THE IMPACT OF ENVIRONMENTAL REGULATIONS ON TOTAL FACTOR PRODUCTIVITY: KOREAN STEEL INDUSTRY

by

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ABSTRACT

Environmental regulations are often blamed, at least partially, for the current productivity slowdown in most advanced countries. In Korea, public demand and international pressures are forcing the government to stiffen environmental controls. At the same time, industrial productivity growth is slowing. This study examines Korea's fastest growing industry, steel, to find out whether its declining productivity is a result of environmental regulations.

Time-series data from 1967 to 1993 are used to estimate total factor productivity (TFP). The first of three translog models estimates only TFP, ignoring environmental constraints. The second examines only pollution abatement costs, or direct effects on productivity growth. The third investigates the full effects of abatement, both direct and indirect. The study concludes that environmental regulations are one factor contributing to declining productivity, accounting for 31 to 44 percent of the slowdown in the Korean steel industry.

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Chapter 1

INTRODUCTION

This study examines the effects of environmental regulations on productivity growth in the Korean steel industry between 1967 and 1993. Since the 1960s, economic development has been a top priority in Korea. Environmental concerns, until recently, have received little attention. Now Korea is faced with severe environmental problems both domestically and internationally. Domestically, people are demanding a cleaner environment as a result of the country's increased standard of living. Environmental damage, once considered a symbol of economic growth, is now one of the factors that threaten economic growth.

The steel industry, Korea's fastest growing industry since the late 1960s, is important to the country's economic development. It has enjoyed full government support and, until recently, high domestic demand. The production of steel requires large capital investments, uses tremendous amounts of energy, and generates significant levels of pollutants. The industry is now faced with both external and internal problems. Profits are decreasing because of worldwide price reductions and increased production costs. Decreased domestic demand, a weakening of international competitiveness, and environmental restrictions may combine to make conditions for the Korean steel industry increasingly difficult (KDB 1993, 12).

Environmental regulations are often cited as a partial explanation for the slowdown in productivity growth experienced by most industrialized countries. Because productivity growth in the Korean steel industry is also slowing, it is worth examining whether environmental regulations are a factor. Two views exist on the effects of environmental regulation. The first is that environmental regulations are likely to increase production costs. The second view is that environmental regulations, by inducing cost-saving and quality-improving innovation, can result in increased productivity growth.

Environmental Regulations and Productivity: Two Views

Many studies have examined the impact of environmental regulation on productivity growth. Studies using growth accounting calculate the effect of environmental regulation on productivity based on measured compliance costs. These studies find that environmental regulation has little effect on productivity. The reason is that compliance costs are only a small portion of total cost. On the other hand, studies using regression analysis to estimate the impact of environmental regulation on productivity growth often find that environmental regulations reduce productivity growth.

Most studies, however, support the view that environmental regulations decrease productivity. Most do not consider the impact of pollution abatement expenditures on capital formation and growth. They also ignore the benefits of improved environmental quality. Other economists, however, have a different point of view. For example, Porter (1990) in his book, *The Competitive Advantage of Nations,* argues that "properly constructed regulatory standards will encourage companies to re-engineer their technology. The result, in many cases, is a process that not only pollutes less but lowers costs or improves quality." He also points out that strict product regulation can push polluting companies into innovations that will produce less pollution or more resource-efficient products that would enhance both productivity and profits.

Scope of Study

To evaluate the effect of environmental regulations on productivity growth in the Korean steel industry between 1967 and 1993, we apply the annual industry level data to a translog cost model developed by Barbera and McConnell (1990). To see how the presence of environmental requirements affect the cost function, all estimations will be done with and without abatement requirements in the cost function to look at how the coefficients of other inputs are affected.

The study focuses only on the contribution of environmental regulations to measured productivity. The model does not include variables for estimating social welfare improvements since most the studies, in general, do not include changes in environmental quality. Capital is divided into productive and abatement capital.[1]

Organization of Study

This study is organized as follows: Chapter 2 covers

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[1] Definitions of productive and abatement capital are not clear. Productive capital could be used for both pollution reduction and production increases. Pollution abatement costs associated with completely redesigning the production process are difficult to identify, since there are typically other objectives besides pollution reduction such as lower energy costs, reduced labor requirements, or higher quality output. But some abatement requirements are easily identified. Pollution control equipment which is 'end-of-line' is relatively easy to identify. In this study, productive capital is used for the production of products, but it does not mean that productive capital does not have an effect on pollution control. In the same sense, abatement capital could influence the production of products.

the evolution of environmental regulations in Korea and economic contributions of the Korean steel industry. The literature review in chapter 3 reviews conflicting views about the impacts of environmental regulations on productivity growth. The review focuses mainly on U.S. studies, since few studies are to be found in Korea. The basic methodology is addressed in chapter 4 covering the measurement of total factor productivity (TFP), to show the impacts of abatement requirements on TFP growth, and a formation of translog cost function described. Chapter 5 describes sources of data and presents empirical results. Summary, conclusions, and future research follows in chapter 6.

Chapter 2

THE KOREAN STEEL INDUSTRY: BACKGROUND AND ENVIRONMENTAL REGULATIONS

Many studies point to a significant relationship between environmental regulation and productivity slowdown. Environmental regulations are becoming stricter in Korea, and productivity in the steel industry is decreasing. First, we briefly review the contributions of the steel industry to the Korean economy, including steel consumption, exports, and imports. Second, and in more detail, we review environmental regulations affecting the steel industry, look into the country's environmental problems, and examine the trend of abatement investment in the industry.

Background

Steel, the basic metal of industrial societies, is important to Korea for both national security and economic well-being. Since the 1960s, the industry has concentrated on increasing production capacity and quality; it has made great contributions to other industries in cost savings, improved competitiveness, and in import substitution. The steel industry started after the Korean War (1950-53), the period of economic reconstruction.[2] Small companies began collecting scrap. SamHwa steel company with three unique blast furnaces, produced 21,000 metric tons (MT) of steel until 1961. Steel has been a strategic industry since Korea's first economic development plan in 1962. In 1973, the Pohang Integrated steel company began producing 3 million MT annually. Increasing domestic and international demand influenced growth during the 1970s and 1980s. From 1967 to 1992, annual finished steel production was 29.3 million MT, an average annual growth of 20.76 percent (appendix table A.1). Aided by this growth, the industry's share of total exports rose to 7 percent of nation's total exports in 1992 from 5.85 percent in 1973 (KDB 1993, 12).

The Korean steel industry consists of about 200 companies, including one fully-integrated steel company, 12 electric furnace companies, 83 rolling mills, and 104

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[2] See Choi, Ryung-Hwan (1985, 12-16). The beginning of Korean steel industry was Nippon iron and steel company with 50,000 tons annual capacity in the northern part of Korea in 1918. Production capacity was increased continuously to a 540 thousand ton annual base at the end of Japanese colonial rule due to military demand. However, the Korean steel industry began in the 1950s after the Korean war, because, first of all, most of the steel facilities were located in the northern part of Korea. Second, most of the steel facilities located in the southern part of Korea could not operate properly due to a lack of raw materials, lack of technology, social disorder, and destroyed facilities during the Korean war.

secondary steel production mills (KDB 1993, 15). Firms in this industry manufacture pig iron from iron ore, convert pig iron and steel scrap into steel, and produce basic products such as plates, sheets, strips, rods, bars, and tubes (Business Korea Yearbook 1994, IV-308-309).

Supply and Demand Trends

Through increased exports and improved and expanded production facilities, crude steel production in Korea rose significantly from 130,000 MT in 1962 to 28 million MT in 1992. In the 1970s and 1980s, the domestic demand for iron and steel increased from 1 million MT in 1970 to 32 million MT in 1992, based on finished steel products used in roads, subways, and housing construction, and by the automobile, electronics, shipbuilding, and machinery industries (KDB 1993 and Business Korea Yearbook 1994, IV-308).

The total demand for steel rose from 15.6 million MT in 1985 to 32 million MT in 1992. Steel production rose significantly from 14.3 million MT in 1985 to 29.3 million MT in 1992 based on finished steel products, and the supply and demand of steel increased annually by 12 percent and 12.7 percent respectively over the same period (table 1).

Table 1. Demand and Supply of Finished Steel Products (in thousands of MT)

	1985	1990	1991	1992	Annual growth rate (%)	
					1985-92	1992/91
Total demand	15,633	27,180	31,982	32,036	12.7	0.2
Domestic consumption	10,020	20,054	24,454	21,818	16.0	-10.8
Exports	5,613	7,126	7,528	10,218	5.0	35.7
Production	14,305	24,868	28,264	29,364	12.0	3.9
Imports	2,628	5,559	8,511	6,061	21.6	-28.8

Source: Korea Iron and Steel Association, Steel Yearbook, 1993, 70.

Table 2. Crude Steel Consumption by Countries (in thousands of MT)

	Crude Steel Consumption Equivalent								
	1983	1984	1985	1986	1987	1988	1989	1990	1991
Korea	8,916	10,669	11,313	12,182	15,048	15,825	18,267	21,478	26,068
Taiwan	5,770	6,086	6,316	7,835	9,401	11,630	14,100	15,350	18,850
U.S.	96,469	113,177	109,069	97,823	105,890	112,891	105,342	105,335	93,325
France	15,298	15,492	14,812	14,522	14,820	16,983	17,563	18,076	16,588

Source: Korea Iron and Steel Association, Steel Statistical Yearbook, Korea, 1993, 51-59.

Table 3. Supply and Demand for Major Raw Materials
(in thousands of MT)

	1986	1988	1989	1990	1992
IRON ORE					
Demand	12,918	16,457	22,057	23,082	29,048
Domestic Supply	525	500	422	375	338
Imports	12,394	15,957	21,653	22,707	28709
(Ratio of Import)	(95.9)	(97.0)	(98.1)	(98.4)	(98.8)
COKING COAL					
Consump.	6,974	8,369	11,135	11,734	13,963
Imports	7, 050	8,045	11,054	11,564	14,578
(Ratio of Import)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
STEEL SCRAP					
Demand	8,891	8,904	10,342	11,070	11,949
Domestic Supply	4,783	4,943	6,253	7,185	8,817
Imports	4,108	3,961	4,089	3,885	2,022
(Ratio of Import)	(46.2)	(44.5)	(39.5)	(35.1)	(16.9)

Source: Korea Iron and Steel Association, Steel Statistical Yearbook, 1993.

In response to growing domestic demand, Korean steelmakers expanded production facilities in the 1980s (Steel Statistical Yearbook 1993 and D'Costa 1994).

The steel industry depends almost totally on imported raw materials. Imports of iron ore, a major raw material used in blast furnaces, were 29 million MT in 1992, up from 12 million MT in 1986. The import-dependency ratio of iron ore reached 98.8 percent in 1992 from 95.9 percent in 1986 due to higher domestic demand following the full-scale operation of the Kwangyang Works (KDB 1993, 15).

All of Korea's coking coal is imported. Domestic steel demand caused imports to increase from 7 million MT in 1986 to 14.6 million MT in 1992.

Steel scrap is a raw material used in electric furnaces. Its demand increased from 8.8 million MT in 1986 to 11.9 million MT in 1992 because of facility expansions. But imports decreased from 4.1 million MT in 1986 to 2 million MT in 1992. The slowdown was a result of the enhancement of the recycling ratio. In 1992, the steel scrap import-dependency ratio was 16.9 percent, down from 46.2 percent in 1986 (table 3).

Investment Trends

Investments in the steel industry since 1970 have focused on capacity expansion to meet growing domestic and overseas demand. Korea is maintaining its competitiveness in ironmaking against other advanced countries, but has a disadvantage in steelmaking and special steels since the industry has produced much more iron than steel.

Table 4. Investment in Major Korean Industries
(in billions of Korean won)

	All industries (%)	Manufacturing sector	Electric & electronics	Machinery	Transportation	Steel (%)
1985	8,618.5 (100.0)	4,894.6	1,043.8	128.3	657.8	701.8(8.1)
1986	11,355.4 (100.0)	7,221.7	1,240.4	174.9	1,227.9	1,672.2(14.7)
1987	13,271.9 (100.0)	8,805.8	1,641.9	244.3	1,296.0	1,389.7(10.5)
1988	15,462.1 (100.0)	11,073.7	2,176.0	281.2	1,271.6	1,922.3(12.4)
1989	17,456.3 (100.0)	12,904.9	2,565.3	280.4	1,319.5	2,579.7(14.8)
1990	22,311.3 (100.0)	16,227.3	2,154.1	522.1	1,945.8	2,524.1(11.3)
1991	26,260.5 (100.0)	18,115.0	2,474.8	639.6	2,229.7	2,567.1(9.8)
1992	26,070.8 (100.0)	15,630.4	2,455.4	550.4	2,306.3	2,293.3(8.8)

Source: Korea Iron and Steel Association, Steel Statistical Yearbook, Korea, 1993, 107.
Note: Number in parenthesis are percentages

Table 5. Investments in the Korean Steel Industry
(in billions of Korean won)

Reason for investment	1991	1992	1993	1994 (est)
Expansion of production capacity	2,037.9 (79.4)	1,367.8 (59.7)	1,258.5 (59.0)	1,448.9 (57.6)
Repair & replacement	222.6 (8.7)	400.8 (17.4)	289.8 (12.2)	422.0 (16.8)
For automation	44.8 (1.7)	139.8 (6.1)	116.5 (5.5)	210.3 (8.4)
Energy conservation	39.1 (1.5)	20.5 (0.8)	38.0 (1.8)	81.7 (3.2)
Pollution control	87.0 (3.3)	44.9 (2.0)	94.8 (4.4)	103.3 (4.1)
R&D	21.7 (0.8)	22.5 (0.9)	24.0 (1.1)	49.6 (1.9)
Other	114.0 (4.5)	297.0 (13.0)	309.6(14.5)	198.0 (7.9)
Total	2,567.1 (100.0)	2,293.3 (100.0)	2,131.2 (100.0)	2,513.8 (100.0)

Source: Chulgangbo, Investment Trends and Steel Production Capacity, 1993, Vol. 20, No. 7, July 1994, 6-14.
Note: Numbers in parenthesis are percentages

To overcome this disadvantage, domestic steelmakers appear to be accelerating investments in high-tech steel mills, commonly called "COREX" mills.[3] The Ministry of Trade, Industry and Energy(MOTIE) encourages steelmakers to set up the mills as part of its effort to catch up with rapid worldwide technological innovation.

Investments in the steel industry rose from 701 billion won in 1985 to 2.293 trillion won in 1992 (table 4). The

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[3] See Yu, Kun-Ha (Newsreview, 1994, September 24) and D'Costa (1994). COREX mills use a simplified production process. While conventional blast furnace mills use coke as fuel, COREX uses ordinary coal, eliminating the process of producing coke which is made from soft coal.

share of investments in the steel industry from all industries was 8.8 percent in 1992. Most steel industry investments have been for expansion of production capacity, but in recent years, capacity investments have dropped from 79.4 percent in 1991 to 57.6 percent in 1994. Now, investments in automation, energy conservation, pollution control, and research and development (R&D) are growing significantly. For example, the share of investment in automation was 8.4 percent of total investment in 1994, up from 1.7 percent in 1991; investment in energy conservation was 3.2 percent of total investment in 1992, up from 1.5 percent in 1991; and pollution control and R&D expenditures were 4.1 percent of total investment and 1.9 percent in 1994 from 3.3 percent and 0.84 percent, respectively. The trend is that as investment decreases for expansion of production capacity, it increases for automation, energy conservation, pollution control, and R&D.

Tables 6 and 7 illustrate the progress of new steelmaking technology. The ratio of continuous casting for semi-finished products increased to 96.75 percent in 1992 from 71.7 percent in 1986. R&D investment was 1.9 percent of total investments in 1994 from 0.84 percent of total investment in 1986, and the ratio of factory automation

Table 6. Steel Production Index Trends
(%)

	1986	1987	1988	1989	1990	1991	1992
Operation Ratio	91.9	91.7	88.3	98.6	90.6	100.5	87.2
C.C. Ratio	71.7	83.5	88.3	94.1	96.1	96.35	96.75

Source: Korea Iron and Steel Association, Steel yearbook, 1993.
Note: C.C. is Continuously Cast Steel Production

Table 7. Comparison of Kwangyang Mills with Japanese Mills

	Kwangyang(phase 1)	Japanese Maximum	Japanese Average
Blast furnace (volume in cubic meters)	3,800	5,070	2,447
Blast furnace (thousand tons/year)	2,840	4,110	2,020
BOF (thousand tons/charge)	250	340	156
Casting (thousand tons/year)	2,700	2,760	1,460
Hot rolling (thousand tons/year)	2,638	5,400	3,050

Source: D'Costa (1994)

increased 53.1 percent in 1992 from 28 percent in 1990 (KDB 1993, 16).

In 1992, Pohang Iron and Steel Company Ltd. (POSCO) developed a new-strip casting technology. Worldwide, the industry is developing new technologies including direct steel making and direct iron ore smelting. These technologies allow reduction, melting, and refining functions to occur and be controlled in a single reactor, thereby eliminating coke ovens. The new technology reduces processing costs and limits the discharge of toxic materials (KDB 1993, 17).

Adopting foreign technology has meant progressive changes in equipment size. The first blast furnace in Pohang (completed in 1973), for example, had an internal volume of 1,660 cubic meters; the second, 2,225; and the third and fourth, 3,795. Similarly, the capacity of basic oxygen furnaces at Pohang increased from 100 tons to 300 tons with successive expansions (D'Costa 1994, 64).

Table 7 compares the Kwangyang facilities (one of POSCO's mill) with Japanese mills. Most of the capacity in Kwangyang is higher than the Japanese average, but a little lower than the Japanese maximum.

Export and Import Trends

Exports and imports of finished steel products have increased significantly due to increased domestic and overseas demand during the last two decades. In 1992, exports and imports of the steel products were $5.4 billion (in U.S. dollars) and $4 billion, respectively, with a $1.4 billion trade surplus. This was up from $3.8 billion and $3 billion, respectively, with a $0.8 billion trade surplus in 1988. One reason for the high trade surplus is that steel exports to China and South East Asia are increasingly significant due to the rapid economic growth of these areas. Another reason is the relative decrease in imported steel products due to increased steel production capacity (Commerce, Industry and Resource White Paper 1994, 313). For the export and import market, the percentage of exports to the United States, European Community, and Japan decreased, but those for China and South East Asia increased significantly (Commerce, Industry and Resource White Paper 1994, 313).

Table 8. Exports and Imports of Steel Products by Year
(in thousands of Korean won and thousands MT)

		1988		1990		1992	
		QUANTITY	VALUE	QUANTITY	VALUE	QUANTITY	VALUE
LONG PRODUCT	EXPORT	1,332,082	509,248	808,888	399,912	1,791,873	6,87,419
	IMPORT	648,301	320617	1,405,431	594,614	1,486,830	598,533
	TRADE BALANCE	683,781	188,631	-596,543	-194,702	305,043	88,886
FLAT & FORGING	EXPORT	4,859,160	2,364,667	5,938,516	2,921,573	7,903,557	3,562,280
	IMPORT	20,72,884	1,560,585	2,998,477	1,915,551	2,517,114	1,600,141
	TRADE BALANCE	2,786,276	804,082	2,940,039	1,006,022	5,386,443	1,962,139
CASTING & FORGING	EXPORT	70,697	119,423	47,691	92,090	51,518	103,038
	IMPORT	8,552	54,684	13,290	83,001	38,217	87,331
	TRADE BALANCE	62,145	64,739	34,410	9,089	13,301	15,707
Foundry	EXPORT	88,166	87,182	83,652	152,757	83,472	141,052
	IMPORT	5,417	11,933	19,462	91,667	118,819	128,379
	TRADE BALANCE	82,749	76,040	64,190	61,090	-35,547	12,673
SEMI-FINISHED	EXPORT	353,291	101,327	331,211	90,253	470,735	101,111
	IMPORT	632,114	161,947	1,142,140	300,678	2,018,994	509380
	TRADE BALANCE	-278823	-60620	-810929	-210425	-1638259	-408269
SECON-DARY PRODUCT	EXPORT	581,501	647,334	445,624	561,736	503,675	763,719
	IMPORT	38,648	78,677	50,288	93,314	80,390	153,593
	TRADE BALANCE	542,853	568,657	395,336	468,422	423,285	610,126
RAW MATERIAL	EXPORT	-	13,212	-	19,888	-	12,797
	IMPORT	-	804,885	-	1,010,895	-	904,875
	TRADE BALANCE	-	-791,673	-	-991,007	-	-892,078
TOTAL	EXPORT	-	3,843,184	-	4,238,209	-	5,371,416
	IMPORT	-	2,993,328	-	4,091,384	-	3,982,231
	TRADE BALANCE	-	849,866	-	146,825	-	1,389,185

Source: Korea Iron and Steel Association, Steel Statistical Yearbook, 1993.

Table 8 shows the quantity and value of exported and imported steel products by year. Korea mostly exports flat and forging, secondary product, long product, and foundry products. It mostly imports flat & forging, raw material, long product, and semifinished steel products.

Table 9. Exports and Imports of Finished Steel 1986-1991
(in thousands of MT)

	1986	1987	1988	1989	1990	1991
Export	5,891	6,124	6,992	7,580	7,598	7,734
Import	2,703	3,542	2,742	3,455	3,366	5,365

Source: Korea Iron and Steel Association, <u>Steel Statistical Yearbook</u>, 1993, 147.

Table 10. Korean Imports of Finished Steel, 1991
(in thousands of MT)

Destination	Japan	Belgium	France	Germany	Italy	Netherlands
Korea	1,952.7	127.4	101.3	126.4	6.7	1.0

Destination	U.K.	Spain	E.C Total	Austria	Sweden	U.S.
Korea	255.3	177.1	795.3	2.0	52.6	797.4

Destination	Canada	Brazil	Australia	Total
Korea	521.1	1040.6	203.8	5365.4

Source: Korea Iron and Steel Association, <u>Steel Statistical Yearbook</u>, 1993, 153.

Table 11. Korean Exports of Finished Steel, 1991
(in thousands of MT)

Destination	Japan	South East Asia	Iran	Kuwait	Saudi Arabia	Middle East Total	Asia Total	Belgium	Germany	Italy	Nether-lands	U.K.	E.C. Total	Sweden	Western Europe	C.I.S.	Eastern Europe Total	Europe Total	U.S.	Canada	North America Total	Central & South America	America Total	Africa	Australia	Oceania	Total
	3,380.9	5,395.8	122.0	3.1	176.8	363.5	5,759.3	31.5	7.4	14.8	34.0	14.3	138.9	4.1	28.4	129.9	131.0	298.2	1,347.5	29.3	1,376.8	100.3	1,477.1	17.0	123.7	159.4	7,734.8

Source: Korea Iron and Steel Association, Steel Statistical Yearbook, 1993, 153.

Exports and imports have been increasing continuously. Table 9 shows that exports of steel rose 7,734,000 MT in 1991 from 5,891,000 MT in 1986. Imports rose 5,365,000 MT in 1991 from 2,703,000 MT in 1986.

Impact of the Steel Industry on Korea's Economy

Low prices for steel in Korea have helped the country's downstream activities. Since many steel-intensive products such as automobiles, machinery, construction, and shipbuilding are also exported by Korea, the steel industry has contributed to the general competitiveness of Korean industries (Commerce, Industry and Resource White Paper 1994, 311).

Table 12. The Industrial Position of the Steel Industry
(%)

	1970	1980	1985	1989	1993
Steel/GNP	0.5	2.1	2.5	2.2	2.4
Steel EX/Total Ex	1.2	8.1	5.5	6.9	8.0
Steel/Manufacturing production	5.0	7.8	7.5	7.0	8.1
Steel/# Employee	3.1	3.4	3.0	2.3	2.6

Source: Ministry of Commerce, Industry and Resources, Steel Industry, Commerce, Industry and Resource White Paper, 1994, 311.

Gross output in the steel industry rose to 2.4 percent of GNP in 1993 from 0.5 percent in 1970. Exports rose to 8 percent of total exports in 1993 from 1.2 percent in 1970. Production rose to 8.1 percent of manufacturing in 1993 from 5 percent in 1970. However, the number of employees decreased from 3.1 percent of the nation's total in 1970 to 2.6 percent in 1993. Production of steel in 1993 was 33 million MT with 5.5 percent of world production. Consumption was 27 million MT with 4.5 percent of world consumption in 1993. Exports were 11 million MT with 6.3 percent of world share in 1993 (table 12).

Productivity Growth Trends

Many factors contributing to Korea's economic growth are non-economic, stemming from political leadership and public demand. General economic factors include the favorable international economic climate and an emphasis on government-led, export-oriented growth strategies. However, these factors alone cannot stimulate growth. There also needs to be an adequate supply of production factors and continuous improvement in productivity. Many studies in the literature focus on identifying, by quantitative methods, the sources of Korea's growth by estimating growth contributions from changes in production factors and productivity. However, an omission in the literature regards the environmental regulatory impact on productivity growth in Korea.

Four studies are examined here that evaluate productivity in Korea's manufacturing industries.

Pyo, et al., (1993) study the source of industrial growth and productivity estimates in Korea between 1970 and 1990. The purpose is to find sources of Korean economic growth by analyzing production by industrial sectors. In their study, the authors include 28 industries and analyze sources of growth and estimate value-added factor productivity by industry. The basic method employed is the growth accounting to valued-added being measured as output in the industrial production process. Both value-added and factor inputs are measured by nine broad classifications for industries and twenty-eight manufacturing industries. In their model, they include labor, capital, and materials to estimate total factor productivity. The rates of growth in total factor productivity of all industries and manufacturing have increased from the 1970s to 1980s. They found that the annual TFP growth rate in the steel industry was 9.85 percent from 1970 to 80 and 6.25 percent from 1980

Table 13. Existing Studies of Productivity Growth in Korean Steel Industry

Authors	Po, et al. (1993)	Lee (1992)	Kim and Hong (1992)	Jungmo Kang (1992)
Scope of Analysis	Manufacturing 28 industries	Manufacturing 20 industries	Manufacturing 36 industries	Manufacturing 26 industries
Methods of Estimation	Growth accounting approach (production function)	Translog approach (production function)	Growth accounting and translog approach (production function)	Translog approach (production function)
Input Data	Capital and labor quantity	Capital, labor, materials, and technology	Capital, labor, materials, and technology	Capital, labor, materials, technology, and capital utilization.
Time Period Covered	1970-90	1970-87	1967-89	1963-83
Growth Rate of TFP	Steel industry 1970-80 9.85% 1981-90 6.25% 1970-90 8.05%	All manufact. 1970-78 9.76% 1978-87 10.54% 1970-87 10.03% Steel industry 1970-78 -6.01% 1978-87 1.18% 1970-87 -2.20%	All manufact. (Growth accounting) 1967-77 3.42% 1977-88 0.61% 1967-88 1.94% (Translog) 1967-88 1.35% Steel industry (Growth accounting) 1967-77 2.35% 1977-88 0.19% 1967-88 1.21% (Translog) 1967-88 0.63%	All manufact. 1963-73 3.43% 1973-83 0.16% 1963-83 1.66% Steel industry 1963-73 3.55% 1973-83 0.13% 1963-83 1.69%

to 90. The annual TFP growth rate for the entire period was 8.08 percent.

Lee (1992), in a comparative analysis of Japanese and Korean manufacturing from 1970 to 1987, used a basic translog production model to study productivity changes and the level of technology. The translog function relaxes some of the restrictions in order to evaluate substitution and technical effects among the variables. His conclusion is that even though the Korean manufacturing sector has grown significantly, the growth rate of total factor productivity is very low; thus, the contribution of TFP to the manufacturing growth is low. However, in other industries, such as food and beverages, petroleum refining and coal, and iron and steel, TFP also decreased. For the iron and steel industry, the growth rate of TFP was -6.01 from 1970 to 78 and 1.18 from 1978 to 87. For the entire period, TFP growth was -2.20 percent.

Kim and Hong (1992) considered the TFP trends and its determinants in the manufacturing sector between 1967 and 1989. The basic methods used were the growth accounting and the translog production function. Using the growth accounting approach for the iron and steel industry, the TFP growth rate was 2.35 from 1967 to 77 and 0.19 from 1977 to

88. It was 1.21 percent during the entire period. Using the translog approach, the growth rate of TFP was 0.63 percent during the entire period.

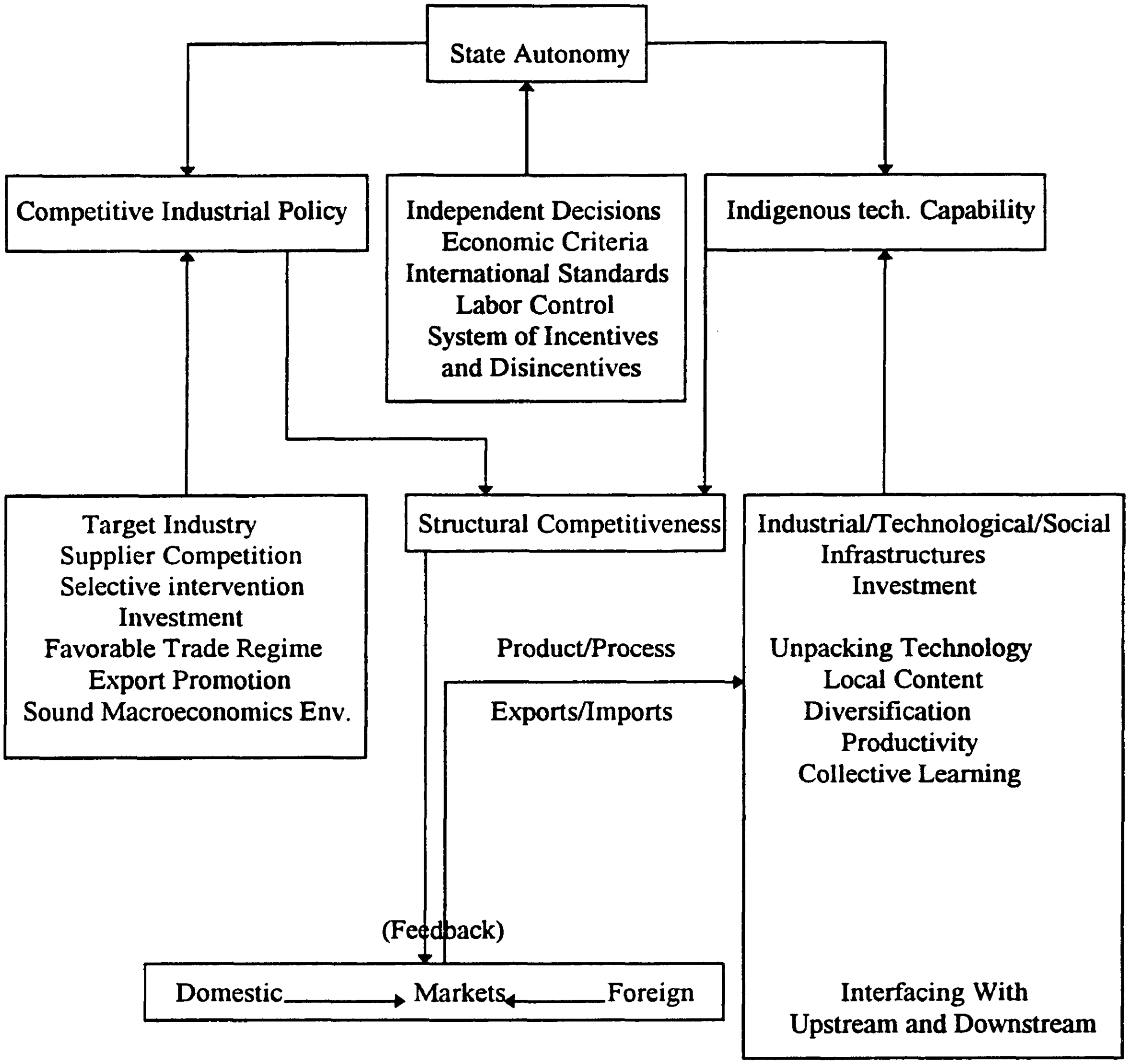
Jung Mo Kang (1992) studied the role of returns-to-scale and capital utilization on productivity changes in the Korean manufacturing sectors from 1963 to 1983. He employed the Denny, et al. (1981), and Kwon (1986) models. The translog model can be decomposed into three effects: technical change, returns-to-scale, and capital utilization. For the steel industry, he found that the growth rate of TFP was 3.55 percent from 1963-73 and 0.13 percent from 1973-83, and for the entire period, 1.69 percent.

Most productivity studies show that the Korean manufacturing industries have experienced a decline in productivity growth. The heavy and chemical industry experienced a significant productivity decline. One explanation for this is the Heavy and Chemical Program that was pursued vigorously by the Korean government during the 1970s. The program induced a significant over capital investment in these industries. The first and second oil shocks also contributed to the decline in productivity, while they induced a significant level of energy intensity in these industries. The other reasons are relatively high interest rates, wage increases during late 1980s, and the economic recession during the early 1990s.

Important factors influencing productivity growth in the Korean steel industry are structural competitiveness as affected by state autonomy, sound economic policies and indigenous technological capability (D'Costa 1994, 53). State autonomy enhances bargaining capacity, easing the transfer of state-of-the-art technology. Effective adoption, assimilation, and utilization of imported know-how creates technological capability. An economic policy that maintains low inflation, positive real interest rates, realistic exchange rates, and an industrial policy that does not completely and indefinitely shelter domestic firms from international competition contribute to structural competitiveness (figure 1).

The political insulation and centralization of the decision-making apparatus allowed the Korean government to implement a flexible industrial policy and, by extension, promote technological capability (D'Costa 1994, 53).

The steel Industry Promotion Law of 1970 granted the steel industry long-term, low-cost foreign capital,



Source: D'Costa (1994, p.52).

Figure 1. A Schematic Outline of Structural Competitiveness: National Policy on Industrialization Strategic Industries/Policy Instrument

reduced prices of electricity, discounts for rail transport, and limited steel imports (D'Costa 1994, 57).

The key to government insularity was the sacking of various officials, the creation of a technocratic Economic Planning Board (EPB), a centralized and autonomous decision-making center and the nationalization and reorganization of the banking sector. The military dictatorship and rapid employment through import substitution and exports allowed Korea to silence the popular forces. These measures ensured the Korean state autonomy and virtually eliminated civilian interference from all economic decision-making.

Institutional measures during the 1960s included the establishment of the Export Promotion Council (EPC) to assist exporters and the creation of the National Tax Administration (NTA) to reduce government deficits and increase savings. Policy instruments included incentives for exports, such as direct subsidies, tax exemptions, discounts for utilities, tariff rebates for re-exports, and low-cost credit. The results of these state-initiated policies were very favorable for almost all dimensions of the Korean economy (D'Costa 1994, 53-55).

Costs are influenced by wage rates and, given Korea's relatively low wage rates, one would theoretically expect

Korea to be cost competitive. The development of the Korean steel industry underscores the importance of economic policy and technological capability. The military regime's "guided capitalism" was the basis for structural competitiveness.[4]

Environmental Regulations in Korea

Before 1980, concern about the environment received little attention in Korea.[5] Only two laws of significance were enacted. A Public Pollution Prevention Law (PPPL) was enacted in 1963 to protect public health and to limit air, water, noise, and vibration pollution. To administer the law, a pollution control office was established in the Ministry of Health and Social Affairs. To address an increase in public concern about pollution, the Environmental Preservation Law (EPL) was enacted in 1977, to achieve two objectives. First, it amended the constitution to include a provision calling for the right to a quality

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[4] The presidencies of Park, Jhung-Hee (1962-1979), Jun, Doo-Hwan (1980-1987), and Ryo, Tae-Woo (1989-1992) are considered as the military regime. During the Park regime, guided capitalism was practiced strongly; however, during the Jun and Ryo regime, guided capitalism was weaker since people were demanding more freedoms.

[5] See the National Business men's Association (Firms and environmental problems, 1992, 67-76, February), the Korea Chamber of Commerce(Environmental Policy for Continuing Economic Growth, 1992, 11-12 and 89-91, August), Ministry of Environment (Korea Environment Yearbook, 1993, 534-550), and Ferrie (1993, 125-187).

environment. Second, it established an environmental office under the Ministry of Health and Social Affairs.

In the early 1980s, pressure from developed countries encouraged Korea to look more closely into its domestic environmental problems. At the same time, the Korean people began to realize the benefits inherent in a clean environment. In an effort to address environmental problems, the government established the Office of Environmental Administration in 1980. For the next ten years, public concern for a clean environment gained momentum. Sensing the relative importance of the environment, the government upgraded the Office of Environmental Administration to a complete ministry, the Ministry of the Environment in 1990. Its primary objective is to enforce government-mandated environmental laws.

Command and control and centralized environmental policies have dominated environmental legislation in Korea. The country has little experience with the application of incentive instruments for environmental regulation, but is in the beginning stage of applying such economic instruments. In 1983, the effluent charge system was introduced to provide polluters with financial incentives to meet effluent standards. Environmental quality improvement charges were introduced in 1991 to provide pollution abatement incentives to potential polluters and to help finance investment projects to improve the environment. In 1993, the Environmental Pollution Control Fund was increased to U.S.$45 million. This fund promotes the installation of pollution control equipment and supports the development of clean technologies. A waste disposal deposit-refund system was introduced to promote resource recycling.

No longer adequate, the Environmental Preservation Law was replaced by six new environmental laws early in 1990.[6] These laws, which cover air, water, noise and vibration and toxic are addressed below (Information is from Environmental Law in Korea and Ferrie 1993). However, basic environmental policy law and environmental damage dispute mediation are not addressed here since these laws are not related to our study.

Air pollution: The Atmospheric Environmental Policy Law (AEPL) is designed to protect and manage air quality. The Atmospheric Environmental Preservation Act (AEPA) provides

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[6] The Environmental Preservation Law, which regulated air, water, noise and vibration in one piece of legislation, could not deal adequately with environmental problems because of their increasing complexity. To overcome the problem, the EPL was abolished, and six new laws were enacted on August 1, 1990, and implemented on February 2, 1991. See Environmental Law in Korea (1991, 5-7).

for "permissible emission standards" to be determined by the Ministry of Environment (MOE). To support the control of stationary source air pollution, the AEPA demands that permits be issued prior to the use of new emissions discharging equipment.

Noise pollution: The purpose of the Noise and Vibration Control Law is to prevent damage from noise and vibration. The Noise & Vibration Control Act sets standards for allowable noise levels in residential areas. It also authorizes local governments to determine noise regulation areas. The Ministry of Environment can require the establishment of noise abatement barriers or other remedial measures to reduce noise and vibration.

Water pollution: The Water Environmental Protection Law is designed to protect the nation's rivers, lakes, and public water sources. Permissible emission standards are instituted under article 14 of the Water Environment Protection Act which sets the maximum amount of pollutants permissible as discharge into waters. The Basic Environment Policy Act (BEPA) bans specifically the dumping of certain wastes, such as industrial effluent, animal carcasses, and sewage into inland lakes, rivers, and streams.

Toxic substance pollution: The purpose of the Toxic

Chemical Control Law is to investigate damage and to control the amount of toxic substance pollution. The Toxic Chemicals Control Act of 1990 regulates the manufacture, import, export, and handling of toxic substances.

Environmental Regulations in the Steel Industry

Environmental expenditures by the Korean government increased significantly from 100.7 billion won in 1986 to 496.3 billion won in 1991 because of increased public demand for a cleaner environment (table 14). Expenditures, mainly for water, air quality improvements, and waste management, rose from 0.12 percent of GNP in 1986 to 0.24 percent of GNP in 1991. Indications are that the ministry will have spent about 12,191.7 billion won in the years 1992 to 1996 on the environment.

A new emissions standard for the steel industry went into effect on January 1, 1995, and on January 1, 1996 (appendix table A.2). Water standards were also raised on January 1, 1996 (appendix tables A.3, A.4).

Table 14. Korean Government Environmental Expenditures
(in billions of Korean won)

	1986	1987	1988	1989	1990	1991
Total	100.7	165.8	216.0	180.6	252.4	496.3
Env. Exp./GNP	0.12%	0.17%	0.16%	0.13%	0.16%	0.24%

Source: Ministry of Environment, Korea Environmental Yearbook, 1991

Table 15. Sectoral Environmental Expenditures, 1992-1996
(in billions of Korean won)

Total	Water quality	Waste management	Air quality
12191.7(100%)	3872.6(31.76%)	3163.1(25.94%)	4648.3(38.12%)

Source: Ministry of Environment, Korea Environmental Yearbook, 1991

Internationally, advanced countries have prepared international treaties related to environmental regulations and have recommended that developing countries comply (Kim, Dong-Moon 1992, 32-43):

1. Montreal Protocol (ban on freon gas production, 1987)

2. Basel Convention (ban on movement of toxic wastes from nation to nation)
3. Convention on Climate Change (measures to alleviate green house effects, UNCED, 1992)
4. Convention on Biological Diversity (protection of biological resources, UNCED, 1992)

Advanced countries are applying stricter environmental standards on imported goods to protect both the environment and their industries. There are 152 international environmental agreements, 18 of which are used for trade regulation (Sim 1994).

Table 16. International Environmental Agreements Affecting Trade

	Total Number of Agreements	Number of Agreements Affecting Trade
Protection of the sea*	66	0
Protection of flora and fauna	29	15
Nuclear energy and air pollution	13	1
Toxic waste	2	2
Others	44	0
Total	152	18

*In 1994, an additional environment agreement was adopted that contains a provision affecting trade.
Source: Sim, Hoo-Sup, 1994, 57-60.

Since 1993, the United States has required that all imported goods containing CFCs carry a warning label. Germany requires manufacturers or sellers to collect used product packaging materials. The regulation went into effect in 1993 and has been extended to home appliance disposal collection. Most advanced countries are practicing the recognized system of the environmental mark to encourage clean environmental products. The mark is not easy to obtain and could be a barrier to trade for some countries (Sim 1994). The trade regulations in environmental agreements, such as the Montreal Protocol, Basel Convention, Convention on Climate Change, Convention of Biological Diversity, and standardization of international environment management could have a significant effect on the Korean steel industry.

Environmental Considerations in the Steel Industry

Pollution, a symbol of economic growth, is now a factor that threatens economic growth in Korea. Steel industry processes, from iron ore to steelmaking, require huge facilities and capital investments, are highly energy-consuming, and produce significant pollution. According to the general environmental situation, the environmental regulations for the industry are becoming stricter, and abatement expenditures are rising. Pollution control expenditures focus mostly on steel slag, particle, mill-scale, sludge, and related waste treatment (NBMA 1992, 18).

Abatement Investment Trends

Pollution control investments in the steel industry increased significantly from 237 billion won in 1987 to 359 billion won in 1992 (table 16). Air pollution control expenditures rose to 187 billion won in 1992 from 180 billion won in 1987. For water to 136 billion won from 46 billion won in 1987. For noise and vibration, expenditures rose to 13.8 billion won in 1992 from 1.6 billion won in 1987. Especially significant, percentage of environmental expenditures allocated to water quality rose from 19.6 percent of total environmental expenditures in 1987 to 37.9 percent in 1992. In 1992, environmental expenditures went mostly for air pollution control (52.2 percent),

Table 17. Environmental Investments in the steel Industry
(in millions of Korean won)

	1987	1988	1989	1990	1991	1992
Air	180,908 (75.8)	104,052 (79.8)	61091 (60.0)	137,033 (55.3)	65,334 (62.4)	187,801 (52.2)
Water	46,805 (19.6)	23,819 (18.3)	34,407 (33.7)	77,196 (31.2)	27,488 (26.2)	136,218 (37.9)
Noise & Vibration	1,682 (0.7)	1,373 (1.1)	5,372 (5.3)	25,435 (10.3)	803 (0.8)	13,898 (3.6)
Waste	- -	- -	- -	- -	- -	9,824 (2.7)
Others	9,393 (3.9)	1,109 (0.8)	1,021 (1.0)	7,932 (3.2)	11,137 (10.6)	12,092 (3.3)
Total	238,788	130,353	101,891	247,696	104,62	359,833

Source: see Chulganbo, Rational approval discharge standard of steel industry, 1994, 63
Note : Figures in Parentheses are Percentages

water pollution control (37.9 percent), noise an vibration control (3.6 percent), waste control (2.7 percent), and others (3.3 percent).

Waste Matter Production and Treatment

Although the amount of pollution in Korea is increasing significantly, the growth ratio of recycling is increasing even more rapidly (NBMA 992).

Steel slag: The major waste from the steel industry is

Table 18. Statistics on Waste Matter Production and Treatment (MT)

Items	Year	Amount of Production	Recycling		End Treatment	
			Internal Recycle	Selling	Internal Treat.	Commiss-ional Treat.
Steel Slag	89	8,269,781	1,749,026	2,487,655	3,692,127	100,051
	90	8,908,684	1,505,103	2,744,202	4,913,362	119,967
Particle	89	653,794	446,340	25,579	104,125	56,015
	90	790,339	563,944	41,913	97,792	76,921
Mill-Scale	88	401,081	-	401,081	-	-
	89	422,874	318,088	102,277	-	-
	90	461,972	346,961	122,331	-	-
Sludge	88	447,974	-	221,030	206,119	20,825
	89	541,589	98,302	122,330	300,261	20,612
	90	687,419	120,333	133,513	409,866	23,244
Waste Oil	88	7,606	-	1,008	2,258	4,340
	89	8,546	-	822	3,575	4,093
	90	10,031	-	935	3,575	3,770
Waste Acid	88	35,598	-	8,739	7,200	19,659
	89	32,271	17,180	9,352	-	5,739
	90	4,401	26,035	11,179	-	7,074
Waste Tile	88	162,192	-	13,028	144,664	50,800
	89	193,238	-	7,703	142,000	45,231
	90	198,985	-	4,639	148,000	59,030
Waste Sand	88	53,793	-	-	2,993	50,800
	89	66,070	-	-	10,561	45,231
	90	83,217	-	-	10,679	59,030
Ferro Oxide	89	18,600	4,800	11,000	-	-
	90	21,400	6,200	12,200	-	-

Source: National Business man Association, Firm and environmental problems, 1992, 75 steel slag. The amount of steel slag has increased significantly: 7.6 million MT in 1988, 8.3 million MT in 1989, and 8.9 million MT in 1990. In 1990, the steel industry managed the steel slag internally: recycling, 1.5 million MT; selling, 2.7 million MT; internally treatment, 4.9 million MT; and commission treatment, 0.12 million MT. Recycled slag is useful for construction materials, fertilizer, cement block.[7]

Particle: Based on 1990 steel statistics, 790,339 tons of particle were produced. Of that amount, 700,000 tons were produced by POSCO (88.9 percent of total particle), 90,000 tons electric utility furnace firms. POSCO recycled 560,000 tons, sold 36,000 tons, and self-treated 100,000 tons. Electric furnace companies sold 7,000 tons and treated 77,000 tons by commission treatment. Compared to advanced countries, the ratio of dust occurrence in the Korean steel industry is high due to the use of a low quality of steel

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[7] See Steel Yearbook (1993, 301-303) and Kim, Doo-Won (Environmental Manager, 1992, 6-9). To increase recycling of the steel slag, the government needs to relax some restrictions of slag use (Ministry of Environment does not allow the use of steel slag for the road construction, if the ministry allows the steel slag to use road construction, the amount of slag recycled will increased), and the steel maker need to develop the method of recycle.

scrap as a source material (Chulgangbo 1994, 63).

Mill-scale: The production of mill-scale, the by-products of rolled steel, is increasing significantly; however, all mill-scale is sold as a raw material for other products. Mill-scale production has increased as follows: 401,081 MT in 1988, 422,874 MT in 1989, and 461,972 MT in 1990. In 1990, it internally recycled 346,962 MT and sold 112 thousand MT.

Sludge: The production of sludge has increased 20 percent annually since 1988: 97 percent is treated by producers and 3 percent by commission. The data show that 447,974 MT in 1988, 541,589 MT in 1989, and 687,419 MT in 1990 sludge was produced. In 1990, about 255,846 MT was recycled and 433,110 MT end treated.

Others: Most waste matter, such as waste oil, waste tile, waste sand, and ferro oxide are recycled (table 18).

Summary

The steel industry has had a significant role in economic development the last two decades. The contributions of the steel industry in the economy is 2.4 percent of GNP, 8 percent of total nation's export, 8.1 percent of total manufacturing production, and 3.2 percent of nation's employment in 1993.

Most productivity studies show that the steel industry has experienced a productivity slowdown. This is particularly true of the steel industry which is lower than the industrial average. Some factors of the productivity slowdown are the Heavy and Chemical Program, the first and second oil shocks, the high interest rate, the economic recession, and the high wage hike during 1970s and 1980s.

The environmental investment by the Korean government has increased significantly from 100.7 billion won in 1986 to 496.3 billion won in 1991 to meet public and international demand for a cleaner environment. Thus, the Minister of Environment announced stricter environmental standards. To comply with these standards, the Korean steel industry has significantly increased environmental investments from 238 billion won in 1987 to 359 billion won in 1992.

The steel industry has produced a significant amount of waste matter such as steel slag, mill-scale, particle, and sludge. However, the rate of waste matter recycling is increasing faster than its production. At this time it is important to determine the impact that environmental regulations have had on productivity growth.

Chapter 3

LITERATURE REVIEW

The unbridled growth of the Korean steel industry has damaged the environment to an extent unacceptable to the nation. In response, the government has implemented a much stricter set of environmental measures. However, the Korean steel industry itself now faces new problems. With profits down, and demand diminishing, the industry is finding it difficult to comply with environmental restrictions.

The literature reveals conflicting views about the impact of environmental regulations on productivity. The first is that the cost of environmental protection is a cost of production, and, as such, is causing a slowdown in productivity growth. The other view is that environmental regulation could improve overall production efficiency and encourage technical change, and finally, it could help to improve productivity growth.

Traditional View of Environmental Regulations

Most studies regard expenditures to implement environmental requirements as a cost of production, and a reason for the productivity slowdown experienced by most developed countries. The main idea behind this argument is that some of the available investment capital for production goes to pollution control to comply with environmental regulations. This view has been explored by Denison (1979) who used a growth accounting approach to productivity measurement. His model includes environmental requirements as a variable to derive an estimate of the contribution of these requirements to productivity growth. He estimates the effects of environmental regulation by estimating the incremental costs of production due to environmental requirements. The cost of environmental requirements indicates the level of reduction in output. He finds that average annual productivity fell by between 0.05 and 0.25 percent points in the 1970s as a result of direct environmental control expenditures.

Conrad and Morrison (1989), in a comparative study of the United States, Germany, and Canada on the impact of pollution abatement investments on productivity change between 1960 and 1980, also used a growth accounting approach. They assumed that pollution abatement capital is not productive in the usual sense. Their method, as in other productivity studies, does not recognize pollution abatement as a benefit. They include pollution abatement capital as an independent variable to estimate pollution abatement requirements on productivity growth. They conclude that there is evidence to show that pollution abatement capital has depressed productivity growth for all three countries with the highest impact in the United States, even though treating pollution abatement capital incorrectly in productivity computations has biased productivity measures downward, especially for the late years in the sample and for poor productivity growth years.

Gray (1983) examined the impacts of environmental regulation on productivity growth, focusing on worker health and safety regulations of the Occupational Safety and Health Administration (OSHA) and environmental regulations of the Environmental Protection Agency (EPA). He used data for 450 manufacturing industries between 1958 and 1978. He concentrated on total factor productivity measures of productivity growth. Productivity growth for each industry is calculated from 1958 to 1978, based on a growth accounting model with five inputs. The measure of EPA regulation is operating cost for pollution control. The data are based on surveys by the Bureau of Census since 1973. Gray found a negative relationship between environmental regulations and productivity growth. He compared TFP growth for the periods 1959-69 and 1973-78. He found that during the latter period, approximately 30 percent of the productivity decrease in the manufacturing sector was due to environmental regulations.

Several advantages accrue when using the growth accounting approach to estimate productivity growth. The greatest advantage is that it is easy to estimate productivity. Also, the growth accounting method allows each observation's data to influence only its own productivity value. In contrast, estimation methods whose parameters depend on all the observations allow all of the calculated productivity growth to be affected by each period's data. When some of the data are of poor quality it may be just as useful to focus the effect of each data point only on that period's productivity estimation.

On the other hand, there are several disadvantages to using the growth accounting method. The greatest disadvantage is that we cannot fully examine the assumptions that led to the results. Also, because the growth accounting framework does not definitely identify interactions between inputs in production, it is not possible to calculate substitution elasticities (Sim 1994, 58).

Gray and Shadbegian (1993) used plant-level data from 1979 to 1990 to examine the impact of environmental regulations on productivity growth. They used the production function approach. To estimate the production function, they estimated a plant's outputs and inputs, such as labor, capital, and materials. They include pollution abatement costs as an explanatory variable to see how the contribution of different inputs is affected by abatement costs. To do this, they used the translog production function, which is a second-order logarithmic approximation to an arbitrary production function, allowing for interactions between different inputs. The data includes three industries--paper, oil refining, and iron and steel. They found that industries with higher compliance costs have significantly lower productivity levels and slower productivity growth rates. They conclude that a $1 increase in abatement costs is always associated with a decrease in output of significantly more than $1, closer to $3.

Gollop and Roberts (1983) estimated the effects of sulfur dioxide emission restrictions on the rate of productivity growth in the electric industry from 1973 to 1979, using a cost-function approach for the regulated industry. The model of total factor productivity was based on a factor-minimal cost function for an electric utility. Production costs are assumed to be a twice-differentiable function of the input prices of labor, capital, low-sulfur fuel, high-sulfur fuel, the output of kilowatt hours, regulatory intensity, and time. They defined the regulatory intensity for each utility as a function of the legally mandated reduction in emissions and the effective enforcement imposed on the utility. The results show that emissions regulations result in significantly increasing production costs of electricity because of the use of increasing low-sulfur fuels in order to decrease pollution. The average rate, the slowdown in productivity growth, was 0.59 percent per year for constrained electric utilities compared to unconstrained firms during the period 1973-79.

Barbera and McConnell (1990) developed an approach to measure the impact of environmental regulations on total factor productivity (TFP) growth which is less restrictive than a simple growth accounting approach.[8] The authors point

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[8] Norsworthy and Jang (Empirical Measurement and Analysis of Productivity and Technological Change, 1992, 9-13) define Total Factor Productivity (TFP) as the productivity of all purchased inputs, the broadest measure of productivity, and the only measure whose increase is unambiguously beneficial in the sense that it corresponds to a decline in the total unit cost of production.

TFP = tons of output/total factor inputs in constant dollars. Then TFP is simply the ratio of the total cost of producing all outputs to total cost of all inputs: after all variable input factors have been paid, the remainder of total revenues is defined as the cost of capital out that environmental regulations have a direct impact on productivity growth due to the diversion of resources toward required abatement capital.[9] Furthermore, there can be a further indirect effect as conventional inputs and production processes are changed in response to requirements to purchase abatement capital.[10] The authors estimate this indirect effect using a flexible functional form cost function.

Their study focuses on five heavily polluting industries: paper; chemicals; stone, clay, and glass; iron and steel, and non-ferrous metals to measure total factor

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input.

[9] Barbera and McConnell assume that environmental regulations require the firm to buy abatement capital, and that industries combine this abatement capital with conventional inputs to produce output and to reduce pollution. They define direct effect of abatement capital that abatement capital imposes a direct cost on the industry causing total input cost to be higher for the same level of output.

[10] Barbera and McConnell define indirect effect of pollution abatement requirements that the requirements are likely to affect the amount of combination of conventional inputs necessary to produce output. This is a move in the production function for manufactured output and it will be defined as the indirect effect. Indirect effect of pollution abatement requirement on output could be either positive or negative. It may mean that more labor and energy should be used in combination with the abatement capital, in this case, productivity of the conventional output will decline.

productivity and the direct and indirect productivity effects due to environmental regulations. They use a cost function to estimate productivity growth between 1960 and 1980. The model consists of eight variables: output, capital, labor, energy, material, abatement capital for the indirect effect, time for technical change, and abatement costs for direct effects. The authors find that the indirect effect can be either positive or negative. The net impact of environmental regulations on total factor productivity growth is fairly small, given that these are the most polluting industries. The authors account for about 10-30 percent of the productivity decline of the 1970s in these industries.

Christensen and Haveman's (1981) survey of research studies which includes an allocation study, a wide range of other industry-specific, cross-section and time-series regression studies, and macroeconometric studies investigated the causes of the post-1965 slowdown in productivity growth. They review studies done by analysts such as Denison (1974 and 1979), Kendrick (1978), Siegel (1980), Kutscher et al. (1977), Mark (1978), Evans (1978), Clark (1978), and Norsworthy et al. (1979).

Christensen and Haveman observed that environmental regulations can have major adverse output and productivity impacts on certain sectors or industries. They conclude that environmental regulations are responsible for between 20 and 30 percent of the observed slowdown in labor productivity. In general, environmental regulations account for from 8 to 12 percent of the 1970s decline in productivity for the entire manufacturing sector.

These authors also point out reasons why environmental regulation could lead to decreased productivity growth.

First, environmental regulations demand investments in pollution control equipment which compete with non-abatement investments in productive plant and equipment. Therefore, labor could get less capital than it otherwise would and, as a result, output may decrease. Second, environmental regulations tend to encourage an inefficiently high level of capital investment and intensity because regulations are performance standards rather than engineering standards. Third, new sources of pollution are subject to stricter standards than existing sources that may cause a holdup in the introduction of new capital and progressive technology. Fourth, installed pollution control equipment requires labor for its operation and maintenance which does not seem to contribute to output. They explain that environmental regulations are one of the factors contributing to productivity slowdown. The main idea of most traditional studies and the reaction from industry managers is that environmental regulation is considered only as a cost of production.

New View of Environmental Regulations

Many studies point out that environmental regulations are frequently cited as a partial explanation for the slowdown in productivity growth experienced by many advanced countries. Regulations could possibly discourage new investments, slow down new product development, and delay employment of new production procedures. However, some studies show that regulations may have useful effects on productivity growth. Due to pressures to reduce waste discharges, some firms employ more productive production procedures and cost-saving processes from recycling raw materials which could reduce total costs.

Firms may also increase pressure on workers and managers to be more productive in order to recover some of their increased costs caused by environmental regulations. Some of the research in the United States supports these views (Porter 1990, Clark 1980, Tobey 1990, and Jaffe et al., 1993). These studies show that in some cases, regulation may have beneficial effects on productivity growth. Porter (1990) claims that strict product regulations can also encourage firms to produce less polluting or more resource-efficient products. One example he cites is the 3M company. Since 1975, it has saved $482 million by decreasing more than 500,000 tons of waste and pollutants, and another $650 million by conserving energy. However, he does not say that all firms are happy about strict environmental regulation, because it might increase production costs in the short term. Porter points out that even though Germany and Japan have strong environmental regulations, both countries have experienced tremendous growth in industrial productivity.

Clark (1980) examines the effect of unionization on productivity growth by using time-series data from the U.S. cement industry between 1953 and 1976. His study focuses basically on the change in output within a given establishment over time and the influence of technological innovation in improving the efficiency of operation and management. The empirical results show that unionization has led to gains in productivity of between 6 and 8 percent, and that unionization has led to changes in the behavior of workers and managers. Although this study is not directly related to environmental regulations, it does show that some kinds of intervention -- unionization, for example -- could improve productivity by improving efficiency and innovations.

Tobey (1990) analyzes the effect of environmental regulations on net exports by using the cross-section Heckscher-Ohlin-Vanek model of international trade. He measures the degree of environmental stringency on a scale from one to seven.[11] He finds that stringent environmental regulations did not significantly affect international trade patterns in the most polluting industries in industrialized countries in the 1960s and early 1970s.

Jaffe, et al. (1993), reviewed the literature regarding environmental regulations and the competitiveness of U.S. industry. Much of the literature has shown that environmental regulation may decrease exports and increase imports in the manufacturing sector, especially in "pollution-intensive" goods. The authors were not able to find empirical studies which confirm the innovation-

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[11] Tobey (1990, 196) defined the degree of environmental stringency: one is the degree of tolerant (such as, Cyprus and Liberia), seven is the degree of strict(such as, United States, Sweden, and Japan).

stimulating effects of environmental regulations. However, they found that some of the literature suggests that the short-run costs of environmental regulation could be offset in the long run by stimulating innovation and efficiency.

Several case studies in Korea show that environmental regulations could encourage productivity growth (Jang 1993, Jung Foods 1993, Sunyang 1994, You and Yan 1994, Jung and Choi 1994, and Kwon 1994).

Jang (1993) states that stringent environmental regulations could encourage faster economic development. He cites as an example the success of the Japanese automobile which is due to strong air quality controls imposed by the Japanese government.

Jung Foods producer of soybean drink is a good practical example that environmental regulations work on improving productivity. The company has reduced its waste water through an efficient producing procedure that uses byproducts as an animal food by introducing the Steam Indirect Drying System (SIDS) and has earned $240,000 annually from the sale of the byproduct (Bulletin of Korean Environmental Managers Federation 1993, 7-9).

Another industry example is Sunyang, a firm that produces 50,000 barrels of wine per year (Environment and

Life 1994). The firm reduced production costs and improved production efficiency through the standardization of intermediate material inputs and the degree of chemical inputs. This action resulted in preventing the generation of pollution and polluted water from the producing procedure, they could reduce 17 percentage pollution of the discharge affecting biochemical oxygen demand.

You and Yan (1994), in a descriptive study compared similarities and differences in quality control and pollution control to suggest a firm's basic strategy for structuring environmental management by applying quality control management. They found that there are many similarities between environmental pollution and quality control, and that firms do not try to solve pollution problems on their own without enforcement. Also they found that the environment regulations could be a source of competitive advantage. However, this study did not use statistical methods, but was descriptive.

Jung and Choi (1994) analyzed how carbon taxes impact major Korean industries. They argue that environmental regulations, such as a carbon tax, could improve energy efficiency through changes in the energy consumption structure.

Kwon's (1994) view is similar to Porter's. He believes that although environmental regulations could be a factor in cost increases in the short run, they could create markets for environmental equipment and new businesses related to environment protection, and stimulate the technology for environmental products. Also, environmental regulations can be a factor in international competitiveness in the industry in the long run.

Most of these studies could not show statistical data or an econometric model to support their ideas, and these studies are not directly related to productivity growth. However, these views show that environmental regulations could encourage an increase in the efficiency of production and decreasing pollution at the industry level.

Existing studies show the two different views of environmental regulation on productivity growth. Many studies support the view that environmental regulations are one significant factor in the productivity slowdown. However, some of the studies argue that environmental regulations could be one factor contributing to productivity growth.

Summary

There are two conflicting views on the effects of environmental regulations on polluting industries in general. The first view has been proved by many empirical studies. Denison (1979), Conrad and Morrison (1989), Gray (1983), Christensen and Haveman (1981), Gray and Shadbegian (1993), Gollop and Roberts (1983), and Barbera and McConnell (1990), suggest that environmental regulation will reduce productivity growth in industries. Even though much of the empirical evidence shows the negative effects of environmental regulations on industries, some other studies have a different point of view. The regulations may improve productivity by improving efficiency and innovations. Not many studies support this view. Porter (1990), Clark (1980), Tobey (1990), and Jaffe, et al. (1993) studies in the U.S. and the Jang (1993), Jung Food (1993), Sunyang (1994), You and Yan (1994), Jung and Choi (1994), and Kwon (1994) in Korea show that there is a possibility that some regulation could improve productivity growth by stimulating the innovation and efficiency of production.

Chapter 4

METHODOLOGY

In this study, we use the Barbera and McConnell (1990) total factor productivity model to estimate the impacts of environmental regulation on productivity growth in the Korean steel industry. The period under study is between 1967 and 1993.

We will use the TFP model for several reasons. First, the main advantage of the translog function is that it allows us to examine the interactions among the different inputs which is not possible with the gross accounting approach. Second, many studies of productivity measurement are based on a model of the production process which recognizes pollution abatement capital costs (direct effects) but not pollution abatement capital (indirect effects). Barbera and McConnell's model recognizes both. Third, a model that explicitly incorporates a cost function provides tests for whether regulations affects on productivity differ across inputs, and allows a more complete explanation of how regulation effects productivity.

This chapter covers the measurement of total factor productivity by decomposing the measured growth in TFP into technology, direct, and indirect effects.[12] Capital is separated into productive and abatement. Direct and indirect effects of required abatement capital are separated to examine the direct and indirect effect of abatement requirements on productivity growth. A translog cost function for production of steel is used to calculate the effect of abatement requirements on productivity growth.

To investigate the impacts of environmental regulations on productivity growth, we employ three models. The first will estimate only TFP. Model 1 assumes no environmental restrictions. Pollution abatement capital cost and capital are not included in the model.

Second, to see only pollution abatement cost effects on productivity growth, a translog cost model is used that includes pollution abatement capital cost as one of the independent variables. In this model, we assume that environmental regulations exist but are considered only as a cost of production.

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[12] The direct abatement effect reduces TFP as long as abatement capital costs are increasing. The indirect effect of abatement requirements can either increase or decrease TFP depending on how these requirements affect the production process for output, therefore, the total effect can be either positive or negative depending on the magnitude of the changes.

The third model will examine all of the abatement effects on the productivity side by including pollution abatement capital costs and capital to analyze direct and indirect effects since there are environmental regulations in the real world. Even though we include two other models in this study, the primary focus is on model 3 since we are mainly looking for abatement effects.

First TFP Model

If there are no environmental regulations, and firms have no obligations to comply. A single output (Q) is produced by inputs of capital (K), labor (L), energy (E), and material (M). The production function can be expressed as

$$Q = Q(K, L, E, M, t) \tag{1}$$

We assume that the industry minimizes production costs (C) subject to an exogenous level of production, input prices (P_i), and technology (t). Under the assumption of cost-minimizing behavior, the theory of duality between cost and production implies that for any production function of the form (1), there exists a cost function that provides an equivalent description of the technology. The cost function can be written as follows:

$$C = C(Q,\ P_i,\ t) \tag{2}$$

where P_i is the vector of input prices, which are composed of P_K, P_L, P_E, and P_M, representing capital, labor, energy, and material price, respectively [$C = P_K{*}K + P_L{*}L + P_E{*}E + P_M{*}M$]. t represents technology which is simply defined as a time function. Q is the production of the firm.

If we totally differentiate the cost function with respect to time, we obtain the shifting of the cost function through time.

$$\frac{dC}{dt}=\sum_i \frac{\partial C}{\partial P_i}\frac{dP_i}{dt}+\frac{\partial C}{\partial Q}\frac{dQ}{dt}+\frac{\partial C}{\partial t} \tag{3}$$

Rearranging equation (3) by dividing through by C and using Shepard's Lemma, we obtain the following expression for the growth in total costs.[13]

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[13] Equation (4) is in terms of instantaneous changes, and data are available on a yearly base. In order to convert from the discrete approximation to the continuous formula the Tornqvist approximation is used. If we set ΣSi dlnPi/dt is F:

$$\frac{dlnC}{dt}=\sum_i S_i\frac{dlnP_i}{dt}+E_{CQ}\frac{dlnQ}{dt}+\frac{\partial lnC}{\partial t} \qquad (4)$$

where $S_i = X_i p_i/C$, I = K, L, E, and M.
$E_{CQ} = \partial lnC/\partial lnQ$

We define the growth rate of TFP as the growth in cost not accounted for by growth in prices and output. Therefore, TFP is defined (Denny, et al. 1981) as

$$TFP=-\frac{dlnC}{dt}+\sum_i S_i\frac{dlnP_i}{dt}+\frac{dlnQ}{dt} \qquad (5)$$

To obtain reasonable results in the model, we use the assumption of constant returns to scale (CRS) because this assumption gives us several important properties. It is not always easy to obtain reasonable results from the industry data set by using the translog cost function. We need much a abundant more data set, and the cost model should satisfy the monotonicity condition that marginal production should

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$\Delta logF=log(F_t/F_{t-1})=0.5\Sigma_i(s_{it}+s_{i,t-1})log(X_{it}/X_{i,t-1})$,

where X_{it} is the quantity of input X_i used in period t, $s_{it}=P_{it}X_{it}/\Sigma_j P_{it}X_{it}$ the cost share of input X_i in TC during period t (Denny, et al. 1981, 188).

always be stable in order to relax the CRS assumption. However, since we use annual steel industry data to estimate TFP by using the translog cost function (we have only 27 observations), it is not easy to obtain reasonable results. To avoid this problem, the assumption of CRS is necessary in the cost model to obtain the monotonocity condition in our model. Second, CRS allows a simplification of the translog model and convenience of estimation.

Production exhibits constant returns to scale (E_{CQ} = 1), we join equation (4) and (5) which yield:[14]

$$TFP=-\frac{\partial lnC}{\partial t} \tag{6}$$

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[14] Barbera and McConnell (1990, 54) use Haxilla and Kopp's (1982) results to assume constant returns to scale (CRS) in their translog cost model. Haxilla and Kopp point out that an assumption of CRS is necessary in the translog cost function to estimate the cost function by using an industry data set. Because, in order to relax the CRS assumption, we need a more abundant data set than the annual industry data set. Without the assumption of CRS, the cost function, it is difficult to satisfy the concavity and monotonicity conditions that marginal production should always be stable. And they find out that most of manufacturing industries are CRS.

Kim and Hong (1992, 33) also point out that an assumption of CRS in the translog function is necessary, because, in general, it is difficult to obtain reasonable results from the translog function. To obtain a satisfaction results, the translog function should satisfy the monotonicity condition. To do this, all of T_{ij} should be zero ($\Sigma_i T_{ij}=\Sigma_j T_{ij}=0$). And if we accept CRS assumption, the translog function can be simplified (since E_{CQ}=òlnC/òlnQ=1).

In this case the total factor productivity growth is identically equal to the technical change.

Using equation (2), a cost function can be approximated by the second-order translog cost function (Christensen et al. 1973 and Binswanger 1975).

$$\begin{aligned} \ln C = {} & \beta_o + \textstyle\sum_i \beta \ln P_i + 0.5 \textstyle\sum_I \sum_j \tau_{ij} \ln P_i \ln P_j + \beta_t t \\ & + 0.5 \tau_{tt} t^2 + \Theta_Q \ln Q + \textstyle\sum_i \tau_{itln} P_i t, \end{aligned} \tag{7}$$

where $I = \{K, L, E, M\}$.

To estimate equation (7), we need additional information. First, to calculate (7) alone would cause degree-of-freedom problems. We have annual industry data from 1967 through 1993 for the steel industry (in model 3, we have 29 parameters with 27 observations). Second, if we calculate (7) alone, it is not obvious that the resulting parameter estimates would be based on a cost function which satisfies convexity and monotonicity conditions. Both of these problems are solved by calculating jointly with the cost function (7), the factor share equations (8).[15]

In the cost share equation, we can get by the partial derivatives cost function with respect to the factor prices, so that the share equations are given by $S_i = \partial \ln C/\partial \ln P_i$ or:

$$S_i = \beta_i + \sum_j \tau_{ij} \ln P_i + \tau_{it} t, \qquad \text{where } I,\ j = K,L,E,M. \tag{8}$$

The cost function must be homogeneous of degree one in prices (a doubling of prices doubles cost), and satisfy the

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[15] Since we use a translog cost function ($\ln C_t - \ln C_{t-1} = \beta[\ln C'_t(Q:P) - \ln C_{t-1}] + e_t$), the error terms for different observations are correlated, as in: $e_t = \delta e_{t-1} + u_t$. These errors increase the variance of the distribution that any given estimate is likely to differ from the true β. This serial correlation causes OLS to underestimate the variances (and standard errors) of the coefficients. It will cause it to overestimate the t-statistics of the estimated coefficients. To eliminate this problem (serial correlation) the model should have been estimated by a simultaneous estimation procedure (Mohr 1975, 148).

The system of cost-share equations is assumed to have no contemporaneous cross equation correlation in the vector of error terms ($e_{1t}, e_{2t}, \ldots, e_{nt}$) for all t (Mohr 1975, 162). The cost share equations can be obtained from Shephard's lemma as $S_i = \partial \ln C/\partial \ln P_i$. The fact that $\Sigma S_i = 1$ implies the constraints $\Sigma_i \beta = 1$, $\Sigma_j \tau_{ij} = 0$, and $\Sigma \tau_{it} = 0$. The second-order approximation property of the function implies the additional constraints $\tau_{ij} = \tau_{ji}$ (in our study we treat the translog cost function as a second-order approximation to any conditions, twice differentiable cost function. As a result, the matrix of τ_{ij}'s in cost function is equivalent to the Hessian of the Taylor series expansion of the true cost function. Thus, this matrix must be symmetric or $\tau_{ij} = \tau_{ji}$. (Mohr 1975 and Denny, et al. 1981)).

conditions corresponding to a well-behaved production function. This implies the following parameter restrictions:[16]

$$\sum_i \beta_i=1, \quad \sum_j \tau_{ij}=\sum_i \tau_{ij}=0, \quad \sum \tau_{it}=0, \tag{9}$$

The system of equations consisting of the cost function (7) and four cost-share equations (8) can be estimated as a simultaneous system. To estimate TFP, we employ Zellner's seemingly unrelated regression technique, and estimate the cost function (7) with cost share equation (8) with respect to restrictions (9) since OLS estimators are no longer

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[16] The definition of linear homogeneity (if $\partial \ln C/\partial \ln Q=K$, a constant, then the structure of production is homogeneous) is that proportional rise in prices should not change composition of cost minimize bundle, or cost must rise by exactly fraction of price increase. Some restrictions require linear homogeneity in factor prices in the cost function such as $\Sigma_i\beta=1$, $\Sigma_j\tau_{ij}=\Sigma_i\tau_{ij}=0$, $\Sigma\tau_{it}=0$ (Pindyck 1979, 170 and Christensen, et al. 1973).

The parameters(τ_{ij}) have little economic meaning of their own. They are related to variable elasticities of substitution and of factor demand (Binswanger 1974, 379). The first constraint is related to cost shares ($\Sigma_i\beta_i=1$) which should sum up to one. The second constraint is related to the linear homogeneity in factor prices in the cost function ($\Sigma_i\tau_{ij}=\Sigma_j\tau_{ij}=0$, homogeneity in prices). The coefficients in the cost share equations should have symmetry specification ($\tau_{ij}=\tau_{ij}$, symmetry condition). The third constraints show the technical interaction among the inputs such as capital, labor, energy, and materials and non-neutral technical change ($\Sigma\tau_{it}=0$).

efficient.[17]

The change in C, attributable to technical change is found by taking the partial derivative of (7) with respect to t. Technical change estimates can be obtained when the parameters of the cost function are estimated.

$$\frac{\partial \ln C}{\partial t}=\beta_t+\tau_{tt}t+\sum \tau_{it}\ln P_i. \qquad (10)$$

Second TFP Model

Under the assumption of cost-minimizing behavior, there exists a cost function that can be written as follows:

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[17] The system can be estimated by Zellner's (1962) seemingly unrelated regression technique. In this procedure regression coefficients in all equations are estimated simultaneously by applying Aitken's Generalized Least-Squares (GLS) to the whole system of equations. The feature of the application of using this technique is that the independent variables of different equations are not highly correlated. To avoid serial correlation of this translog cost function, we use Zellner's technique to estimate the cost function because the error terms across share equations are correlated. The error terms are assumed deviations, random and serially uncorrelated.

In our model, restrictions across equations ($\tau_{ij}=\tau_{ji}$) are imposed (because the cost function must be homogeneous of degree one in prices, and satisfy the conditions corresponding to a well-behaved production function. This implies the following parameter restrictions: $\Sigma_i\beta=1$, $\Sigma_j\tau_{ij}=\Sigma_i\tau_{ij}=0$, $\Sigma\tau_{it}=0$) OLS estimators are no longer efficient despite the fact that all equations constrain the same explanatory variables on the right-hand side. Thus, the seemingly unrelated regression is applied (Binswanger 1974, 381).

$$C = C(Q, Pi, t), \tag{11}$$

To see the direct costs of abatement capital effects on TFP, model 2 incorporates abatement costs for production. Thus, in equation (12), the total capital costs (C*) include abatement costs (AC).

$$C^* = C(Q, Pi, t) + AC \tag{12}$$

In differentiating equation (12) with respect to time we obtain

$$\frac{dC*}{dt} = \sum \frac{\partial C}{\partial P_i}\frac{dP_i}{dt} + \frac{\partial C}{\partial Q}\frac{dQ}{dt} + \frac{\partial C}{\partial t} + \frac{dAC}{dt} \tag{13}$$

In equation (13), we divide by C and apply Shephard's Lemma,

$$\frac{d\ln C*}{dt} = S_c\left(\sum S_i\frac{d\ln P_i}{dt} + E_{CQ}\frac{d\ln Q}{dt} + \frac{\partial lnC}{\partial t}\right) + S_{AC}\frac{d\ln AC}{dt} \tag{14}$$

Where:

S_C = C/C*
S_{AC} = AC/C*

$S_i \quad = XiPi/C, i = K,L,E,M$
$E_{CQ} \quad = \partial LnC/\partial LnQ$

TFP is defined as

$$TFP = -\frac{d\ln C*}{dt} + \sum S_i \frac{d\ln P_i}{dt} + \frac{d\ln Q}{dt} \qquad (15)$$

By using this definition of TFP, and assuming that C exhibits constant returns to scale ($E_{CQ} = 1$), we join equations (14) and (15), which yield

$$TFP = (-S_C \frac{\partial \ln C}{\partial t}) - S_{AC} \frac{d\ln AC}{dt} + S_{AC}(\sum S_i \frac{d\ln P_i}{dt} + \frac{d\ln Q}{dt}) \qquad (16)$$

Using equation (11), a cost function can be approximated by the second-order translog cost function.

$$\begin{aligned} \ln C = {} & \beta_o + \textstyle\sum_i \beta \ln P_i + 0.5 \textstyle\sum_I \sum_j \tau_{ij} \ln P_i \ln P_j + \beta_t t \\ & + 0.5\tau_{tt} t^2 + \Theta_q \ln Q + \textstyle\sum_i \tau_{itln} P_{it} \end{aligned} \qquad (17)$$

where I = {K,L,E,M} and

We can get factor shares from the partial derivatives of equation (17) with respect to the factor prices.

$$S_i = \beta_i + \sum \tau_{ij} \ln P_i + \tau_{it} t,$$

where I, j = K,L,E,M. (18)

To confirm linear homogeneity in factor prices in the cost function, the following restrictions are required.

$$\sum_i \beta_i = 1, \quad \sum_j \tau_{ij} = \sum_i \tau_{ij} = 0, \quad \sum \tau_{it} = 0, \qquad (19)$$

The system of equations consisting of the cost function (17) and four cost-share equations (18) can be estimated as a simultaneous system. To estimate TFP, We need to estimate equation (17) and equations (18) together with respect to the constraints in (19), employing an iterative version of Zellner's seemingly unrelated regression technique.

The technical change is found by the partial derivative of equation (17) with respect to t. Technical change estimates can be obtained when the parameters of the cost function are estimated.

$$\frac{\partial \ln C}{\partial t} = \beta_t + \tau_{tt} t + \sum \tau_{it} \ln P_i. \qquad (20)$$

Third TFP Model

The third model is designed to examine the impact of abatement requirements on industry costs and TFP growth in the Korean Steel industry. To calculate the effect of abatement requirements, a translog cost function for production of the manufactured output is used. The industry is assumed to minimize cost subject to the chosen output, a vector of input prices, and abatement capital.

The model is decomposed to evaluate growth in TFP into technology (its effect on the shifts of the production function and the cost function), direct and indirect effects. In this study, capital is separated into productive and abatement capital.[18] To see pollution abatement effects, two effects of required abatement capital on TFP were separated to investigate direct and indirect effect of abatement requirements. First, abatement capital costs impose a direct cost on the steel industry because total costs are higher for the same level of steel production. Second, abatement capital may have an indirect effect by

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[18] We define productive capital as capital used to produce conventional output such as steel. Abatement capital is used to reduce pollution.

Abatement capital costs (AC) always decrease productivity growth since that impose a direct cost on production. However, abatement capital (AK) could increase or decrease productivity growth depending on how abatement capital affects the production process for output.

changing the input combination used to produce steel.

The direct effect is always negative; however, the indirect effect could be positive or negative. If the productivity of steel decreases, it may imply more capital, labor, energy, or material is used in conjunction with the abatement capital.

If we assume that Q represents the homogeneous output of firms and B represents pollution, then the transformation function for a two-output (Q and B), four-inputs (K, L, E, and M), and technology is

$$D(Q, B, K, L, E, M, t) = 0 \tag{21}$$

where K, L, E, M, and t represent productive capital, labor, energy, and non-energy materials, and time (technology) respectively. Since there are environmental regulations in the real world imposed by government, firms should comply with regulations and employ facilities for reducing pollution. If we consider pollution as a function of abatement capital (AK) then:

$$B = B(AK, K, L, E, M, t). \tag{22}$$

By equations (21) and (22), we can describe the production function for Q as

$$Q = Q(AK, K, L, M, E, t), \tag{23}$$

where the inputs are used to produce Q or to reduce pollution associated with abatement capital.

Under the assumption that the industry minimizes production costs © subject to an exogenous level of production, input prices, abatement capital and technology, there is a restricted cost function. The cost function can be written as follows:

$$C' = C(Q, P_i, AK, t), \tag{24}$$

where AK is defined as abatement capital which is measured in quantity. AK is included to examine indirect abatement effects by changing the input combination used to produce output.

In equation (25), the total costs (C**) of producing output, Q, are indirect costs plus the direct costs of the abatement capital, P_{AK}*AK, which we call AC, where P_{AK} is the price of abatement capital, AK is abatement capital, and AC is cost of abatement capital. AC as a cost of production is included to examine direct abatement effects. By including pollution abatement capital cost and capital we are able to examine direct and indirect environmental effects on productivity side:

$$C^{**} = C(Q, P_i, AK, t) + AC. \tag{25}$$

We differentiate equation (25) and divide by t to obtain an explanation which decomposes the change over time in total cost into its source components to calculate the effect of environmental requirements on TFP,

$$\frac{dC^{**}}{dt} = \sum \frac{\partial C}{\partial P_i}\frac{dP_i}{dt} + \frac{\partial C}{\partial Q}\frac{dQ}{dt} + \frac{\partial C}{\partial AK}\frac{dAK}{dt} + \frac{\partial C}{\partial t} + \frac{dAC}{dt} \tag{26}$$

In equation (26), total cost is decomposed into five effects: factor price change, output change, the indirect effect of abatement on the cost function, technical change, and the direct abatement cost. If we divide equation (26) by total costs, C**, which consists of the abatement cost, and apply Shepard's Lemma, we obtain an expression for the growth in total costs,

$$\frac{d\ln C^{**}}{dt}=S_c\left(\sum S_i\frac{d\ln P_i}{dt}+E_{CQ}\frac{d\ln Q}{dt}+E_{CAK}\frac{d\ln AK}{dt}+\frac{\partial \ln C}{\partial t}\right)+S_{AC}\frac{d\ln AC}{dt} \qquad (27)$$

Where:

S_C = C/C**
S_{AC} = AC/C**
S_i = X_iP_i/C, i = K,L,E,M
E_{CAK} = òLnC/òLnAK
E_{CQ} = òLnC/òLnQ

TFP is defined as:

$$TFP=-\frac{d\ln C^{**}}{dt}+\sum S_i\frac{d\ln P_i}{dt}+\frac{d\ln Q}{dt} \qquad (28)$$

By using this definition of TFP and the assumption of CRS (E_{CQ} = 1), we join equation (27) and (28) which yields:

$$TFP=\left(-S_C\frac{\partial \ln C}{\partial t}\right)-\left(S_CE_{CAK}\frac{d\ln AK}{dt}\right)-S_{AC}\frac{d\ln AC}{dt}+S_{AC}\left(\sum S_i\frac{d\ln P_i}{dt}+\frac{d\ln Q}{dt}\right) \qquad (29)$$

Equation (29) demonstrates that TFP can be decomposed into three major components: the shift in C because of technical change (Sc(òlnC/òt)), the shift in C because of abatement capital purchase, or the indirect abatement effect (Sc(E_{CAK}dlnAK/dt)), and the increase in the direct cost of abatement requirements per unit of conventional output (or the direct abatement effect, $S_{AC}(d\ln AC/dt)$). Other components are price and scale terms.

In order to decompose TFP, structural information about the production process is required. This information can be obtained from estimating the cost function for the Korean steel industry. Elasticities can also be estimated from the cost function.

To estimate the necessary values, a four-input translog variable cost function with constant returns to scale is used. Using equation (24), a cost function can be approximated by the second-order translog cost function.

$$\begin{aligned} \ln C = {} & \beta_o + \sum_i \beta \ln P_i + 0.5 \sum_I \sum_j \tau_{ij} \ln P_i \ln P_j + \beta_t t \\ & + 0.5\tau_{tt} t^2 + \beta_{AK} \ln AK + 0.5\tau_{AKAK} \ln AK^2 + \tau_{AKt} \ln AKt \\ & + \Theta_Q \ln Q + \sum_i \tau_{iAK} \ln P_i \ln AK + \sum_i \tau_{it} \ln P_i t, \end{aligned} \tag{30}$$

where I = {K,L,E,M}.

We can get factor shares by the partial derivatives at the cost function (30) with respect to the factor prices.

$$S_i = \beta_i + \sum \tau_{ij} \ln P_i + \tau_{iAK} \ln AK + \tau_{it} t,$$

$$\text{where } I,\ j = K, L, E, M. \tag{31}$$

To confirm linear homogeneity in factor prices in the cost function, the following restrictions are required.

$$\sum_i \beta_i = 1, \quad \sum_j \tau_{ij} = \sum_i \tau_{ij} = 0, \quad \sum \tau_{iAK} = \sum \tau_{it} = 0, \tag{32}$$

The system of equations consisting of the cost function (30) and four cost share equations (31) can be estimated as a simultaneous system.

The change in C, attributable to technical change is found by taking the partial derivative of (30) with respect to t. We can calculate technical change estimates after the parameters of the cost function are estimated.

$$\frac{\partial \ln C}{\partial t} = \beta_t + \tau_{tt} t + \tau_{AKt} \ln AK + \sum \tau_{it} \ln P_i. \tag{33}$$

In order to separate the abatement effects from the technical change effects, we need an estimate of the cost abatement elasticity (E_{CAK}). The cost abatement elasticity (E_{CAK}) is obtained from the parametric estimates of the model in the cost function. We can obtain E_{CAK}, by partial derivation of (30) with respect to lnAK.

$$\frac{\partial lnC}{\partial lnAK}=\beta_{AK}+\tau_{AKAK}lnAK+\sum\tau_{AKi}lnP_i+\tau_{AKt}t \qquad (34)$$

To estimate TFP, we can directly calculate some components of TFP by using available data such as direct abatement effect, price, and scale terms. However, the components of indirect abatement effects and technical change cannot be calculated by available data. To estimate these components, we need to estimate equation (30) and equation (31) together with respect to the constraints in (32) employing an iterative version of Zellner's seemingly unrelated regression technique. After estimating the cost function and deriving the expression for E_{CAK} and $\partial lnC/\partial t$, we plug these components into equation (29), we get TFP with all the components.

Summary

In this chapter, we have presented a method of estimating and interpreting changes in TFP, the basic chosen method for estimating the impacts of environmental regulations on the Korean steel industry.

To investigate pollution abatement effects on productivity, three translog cost functions are employed.

The major reason for the first TFP model (equation 6) was to calculate TFP without pollution abatement capital cost and capital in order to compare environmental impacts. The second TFP model (equation 16) was employed to see if abatement capital costs affect productivity. The third TFP model (equation 29) was employed to examine direct and indirect abatement effects on productivity. However, the third translog model is the main concern of this chapter since we focus on environmental regulation impacts on productivity growth. The first and second model were employed for comparison purpose.

To estimate cost, a translog cost function is used. To derive the model several assumptions were made. First, abatement capital represents effects of environmental regulations and could encourage efficiencies in production and technological improvements. Second, firms are assumed to minimize cost subject to a chosen output, a vector of input prices, and the required level of abatement capital. Third, to gain reasonable results and convenience, we assumed constant returns to scale. The next chapter presents the empirical results for model 3.

Chapter 5

EMPIRICAL ANALYSIS OF PRODUCTIVITY GROWTH

This chapter covers data collection and sources used for estimating total factor productivity and the empirical analysis of productivity growth in the Korean steel industry. The results of this study are similar to U.S. studies. Environmental regulations are one of the factors slowing productivity growth in the Korean steel industry.

Data and Sources

The data set used to estimate TFP is listed in appendix B.1. The basic data used is from the Report on Mining and Manufacturing Survey, a publication of the Economic Planning Board and the Steel Statistical Yearbook, compiled by the Korean Iron and Steel Association. The annual data covers the period 1967 through 1993. All price and cost data are in current won (Korean currency). To convert the data to constant values for the TFP analysis, the wholesale price index from the Bank of Korea, base year 1990, was used.

To obtain output (Q), we used gross output from the Report on Mining and Manufacturing Survey. For comparison purposes, we considered output data from the Kim and Hong (1992) data set. Capital cost (KC) data is from the Report on Mining and Manufacturing Survey and Steel Statistical Yearbook.[19] Price of capital (P_K) is from the Bank of Korea. To make a reliable data set, we considered the Kim and Hong (1992) and Pyo (1992) data sets of capital stock. The abatement capital cost is estimated by using abatement capital stock (AK).[20] To estimate AK, we used the abatement investment data set from the Steel Statistical Yearbook, and following calculation:[21]

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[19] Capital cost (KC) can be estimated by multiplying the price of capital (P_K) and the capital stock (K) ($KC = P_K * K$, see Barbera and McConnell 1990; Kwon 1986, and Kim and Hong 1992). The data of capital cost is directly available from the Report on Mining and Manufacturing Survey. The data of price of capital is also directly available from the Bank of Korea.

[20] See Conrad and Morrison (1989, 685) and Barbera and McConnell (1990 and 1986). Conrad and Morrison separate pollution abatement cost (AC) from total capital cost (TKC). Barbera and McConnell separate pollution abatement capital (AK) from total capital stock (TK) by use of abatement capital expenditures. We assume that a unit of productive capital and pollution abatement capital cost and price are the same. Based on this assumption, we separate pollution abatement cost from total capital cost by use of abatement capital stock.

[21] Kim and Hong (1992, 223). KISA (1994, 1993, 1991, 1987, 1985, 1981, 1978, 1975, and 1970). Abatement cost (AC) can be calculated by multiplying the price of capital (P_K) and the abatement capital (AK) ($AC = P_K * AK$). To calculate the abatement capital stock, we assumed that the rate of depreciation is 10 percent since most of the average span of furnace life and environmental facilities are 10 years, the environmental equipment usually install when the new furnace is installed or the old furnace changes (see Chulgangbo, July 1994, 62-69).

Abatement capital stock (AK) is

$$AK_t=\zeta_t+(1-\alpha)AK_{t-1}$$

where, Ak_t = capital stock
Ak_{t-1} = capital stock(one year lag)
α = amortization ratio of investment
ζ_t = capital investment

Employment data, the number of man-hours worked, and the wages taken directly from the Report on Mining and Manufacturing Survey and Steel Statistical Yearbook. The price of labor is the implicit price derived by dividing the quantity of labor into the total employee expenses (Denny, et al. 1981, 218).

Expenditures for coal and electricity are obtained from the Report on Mining and Manufacturing Survey. To calculate energy price, we use a weighted average of price of coal and electricity. The price of coal and electricity are from the Yearbook of Energy Statistics. We selected coal and electricity because since they are the major energy source for the Korean steel industry. The weighted average energy price was calculated as follows:

$$P_C * [C_C/(C_C+C_{ELEC})] + P_{ELEC} * [C_{ELEC}/(C_C+C_{ELEC})]$$

where, P_C = price index of coal
C_C = coal consumption (amount)

P_{ELEC} = price index of electricity
C_{ELEC} = consumption of electricity (amount)

Material cost is directly available from the Report on Mining and Manufacturing Survey. Price of material is from the Kim and Hong (1992) price data set. In this study, technical change is assumed to be represented by a time trend (see Barbera and McConnell 1990, Kim and Kwon 1986, and Denny, et al. 1981). Total cost is directly available from the Report on Mining and Manufacturing Survey. Total costs are defined as the sum of expenditures on capital, labor, energy, and materials (see Barbera and McConnell 1990, 53); (Kwon 1986, 77); (Christensen and Haveman 1980, 323)). To calculate the cost share of capital, labor, energy, and materials, we first need to calculate total cost, then divide each expenditure by total cost.

Analysis of Productivity Growth

To investigate environmental impacts on productivity growth in the Korean steel industry, three models are used as described in chapter 4. To analyze the environmental impacts, we mainly concentrated on model 3.

For economic and comparison reasons, we divided the data set into three periods: 1967-74, 1975-83, and 1984-93. The years 1967 to 74 represent a self-sustaining growth economy and the beginnings of the steel industry. The Pohang Iron and Steel company started producing steel after 1973. During the second period, the Korean government implemented the strong heavy/chemical intensive policy. From 1984 to 1993, the rate of growth in the steel industry was relatively slower than in the previous stage and the environmental issues gained attention.[22]

Some econometric problems arose in estimating a translog cost function for the Korean steel industry stemming from our use of industry and time series data and a translog model to estimate environmental impacts on Korean steel productivity. Degrees of freedom and serial correlation were the major problems.

One of the major problems is a lack of degrees of freedom since the translog cost function gains explanatory power with many fewer input variables.[23] We have 29 parameters to estimate in the cost function with 27

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[22] See Steel Statistical Yearbook (1993, 5), Steel Yearbook (1993), and National Business Man Association (1992, 67-76).

[23] To obtain a translog cost function, we use the Taylor series expansion (see Binswanger (1974, 378-379), and Christensen and Jorgenson (1973, 33-35)

observations. To avoid the problem, equation 30 was run with cost-share equations composed of four cost-shares: capital, labor, energy, and material. These provide 27 observations for each equation, or allow 108 degrees of freedom.

Another major difficulty in the estimation of the system of equations is the serial correlation among the independent variables of different equations. To avoid problems of serial correlation, Zellner's seemingly unrelated regression technique was used, because it assumes that the error terms are serially uncorrelated.

The t-test tests hypotheses of individual regression coefficients. It is the appropriate test to use when the stochastic error terms are normally distributed and when the variance of that distribution must be estimated. To test a null hypothesis, we used one-sided t-test. To reject a null hypotheses based on a calculated t-value, we used a critical t-value (1% level of significance; critical t-value is 2.358, 5% level of significance; 1.658, and 10% level of significance; 1.289). The level of significance indicates the probability of observing an estimated t-value greater than the critical t-value if the null hypothesis were correct.

Parameter estimates of the constrained translog cost function in the Korean steel industry during the period 1967-1993 are listed in table 19.

Table 19. Parameter Estimates of the Constrained Translog Cost Function: Korean Steel Industry, 1967-1993

Parameters	Model 1: Estimates (t-ratio)	Model 3: Estimates (t-ratio)
β_0	954.468(2.857)*	-121.982(-0.066)
β_K	-20.416(-5.626)*	-14.180(-1.852)**
β_L	1.974(1.430)***	-4.019(-1.604)***
β_E	-1.256(-0.412)	-20.020(-3.087)*
β_M	20.699(5.720)*	39.219(4.663)*
τ_{KK}	0.054(1.009)	0.101(1.582)***
τ_{LL}	0.021(3.715)*	0.026(3.994)*
τ_{EE}	0.038(1.570)***	0.447(1.991)**
τ_{MM}	-0.149(-3.977)*	-0.201(-5.321)*
τ_{KL}	-0.025(-1.834)**	-0.042(-2.608)*
τ_{LE}	-0.004(-0.634)	-0.011(-1.420)***
τ_{EM}	0.067(2.748)*	0.099(4.212)*
τ_{KE}	-0.101(-4.104)*	-0.132(-5.148)*
τ_{LM}	0.008(0.869)	0.027(2.540)*
τ_{KM}	0.072(1.939)**	0.074(1.797)**
β_t	-0.959(-2.856)*	0.128(0.067)
τ_{tt}	0.001(2.855)*	-0.001(-0.069)
Θ_Q	0.995(99.459)*	1.001(181.919)*
τ_{Kt}	0.010(5.695)*	0.007(1.808)***
τ_{Lt}	-0.001(-1.378)***	0.002(1.644)***
τ_{Et}	0.001(0.434)	0.102(3.090)*
τ_{Mt}	-0.010(-5.548)*	-0.019(-4.519)*
β_{AK}		-0.860(-0.129)
τ_{AKAK}		0.001(0.087)
τ_{AKt}		0.001(0.124)
τ_{KAK}		0.023(1.430)***
τ_{LAK}		-0.009(-1.790)**
τ_{EAK}		-0.033(-2.533)*
τ_{MAK}		0.019(1.144)

Notes: 1). t ratio are in the parenthesis

2). K, L, E, M, t, Q, and AK are capital, labor, energy, material, technology, and steel output, respectively.

3). *1% level of significance (99% level of confidence)

**5% level of significance (95% level of confidence)

***10% level of significance (90% level of confidence)

Most t-values are high enough to reject the null hypotheses. However, we found that some t-values of parameters are lower than the critical t-value, so we could not reject the null hypotheses, because t-values are statistically insignificant at the 90% level of confidence. For instance, the t-value of β_L is not statistically significant since cost components of labor are relatively low compared to the industry's total costs. Overall the results of these parameter estimates and t-values seem to be reasonable, even though some of them are statistically insignificant. They are important in estimating environmental effects on productivity growth and calculating productivity growth.

A likelihood ratio test was used to examine the model specification for model 3 (table 20).

Table 20. Model 3: Likelihood Ratio Test Results

	Test 1	Test 2	Test 3
Iron and Steel	10.53	17.90	17.02

Note: 95% level of confidence:

Test 1: $\tau_{KT} = \tau_{LT} = \tau_{ET} = \tau_{MT} = 0$, & $\tau_{KAK} = \tau_{LAK} = \tau_{EAK} = \tau_{MAK} = 0$.

Test 2: $\tau_{KAK} = \tau_{LAK} = \tau_{EAK} = \tau_{MAK} = 0$.

Test 3: $\tau_{KT} = \tau_{LT} = \tau_{ET} = \tau_{MT} = 0$

τs are coefficients estimated from cost function

Test 1 validates all restrictions in the model. The likelihood ratio test value was greater than the critical chi-square (5.99). Thus, the null hypothesis for the all restrictions was rejected at the 95% level of confidence, implying that all restrictions are valid at the 5 percent level of significance. Test 2 tests for abatement requirements. The null hypothesis is that pollution abatement has no effect on cost. The hypothesis is rejected at the 5 percent level of significance implying that abatement requirements influence input costs. This specification allows us to determine indirect abatement effects.

Test 3 tests for non-neutral technical change. The null hypothesis is that there is no non-neutral technical change. The hypothesis is rejected at the 5 percent level of significance since abatement effects have a non-neutral component, the implication may be that there is non-neutral technical change. The results of this test show that it is valid to use all restrictions in this model with a 5 percent level of significance.

Productivity growth results in the three models(equations 6, 16, and 19) are presented in table 21.

Table 21. Productivity Growth Rate in Korean Steel Industry between 1968 and 1993
(%)

Iron and Steel	Model 1	Model 2	Model 3
1968-74	1.3071	1.3011	1.2903
1975-83	0.8068	0.7575	0.6645
1984-93	0.1216	-0.0631	-0.0901
1967-93	0.6791	0.5890	0.5445

In the first model productivity increased over the total period (1968-1993), but the rate of productivity growth decreased over time. The growth rate of productivity in the first model is higher than in the others. One reason may be the exclusion of pollution abatement requirements in the first model. The implication is that abatement costs and capital have affected productivity growth during the entire research period. The productivity of the third model is lower than the second model, suggesting that the pollution abatement capital affect to the slowdown of productivity growth.

Previous Korean TFP studies show that the trend of the average growth rate in all manufacturing sectors is decreasing, but remains higher than the rate in the steel industry (see table 13). There are significant reasons why. One factor is relatively high capital intensity than the other industries since government has implemented the Heavy and Chemical Program (HCP) during the 1970s (see chapter 2, 27). Other reasons are that Korea has had a relatively high interest rate and high growth in real wage since the mid 1980s. Table 21 shows that the TFP results (model 1) are a little higher than those in Kim & Hong (1992) and Lee (1992), but lower than those in Jungmo Kang (1992) because we used a different period and model. However, the average growth rate of TFP in our study (model 1) is similar to the Kim and Hong study that is 0.63 percent (see table 13).

In the cost function, technological change is characterized by interactions between output and various inputs since the estimates of efficiency gains due to technical change are residually determined. The interpretation of estimated results is that the estimated change in technology includes any errors resulting from the estimation of four separate effects: the indirect and direct abatement effects and input and output effects. Technology represents a quantitative expression of our ignorance, as with any residual. Technical change may occur with input saving or using, depending upon the relative factor prices.

Technical effects as explained in the first TFP model (equation 10), the second TFP model (equation 20), and the third TFP model (equation 33) are shown in table 22. Technical change, represented by the proportionate shift in the cost function, becomes less important over time, declining in all three models. Table 22 presents technical effects on productivity growth.

Table 22. The Effects of Technology on Productivity Growth

Iron and steel	Model 1	Model 2	Model 3
1967-74	1.3071	1.3047	2.1074
1975-83	0.8068	0.8037	1.1433
1984-93	0.1216	0.1211	0.1526
1967-93	0.6791	0.6772	1.0249

All three models show that technical effects significantly influenced productivity growth during the entire research period. However, the technical effects declined over the whole research period. The role of technical effects in the first model is a little higher than in the second, which may imply that simply including abatement costs in the second model may have caused the decrease. Technical effects in the third model are higher than in the first and second models, which could imply that abatement capital may significantly influence technical improvement.

Table 23 presents the estimated abatement requirements coefficients which are used to obtain cost elasticities and indirect abatement effects. These coefficients allow a brief illustration of how the Korean steel industry adjusts its cost minimizing factor ratios in reaction to demanded abatement purchases.

Table 23. Model 3: Abatement-Related Estimated Coefficients

	β_{AK}	τ_{AKAK}	τ_{KAK}	τ_{LAK}	τ_{EAK}	τ_{MAK}
Iron and Steel	-0.86041 (6.6944)	0.00113 (0.1296	0.02399 (0.0167)	-0.00961 (0.0053)	-0.03378 (0.0133)	0.01939 (0.0169)

Note: numbers in parenthesis are standard errors.

The values of β_{AK} and τ_{AKAK} from the estimated parameters present costs as increasing since E_{CAK} has positive sign. Abatement-related estimated coefficients for capital and materials are 0.02399 and 0.01939. These positive coefficients may imply that abatement capital has influenced more capital and materials to be used (but material parameter is not statistically significant). However, the coefficients of labor and energy are -0.00961 and -0.03378 respectively, which may imply that abatement capital has influenced less use of labor and energy.

Empirical estimates of E_{CAK} based on equation 34 in the third model is presented in table 24. These elasticities show the effect of abatement requirements on non-abatement cost. They are an important component of the indirect productivity effect (see equation 29 in the third TFP model).

Table 24. Model 3: Elasticity of Cost With Respect to Abatement, E_{CAK} Annual Averages over the Selected Periods

	1967-74	1975-83	1984-93	1967-1993
Iron and steel	0.03778	0.01694	0.00190	0.01775

In the Korean steel industry, the average elasticities over the entire period are positive. Abatement requirements still drive unit cost increases, implying that abatement purchases do not lead to higher productivity growth. Thus, the regulations do not induce greater innovation. Rather, they simply force this industry to increase use of all inputs to maintain a given level of steel production. However, the decrease of E_{CAK} over time may imply that the efficiency of abatement capital use may improve during the researched period.

In equation 29 (third TFP model), the three main components of TFP for the steel industry are 1) technical change ($S_C\{\partial lnC/\partial t\}$), 2) the direct effects of the abatement capital purchase ($S_{AC}\{dlnAC/dt\}$), and 3) the indirect effect ($S_C E_{CAK}\{dlnAK/dt\}$) on the other factors which combine to produce steel.

Abatement requires additional materials and conventional capital. The net effect of abatement requirements, including both direct and indirect effects, is to lower productivity. Abatement accounts for between 31 and 44 percent of the decline in productivity in all research periods.

Table 25 presents average annual productivity growth and the direct and indirect effect of abatement requirements for selected periods. The total abatement contribution to TFP is also shown in table 25, along with its two components, the direct and indirect abatement effects as defined earlier.

Table 25. Model 3: Average Annual Productivity Growth and Direct and Indirect Effects of Abatement Requirements for Selected Periods

	1968-74	1975-83	1984-93	1968-93
Iron and steel	1.2903	0.6645	-0.0901	0.5445
Abatement effect	-0.8847	-0.6011	-0.3598	-0.5847
Indirect	-0.8136	-0.4506	-0.0576	-0.3972
Direct	-0.0711	-0.1505	-0.3022	-0.1875

TFP grew more slowly in the 1975-83 period than it did in the 1967-74 period. In the 1984-93 period, TFP move from positive to negative. This result may imply that environmental requirements contributed to the slowdown in TFP during the 1984-93 period since environmental regulations then were more strict than in the other periods. The direct effect of abatement capital cost increased over the entire period due to increases in environmental requirements. However, even though the total abatement requirement effect is negative on TFP growth over the entire period, its negative effects decreased over the period, perhaps implying that the influence of abatement capital on input prices, the negative relationship, is decreasing over time.

The results of Barbera and McConnell's study (1990) show that the total abatement effect in the U.S. steel industry was -0.219 during the period 1960-80. The indirect and direct abatement effects were -0.095 and -0.124 during the same period. The abatement effects in the Korean steel industry are significantly higher than U.S. effects reported in the Barbera and McConnell study. It could be that Korea, as a developing country, has a relatively high environmental standard for the steel industry. The industry imports most of its capital goods and environmental standards from advanced countries.

Table 26 shows the difference in TFP in comparing 1975-83 to 1968-74 and comparing 1984-93 to 1975-83 periods. It shows that abatement requirements may have contributed to the productivity slowdown in the steel industry during the research periods. The second column of table 26 presents the average percentage point change in TFP compared to the previous stage.

Table 26. Model 3: A Comparison of TFP and Abatement Contributions to TFP over Three Periods

Time period	Average % change in TFP	Average % change productivity due to abatement	% of TFP decline due to abatement
1975-83 vs 1968-74	-0.63	-0.28	44.44
1984-93 vs 1975-83	-0.75	-0.24	31.45

The average percentage point change in TFP was -0.63 percent comparing the second to the first stage, and it was -0.75 percent when comparing the third to the second stage. The third column presents an average percent point change in productivity due to the abatement effect, it shows that abatement requirements negatively effect productivity growth. However, the degree of impact in the first period decreased compared to the previous stage. The fourth column presents the difference in the pollution abatement contribution to TFP across the research periods. The results show that productivity fell due to pollution abatement in the first compared to the second and the second compared to the third periods, by 44.44 percent and 31.45 percent, respectively.

Barbera and McConnell found that the percentage of TFP decline due to abatement in the U.S. steel industry during the period 1960-80 was 10.8 percent, much lower than our result for the steel industry in Korea.

Table 27 shows average annual percentage rates of growth of real GNP, inputs, outputs, and pollution abatement capital.

Table 27. Model 3: Average Annual Percentage Rates of Growth of Real GNP, Inputs, Outputs, and Abatement Capital

Iron and Steel	GNP	Steel Output	Abate. Capital	Total Inputs	Factor Inputs			
					Capital	Labor	Energy	Material
1968-74	10.7470	35.6002	26.3705	24.8299	34.2226	8.2091	20.4410	36.4471
1975-83	7.4830	14.3859	28.0979	13.3012	12.8135	8.1437	18.4862	13.7613
1984-93	8.8403	10.8152	27.1350	6.7797	10.9013	-0.0242	3.6235	12.6111
1968-93	8.8764	18.2954	27.2607	13.6044	17.4418	4.9431	13.0298	19.0030

The Korean steel industry, as an important basic industry, has had a large role in the economy since the 1960s. The growth rate of steel output is greater than the GNP growth rate during the entire research period. The growth rate of capital input is relatively higher than that of total inputs. It may imply that steel production requires high capital investments. Labor inputs decreased over time compared to total input growth, even though the cost share of labor increased slightly over the entire period. It could be that the rise in wages caused less use of labor (see table 28). The growth rate of energy compared to total input decreased over time. The oil shocks may be a factor. The growth rate of material input is relatively higher than total input. And the cost share of material is still high even though it has decreased over time, and may imply that the industry produces a relatively small amount of high value-added steel products.

In equation 31 (third TFP model) presents the estimation method of this share equation. Table 28 shows cost share of capital, labor, energy, and materials. For the 1967-74 period, the cost share is 22.14 percent, 5.94 percent, 7.29 percent, and 64.61 percent for capital, labor, energy, and materials, respectively. For the 1975-83 period, cost shares are 22.01 percent, 6.14 percent, 9.66 percent, and 62.12 percent, showing a slight decline in the cost share of capital and materials.

Table 28. Model 3: Cost Share of Capital, Labor, Energy, and Material
(%)

Iron and steel	Capital	Labor	Energy	Material
1967-74	22.1422	5.9498	7.2945	64.6135
1975-83	22.0679	6.1461	9.6612	62.1248
1984-93	26.0190	6.6933	7.7068	59.5810
1968-93	23.5532	6.2906	8.2361	61.9200

For the 1984-93 period, cost shares are 26.01 percent, 6.69 percent, 7.70 percent, and 59.58 percent, showing slight increases in the cost share of capital and labor, but energy and materials decreased. The average cost shares for the 1967-93 period are 23.55 percent, 6.29 percent, 8.23 percent, and 61.92 percent, respectively. These cost shares show that the steel industry is heavily using capital and materials.

Table 29 shows the various contributors to the productivity growth. During the 1968-74 period, while TFP growth was relatively higher than in the other two periods, technical, input, output effects contributed 2.1072, 0.0240, 0.0520, to TFP growth, respectively. The largest proportion in growth of TFP was explained by the growth of technological effects.

Table 29. Model 3: Contributors to Productivity Growth: (%)

	Q	TFP	Contributors to the growth of productivity				
			Tech. Effect	Ind. A. Effect	Dir. A. Effect	Inputs Effect	Output Effect
1968-74	30.4541	1.2903	2.1072	-0.8136	-0.0711	0.0240	0.0520
1975-83	13.4407	0.6645	1.1420	-0.4506	-0.1505	0.0573	0.0474
1984-93	10.2694	-0.0901	0.1521	-0.0576	-0.3022	0.0326	0.0864
1968-93	16.8015	0.5445	1.0211	-0.3972	-0.1875	0.0389	0.0636

During the 1975-83 period, the contribution of technical and output effects to TFP growth slowed down. However, input effects increased. During the 1984-1993 period, the contribution of output effects to TFP growth increased.

For the entire period, the technical effect was mainly contributed to the TFP growth. However, the direct and indirect abatement effect were mainly contributed to slowdown in TFP growth.

Summary

To examine the effects of environmental regulations on productivity growth in the Korean steel industry, three models are estimated. To test the validity of the restrictions on the model, a likelihood ratio test was used. The results of these tests demonstrate that all restrictions are valid at the 5 percent level of significance. Some econometric problems arose during the estimation of TFP. The major problems were serial correlation and degrees of freedom. To avoid these problems, we used four cost-share equations with a cost function and the seemingly unrelated regression technique.

Even though there are some measurement problems, generally the results of this analysis seem to be reasonable. The results show that the growth rate of annual TFP in the third model is 1.2903 percent in the 1967-74 period, 0.6645 percent in the 1975-83 period, and -0.0901 percent in the 1984-93 period. For the entire research period, the growth rate is 0.5445 percent. This implies that productivity in the Korean steel industry has been decreasing over time. The trend of TFP growth in the manufacturing sector is decreasing. The TFP in the steel industry is lower than the average growth rate in all manufacturing sectors.

Technical effects are significant effects on productivity growth in all three models during all research periods. Abatement effects on input costs show that pollution abatement influence improves efficiency of energy and labor use, but encourages the use of more capital and materials.

Elasticity of cost with respect to abatement (E_{CAK}) shows that abatement requirements drive costs up. However, the effects decreased over the research periods.

Direct abatement effects increased while abatement costs increased over time. However, indirect abatement effects decreased over time, which may imply that abatement capital is turning to improve efficiency of using inputs.

The percentage of TFP decline due to abatement was 31 percent during 1984-93 compared to 1975-83, and 44 percent during 1975-83 compared to 1968-74, implying that pollution abatement effects have decreased over time.

Chapter 6

SUMMARY, CONCLUSIONS AND FUTURE RESEARCH

Environmental regulations are usually mentioned as a partial explanation for the productivity slowdown experienced by most advanced countries. In Korea, environmental regulations are tightening to meet public and international demand. Therefore, it is important to determine whether environmental regulations are one of the factors slowing productivity growth in order to obtain insight into how environmental regulations affect the steel industry.

Summary

In this study, we use time-series data to econometrically estimate TFP in a translog models. To investigate the impacts of environmental regulations on productivity growth, we employ three translog models. First, to estimate only TFP, a simple translog cost model is employed. In the model, we assume that there are no environmental requirements on polluting firms. Second, to examine only pollution abatement cost effects on productivity growth, the translog cost model included pollution abatement cost as one of the independent variables. Third, to investigate the full effects of abatement, the model included abatement cost and capital to see direct and indirect abatement effects. However, we mainly analyze the third model since the main purpose of this study is to examine the environmental regulations effects on productivity growth in the Korean Steel industry. We include two models for comparison.

To run these model, we needed to make some assumptions. First, abatement capital represents effects of environmental regulations and it could encourage efficiency of production process and technological improvements. Second, industry is assumed to minimize cost subject to the chosen output, a vector of input prices, and the required level of abatement capital. Third, we assumed constant returns to scale.

To examine specification of the model a likelihood test is used. The results of this test were satisfied with all restrictions at the 5 percent level of significance.

The results of productivity growth in the three models were slightly different. The TFP of the first model was a little higher than the others. The third was lower than the others during the entire period, maybe implying that abatement cost and capital affect the slowdown of productivity growth in the steel industry.

Technical effects on productivity were quite interesting. The second model was lower than the first and third which may imply that abatement costs which were simply included in the model may be causing decreasing technical effects. The third model was higher than the others which may imply that even though environmental regulations affect productivity growth in the steel industry, the abatement capital may encourage improvement in the technology in the industry.

Abatement related estimated coefficients show that the steel industry increased productive capital purchases, which may have led to labor and energy productivity increases.

The net effect of abatement requirement including direct and indirect effects was lower productivity accounting for between 31 and 44 percent of the decline over the entire research period. Total abatement effects are becoming lower. Direct abatement effects are becoming higher while abatement cost is increasing over the time. However, indirect abatement effects are becoming lower which suggests that abatement capital encourages improved efficiency and technological changes.

Cost shares and growth rate of inputs show that the growth rate of material input is relatively higher than total input. Cost shares of material is still high even though it has slightly decreased over time, it may imply that industry produces relatively small amount of high value-added steel products.

Using industry data for the Korean steel industry, we found a significant negative relationship between pollution abatement requirements and productivity growth. Some of the findings are as follows. First, environmental regulations are one factor in the declining productivity of the Korean steel industry by 31 to 44 percent over the study period. Second, the direct abatement cost decreases the TFP while abatement cost is increasing over time. However, the effects are decreasing over the time, even though the indirect abatement effects result in a productivity slowdown. Third, technical effects were the main stimulus to productivity growth in the three models. Fourth, abatement capital effects have decreased labor and energy use in the industry. It maybe that abatement capital has encouraged improved efficiency of labor and energy use. Fifth, the industry still produces relatively small amounts of high valued-added steel products. Sixth, the results of this study still support the view that environmental regulations are one partial explanatory variable for the slowdown of productivity growth which.

Conclusions

Based on the findings, environmental regulations have had negative effects on productivity growth in the Korean steel industry. Even though environmental regulations have reduced productivity growth in the Korean steel industry, there is strong evidence that abatement capital encourages efficiency of energy and labor use. And the pace of total abatement effects has decreased over time. This may imply that the percentage of negative abatement effects are decreasing.

Some points need to be highlighted. First, to improve productivity, Korean steelmakers will be required to reduce costs through facility efficiency, technology development, and R&D for the development of high value-added and specialty steel. The industry now produces only a small amount of high value-added steel products. Second, Korean steelmakers must become more concerned with environmental issues. The cleaner environment demand, from domestically and internationally has increased, affects international competitiveness. Recycling must be maximized and conventional processes replaced by more environmentally sound processes to reduce waste and costs of production.

Future Research

We see several main areas for future research. First, updating data and expanding the study to include more industries. Updating data will allow an examination of the effect of changing regulations over time, and expanding the study to include more industries allows a more accurate analysis of environmental effects on other industries and the economy. Second, collecting variables measuring other factors such as capital utilization, expansion of production capacity, spending for automation, energy conservation, R&D spending, labor quality, and market structure may help explain more of the productivity change. Finally, production and cost-oriented studies may not measure the social benefits from abatement requirements. However, it is worth trying to include these benefits in the study. The costs of regulation may well be worth the benefits of a cleaner environment.

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Appendix A

Steel Production and Environmental Standards

Table A.1 Steel Production

(MT)

	Pig Iron	% Change	Crude Steel	% Change	Finished Steel	% Change
1962	2,503	-	130,360	-	112,474	-
1963	7,723	208.5	144,493	10.8	165,055	46.2
1964	7,148	-7.4	185,683	28.5	180,283	9.2
1965	25,051	205.5	227,037	22.3	215,221	19.4
1966	43,461	73.5	222,723	-1.9	272,682	26.7
1967	32,663	-24.8	331,040	48.6	393,578	44.3
1968	45,971	40.7	383,175	15.7	636,833	61.8
1969	47,038	2.3	438,409	14.4	915,598	43.8
1970	49,158	4.5	504,149	15.0	1,178,472	28.7
1971	22,606	-54.0	546,507	8.4	1,358,938	15.3
1972	14,120	-93.8	608,333	11.3	1,760,732	29.6
1973	454,071	3200.1	1,240,287	103.9	2,672,368	51.8
1974	1,022,565	125.2	2,307,963	86.1	3,119,119	16.7
1975	1,374,439	34.4	2,557,960	10.8	2,726,943	-12.6
1976	2,009,430	46.2	3,510,909	37.3	3,796,189	39.2
1977	2,425,512	20.7	4,346,358	23.8	4,951,442	30.4
1978	2,749,104	13.3	4,969,323	14.3	6,346,164	28.2
1979	5,076,931	84.7	7,610,250	53.1	7,479,172	17.9
1980	5,582,400	10.0	8,558,332	12.5	7,852,418	5.0
1981	7,934,563	42.1	10,753,136	25.6	10,114,529	28.8
1982	8,442,205	6.4	11,758,016	9.3	10,858,152	7.4
1983	8,024,437	-4.9	11,914,881	1.3	12,088,876	11.3
1984	8,763,494	9.2	13,034,421	9.4	13,427,154	11.1
1985	8,832,717	0.8	13,539,145	3.9	13,931,107	3.8
1986	9,002,787	1.9	14,554,549	7.5	15,307,568	9.9
1987	11,057,187	22.8	16,782,075	15.3	17,506,532	14.4
1988	12,577,774	13.8	19,117,761	13.9	18,887,439	7.9
1989	14,816,210	18.0	21,872,966	14.4	21,756,414	15.2
1990	15,338,609	3.3	23,124,814	5.7	24,536,307	12.8
1991	18,510,402	20.7	26,011,329	12.4	27,827,508	13.5
1992	19,322,860	4.4	28,054,529	7.9	29,374,333	3.8

Source: Korea Iron and Steel Association, Steel statistical Yearbook, Korea, 1993, 5.

Table A.2 Emission Standard for the Steel Industry

Polluted material (gaseous materials)	Emission standard and period		
	Until Dec. 31 1994	Jan. 1 1995- Dec. 31 1998	From Jan 1 1999
Ammonia(NH_3)	below 200 ppm	below 200 ppm	below 100 ppm
CO_2	below 700 ppm	below 700 ppm	below 700 ppm
Chloride hydrogen	below 10 ppm	below 5 ppm	below 2 ppm
Chlorine(CI)	below 10 ppm	below 10 ppm	below 10 ppm
SO_2	below 650 ppm	below 650 ppm	below 650 ppm
NO_2	below 200 ppm	below 200 ppm	below 200 ppm
Sulfuration hydrogen	below 15 ppm	below 15 ppm	below 15 ppm
F	below 5 ppm	below 5 ppm	below 5 ppm
Br	below 5 ppm	below 5 ppm	below 5 ppm
C_4H_6	below 50 ppm	below 50 ppm	below 50 ppm
C_4H_6OH	below 10 ppm	below 10 ppm	below 10 ppm
Hg	below 5 mg/sm^3	below 5 mg/sm^3	below 5 mg/sm^3
As	below 3 ppm	below 3 ppm	below 3 ppm

Table A.3 Emission standards in the Steel Industry

Polluted materials	Emission equipment	Emission standard and period		
		Until Dec. 31, 1994	Jan. 1 1995-Dec. 31 1998	From Jan. 1 1999
Dust	Electric arc furnace	below 30mg/sm^3	below 20mg/sm^3	below 10mg/sm^3
	Blast furnace	below 70mg/sm^3	below 50mg/sm^3	below 50mg/sm^3
	Sokyul furnace	below 200mg/sm^3	below 70mg/sm^3	below 50mg/sm^3
	Garyul furnace	below 100mg/sm^3	below 100mg/sm^3	below 70mg/sm^3
Cd		below 1.0mg/sm^3	below 1.0mg/sm^3	below 1.0mg/sm^3
Pb		below 20mg/sm^3	below 20mg/sm^3	below 10mg/sm^3
Cr		below 1.0mg/sm^3	below 1.0mg/sm^3	below 1.0mg/sm^3
Cu		below 10mg/sm^3	below 10mg/sm^3	below 10mg/sm^3
Nikel		below 20mg/sm^3	below 20mg/sm^3	below 20mg/sm^3
Zn		below 30mg/sm^3	below 30mg/sm^3	below 30mg/sm^3
Arsenic acid dust		below 1.5mg/sm^3	below 1.0mg/sm^3	below 0.5mg/sm^3
Smoke		bellow 2 degree	below 2 degree	below 2 degree

Source: Environmental Law, 1992, 505-509

Table A.4 Water Standard Until December 31, 1995

	Waste discharge above 3000m^3/ per day			Waste discharge bellow 3000m^3/per day		
	Bioche-mical required O_2	Chemical required O_2	floating matters	Bioche-mical required O_2	Chemical required O_2	floating matters
First area	below 50	below 50	below 50	below 50	below 50	below 50
Second area	below 80	below 80	below 80	below 100	below 100	below 100
Third area	below 100	below 100	below 100	below 150	below 150	below 150
Special area	below 30	below 50	below 50	below 30	below 50	below 70

Source: Environmental law, 1992, 272.

Note: First area: A area that is required to keep the first degree of water quality appointed by minister of environment.

Second area: A area that is required to keep the second degree of water quality appointed by Minister of environment.

Third area: A area that is required to keep the third degree of water quality appointed by minister of environment.

Special area: End waste water treatment area and agricultural & industrial area appointed by minister of environment.

Table A.5 Water Standards From January 1, 1996.

	Waste discharge above $3000m^3$/per day			Waste discharge bellow $3000m^3$/per day		
	Biochemical required O_2	Chemical required O_2	floating matters	Biochemical required O_2	Chemical required O_2	floating matters
First area	below 30	below 40	below 30	below 40	below 50	below 40
Second area	below 60	below 70	below 60	below 80	below 90	below 80
Third area	below 80	below 90	below 80	below120	below130	below120
Special area	below 30	below 40	below 30	below 30	below 40	below 30

Source: Environmental law, 1992, 273.

Table A.6 Polluted Matters From February 2, 1991

Items \ Area		First area	Second area	Third area	Special area
Hydrogen ion intensity		5.8-8.6	5.8-8.6	5.8-8.6	5.8-8.6
Normal nucleir acid deportation matter contents	Mineral oil(mg/l)	below 1	below 5	below 5	below 5
	Animal and vegetable oil(mg/l)	below 5	below 30	below 30	below 30
Phenol contents(mg/l)		below 1	below 5	below 5	below 5
Cyanogen contents(mg/l)		below 0.2	below 1	below 1	below 1
Chrome contents(mg/l)		below 0.5	below 2	bellow 2	below 2
Solubility Fe contents(mg/l)		below 2	below 10	bellow 10	below 10
Zinc contents(mg/l)		below 1	below 5	bellow 5	below 5
Copper contents(mg/l)		below 0.5	below 3	bellow 3	below 3
Cadmium contents(mg/l)		below 0.02	below 0.1	bellow 0.1	below 0.1
Mercury contents(mg/l)		None	below 0.005	bellow 0.005	below 0.005
Organic matter phosphorus contents(mg/l)		below 0.2	below 1	bellow 1	below 1
Arsenic contents(mg/l)		below 0.1	below 0.5	bellow 0.5	below 0.5
Pb contents(mg/l)		below 0.2	below 1	bellow 1	below 1
Hexi-valent chromium contents(mg/l)		below 0.1	below 0.5	bellow 0.5	below 0.5
Solubility manganese contents(mg/l)		below 2	below 10	bellow 10	below 10
Fluorine contents(mg/l)		below 3	below 15	bellow 15	below 15
PCB contents(mg/l)		None	below 0.003	below 0.003	below 0.003
# of colitis germs(#/mg)		below 100	below 3000	below 3000	below 3000
Degree of color		below 200	below 300	below 400	below 400
Centigrade (C°)		below 40	below 40	below 40	below 40
Total nitrogen contents(mg/l)		below 30	below 60	below 60	below 60
Total phosphorus contents(mg/l)		below 4	below 8	below 8	below 8
Tri-chloroethelene contents(mg/l)		below 0.06	below 0.3	below 0.3	below 0.3
Detra-chloroethelene contents(mg/l)		below 0.02	below 0.1	below 0.1	below 0.1

Source: Environmental law, 1992, 274.

Table A.7 Export & Import of Steel Products by Year (in thousands dollar and MT)

		1988		1990		1992	
		QUALITY	VALUE	QUALITY	VALUE	QUALITY	VALUE
LONG PRODUCT	EXPORT	1,332,082	509,248	808,888	399,912	1,791,873	687,419
	IMPORT	648,301	320,617	1,405,431	594,614	1,486,830	598,533
	TRADE BALANCE	683,781	188,631	-596,543	-194,702	305,043	88,886
FLAT & FORGING	EXPORT	4,859,160	2,364,667	5,938,516	2,921,573	7,903,557	3,562,280
	IMPORT	2,072,884	1,560,585	2,998,477	1,915,551	2,517,114	1,600,141
	TRADE BALANCE	2,786,276	804,082	2,940,039	1,006,022	5,386,443	1,962,139
CASTING & FORGING	EXPORT	70,697	119,423	47,691	92,090	51,518	103,038
	IMPORT	8,552	54,684	13,290	83,001	38,217	87,331
	TRADE BALANCE	62,145	64,739	34,410	9,089	13,301	15,707
FOUNDRY	EXPORT	88,166	87,182	83,652	152,757	83,472	141,052
	IMPORT	5,417	11,933	19,462	91,667	118,819	128,379
	TRADE BALANCE	82,749	76,040	64,190	61,090	-35,547	12,673
SEMIFINISHED	EXPORT	353,291	101,327	331,211	90,253	470,735	101,111
	IMPORT	632,114	161,947	1,142,140	300,678	2,018,994	509,380
	TRADE BALANCE	-278,823	-60,620	-810,929	-210,425	-1,638,259	-408,269
SECONDARY PRODUCT	EXPORT	581,501	647,334	445,624	561,736	503,675	763,719
	IMPORT	38,648	78,677	50,288	93,314	80,390	153,593
	TRADE BALANCE	542,853	568,657	395,336	468,422	423,285	610,126
RAW MATERIAL	EXPORT	-	13,212	-	19,888	-	12,797
	IMPORT	-	804,885	-	1,010,895	-	904,875
	TRADE BALANCE	-	-791,673	-	-991,007	-	-892,078
TOTAL	EXPORT	-	3,843,184	-	4,238,209	-	5,371,416
	IMPORT	-	2,993,328	-	4,091,384	-	3,982,231
	TRADE BALANCE	-	849,866	-	146,825	-	1,389,185

Source: Korea Iron and Steel Association, Steel Statistical Yearbook, 1993.

Appendix B

Date Set

Table. B.1 Input Prices Indices, Inputs Costs, and Output.

	Price Indices				Input Costs (bill. of current won)				Output (thou.)	Abate. capital stock (mill.)	Cost of abatement (Bill. of current won)
	PK	PL	PE	PM	KC	LC	EC	MC	Q	AK	AC
1967	0.0880	0.0041	0.0454	0.1656	5.9	0.9	1.7	16.3	188	583	0.05136
1968	0.0985	0.0068	0.0534	0.1610	8.3	1.7	3.2	21.7	274	670	0.06600
1969	0.1102	0.0128	0.0534	0.1612	10.9	3.5	4.2	32.7	389	695	0.07662
1970	0.1234	0.0213	0.0624	0.2184	13.0	6.0	4.3	43.4	388	1061	0.13089
1971	0.1318	0.0277	0.0719	0.2267	14.0	6.0	9.1	52.0	455	1482	0.19531
1972	0.1486	0.0335	0.0827	0.2312	22.0	7.5	5.9	80.7	596	1972	0.29309
1973	0.1822	0.0437	0.0828	0.3086	69.7	13.8	19.6	176.6	1129	2506	0.45652
1974	0.2434	0.0553	0.1252	0.3436	128.7	20.9	18.1	298.4	1586	3003	0.73095
1975	0.3012	0.0580	0.1571	0.5003	87.9	22.8	56.6	261.6	1099	3538	1.06549
1976	0.3183	0.0811	0.1761	0.4981	152.3	39.1	54.0	494.6	1782	5299	1.68655
1977	0.3483	0.1162	0.2359	0.4736	200.7	72.0	57.6	687.8	2483	6419	2.23584
1978	0.3977	0.1560	0.3142	0.4253	245.3	112.4	65.1	874.7	3312	10362	4.12119
1979	0.4731	0.1893	0.4107	0.6161	482.7	148.1	129.5	1231.5	3710	16821	7.95829
1980	0.6134	0.2293	0.5826	0.8389	577.4	167.8	179.7	1890.1	3795	27285	16.7376
1981	0.6825	0.2813	0.7885	0.8774	885.5	201.1	620.5	2048.5	4775	27640	18.8528
1982	0.7263	0.3130	0.7291	1.0794	1069.7	218.4	654.0	2197.2	4633	27316	19.8410
1983	0.7584	0.3084	0.7590	1.0346	1187.3	236.2	506.1	2868.2	5317	27889	21.1499
1984	0.7737	0.4067	0.7804	0.9523	1364.6	320.6	356.7	3497.9	6389	34707	26.8513
1985	0.8174	0.4484	0.8342	1.0478	1389.5	349.7	361.2	3626.4	6066	41737	34.1174
1986	0.8695	0.4756	0.8943	1.0443	1562.7	397.4	813.4	3656.2	6759	48426	42.1084
1987	0.8842	0.5645	0.9373	0.9033	1887.2	490.6	816.8	4589.8	8806	54183	47.9079
1988	0.9139	0.6762	0.9999	0.7662	1933.8	619.3	660.1	5941.1	11275	56933	52.0321
1989	0.9441	0.8565	0.9999	0.8072	2483.9	785.4	733.2	6626.8	12368	65648	61.9786
1990	1.0000	1.0000	1.0000	1.0000	3302.0	945.0	803.7	7100.7	12151	132100	132.0996
1991	1.0628	1.2231	1.0130	1.1465	4050.0	952.7	1075.9	7483.8	12018	225293	239.4500
1992	1.1130	1.3185	1.0727	1.1291	4334.9	1005.4	909.8	8188.7	12553	287223	319.6743
1993	1.1842	1.4498	1.0925	1.0295	5218.1	1108.0	1040.0	9360.0	14849	307670	364.3471

Sources: P_K price indices: the Bank of Korea.
P_L price indices: calculated from the Steel Statistical Yearbook.
P_E Price indices: calculated from the Yearbook of Energy Statistics.
P_M Price indices: the Kim and Hong (1992).
KC, LC, EC, and MC input costs: the Report on Mining and Manufacturing Survey.
AK abatement capital stock: calculated from the Steel Statistical Yearbook.

Appendix C

SAS Program and Output

C.1 SAS Programs

```
*
*TFP: THE KOREAN STEEL INDUSTRY, 1967-1993:Model 3
*;

option pagesize=57 linesize=77 nodate nonumber;
data TFP;
INFILE 'F:\DATA1.DAT' FIRSTOBS=2;
INPUT T Y CT C Q QI;
INFILE 'F:\DATA2.DAT' FIRSTOBS=2;
INPUT KC PK K AC PAK AK AI;
INFILE 'F:\DATA3.DAT' FIRSTOBS=2;
INPUT LC PL L EC PE E;
INFILE 'F:\DATA4.DAT' FIRSTOBS=2;
INPUT MC PM M;
INFILE 'F:\DATA5.DAT' FIRSTOBS=2;
INPUT SK SL SE SM;

LNPK=LOG(PK);
LNPL=LOG(PL);
LNPE=LOG(PE);
LNPM=LOG(PM);
LNA=LOG(AK);
LNQ=LOG(Q);
LNC=LOG(C);

LN2PKPK=0.5*LNPK*LNPK;
LN2PLPL=0.5*LNPL*LNPL;
LN2PEPE=0.5*LNPE*LNPE;
LN2PMPM=0.5*LNPM*LNPM;
LNPKPL=LNPK*LNPL;
LNPLPE=LNPL*LNPE;
LNPEPM=LNPE*LNPM;
LNPKPE=LNPK*LNPE;
LNPLPM=LNPL*LNPM;
LNPKPM=LNPK*LNPM;

lnpkt=lnpk*t;
lnplt=lnpl*t;
lnpet=lnpe*t;
lnpmt=lnpm*t;
lnqt=lnq*t;
lnqak=lnq*lnak;
lntak=t*lnak;
T22=0.5*T*T;
LN2AK2=0.5*LNAK*LNAK;
LNAKT=LNAK*T;

LNPKAK=LNPK*LNAK;
LNPLAK=LNPL*LNAK;
LNPEAK=LNPE*LNAK;
LNPMAK=LNPM*LNAK;
RUN;
```

```
PROC SYSLIN SUR VARDEF=N DATA=TFP;
TITLE 'TFP COST FUNCTION:DIRECT & INDIRECT WITH ABATEMENT';
COST : MODEL LNC = lnpk lnpl lnpe lnpm
                   ln2pkpk ln2plpl ln2pepe ln2pmpm
                   lnpkpl lnplpe lnpepm lnpkpe lnplpm lnpkpm
                   t t22 lnak ln2ak2 lnakt lnq
                   lnpkak lnplak lnpeak lnpmak
                   lnpkt lnplt lnpet lnpmt;

CAP  : MODEL SK = LNPK LNPL LNPE LNPM LNAK T/DW;
LAB  : MODEL SL = LNPK LNPL LNPE LNPM LNAK T/DW;
ENE  : MODEL SE = LNPK LNPL LNPE LNPM LNAK T/DW;
MAT  : MODEL SM = LNPK LNPL LNPE LNPM LNAK T/DW;

SRESTRICT CAP.INTERCEPT+LAB.INTERCEPT+ENE.INTERCEPT+MAT.INTERCEPT=1;
SRESTRICT CAP.INTERCEPT = COST.LNPK;
SRESTRICT CAP.LNPK = COST.LN2PKPK;
SRESTRICT CAP.LNPL = COST.LNPKPL;
SRESTRICT CAP.LNPE = COST.LNPKPE;
SRESTRICT CAP.LNPM = COST.LNPKPM;
SRESTRICT CAP.LNAK = COST.LNPKAK;
SRESTRICT CAP.T = COST.LNPKT;


SRESTRICT LAB.INTERCEPT = COST.LNPL;
SRESTRICT LAB.LNPL = COST.LN2PLPL;
SRESTRICT LAB.LNPK = COST.LNPKPL;
SRESTRICT LAB.LNPE = COST.LNPLPE;
SRESTRICT LAB.LNPM = COST.LNPLPM;
SRESTRICT LAB.LNAK = COST.LNPLAK;
SRESTRICT LAB.T = COST.LNPLT;

SRESTRICT ENE.INTERCEPT = COST.LNPE;
SRESTRICT ENE.LNPE = COST.LN2PEPE;
SRESTRICT ENE.LNPK = COST.LNPKPE;
SRESTRICT ENE.LNPL = COST.LNPLPE;
SRESTRICT ENE.LNPM = COST.LNPEPM;
SRESTRICT ENE.LNAK = COST.LNPEAK;
SRESTRICT ENE.T = COST.LNPET;

SRESTRICT MAT.INTERCEPT = COST.LNPM;
SRESTRICT MAT.LNPM = COST.LN2PMPM;
SRESTRICT MAT.LNPK = COST.LNPKPM;
SRESTRICT MAT.LNPL = COST.LNPLPM;
SRESTRICT MAT.LNPE = COST.LNPEPM;
SRESTRICT MAT.LNAK = COST.LNPMAK;
SRESTRICT MAT.T = COST.LNPMT;

SRESTRICT CAP.LNPL = LAB.LNPK;
SRESTRICT CAP.LNPE = ENE.LNPK;
SRESTRICT CAP.LNPM = MAT.LNPK;
SRESTRICT LAB.LNPE = ENE.LNPL;
SRESTRICT LAB.LNPM = MAT.LNPL;
SRESTRICT ENE.LNPM = MAT.LNPE;
```

```
SRESTRICT CAP.LNAK + LAB.LNAK + ENE.LNAK + MAT.LNAK = 0;
SRESTRICT CAP.T + LAB.T + ENE.T + MAT.T = 0;
RUN;
```

C.2 SAS Outputs

```
Model: COST: Model 3
Dependent variable: LNC
                        TFP COST FUNCTION:DIRECT & INDIRECT WITH ABATEMENT

                                     SYSLIN Procedure
                              Seemingly Unrelated Regression Estimation

                                    Parameter Estimates

                        Parameter      Standard     T for H0:
   Variable   DF         Estimate         Error   Parameter=0    Prob > |T|

   INTERCEP    1      -121.982193   1859.950634        -0.066           0.0
   LNPK        1       -14.180198      7.658686        -1.852           0.0
   LNPL        1        -4.019481      2.506170        -1.604           0.0
   LNPE        1       -20.020054      6.485780        -3.087           0.0
   LNPM        1        39.219734      8.410805         4.663           0.0
   LN2PKPK     1         0.101532      0.064184         1.582           0.0
   LN2PLPL     1         0.026124      0.006541         3.994           0.0
   LN2PEPE     1         0.044744      0.022469         1.991           0.0
   LN2PMPM     1        -0.201588      0.037886        -5.321           0.0
   LNPKPL      1        -0.042895      0.016445        -2.608           0.0
   LNPLPE      1        -0.011210      0.007893        -1.420           0.0
   LNPEPM      1         0.099147      0.023542         4.212           0.0
   LNPKPE      1        -0.132718      0.025783        -5.148           0.0
   LNPLPM      1         0.027914      0.010990         2.540           0.0
   LNPKPM      1         0.074385      0.041390         1.797           0.0
   T           1         0.128231      1.909024         0.067           0.0
   T22         1     -0.000067248      0.000980        -0.069           0.0
   LNAK        1        -0.860410      6.694477        -0.129           0.0
   LN2AK2      1         0.001131      0.012969         0.087           0.0
   LNAT        1         0.000426      0.003439         0.124           0.0
   LNQ         1         1.001974      0.005508       181.919           0.0
   LNPKAK      1         0.023997      0.016784         1.430           0.0
   LNPLAK      1        -0.009608      0.005367        -1.790           0.0
   LNPEAK      1        -0.033784      0.013340        -2.533           0.0
   LNPMAK      1         0.019395      0.016953         1.144           0.0
   LNPKT       1         0.007116      0.003937         1.808           0.0
   LNPLT       1         0.002114      0.001286         1.644           0.0
   LNPET       1         0.010292      0.003331         3.090           0.0
   LNPMT       1        -0.019522      0.004320        -4.519           0.0
```

```
Model: CAP
Dependent variable: SK
              TFP COST FUNCTION:DIRECT & INDIRECT WITH ABATEMENT

                              SYSLIN Procedure
                    Seemingly Unrelated Regression Estimation

                             Parameter Estimates

                      Parameter      Standard    T for H0:
    Variable   DF      Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP    1    -14.180198      7.658686        -1.852        0.0789
    LNPK        1      0.101532      0.064184         1.582        0.1294
    LNPL        1     -0.042895      0.016445        -2.608        0.0168
    LNPE        1     -0.132718      0.025783        -5.148        0.0001
    LNPM        1      0.074385      0.041390         1.797        0.0874
    LNAK        1      0.023997      0.016784         1.430        0.1682
    T           1      0.007116      0.003937         1.808        0.0857


                      Durbin-Watson               1.570
                      (For Number of Obs.)           27
                      1st Order Autocorrelation   0.208


Model: LAB
Dependent variable: SL
              TFP COST FUNCTION:DIRECT & INDIRECT WITH ABATEMENT

                              SYSLIN Procedure
                    Seemingly Unrelated Regression Estimation

                             Parameter Estimates

                      Parameter      Standard    T for H0:
    Variable   DF      Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP    1     -4.019481      2.506170        -1.604        0.1244
    LNPK        1     -0.042895      0.016445        -2.608        0.0168
    LNPL        1      0.026124      0.006541         3.994        0.0007
    LNPE        1     -0.011210      0.007893        -1.420        0.1709
    LNPM        1      0.027914      0.010990         2.540        0.0195
    LNAK        1     -0.009608      0.005367        -1.790        0.0886
    T           1      0.002114      0.001286         1.644        0.1158


                      Durbin-Watson               0.516
                      (For Number of Obs.)           27
                      1st Order Autocorrelation   0.716
```

```
Model: ENE
Dependent variable: SE
            TFP COST FUNCTION:DIRECT & INDIRECT WITH ABATEMENT

                          SYSLIN Procedure
                 Seemingly Unrelated Regression Estimation

                         Parameter Estimates

                        Parameter       Standard    T for H0:
    Variable   DF        Estimate          Error   Parameter=0    Prob > |T|

    INTERCEP    1      -20.020054       6.485780        -3.087        0.0058
    LNPK        1       -0.132718       0.025783        -5.148        0.0001
    LNPL        1       -0.011210       0.007893        -1.420        0.1709
    LNPE        1        0.044744       0.022469         1.991        0.0603
    LNPM        1        0.099147       0.023542         4.212        0.0004
    LNAK        1       -0.033784       0.013340        -2.533        0.0198
    T           1        0.010292       0.003331         3.090        0.0058

                    Durbin-Watson                 1.138
                    (For Number of Obs.)             27
                    1st Order Autocorrelation     0.426

Model: MAT
Dependent variable: SM
            TFP COST FUNCTION:DIRECT & INDIRECT WITH ABATEMENT

                          SYSLIN Procedure
                 Seemingly Unrelated Regression Estimation

                         Parameter Estimates

                        Parameter       Standard    T for H0:
    Variable   DF        Estimate          Error   Parameter=0    Prob > |T|

    INTERCEP    1       39.219734       8.410805         4.663        0.0001
    LNPK        1        0.074385       0.041390         1.797        0.0874
    LNPL        1        0.027914       0.010990         2.540        0.0195
    LNPE        1        0.099147       0.023542         4.212        0.0004
    LNPM        1       -0.201588       0.037886        -5.321        0.0001
    LNAK        1        0.019395       0.016953         1.144        0.2661
    T           1       -0.019522       0.004320        -4.519        0.0002
```

```
                TFP COST FUNCTION:DIRECT & INDIRECT WITH ABATEMENT

                               SYSLIN Procedure
                     Seemingly Unrelated Regression Estimation

Cross Model Restrictions:

                              Parameter Estimates

                        Parameter      Standard    T for H0:
   Variable  DF          Estimate         Error  Parameter=0    Prob > |T|

   RESTRICT  -1           -147655         69484       -2.125        0.0462
   RESTRICT  -1       -687.129370     90.783428       -7.569        0.0001
   RESTRICT  -1        902.936989    124.654766        7.244        0.0001
   RESTRICT  -1       1544.078040    255.212622        6.050        0.0001
   RESTRICT  -1       1148.856446    185.567483        6.191        0.0001
   RESTRICT  -1        654.127502    100.297443        6.522        0.0001
   RESTRICT  -1      -5727.084702    931.952685       -6.145        0.0001
   RESTRICT  -1          -1357707        179852       -7.549        0.0001
   RESTRICT  -1       2091.595620    161.008690       12.991        0.0001
   RESTRICT  -1      -8907.308969    882.387759      -10.095        0.0001
   RESTRICT  -1      -4016.792237    405.299522       -9.911        0.0001
   RESTRICT  -1      -5156.133486    525.119052       -9.819        0.0001
   RESTRICT  -1      -3162.469146    318.873738       -9.918        0.0001
   RESTRICT  -1             14912   1034.130949       14.420        0.0001
   RESTRICT  -1           4120553        316551       13.017        0.0001
   RESTRICT  -1       -320.740548    177.787825       -1.804        0.0863
   RESTRICT  -1        874.812571    211.438670        4.137        0.0005
   RESTRICT  -1        783.430932    160.848032        4.871        0.0001
   RESTRICT  -1       1103.755752    325.948287        3.386        0.0029
   RESTRICT  -1        744.702544    118.973641        6.259        0.0001
   RESTRICT  -1      -2029.948029   1890.746723       -1.074        0.2958
   RESTRICT  -1           -631735        352653       -1.791        0.0884
   RESTRICT  -1      -1172.018663    129.028995       -9.083        0.0001
   RESTRICT  -1       1123.438876    123.942761        9.064        0.0001
   RESTRICT  -1       1486.351557    171.136727        8.685        0.0001
   RESTRICT  -1       3069.079874    350.501462        8.756        0.0001
   RESTRICT  -1       1807.473957    238.564392        7.576        0.0001
   RESTRICT  -1      -9846.593652   1311.020507       -7.511        0.0001
   RESTRICT  -1          -2315941        255586       -9.061        0.0001
   RESTRICT  -0                 0             .            .             .
   RESTRICT  -0                 0             .            .             .
   RESTRICT  -0                 0             .            .             .
   RESTRICT  -0                 0             .            .             .
   RESTRICT  -0                 0             .            .             .
   RESTRICT  -0                 0             .            .             .
   RESTRICT  -1          -1760250        807506       -2.180        0.0414
   RESTRICT  -1        -293694313     138185636       -2.125        0.0462

                     Durbin-Watson               1.009
                     (For Number of Obs.)           27
                     1st Order Autocorrelation   0.489
```