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URBAN AIR QUALITY IN CHINA: HISTORICAL AND COMPARATIVE PERSPECTIVES

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INTRODUCTION

Economic growth creates wealth, employment, and also effluents. In China, as in other rapidly industrializing economies, pollution poses serious challenges to both citizens and governments. High growth rates, high population density, and China's long history of intense human pressure on the land magnify environmental hazards. It is therefore no surprise that Chinese episodes now join the Donora Pennsylvania air inversion of 1948, smoke emergencies of the 1950s in London, New York City, and Belgium's Meuse Valley, multiple conflagrations on Cleveland's Cuyahoga River, and Japan's Minamata disease in the annals of environmental disasters associated with industrial growth.

Environmental discussions typically castigate China for allowing pollution levels that exceed present-day limits in the service-dominated economies of North America, Western Europe, and Japan. Since effluents are the mirror image of rapid industrialization, accusing China of generating serious pollution amounts to little more than acknowledging China as "the workshop of the world." The two, as John Gray observes, are "different parts of the same process" (2006, p. 21). As India moves toward Chinese-style dynamism, it is no surprise to learn that "Indian air is highly polluted" (*NY Times*, 4 June 2006, 4).

Focusing on urban air quality, this essay aims to deliver a balanced perspective on one dimension of the environmental consequences arising from rapid Chinese growth. We consider three basic questions. How bad is air quality in major Chinese cities? Is urban air quality improving or deteriorating? How does the path of urban air quality in China compare with the experience of Japan and Korea, which, like China, combined rapid industrialization with high population density?

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The answers proposed in what follows are unambiguous and, in the context of current public discourse, somewhat unexpected. Although Chinese cities suffer from serious air pollution, air quality has improved dramatically and shows a clear upward trend. Information about urban air pollution situates China on a path resembling the experience of previous industrializers. Indeed, China's achievements in controlling ambient air pollution often run ahead of Japanese and Korean attainments at comparable stages of their national development.

HOW BAD IS CHINA'S URBAN AIR QUALITY?

No one can doubt the seriousness of China's problems with urban air quality. The World Bank's summary, prepared ten years ago, continues to provide an accurate overview:

> [Despite past improvements] ambient concentrations of suspended particulates are. . . extremely high in most cities, and ambient sulfur dioxide concentrations and acid rain are also high in areas where high-sulfur coal is consumed. . . . northern cities have more serious particulate pollution. . . while southern cities have serious sulfur dioxide pollution. . . . concentrations of particulates and sulfur dioxide in many Chinese cities are among the highest in the world. . . [Johnson et al 1997, pp. 7-9].

These high levels of airborne effluents resemble historical circumstances in other industrializing nations. Writing in 1993, Vaclav Smil notes that particulate levels in Chinese cities "resemble the Western means of fifty to ninety years ago" (1993, p. 117). Kazuo Hishida notes that urban particulates in China during the mid 1980s resembled Japanese conditions of the late 1960s, when dustfall in Japan exceeded Chinese readings from the mid 1980s (1986, pp. 57-58). When this author lived in Tokyo during the late 1960s, Tokyo policemen inhaled oxygen while directing traffic, "vendors sold oxygen on Tokyo's streets, and children wore masks on their way to school" because Japan "may have been the world's most polluted country" [Schreurs 2002, p. 36].

At that time, Tokyo recorded ambient concentrations of .440 milligrams of particulates (1968) and .220 milligrams of sulfur dioxide (1965 and 1966) per cubic meter of air. The average particulate level for a group of 36 major Chinese cities exceeded the Tokyo peak in 1986 and 1987. Although this average has subsequently declined (see Figure 4), individual cities continue to record high levels of ambient pollution. In 2004, particulates exceeded the 1968 Tokyo level in 11 Chinese cities, all in China's northwest region, where sand rather than industrial effluents predominates (Environment Yearbook 2005, 773). During the late 1990s, Taiyuan exceeded Tokyo's peak levels for sulfur dioxide; Shijiazhuang's 2003 readings matched Tokyo's mid-1960s figures for sulfur dioxide. In 2004, Linfen and Yangquan, both in coal-rich Shanxi province, exceeded Tokyo's peak levels of 0.220 mg per cubic meter for sulfur dioxide (ibid., 769).

Figure 1 presents international data on the particulate content of urban air samples. We compare the arithmetic average of annual measurements of "total suspended particulates" (TSP) for 36 Chinese cities[1] with figures for Pittsburgh[2], Tokyo, Kitakyushu[3], and Seoul. The comparison shows that, on average, ambient TSP concentrations in Chinese cities exceed current figures for the other cities by a large margin. Comparison of recent Chinese results with earlier international figures, however, changes the picture. The Chinese averages never reach the peak Pittsburgh level recorded in the 1920s, rest consistently below the 1968 Tokyo peak beginning in the early 1990s, and are now approaching the levels recorded in Seoul during the late 1980s.

INSERT FIGURE 1 ABOUT HERE

Figures 2 and 3 provide more detail on the location of high TSP readings in China. Figure 2 directs attention to administrative cities by comparing Beijing, Shanghai, and Guangzhou with Tokyo and Seoul. Trends for Guangzhou and Shanghai from 1990 resemble the trend for Seoul beginning in the mid-1980s. The two Chinese cities begin with higher TSP levels than Seoul's, but drop quickly from peak levels of 0.30-0.35 mg per cubic meter. Recent figures for Shanghai and Guangzhou appear to track Seoul's situation ten years previously. Beijing reports TSP levels that are higher than those for Shanghai and Guangzhou and remain quite stable prior to a big drop in 2002/03. The Beijing figures, however, remain well below the peak levels recorded by Tokyo in the late 1960s.

INSERT FIGURE 2 ABOUT HERE

Dustfall, measured in tons per square kilometer per month, is closely correlated with airborne particulates. Chinese dustfall statistics present a pattern similar to TSP. Chinese readings are high by contemporary international norms, but hardly unusual by historical standards. In 2000, 57 Chinese cities reported dustfall above 10 tons per square kilometer-month, of which 18 scored above 20 tons. The 2004 data indicate very slight improvement, with the numbers falling to 54 and 16. The highest figures approach 40 tons: 38.4 tons for Baoding in 2000, 37.6 tons for Handan in 2004 (Environment Yearbook 2001, 601-602; 2005, 774-775).[4] Historic peaks for dustfall elsewhere include 70 tons for Pittsburgh (1923/24; the post World War II peak was 34 tons in 1948), 33.9 tons for Tokyo (1967), 23.7 tons for Kitakyushu (1959), and Japanese readings that "exceeded 100 tons" elsewhere in Japan during the 1960s (Hishida 1986, p. 58).[5] Beijing reported dustfall of 15.1 tons per square kilometer in 2000 and 11.5 tons in 2004 (ibid). By comparison, the most recent observation of dustfall in excess of 10 tons occurred in 1975 for Tokyo, for 1972 in Kitakyushu, and for 1981 in Pittsburgh.

Figure 3 shifts the comparison to Chinese industrial cities, of which Chongqing, Lanzhou, Shenyang, and Taiyuan can serve as examples. In the late 1980s, each of these cities reported levels of TSP far above the peak Tokyo levels of the 1960s. For Taiyuan and Lanzhou, the figures for some years even surpass the peak Pittsburgh figures from the early 1920s, which surely qualify as extreme levels of contamination. Three of the four Chinese cities show a sharp downward trend for TSP concentration, with recent figures well below the Tokyo peaks of the 1960s and, for Chongqing and Shenyang, approaching the readings for Seoul during the mid 1980s. In Lanzhou, by contrast, the TSP readings fluctuate at levels close to the peak Pittsburgh figure, with no visible downward trend.

INSERT FIGURE 3 ABOUT HERE

Figure 4 provides an international comparison for concentrations of sulfur dioxide. As with TSP, recent annual averages of SO2 measurements for major Chinese cities are substantially higher than current readings in Tokyo, Kitakyushu, or Seoul. From a historical perspective, however, Chinese measure for urban SO2 concentrations seem quite moderate. During the early 1980s, average readings for major Chinese cities were similar to observations in Pittsburgh. Recent Chinese averages are far below the historic peaks for Tokyo and Seoul, and slightly below the (much lower) peak for Kitakyushu.

INSERT FIGURE 4 ABOUT HERE

Figure 5 focuses on NOx, the combined quantity of two compounds, NO and NO2, per cubic meter of air. Here the Chinese readings fall near or below contemporaneous measures for Tokyo, Kitakyushu and Seoul, apparently because Chinese cities still lag behind their Japanese and Korean neighbors in the density of motor vehicle traffic, which is the main contributor to NOx. Data from individual Chinese cities bear out this correlation between automotive transport and NOx: the highest Chinese figures come from Beijing, Shanghai, and Guangzhou, cities that lead China in household incomes and auto ownership. Beginning in 2001, China followed international practice by measuring NO2 separately, rather than reporting the combined concentration of NO and NO2. The new series resemble the earlier data for NOx: they show no strong trend, with the highest concentrations of NO2 observed in China's richest cities.

INSERT FIGURE 5 ABOUT HERE

These observations confirm that many Chinese cities experience levels of air pollution that far exceed today's norms for the advanced economies of East Asia. When compared with historic pollution levels during earlier periods of peak industrialization in Japan, Korea, and the United States, however, these Chinese figures appear routine rather than exceptional. We will return to this subject below.

IS URBAN AIR QUALITY IMPROVING?

Figures 1-5 offer clear evidence of general, but not universal improvement in urban concentrations of particulates and of sulfur dioxide, the main effluents from industrial operations, power plants, and other forms of stationary combustion. Ambient concentrations of nitrous oxides, which are associated with motor vehicle traffic, have not declined.

Figure 6 explores the magnitude of the decline in ambient concentration of particulates. Both average readings for (approximately) 36 major cities and the maximum annual figure within this group dropped sharply between 1986 and 2004. The average figure, which initially exceeded the Tokyo peak level for 1968, dropped below that level in 1988 and has remained well below that figure ever since. In 1999, and again in 2003, the major city average approached the TSP level recorded for Pittsburgh in 1957 following that city's ten-year cleanup campaign. The average Chinese figure for 2003 is less than half the reading for 1986. The maximum annual figure reported for major Chinese cities has dropped even faster. Peak figures for the late 1980s include readings well above 1,000 mg per cubic meter, levels associated with air contamination crises in Europe and North America during the 1950s and 1960s (Goklany 1995, 346). Since the late 1980s, TSP concentrations in the most polluted major cities have declined by approximately two-thirds, to levels that approximate Tokyo's 1968 peak.

INSERT FIGURE 6 ABOUT HERE

Results for sulfur dioxide, displayed in Figure 7, are equally dramatic. After fluctuating around 0.1 mg per cubic meter during the 1980s, the average of figures reported for major Chinese cities dropped below that figure in 1990. Further decline ensued. During the late 1990s and into the current decade, the average of SO2 readings for major Chinese cities moved below the New York City reading for 1972. The Chinese urban average now regularly dips below Pittsburgh's SO2 figure for 1984, which presumably informed the selection of this U.S. steel center as "America's most livable city" in the following year. The annual peak figure for major Chinese cities has also dropped sharply, though irregularly.

INSERT FIGURE 7 ABOUT HERE

Table 1 summarizes long-term trends in ambient concentrations of common air pollutants in Chinese cities. The data record the arithmetic average of annual readings for large numbers of cities. The results show a strong downward trend for particulates, sulfur dioxide, and dust. Starting from initial levels above Tokyo's peak figures from the late 1960s, average Chinese readings for particulates in major cities decline sharply. The current Chinese average approximates figures for earlier industrializers 5-10 years after the start of serious efforts to reduce environmental hazards: late 1950s Pittsburgh (dustfall 12.8 tons in 1959), mid-1970s Tokyo (dustfall 13.3 tons in 1972), mid-1980s Taipei (dustfall approximately 14 tons in 1985 and 1991).[6] For sulfur dioxide, the decline begins from levels far below the Tokyo peak of the 1960s. Recent figures approximate Tokyo figures of the mid-1970s and, as noted above, are consistently below New York's SO2 levels of the early 1970s and Pittsburgh's of the mid-1980s.

INSERT TABLE 1 ABOUT HERE

NOx offers the lone exception to the general improvement in urban air quality for major Chinese cities, evidently because the rapid growth of motor vehicle traffic has offset what appears to be a general decline in untreated emissions.

CHINA'S DEVELOPMENT PATH: NORMAL OR ABERRANT?

Studies of multiple economies suggest that an "environmental Kuznets curve," in which pollution first rises, and then declines during the course of economic growth, provides a plausible expectation of the historic path of environmental hazards during the course of development.

If this formulation description accurately describes the long-term relationship between growth and effluents, we should expect the spread of new technology and of new ideas to accelerate the shift from growth-with-more effluents to growth with reduced environmental damage. The concept of environmental stewardship as an important objective of national policy is very recent. National environmental protection agencies did not appear until the early 1970s in the United States and Japan (Schreurs 2002, 35, 45-46). The subsequent trend toward globalization means that nations like China experience both domestic and international pressures to mitigate environmental damage from economic growth much earlier in the development process than occurred in Japan or Korea.

Figures 8 and 9 use East Asian evidence to illustrate this systematic shift toward earlier control of environmental damage during the industrialization process. To avoid the complexities associated with cross-national comparisons of national product, we employ the share of labor in the primary sector (farming, forestry, and fishing), which declines regularly with the growth of aggregate and per capita incomes, to index the process of national development.[7]

Figure 8 plots primary sector labor force shares for China, Japan, and Korea against urban TSP concentration for Tokyo, Kitakyushu, Seoul, and the arithmetic average of readings for 36 major Chinese cities.[8] All three nations show a declining trend in atmospheric concentration of particulates. In Japan, the decline begins when the primary sector labor force share stands in the range of 20-30 percent. In Korea, the decline starts with primary labor share in the 25 percent range. In China, by contrast, ambient concentrations of TSP begin their downward march much earlier in the development process, when the share of primary-sector workers in the national labor force is approximately 50 percent. This result confirms our expectation that new technologies and new thinking will encourage latecomers to tackle the environmental difficulties associated with rapid growth at progressively earlier stages of the development process.

INSERT FIGURE 8 ABOUT HERE

Figure 9, which provides a parallel analysis for sulfur dioxide, points in the same direction. Pollution from sulfur dioxide in Chinese cities never reaches the high levels experienced in Japan and Korea. Reduction of ambient concentrations of SO2 begins far sooner in the development process for China than for either Japan or Korea. Recent readings for urban SO2 pollution in China, where the primary sector's labor force share is

35-40 percent, match those attained at much later stages in Japan and Korea when primary sector labor occupied less than 15 percent of the work force.

INSERT FIGURE 9 ABOUT HERE

These findings regarding urban air quality indicate that the relationship between economic growth and environment in China's strongly resembles the development processes observed elsewhere in East Asia. In China, as in Japan and Korea, an initial phase of high growth with rising pollution intensity yields to a more attractive combination of ongoing growth with declining ambient concentration of major industrial effluents. Figures 8 and 9 show that the second stage of China's development process, in which the trend of pollution intensity turns downward, begins at an earlier phase of industrialization than occurred in Japan or Korea. We attribute this improvement in the trade-off between growth and environment to the spread of new technology and to increased awareness of the negative environmental consequences of unbridled industrial growth.

WHAT ABOUT AIR QUALITY OUTSIDE CHINA'S MAJOR CITIES?

Rising awareness of the environmental costs associated with rapid growth has encouraged Chinese policy-makers to increase efforts to limit harmful effluents. Not surprisingly, major cities have become the initial target of new controls. This raises the possibility that improved urban air quality has come at the expense of environmental deterioration outside major cities, where government and party leaders are strongly motivated to maximize local economic growth.

Extending the present study beyond China's major cities is not possible because systematic quantitative information about air quality appears limited to urban sites.
In a separate project, Zixia Sheng of Carnegie-Mellon University and I use information about emissions, which includes localities down to the county level, and about the output of township and village enterprises, to construct measures of air quality outside China's major cities. Preliminary results show that ambient concentrations of particulates, soot, and sulfur dioxide increased during the decade ending in 2003, but that concentrations of particulates and soot began to decline around 2000.

These findings suggest that the environmental Kuznets curve dynamics visible in urban China may apply beyond Chinese cities, but with a considerable time lag.

CONCLUSIONS AND IMPLICATIONS

Our analysis of urban air quality examines only one dimension of the multiplex interaction between economic growth and environmental consequences during China's long economic boom. Extension of our review to encompass water quality, solid wastes, and airborne contaminants outside China's major cities could alter the picture presented here. With this qualification, what conclusions follow from our study of urban air quality?

Air quality in China's major cities falls far short of contemporary standards prevailing in advanced nations. Although studies linking air pollution with negative health outcomes routinely tilt toward alarmism,[9] Xiping Xu's observation that air pollution in China's major cities "is significantly associated with both acute and chronic adverse health effects" appears to provide a realistic and objective summary (1998, p. 281).

From a historical perspective, however, China's environmental circumstances appear routine rather than exceptional. In China, as in every other nation that has experienced sustained economic growth, development produces soot, smoke, and smog as well as new employment opportunities and rising incomes. The levels of airborne pollutants observed in major Chinese cities are not extraordinary when compared with historical circumstances in Pittsburgh, New York, Tokyo, Kitakyushu, Seoul, or Taipei.

What does appear different about the relationship between Chinese economic growth and air pollution is that the downward trend in ambient concentrations of particulates and sulfur dioxide (but not nitrous oxides) begins at an earlier stage of the development process, as measured by the primary sector's labor force share, than occurred in the United States, Japan, or Korea. This reflects the impact of new technology and the spread of concern over the negative environmental consequences of economic growth.

To emphasize the magnitude of China's achievements in limiting the negative environmental consequences of rapid growth, Figure 10 compares trends in GDP growth and aggregate energy consumption with changes in average SO2 concentrations in major cities.[10] The data show that, despite the presence of dirty industries and widely publicized gaps in enforcement of environmental regulations, China's economy has attained huge reductions in effluents per unit of GDP and of energy consumption. Ambient concentrations of sulfur dioxide have dropped by one-half between 1980 and 2003 (left scale). At the same time, GDP has risen by a factor of ten and energy consumption has nearly quadrupled (right scale). Taking 1980 as 1, these observations imply that ambient urban concentrations of sulfur dioxide in the early years of the current century amount to approximately 0.5/10 or .05 per unit of GDP and approximately 0.5/4 = 0.125 per unit of GDP – indicating respective declines of 95% and 87.5% in ambient urban sulfur dioxide per unit of GDP and per unit of energy consumption over a period of 20-25 years. Even though the preliminary findings noted above indicate that air quality outside China's cities maintained a downward trend until about 2000, it seems likely that the trend of declining air pollution per unit of GDP or energy use applies, though on a more modest scale, to the entire Chinese economy.

INSERT FIGURE 10 ABOUT HERE

These observations invite speculation on the larger issue of whether environmental degradation is likely to pose a serious obstacle to China's future economic growth. Our findings indicate that health hazards arising from air pollution are unlikely to act as an important constraint on China’s future growth. Several considerations reinforce this conclusion.

China has already achieved substantial declines in urban concentrations of major pollutants associated with industrial production. This achievement has occurred without imposing major constraints on China’s ongoing high-speed growth. Together with similar experiences in other nations, this result makes it unlikely that either the health hazards associated with current levels of pollution or the expenses tied to future efforts to reduce effluents will place overwhelming burdens on China’s economy.

It is difficult to doubt that China’s dynamic economy can provide the resources needed to deliver further reduction of effluents. Vermeer writes that “with adequate investment. . . larger facilities can be upgraded and [effluents] controlled at a net profit” (1998, 971-972). Even if such investments are not profitable, international experience indicates that costs of environmental cleanup and protection are modest. Japan’s governments and corporations spent 1.3 percent of GDP on environmental protection and pollution control in 1990. The Federal Republic of Germany spent 1.6 percent of GDP for the same purposes in 1987. The United States devoted 1.8 percent of its GDP to pollution abatement and control in 1989 (O’Connor 1994, 177-178). China, which currently devotes nearly 50 percent of annual GDP to investment spending, can easily assign comparable (or much larger) GDP shares to environmental objectives without slowing the economy’s progress.

Both Vermeer, writing about China, and O’Connor, focusing more broadly on Asia, indicate that environmental management is more difficult and remediation often less economical for small factories than for large plants (Vermeer 1998, 971; O’Connor 1994, 167-174). In China, both market forces and official policy seem likely to push industrial operations in the direction of large-scale facilities. Between 1980 and 2005, the offsetting consequences of entry and consolidation produced a standoff, with no overall trend toward industrial concentration or dispersion (Brandt, Rawski, and Sutton 2006). Continued improvements in domestic transport and communication, ongoing commercialization of the financial system, increased privatization of state enterprises and the gradual removal of legal and administrative restrictions surrounding mergers and bankruptcy all seem likely to encourage a trend toward industrial concentration. In addition, Chinese official policy strongly favors the pursuit of scale economies as well as the closure of small-scale polluters (e.g. “Heavily Polluting Factories to be Demolished,” *China Daily* 13 June 2006, 3).

Changes in economic structure seem likely to ease the burden of reducing effluents. Table 2 shows the sectoral breakdown of China’s GDP growth for 5-year periods beginning in 1980. The share of the secondary sector (mostly industry and construction) in aggregate growth reached what will probably stand as a historic peak of 54.8 percent of incremental growth during 1990/95. The share of the services sector, which jumped from 35-40 percent of incremental growth during 1980/1995 to over half in 1995/2000, will in all probability increase further. This will lessen the pressure of growth on the environment because of the low energy consumption and effluent generation associated with sectors like education, finance, health care, commerce, and public administration.

INSERT TABLE 2 ABOUT HERE

Rising costs will surely encourage Chinese manufacturers to reduce unit consumption of energy and materials, which often lags far behind international norms. In addition, structural change within the industrial sector will continue to reduce the ratio of effluents to outputs. As O'Connor observes, at some point in the industrialization process, "the leading growth sectors tend to be ones of low to intermediate pollution intensity – e.g. electronic/electrical equipment, general machinery, and transport equipment" (1994, p. 28). This description is highly relevant to China's current development phase.

The Beijing Olympics promise to make a major contribution to raising Chinese environmental standards. China's government, following the lead of South Korea's preparation for the 1988 Seoul Olympics, has embarked upon a massive environmental cleanup for its capital.[11] The decision to remove Capital Steel, a nationally prominent firm employing over 100,000 workers, from Beijing's western suburbs underlines the scope of the cleanup and the government's determination to achieve a flawless performance on the world stage. With cities and provinces locked in fierce competition for talent and investment resources, Beijing's new, higher environmental standards have already begun to influence other regions. Thus Shenyang now styles itself as "an ecologically and environmentally friendly city" that is "no longer. . . polluted by industrial waste," while Benxi seeks "to become a model city of environmental protection" (*China Daily* 20 September 2006, p. S6 and 23 June 2006, p. 3).

We conclude that China's urban air quality, although low by current international standards, seems quite typical of circumstances in fast-growing economies during peak periods of industrialization. China's urban air quality has improved substantially during the past quarter-century. This improving trend began at an earlier stage of the development process than in Japan or Korea. The cost of further improvements in air quality seems well within the reach of China's economy. Changes in economic structure, policy, and thinking seem likely to push in the direction of further reductions in airborne pollutants. The constancy of urban concentrations of ambient nitrous oxide stands as the lone exception to this generally favorable outcome. China's recent ban on leaded gasoline and promulgation of auto emission standards beyond those currently in force in the United States indicate that the Beijing authorities are both aware of the problems posed by the spread of car ownership and are prepared to take remedial action. In China, as elsewhere, we cannot yet predict the environmental consequences of humanity's love affair with the automobile.

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NOTES

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[1] The number of cities included in the sample varies from year to year because of data gaps. The number of included cities declines sharply after 2000 as the focus of measurement, following international practice, shifts to small particles, which pose the greatest health hazard. The standard metric has changed from TSP (including particles up to 40 microns) to PM-10 (limited to particles of 10 microns or smaller.

[2] The Pittsburgh air quality data used here were provided by Professor Cliff Davidson. Professor Michael Greenstone kindly supplied additional data used in Chay and Greenstone (2005).

[3] Environmental data for Kitakyushu, the original home of Japan's steel industry, were provided by the Kitakyushu municipal government through the kind assistance of Professor Shoichi Yamashita. Data shown Figure 1 and elsewhere describe conditions in Kitakyushu City. The highest effluent readings, and therefore the steepest improvements in air quality, occurred in the Shiroyama industrial district.

[4] The highest reading in 2000, 41.9 tons for Yinchuan, probably is associated with sand rather than industrial pollution (Envrionment Yearbook 2001, , 774).

[5] The highest reading I have found for Seoul, 7.35 tons per square kilometer-month for 1988, comes after Korea's preparatory cleanup in advance of the 1988 Olympics and is probably not a peak figure.

[6] Taipei data from Hsiao et al, 1993, 67. Data for Pittsburgh and Tokyo from author's file AirPollution.TRmod.062506.

[7] Labor force data for Japan and Korea come from standard official sources. Standard Chinese data appear to overstate the share of primary workers in the national total (Rawski and Mead 1998). I therefore use Loren Brandt's unpublished estimates of sectoral labor force attachment. Use of official Chinese labor data would accentuate the results described below.

[8] The Chinese data are from *China Energy Databook* (to 1994) and from data provided by Professor Zhang Xiao and Ms. Wang Xuelian (beginning 1995). The number of cities included varies from year to year due to gaps in available data.

[9] Conclusions about increased mortality associated with environmental hazards, for example, typically neglect to analyze the life chances of persons whose deaths are linked to pollutants. In addition, the risks associated with environmental hazards are seldom compared with other dangers (smoking cigarettes, riding in automobiles, etc.) to which citizens routinely expose themselves.

[10] GDP data: real growth in 2000 prices computed from official data on real growth in the primary, secondary, and tertiary sectors using 2000 value-added weights. See author's file GDP and Component Indexes 1952-2004. Energy consumption data from Abstract 2006, 145 and Yearbook 1990, 487.

[11] I am indebted to George Schoenhofer of Industry Canada for alerting me to the importance of the 1988 Olympics for environmental policies in Korea.

Table 1
Long-term Trends in Ambient Air Quality in Chinese Cities

Year	TSP	SO2	Dust	NOx	Number of Cities
1980	0.610	0.110	35	0.043	
1981	0.703	0.115	35	0.050	
1982	0.729	0.115	32	0.045	
1983	0.600	0.094	32	0.046	
1984	0.660	0.092	27	0.042	
1985	0.590	0.105	28	0.050	
1986	0.570	0.106	25	0.048	
1987	0.590	0.117	24	0.056	
1988	0.580	0.094	25	0.045	
1989	0.432	0.105	22	0.047	
1990	0.379	0.098	19	0.043	
1991	0.325	0.090	18	0.046	70
1992	0.323	0.094	19	0.048	76
1993	0.329	0.098	19	0.050	77
1994	0.329	0.086	18	0.047	88
1995	0.317	0.081	17	0.047	88
1996	0.308	0.080	16	0.046	90
1997	0.287	0.066	15	0.045	94
1998	0.282	0.057	15	0.045	96
1999	0.259	0.056	14	0.045	97
2000	0.261	0.052	14		94
2001	0.277	0.052	15		97
2002	0.269	0.051	14		98
2003	0.256	0.066	12		113
2004	0.245	0.065	13		113

Source: for 1980-1999, *China Energy Databook* , Chapter 8
When the source reports two figures, we use the average of the the two.

for 2000-2004, *Environment Yearbook,* issues for 2001-2005.

Notes:
TSP, SO2 and NOx measured in milligrams per cubic meter
Dustfall measured in metric tons per square kilometer per month
Number of cities: figures are for SO2; numbers for other measures vary considerably.
Systematic collection of data for Nox apparently ended in 1999

Table 2

Sectoral Shares in Annual GDP and in GDP Growth, 1980-2005

Year	GDP Index	Sectoral Shares in Annual GDP (%)		
		Primary	Secondary	Tertiary
1980	100.0	30.1	48.5	21.4
1985	169.7	28.4	43.1	28.5
1990	245.8	27.0	41.6	31.3
1995	427.7	19.8	47.2	33.0
2000	645.2	14.8	45.9	39.3
2005	1014.8	12.5	47.3	40.3

Period	Total	Sectoral Share of 5-Year GDP Growth (%)		
		Primary	Secondary	Tertiary
1980/1985	100.0	25.9	35.4	38.7
1985/1990	100.0	24.1	38.2	37.6
1990/1995	100.0	10.0	54.8	35.2
1995/2000	100.0	5.0	43.3	51.7
2000/2005	100.0	8.4	49.7	41.9

Sources:

Annual shares: 1980, 1990 from 50 Years, p.3
For 1995 and 2000 from NBS GDP revisions of February 2006
For 2005, NBS Communique, February 2006

GDP data from TR File
GDP and Component Indexes 1925-2004
GDP in 2000 prices and 2000 nominal sector weights.

Figure 1
International Air Quality Comparison - TSP

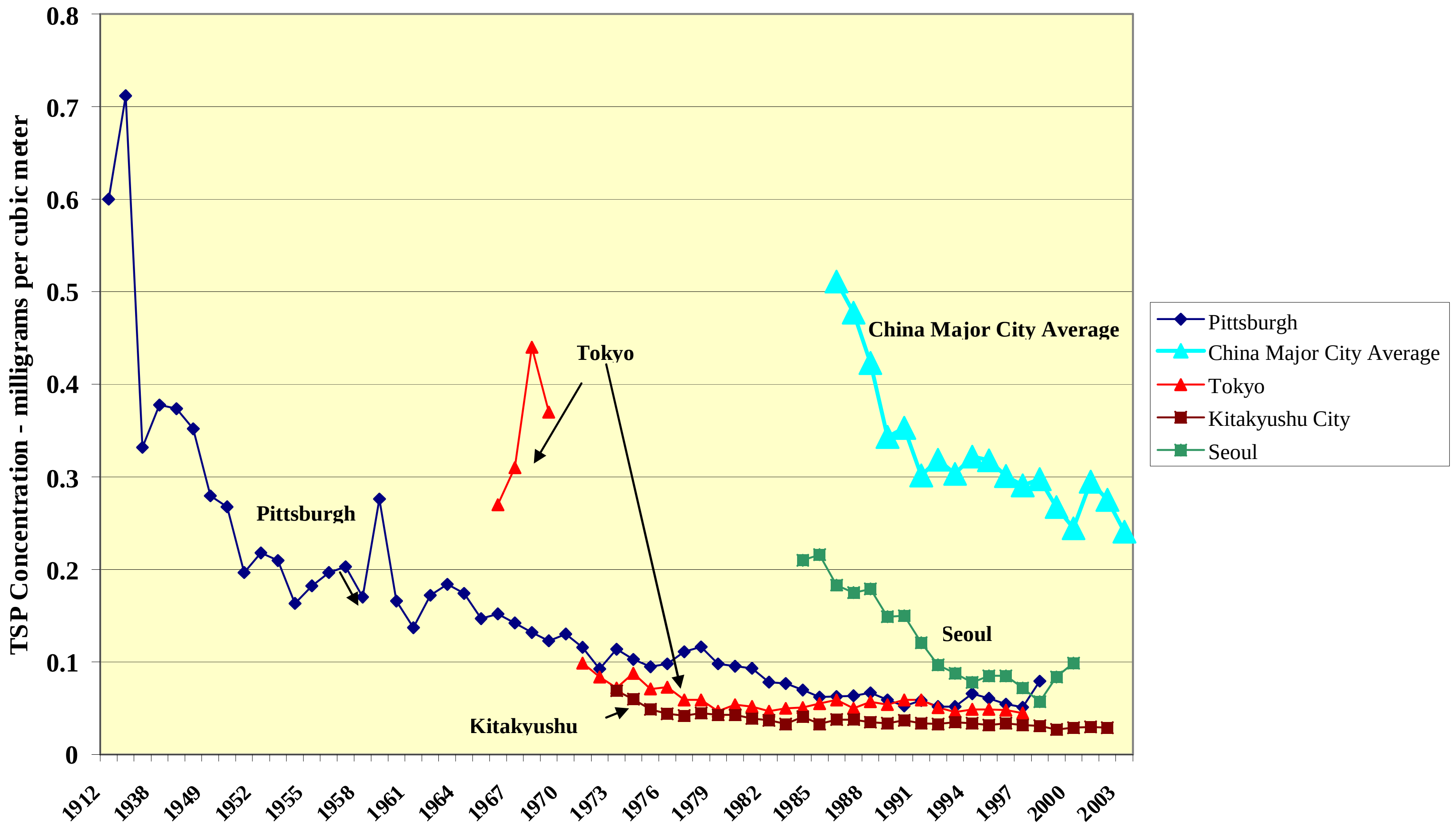

Figure 2
Comparative TSP Levels - Administrative Centers

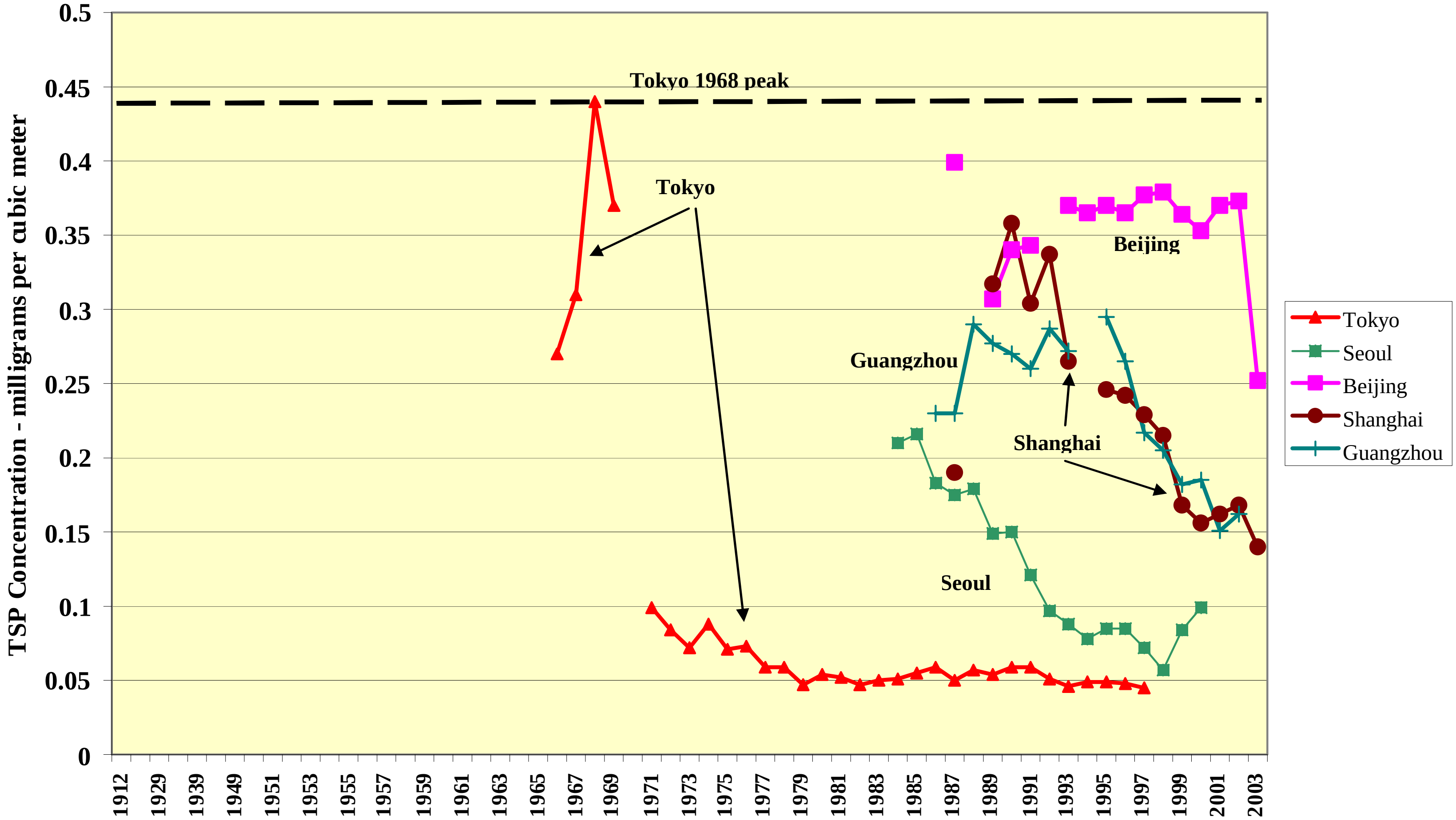

Figure 3
Comparative TSP Levels - Industrial Centers

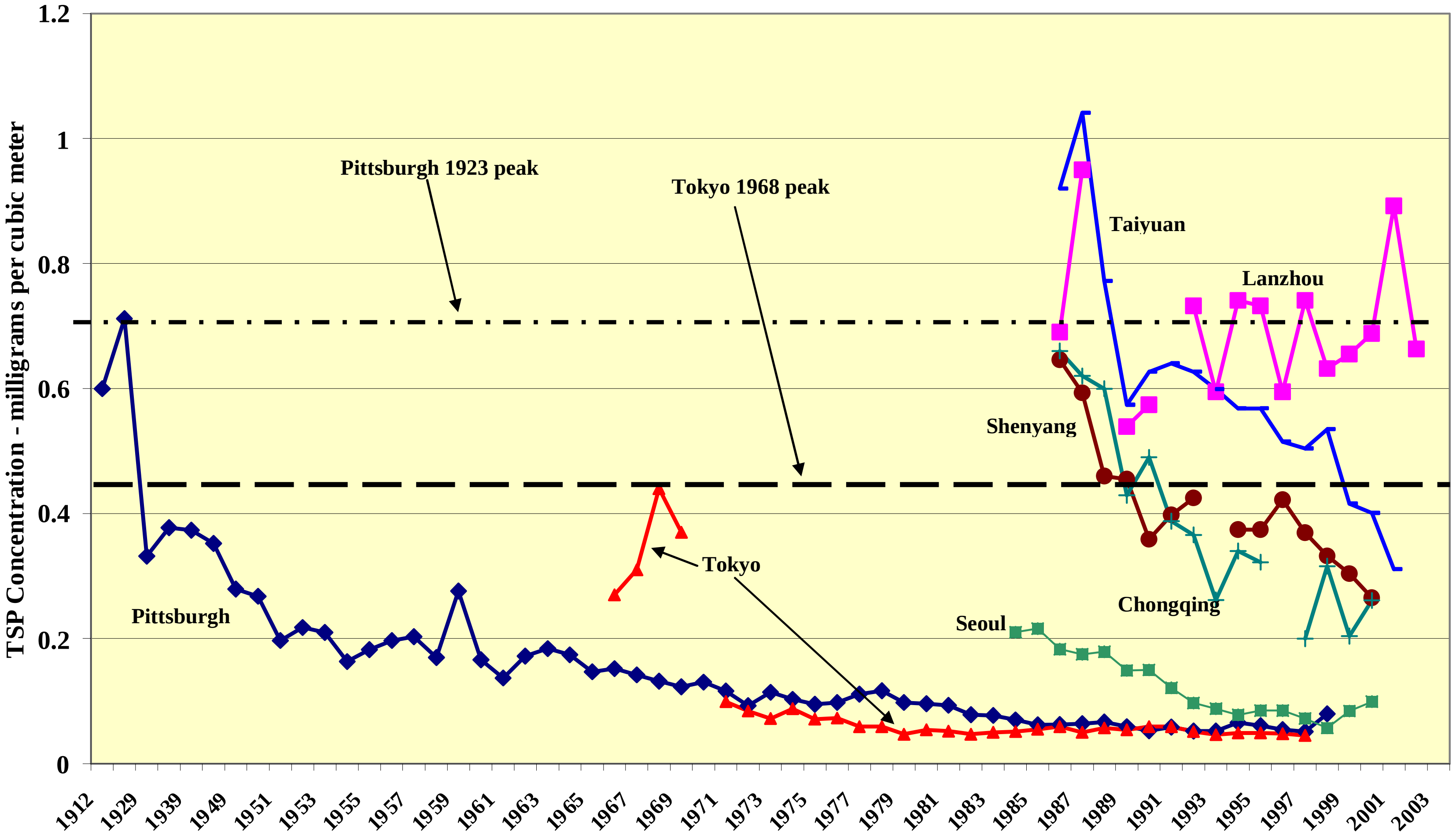

Figure 4
International Air Quality Comparison - SO2

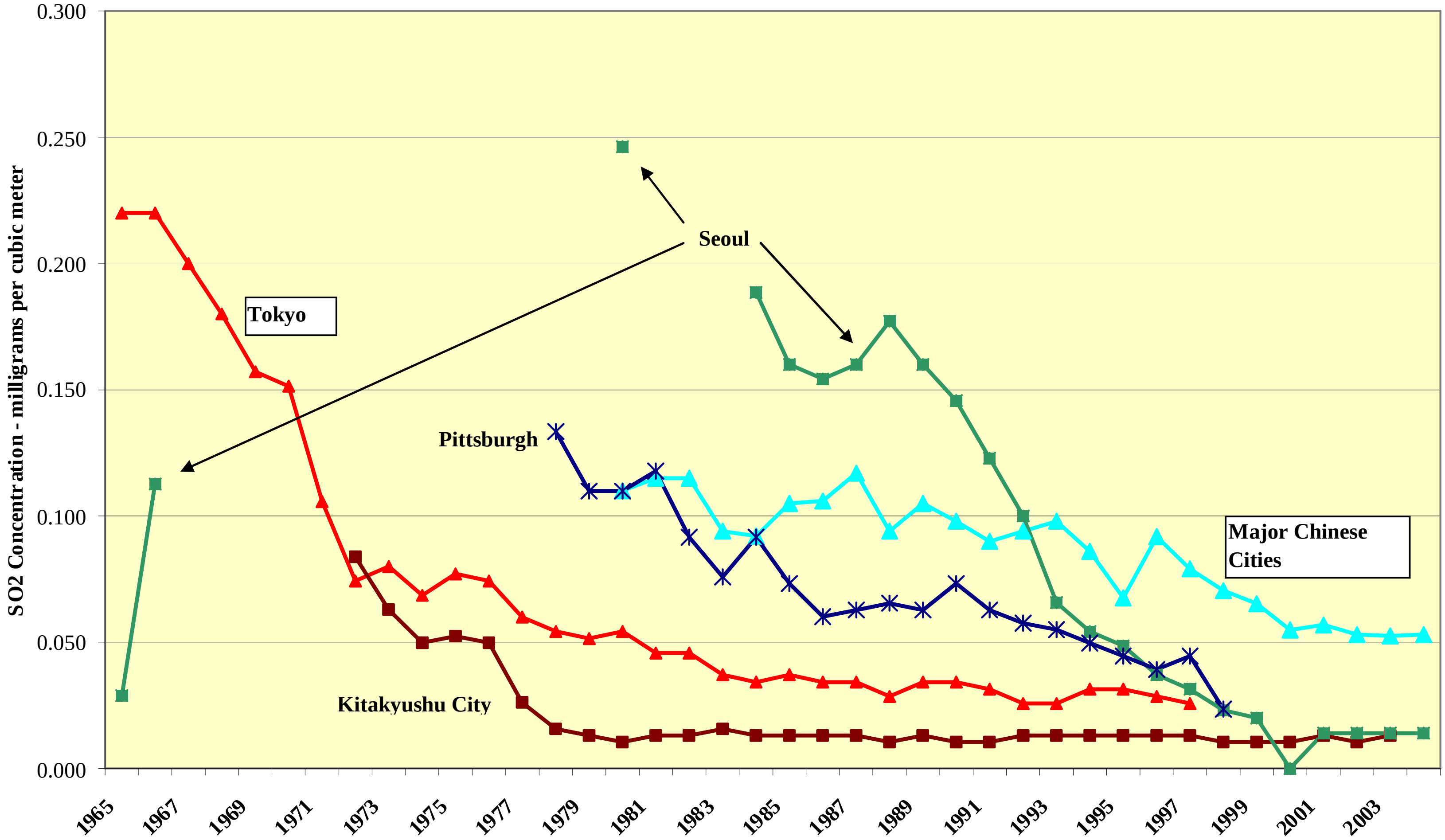

Figure 5
International Air Quality Comparison - NOx

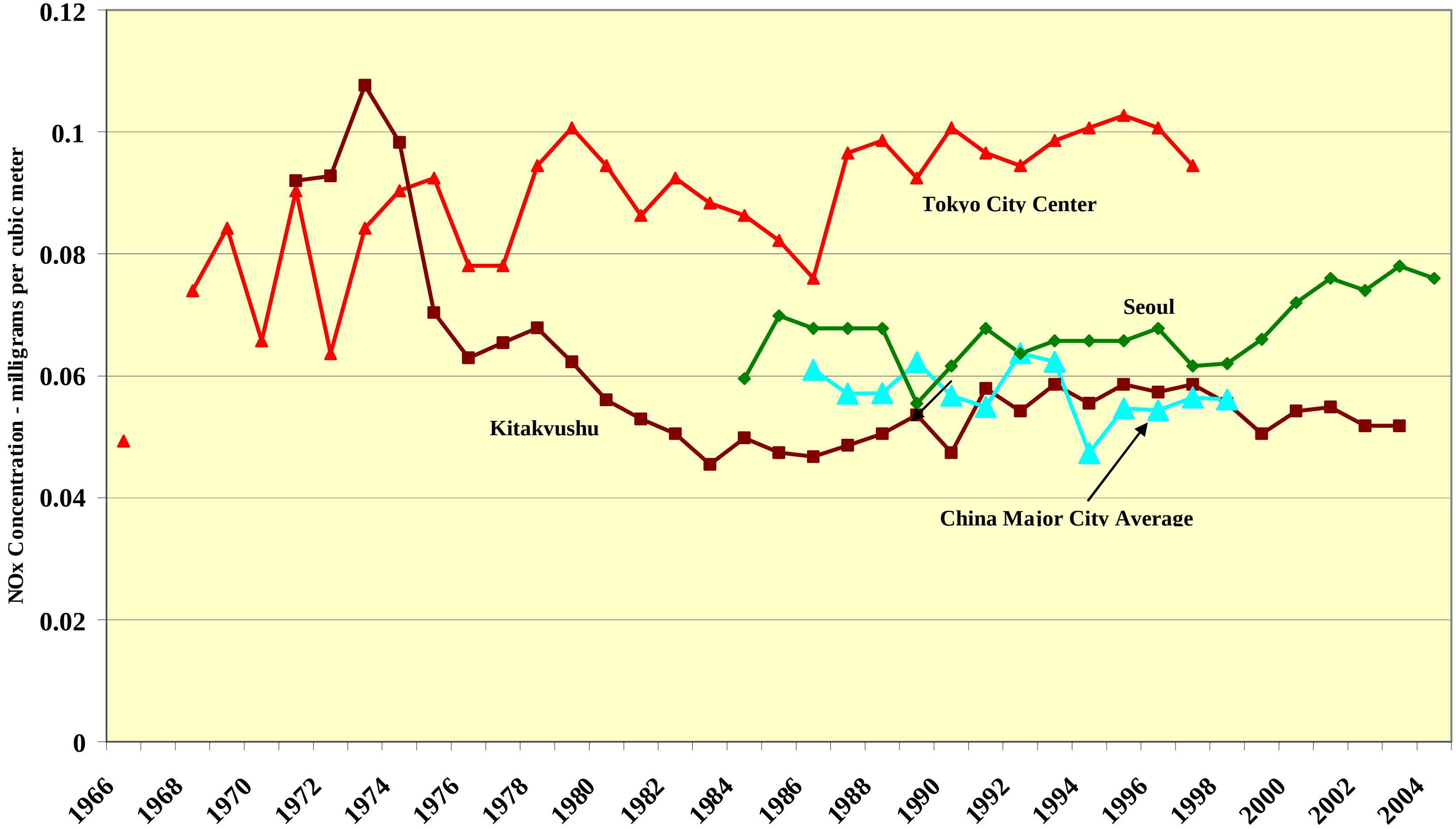

Figure 6
China: TSP Levels in Major Urban Areas, 1986-2003

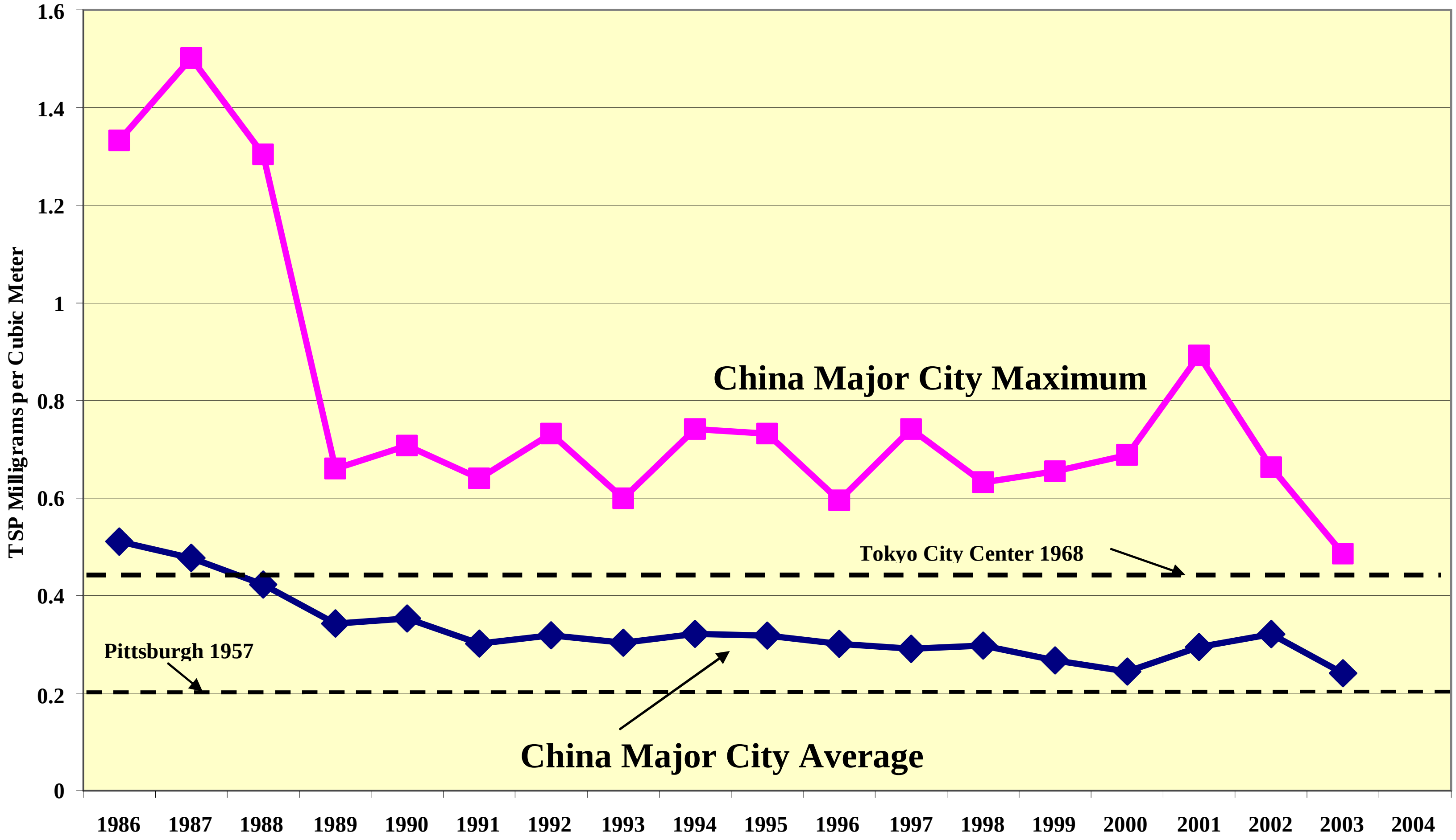

Figure 7
China: SO2 Levels in Major Urban Areas, 1980-2003

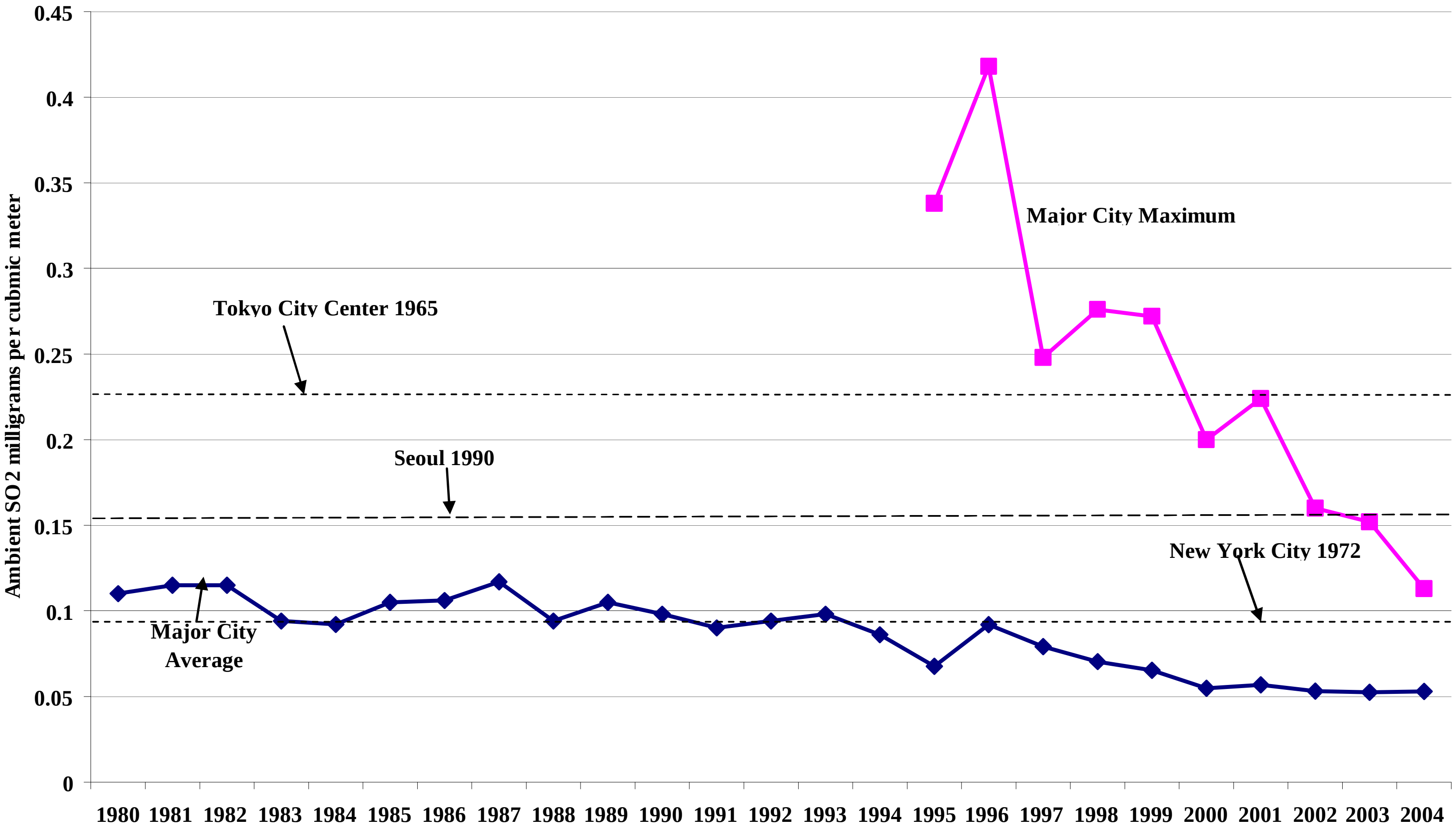

Figure 8

Trend of Primary Labor Force Share vs. Urban TSP Concentration

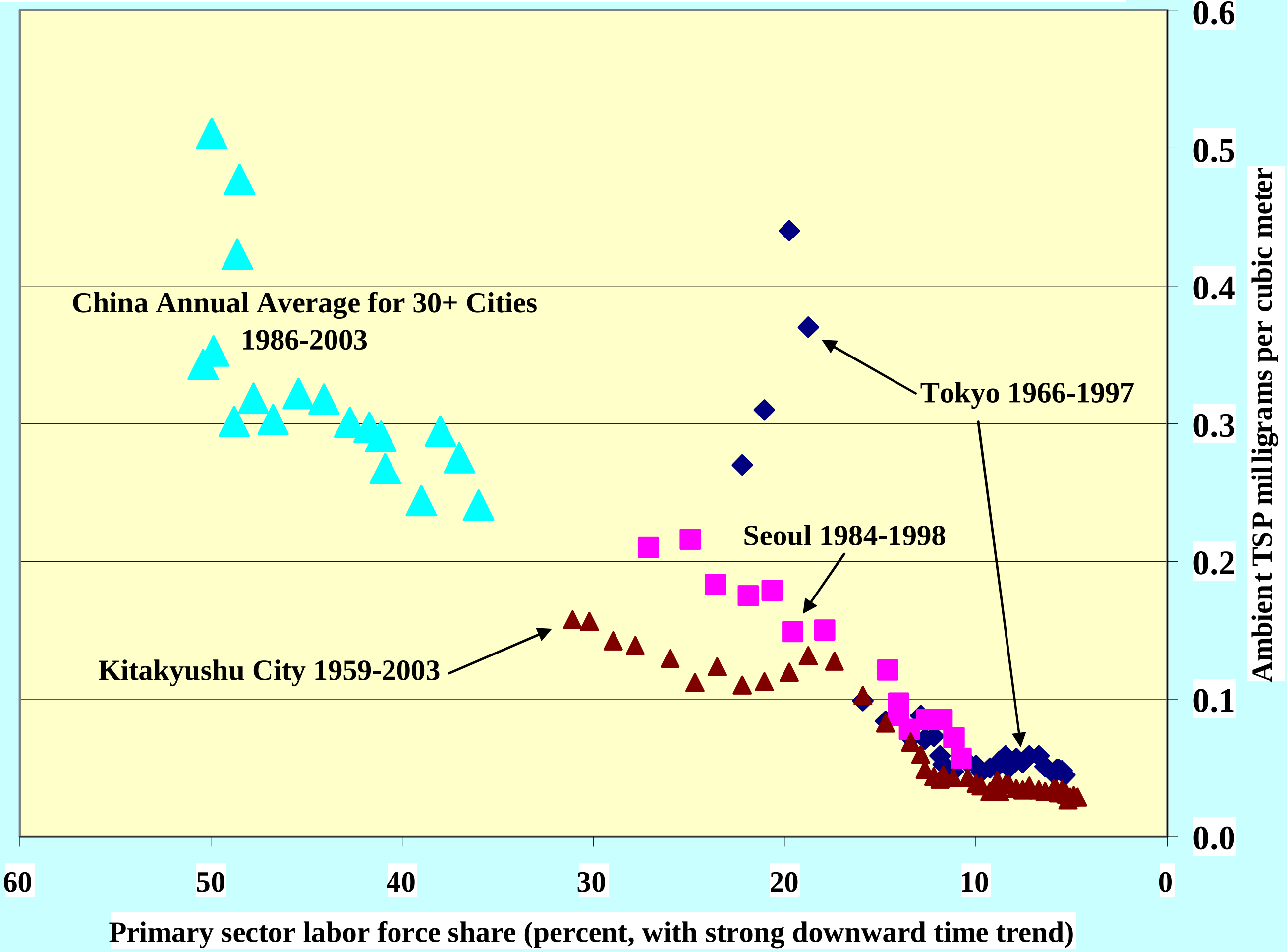

Figure 9

Trend of Primary Labor Force Share vs. Urban SO2 Concentration

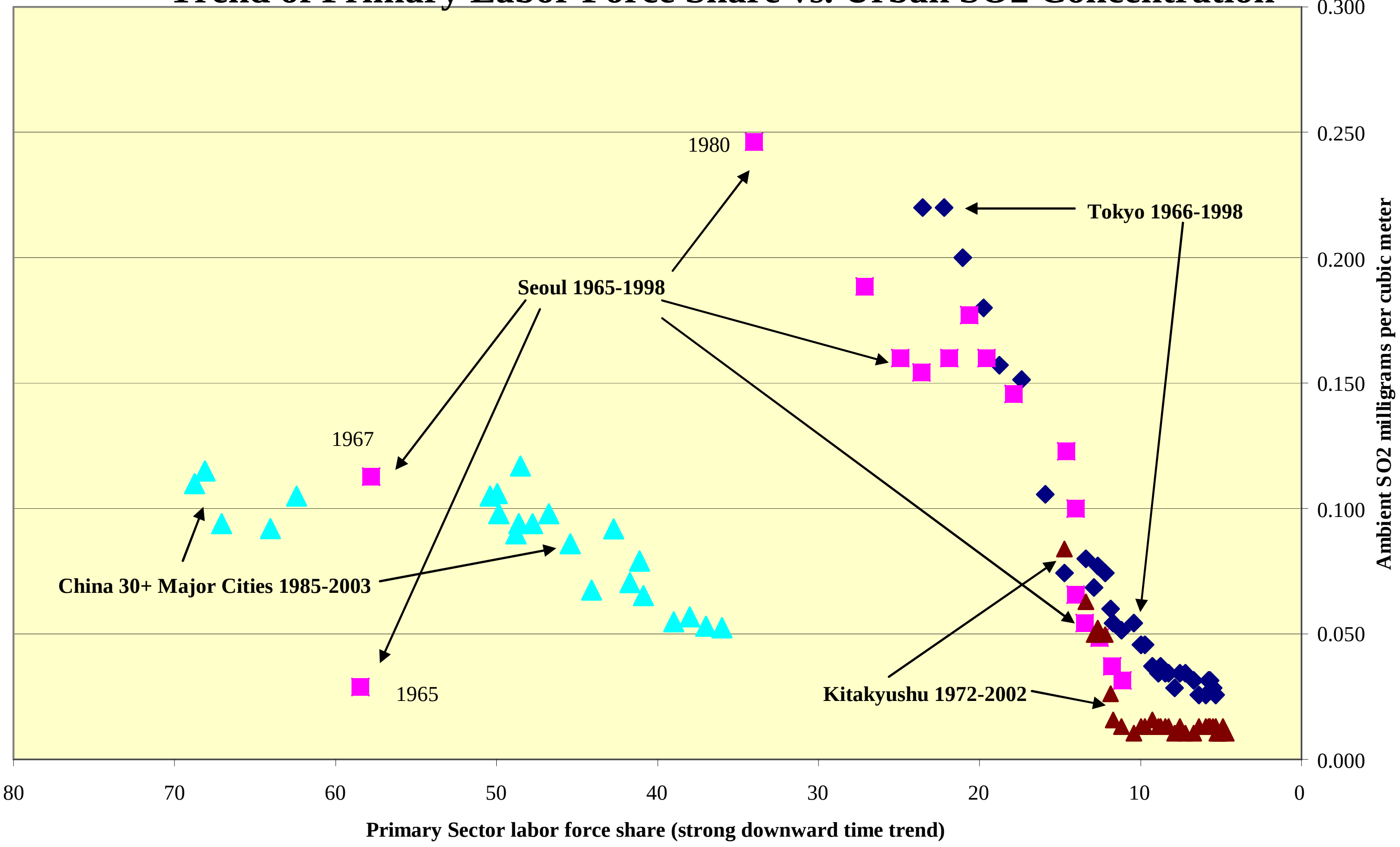

Figure 10
China: GDP, Energy Use, and Ambient SO2 Levels in Major Cities, 1980-2003