) The *L* in front of a variable (e.g., L.ln*K*) means lag of 1 year for the variable ln*K*. vii) The IV next to FE (as in FE.IV) stands for instrumental variables. viii) In the cases where the Hansen test is close to unity, it is because of too many instruments in relation to the number of observations.

Table 5 compares results between before and after the 1998 Financial Crisis (FC). The data are truncated in 1998, thus in effect examining the pre-FC period (1980 to 1997) and the post-FC period (1999 to 2005, hence excluding the year 1998). Note that for the regressions after the FC the data are very limited (for example, for the services sector the number of observations is 52) and hence these regressions are not reliable. Consequently, the comparison between the two periods is indirectly made since not enough data are available for a direct estimation of both FE and GMM models for the after-FC period (this is particularly true for the augmented versions of the production function). Thus, by considering the pre-FC period regression and the whole period regression, inferences can be made indirectly about the post-FC period regression (this was to some extent verified in some regressions directly estimating the post-FC period).

Table 5. Results for Before and After the 1998 Financial Crisis (FC)

Period		Whole period		Before the 1998 F.C			After the 1998 F.C	
Dependent var: ln*Y*		(1) FE.IV	(2) GMM	(3) FE.IV	(4) GMM	(5) GMM	(6) FE	(7) GMM
All Iindu-stries	Variable: ln*E*	0.129***	0.112***	0.155***	0.099***	0.122***	0.089	
	ln*M*	0.548***	0.355***	0.419***	0.373***	0.388***	0.755***	
	ln*S*	0.148***	0.253***	0.129***	0.195***	0.210***	0.045	
	ln*L* or ln*LH*	0.144***	0.140***	0.294***	0.176***	0.158***	0.013	
	ln*K*	0.072***	0.158***	0.162***	0.188***	0.146***	0.017	
	Economies of scale	1.041	1.018	1.159	1.031	1.025	0.919	
	L.ln*inventory*	-0.043***	-0.011*	-0.027**	-0.009***	-0.001	-0.002	
	ln*rd*	0.035**	0.006*	0.027**	0.004	0.010*	-0.013***	
	ln*education*	0.023***	0.013***	0.013*	0.034***	0.049***	0.012	
	ln*debt*	-0.051***	-0.020***	-0.043***	-0.056***	-0.088***	0.006	
	constant	2.419***	2.644***	1.958***	2.832***	2.825***	2.884***	
	R^2 within	0.9756	AR(2): 0.370	0.9832	AR(2): 0.909	AR(2): 0.637	0.9679	
	R^2 between	0.7596	Hansen: 0.742	0.9230	Hansen: 0.789	Hansen: 0.672	0.6987	
	R^2 overall	0.8979		0.9467			0.7207	
	Number of obs	452	456	293	296	296	139	
	Number of industries	22	22	20	20	20	22	
Dependent var: ln*Y*		(8) FE.IV	(9) GMM	(10) FE.IV	(11) GMM	(12) GMM	(13) RE	(14) GMM
Manufa-cturing	Variable: ln*E*	0.180***	0.161***	0.171***	0.150***		0.164***	0.118***
	ln*M*	0.534***	0.543***	0.528***	0.582***		0.572***	0.472***
	ln*S*	0.147***	0.194***	0.097***	0.169***		0.314***	0.227***
	ln*L*	0.146***	0.113***	0.256***	0.123***		-0.024	0.210**
	ln*K*	0.045*	-0.032	0.111***	0.018*		-0.025	0.075

	Economies of Scale		1.052	0.979	1.163	1.042		1.001	1.102
	L.ln*inventory*		-0.033*	-0.061**	-0.030**			-0.016*	
	ln*rd*		0.018	0.031	0.033			0.026***	
	ln*education*		0.026**	0.039	-0.013			0.008	
	ln*debt*		-0.060**	-0.057*	-0.023*			0.010	
	constant		2.118***	3.007***	1.240**	1.899***		1.274***	1.922**
	R^2	within	0.9931	AR(2): 0.727	0.9908	AR(2): 0.089		0.9779	AR(2): 0.133
		between	0.9958	Hansen: 1.000	0.9904	Hansen: 0.704		0.9996	Hansen: 1.000
		overall	0.9943		0.9856			0.9988	
	Number of obs		267	268	179	193		77	77
	Number of industries		11	11	11	11		11	11
Dependent Var: ln*Y*			(15) FE. IV	(16) GMM	(17) FE. IV	(18) GMM	(19) GMM	(20) FE	(21) GMM
Servi-ces	Variable: ln*E*		0.156*		0.054			0.226	
	ln*M*		0.352***		0.318***			0.781***	
	ln*S*		0.178***		0.125**			0.019	
	ln*L*		0.121***		0.267***			-0.080	
	ln*K*		0.234***		0.311***			-0.120	
	Economies of scale		1.041		1.075			0.826	
	ln*inventory*		0.004		-0.012			-0.004	
	ln*rd*		0.037*		0.075**			-0.001	
	ln*education*		0.074***		0.052***			0.010	
	ln*debt*		-0.141***		-0.126***			0.001	
	constant		2.762***		3.180***			4.675***	
	R^2	within	0.9597		0.9732			0.9539	
		between	0.2033		0.8811			0.2917	
		overall	0.8537		0.8989			0.4991	
	Number of obs		163		102			52	
	Number of industries		9		8			9	
			legend: * p<0.1; ** p<0.05; ***p<0.01						

Notes: i) Ln stands for logarithm; *Y* for output, *E* for energy input, *M* for material input, *S* for services input, *L* for number of employees, *K* for capital stock, *inventory* for inventories to sales ratio, *rd* for R&D to sales ratio, *edu* for education expenditure to sales ratio, *debt* for debt to sales ratio. ii) *L* indicates labors employed and is used for (1), (2), (3), (4), (6), (8), (9), (10), (11), (14), (15), (17), (20). iii) *LH* indicates hours worked and is used for (5). iv) For (1): Instr/ed: L.ln*inventory* ln*rd*; **Instr/s**: ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* ln*debt* L.ln*L* L.ln*K* hempe L.ln*rd* L.ln*E* L.ln*S* L.ln*M* trd; For (2): **Instr/s** for orthogonal deviations equation (i) Standard: FOD.(ln*E* ln*M* ln*S* ln*K* ln*rd* ln*education* ln*debt*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*K* ln*rd* ln*education* ln*debt*, GMM-type, DL(2 to 3).(ln*Y* L.ln*E* L.ln*M* L.ln*S* ln*L* L.ln*K* L.ln*inventory* ln*debt* ln*rd* ln*education*); For (3): Instr/ed: L.ln*inventory* ln*rd*; **Instr/s**: ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* ln*debt* empe L.hempe L.trd L.ln*LH* L.ln*S* L.ln*E* L.ln*M* L.ln*rd* L.ln*K*; For (4): **Instr/s** for orthogonal deviations equation (i) Standard: FOD.(ln*E* ln*M* ln*S* ln*rd* ln*education*), GMM type, DL(2 to 3).(ln*Y* ln*M* ln*S* L.ln*education* L.ln*inventory* ln*debt* ln*rd*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd* ln*education*, GMM-type, DL.(ln*Y* ln*M* ln*S* L.ln*education* L.ln*inventory* ln*debt* ln*rd*); For (5): **Instr/s** for orthogonal deviations equation (i) Standard: FOD.(ln*E* ln*M* ln*S* ln*rd* ln*education*), GMM-type, L2.(ln*Y* ln*E* ln*M* ln*S* ln*LH* ln*K* L.ln*education* L.ln*inventory* ln*debt* ln*rd*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd* ln*education*, GMM-type, DL.(ln*Y* ln*E* ln*M* ln*S* ln*LH* ln*K* L.ln*education* L.ln*inventory* ln*debt* ln*rd*); For (8): Instr/ed: L.ln*inventory* ln*rd* ln*debt*; **Instr/s:** ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* salse empe hempe trd L.ln*LH* L.ln*S* L.ln*E* L.ln*M* L.ln*rd* L.ln*K*; For (9): **Instr/s** for orthogonal deviations equation (i) Standard FOD.(ln*E* ln*M* ln*S* ln*rd* ln*debt*), GMM-type, L2.(ln*Y* ln*E* ln*M* ln*S* ln*L* ln*K* L.ln*inventory* ln*rd* ln*education* ln*debt*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd* ln*debt*; For (10): Instr/ed: L.ln*inventory* ln*rd*; **Instr/s**: ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* ln*debt* L.ln*L* L.ln*K* hempe L.ln*rd* L.ln*E* L.ln*S* L.ln*M*; For (11): Instr/s for orthogonal deviations equation (i) Standard FOD.(ln*E* ln*M* ln*S* ln*rd*), L(1 to 2). (ln*Y* ln*E* ln*M* ln*S* ln*L* ln*K*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd*, GMM-type; For (14): **Instr/s** for orthogonal deviations equation (i) Standard FOD.(ln*E* ln*M* ln*S* ln*rd*), L(2 to 3). (ln*Y* ln*E* ln*M* ln*S* ln*L* ln*K*), Instr/s for levels equation (ii) Standard: cons ln*E* ln*M* ln*S* ln*rd*, GMM-type; For (15): Instr/ed: ln*E* ln*debt*; **Instr/s:** ln*M* ln*S* ln*L* ln*K* ln*education* L.ln*inventory* ln*rd* L.ln*K* empe L.ln*debt*; For (17): Instr/ed: L.ln*inventory* ln*rd*; **Instr/s:** ln*E* ln*M* ln*S* ln*L* ln*K* ln*education* ln*debt* L.ln*LH* L.ln*K* hempe L.ln*rd* L.ln*E* L.ln*S* L.ln*M*. v) Hempe stands for total hours worked, empe for number of employees, salse for sales, trd for total R&D expenditure. vi) The IV next to FE (as in FE.IV) stands for instrumental variables. vii) AR(2) indicates Arellano-Bond test for AR(2) in first differences, Hansen indicates Hansen test of overidentified restrictions. viii) In the cases where the Hansen test is close to unity, it is because of too many instruments in relation to the number of observations. ix) Although some regressions after the FC are reported in this Table, their reliability is low due to limited data as already mentioned in the text.

For the GMM regressions, and for all industries, the main differences between the pre-FC regression and the whole period regression are mainly found in the extra variables; thus, during the pre-FC period, the debt ratio and education ratio played a more pronounced role than after the FC; the contrary can be said for the lagged inventories and R&D ratios. This shows that after the FC, firms and sectors became more efficient in terms of production organization and financial scrutiny as well as improvement; on the contrary, the education impact is lessened after the FC. These results are not dissimilar to those generated by the FE models, but not as distinct and clear as in GMM. In addition, the services input has apparently increased after the FC (this is also observed for the FE cases).

The latter is also true for manufacturing: the effect of the services input increased after the FC[13] (in both FE and GMM models). It is well known that Korean firms are

[13] Once more it is much safer to indirectly compare the whole period regression with the pre-FC period regression to gauge the post-FC period regression indirectly as was mentioned above.

re-organized after the FC (Haggard *et al*., 2001) and hence this particularly picks up the services input coefficients. As part of this re-organization, many manufacturing firms improved their production system more efficiently and most probably outsourced services. Still for manufacturing, another important point is that the coefficient of the debt ratio increased after the FC (-0.06 for the whole period and -0.023 for the pre-FC period). This means that output was affected more substantially by financial conditions after the FC. For the services sector, the coefficient of the services input also increases after the FC; for the same sector the effect of the inventory ratio is significant neither before the FC nor after it; the effect of the debt ratio and education ratio most probably increase (although marginally) after the FC whereas the effect of R&D ratio most likely decreases after the FC.

In this section, we also include the summary of coefficients as estimated in our models in order to check for the existence of economies of scale. The sum of all five accounting variables is shown in the previous Tables 3, 4, and 5. In the case of all industries and the whole period, the estimation results of the non-augmented production reveals that Korea has practically constant returns to scale (between 0.98 and 1.022); however, the estimation results of augmented production function, to which we added extra variables, shows more clearly that Korea achieves economies of scale (although at a modest degree). Also note that GMM usually yields results that are consistently closer to unity. These results agree with similar estimates by Basu and Fernald (1995, 1997). Still for the whole period, most models show that there are economies of scale in manufacturing, and services (for both augmented and non-augmented models). If we split up for before and after the 1998 FC, the results reveal some similarities. For all industries there are economies of scale before the FC, but these have been reduced considerably after the FC (for both augmented and non-augmented models). Similarly, manufacturing achieves economies of scale before the FC, but these economies are substantially reduced after the FC (for both augmented and non-augmented models). With regards to the services sector, it has achieved economies of scale before the FC, but these economies of scale have decreased after the FC.

4. DISCUSSION, IMPLICATIONS AND CONCLUSIONS

This paper has examined the role of services both as outputs and inputs. For Korea, according to our search, this is the first attempt to use services sector both as an output and input in estimating production functions in a comprehensive and rigorous way. The overview of Korea's services sector provided with the general observation that Korea's services outputs has grown rapidly since the early 1990s (as seen in Figure 3) and, accordingly, a services input has increased in the same period, having replaced other intermediate inputs such as materials and energy. Particularly, it is noticeable that the contribution of services input to services outputs is much larger than that of a services input to manufacturing. This is verified in our empirical study in terms of growth as shown in our estimated production functions.

We also introduce four non-accounting variables as proxies for organizational efficiency, technological knowledge, human capital, and financial conditions in the production function (we call it the augmented production function, because of the inclusion of both services inputs and these extra four factors). In general, most of our regressions suggest that the inventories ratio (organizational efficiency) and the debt ratio have a positive effect on outputs (via a negative coefficient); whereas the R&D (technological knowledge) ratio and the education expenditure ratio have positive effect on outputs (with positive coefficient) as expected. Moreover, the decreased constants in the augmented production function (for GMM and most FE models) confirm that some unexplained part of the residual error might be specified through these additional variables (for the all industries case).

From our estimation results, the role of services is more precisely determined and some conclusions can be drawn from this role. We find that the effect of services inputs might be over-estimated in the FE (or RE) (and with or without instrumental variables) models, whereas the effect of material might be under-estimated when we estimate a standard production function for all industries together. In general, the coefficients between the augmented and non-augmented models are not the same in the FE (or RE) models which necessitates further attention in similar studies. However, these conclusions might not be true with GMM estimations (we explicitly showed our preferences for these models). It is also found that services industries might be also dependent on other unexplained factors in addition to classical inputs (capital, labor, intermediates) and the four extra non-accounting variables we introduced here. From the comparison of the role of the services input between manufacturing and services sectors, we provide some evidence that the services sector has been much more affected by services inputs than the manufacturing sector has.

We also provide estimates both before 1998 FC and after (the cut-off year being 1998); this comparison shows changes in coefficients of several key variables. The manufacturing sector is reorganized and outsources more services after the FC. The services sector also reorganized itself and depends on services outsourcing in a similar way to manufacturing. In contrast, the labor and capital inputs have decreased in importance after the FC. In addition, the increase of the debt ratio's coefficient shows that output has become more sensitive to financial conditions in the manufacturing sector after the FC, whereas this increase in sensitivity is probably less pronounced for the services sector.

According to our results, Korea's economy achieved small economies of scale (or close to constant returns to scale) when we estimate the augmented production function for all industries together; whereas it shows low diseconomies of scale or much closer to constant returns to scale when the non-augmented production[14] is estimated for all industries together (this is true for both the FE and the GMM models). However, the differences are not substantial between various models. For the manufacturing sector, both augmented and non-augmented functions reveal economies of scale. For the services sector, both the augmented and non-augmented versions show economies of scale or very close to constant returns to scale. However, it seems that after the FC these economies of scale have decreased substantially for both major sectors. All this is not necessarily in disagreement with Kim's (2008) paper which suggests that the services sector is not as "healthy" as the manufacturing sector is in Korea, because Kim's (2008) total factor productivity (TFP) focus may not exclude economies of scale (which might be due to strong contributions of services inputs). In addition, TFP includes many factors of productivity or efficiency not explained by the accounting variables. In our paper we explicitly include some of these factors, thus reducing the effect of TFP impact.

We may add that this decreasing in economies of scale after the FC might be due to its re-organization after 1998 as this can be detected through substantial changes in the coefficients of the accounting variables as well as of the extra variables. For example, the coefficient of services input is much larger after the FC, whereas that of labor is smaller. At the same time, the coefficient of the debt ratio is smaller after the FC than before it for the services sector whereas the contrary prevails for the manufacturing sector. All this suggests that we might see a more substantial increase in both output and productivity of the services sector in the years to come mainly due to the just mentioned ongoing re-organization of both the manufacturing and the services sectors. Regarding the manufacturing sector, economies of scale prevailed before and after the FC but rather in a slowing down motion (as in the Korean economy in general).

Overall, the present paper ends up with suggesting several implications which are related to the services input and other variables. Because the share of services output is increasing in Korean economy, the more extensive use of services inputs can drive the growth of total output through the growth of services output. Although it has been suggested that the services sector might be a slowing down force in the Korean economic development (see Kim, 2008), and our paper agrees with this conclusion in some respects, our findings also suggest that services in Korea are in a rather transition period and most probably go through a process of re-organization. Producer services might be a true engine of growth in the foreseeable future, followed by the other categories (although this extra growth had not taken place till 2005 as yet). In addition, let us not forget that other countries such as Germany still lag behind in terms of services development (one common characteristic between Germany and Korea is that both countries are heavily export-oriented). Reorganization after the 1998 crisis is evident and is picked up in our regressions; services as an input or output play an

[14] Overall, the indication of economies or diseconomies of scale is not as consistent in the non-augmented as it is in the augmented model.

important role in this re-organization (with not necessarily more employment in the services sector after the crisis than before).

Also it follows from our analysis that, when one carries out empirical work with a standard production function, they should pay close attention not to over-estimate or under-estimate the effect of each input (hence it is suggested that some other variables are included as we did in the present paper). In addition, a detailed analysis of the coefficients in our regressions may indicate the various directions Korean industries are taking; we have pinpointed some of these directions, but the reader may detect many others in his/her own will depending on the emphasis someone wants to give to the present analysis (see also the previous section for some more detailed conclusions). Furthermore, our results provide some glimpses into the relationship between manufacturing and services sectors through the differences in coefficients between these two sectors as discussed in the text (thus providing some evidence that there is an ongoing interaction between the two major sectors). Finally, it is recommended that further analysis should be carried out again in the not-too-distant years in order to detect any changes in the coefficients of relevant regressions and adjust conclusions (this is particularly true for the services sector because of the data limitation after the FC in the present study). Nonetheless, our present paper has contributed to the study of the production function in Korea in several ways as already mentioned.

Appendix

Industry Classification of EUKLEMS

	Industry classification	Categorization
1	Agriculture, hunting, forestry and fishing	Agriculture and fishing, mining
2	Mining and quarrying	
3	Food , beverages and tobacco	Manufacturing
4	Textiles, textile , leather and footwear	
5	Wood and of wood and cork	
6	Pulp, paper, paper , printing and publishing	
7	Chemical, rubber, plastics and fuel	
8	Other non-metallic mineral	
9	Basic metals and fabricated metal	
10	Machinery, nec	
11	Electrical and optical equipment	
12	Transport equipment	
13	Manufacturing nec; recycling	
14	Electricity, gas and water supply	Services
15	Construction	
16	Wholesale and retail trade	
17	Hotels and restaurants	

18	Transport and storage and communication
19	Financial intermediation
20	Real estate, renting and business activities
21	Public admin and defense; compulsory social security
22	Education
23	Health and social work
24	Other community, social and personal services

Note: KISS VALUE (for some independent variables) does not have data for sectors 21 and 23; thus, we dropped these industries in this study.

Source: Authors' summary from EUKLEMS and KISS VALUE.

REFERENCES

Banga, R., and B. Goldar (2004), "Contribution of Services to Output Growth and Productivity in Indian Manufacturing: Pre and Post Reforms," Indian Council for Research on International Economic Relations Working Paper, 139.

Basu, S., and J.G. Fernald (1995), "Aggregate Productivity and the Productivity of Aggregates," NBER Working Paper, 5382.

_____ (1997), "Returns to Scale in U.S. Production: Estimates and Implications," *The Journal of Political Economy*, 105(2), 249-283.

Basu, S., J.G. Fernald, and M.S. Kimball (2006), "Are Technology Improvements Contractionary?" *American Economic Review*, 96(5), 1418-1448.

Baumol, W.J. (1967), "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *The American Economic Review*, 57(3), 415-426.

Baumol, W.J., S.A.B. Blackman, and E.N. Wolff (1985), "Unbalanced Growth Revisited: Asymptotic Stagnancy and New Evidence," *The American Economic Review*, 75(4), 806-817.

Cainelli, G. (2008), "Spatial Agglomeration, Technological Innovations, and Firm Productivity: Evidence from Italian Industrial Districts," *Growth and Change*, 39(3), 414-435.

Callen, J.L., M. Morel, and C. Fader (2005), "Productivity Measurement and the Relationship between Plant Performance and JIT Intensity," *Contemporary Accounting Research*, 22(2), 271-309.

Cameron, A.C., and P.K. Trivedi (2009), *Microeconometrics Using Stata*, Texas: A Stata Press Publication.

Capkun, V., A.P. Hameri, and L.A. Weiss (2009), "On the Relationship between Inventory and Financial Performance in Manufacturing Companies," *International Journal of Operations and Production Management*, 29(8), 789-806.

Chen, H., M.Z. Frank, and O.Q. Wu (2005), "What Actually Happened to the Inventories of American Companies between 1981-2000?" *Management Science*, 51(7), 1015-1031.

Clark, C. (1940), *The conditions of Economic Progress*, London: Macmillan.

Chung, D.J., S. Cho, and J.M. Lee (2006), "Knowledge Production Function in South Korea: An Empirical Analysis," *World Academy of Science, Engineering and Technology*, 18, 80-86.

Dalton, J.T. (2009), "Explaining the Growth in Manufacturing Trade," Working Papers, University of Minnesota.

Fisher, A.G.B. (1935), *The Clash of Progress and Security*, London: Macmillan.

Francois, J.F., and K.A. Reinert (1996), "The Role of Services in the Structure of Production and Trade: Stylized Facts from a Cross-Country Analysis," *Asia-Pacific Economic Review*, 2(1), 35-43.

Fuchs, V.R. (1968), *The Service Economy*, New York: National Bureau of Economic Research, Inc.

Groppelli, A.A., and E. Nikbakht (2000), *Finance*, Barron's Educational Series Inc.

Guerrieri, P., and V. Meliciani (2003), "International Competitiveness in Producer Services", Paper prepared for the SETI (Sustainable growth, Employment creation and Technological Integration in the European knowledge-based economy) Meeting in Rome, May.

Haggard, S., W. Lim, and E. Kim (2001), *Economic Crisis and Corporate Restructuring in Korea: Reforming the Chaebol*, Cambridge: Cambridge University Press.

Irvine F.O. (2003), "Long-term Trends in US Inventory to Sales Ratios," *International Journal of Production Economics*, 81, 27-39.

Kim, H. (2008), "Market Services Productivity in Korea: An International Comparison," Institute for Monetary and Economic Research, the Bank of Korea, Working Paper, 325.

Kim, J.H., S.H. Ahn, and J.H. Lee (2006), "Policy Challenges for Productivity Enhancement of Service Industry," KDI, Policy Analysis, 2006/01.

Kim, S., J. Koo, and Y.H. Lee (1999), "Infrastructure and Production Efficiency: An Analysis on the Korean Manufacturing Industry," *Contemporary Economic Policy*, 17(3), 390-400.

Kim, J., G. Wang, and S. Jyoung (2001), "On the Determinants of Productivity in Korean Manufacturing Sectors," *Industrial Organization Research*, 9(1), 1-34.

Kongsamut, P., S. Rebelo, and D. Xie (1997), "Beyond Balanced Growth," NBER Working Paper, 6159.

Kuznets, S.S. (1957), "Quantitative Aspects of the Economic Growth of Nations," *Economic Development and Cultural Change*, 5(4), 1-111.

_____ (1966), *Economic Growth and Structure*, New York: Norton.

_____ (1971), *Economic Growth of Nations: Total Output and Production Structure*, Cambridge: Harvard University Press.

Lee, Y.J., H.S. Nah, and D.S. Lee (1994), "A Study on the Production Structure for the

Japanese, Korean, and Taiwanese Manufacturing Industries: An Interrelated Factor Demand Model Approach," *Journal of Economic Development*, 19(1), 107-136.

Lieberman, M.B., and L. Demeester (1999), "Inventory Reduction and Productivity Growth: Linkages in the Japanese Automotive Industry," *Management Science*, 45(4), 466-485.

Lim, J., and E. Sanidas (2010), "Evaluation and Estimation of the Impact of Organizational Technology on Productivity: The Case of Korean Firms and Sectors," forthcoming in the *Asian Journal of Technology Innovation*.

Lopez, A. (2009), "Organizational Innovation and Productivity Growth: Assessing the Impact of Outsourcing on Firm Performance," Paper to be presented at the Summer Conference 2009 on Copenhagen Business School (CBS).

Nakamura, M., and A. Nakamura (1989), "Inventory Management Behavior of American and Japanese Firms," *Journal of the Japanese and International Economics*, 3, 270-291.

Marshall, J.N., and P.A. Wood (1995), *Services and Space: Key Aspects of Urban and Regional Development*, Harlow: Longman xiv.

OECD (2001), *OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity*, Statistics Directorate, Directorate for Science, Technology and Industry, Paris: OECD.

Park, J., and H.K. Ryu (2006), "Accumulation, Technical progress and Increasing Returns in the Economic Growth of East Asia," *Journal of Productivity Analysis*, 25, 243-255.

Pyo, H.K., and S. Jung (2009), "The Estimation of Capital Stocks, Total Factor Productivity and Potential GDP," Institute for Monetary and Economic Research, the Bank of Korea, Working Paper, 371.

Rask, K.J., and K.N. Rask (1994), "The Central Role of Services in Economic Development: Externalities, Growth, and Public Policy," *Journal of Economic Development*, 19(2), 139-158.

Sanidas, E. (2005), *Organizational Innovations and Economic Growth*, Cheltenham: Edward Elgar.

Schettkat, R., and L. Yocarini (2006), "The Shift to Services Employment: A Review of the Literature," *Structural Change and Economic Dynamics*, 17(2), 127-147.

Shin, T. (2005), "Technological Innovation and Economic Growth: An Empirical Analysis of Factor Substitution and Factor-augmenting Technical Change in Korea," STEPI, Policy Analysis 2005/08.

Summers, R. (1985), "Services in the International Economy," in Inman, R.P., ed., *Managing the Service Economy: Prospects and Problems*, Cambridge: Cambridge University Press, 27-48.

Swamidass, P.M. (2007), "The Effect of TPS on US Manufacturing During 1981-1998: Inventory Increased or Decreased as a Function of Plant Performance," *International Journal of Production Research*, 45(16), 3763-3778.

Wooldridge, J. (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT

press.
Yoo, S.J. (2001), “The Performance of JIT Systems Implementation for Korean service Firms,” *The Journal of Service Business*, 2(2), 139-161.

Mailing Address: Elias Sanidas, Economics Department, Seoul National University, Seoul, 151-746, Korea. Tel: 82-2-880-6374. Fax: 82-2-886-4231. E-mail: ellass@snu.ac.kr.

Received July 8, 2010, Revised November 26, 2010, Accepted March 4, 2011.