Application and Extension of Input-Output Analysis in Economic-Impact Analysis of Dust Storms: A Case Study in Beijing, China

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Abstract

Dust storms can extensively disrupt socioeconomic activities and pose hazards to human health and the ecosystem; yet no one has made a systematic analysis of dust storms from an economic perspective. With a case study in Beijing in 2000, we present a preliminary analysis of socioeconomic impacts of yellow-dust storms, integrating regional economic analysis models with environmental-economic evaluation techniques, and we make an innovative application of input-output techniques by examining supply-side effects. Our analyses demonstrate that the costs of delayed effects of yellow-dust storms can be higher than those of the immediate effects, and that economic impacts caused by supply effects are greater than those caused by demand effects. Our primary purpose is not to produce precise numerical results, but to develop an integrated model that policy analysts can use and further improve to evaluate the comprehensive impacts of other phenomena with similar properties more accurately.

KEY WORDS: Dust storms; Input-output analysis; Socioeconomic impact analysis; China

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1. Introduction

Yellow dust occurs every spring in northern China. It is composed of fine sediments originating in arid and semi-arid regions, mostly from the Gobi Desert and Mongolia, and transported by strong winds. When the concentration of atmospheric particles is so high that visibility decreases to less than one kilometer, the China Meteorological Administration defines it as a dust storm.[1] Severe winds and low visibility during dust storms can extensively disrupt socioeconomic activities, such as construction, tourism, trade, and transportation. Particles in a dust storm hinder sophisticated manufacturing, damage agricultural products and other plant life, and generate risks to human respiratory and cardiovascular systems. Records show that the effects of dust storms have reached 17 provinces in China; moreover, similar impacts are detected in Japan, Korea, Mongolia, and even North America.[2]

Because of the increasingly severe problems with dust storms in the recent decade, scientists have conducted many studies on their causation, source areas, transportation trajectories, and physical damage (Gao et al., 2002; Jie, 1999; Kim & Park, 2001; Lin, 2001; Lin, 2002; Lu et al., 2001; Wang et al., 2000; Zhang et al., 1993; Zhu & Zhang, 1994). However, analysts have not undertaken any socioeconomic-impact evaluations to examine dust storms either quantitatively or qualitatively. Such studies are urgently needed, because socioeconomic information on dust storms will help officials to identify the most vulnerable groups and correspondingly enhance preparedness. They will also provide planners with a basis for appropriate investment in disaster mitigation and control. Moreover, a systematic and uniform research approach will enable analysts to conduct further studies to record and track yellow dust, and to compare it with similar problems, such as acid rain, hail, snowstorms, and severe acute respiratory syndrome (SARS), and seek applicable solutions in common to mitigate the impacts.

Analysts are confronted, however, with many challenges in conducting a socioeconomic-impact evaluation of yellow-dust storms. First, yellow dust may reach every corner of a region and involve almost all industries. In most cases, dust storms actually do not result in mortality or severe infrastructure damage, which are very evident in disasters, such as earthquakes, fires, and floods. Thus, common disaster-assessment techniques may not be applicable to evaluating the socioeconomic impacts of dust storms. Second, in addition to the unknown extent of negative effects, scientists have also suspected possible benefits of yellow dust, such as neutralization of acid rain, absorption of part of the heat from sunshine, and prevention of the occurrence of photochemical smog. This has further complicated any quantitative analysis of dust storms. Third, although yellow-dust storms can cause significant monetary or physical losses to a regional economy, officials in China have been excluding dust storms from the *China Disaster Statistics Yearbook*. The China Meteorological Administration, State Forestry Administration, State Environmental Protection Agency, Ministry of Internal Affairs, and several newly founded agencies all have the function of analyzing the information regarding dust storms and managing the problems that they create. Nevertheless, none of the individual agencies provides a database for yellow-dust storms. Consequently, analysts can gather data only from the limited information published online or in newspapers, or from individual studies in a few regions.

On the basis of such second-hand information, we conducted a case study in Beijing in 2000 with three objectives: (1) integrate economic, environmental, and social impacts of yellow-dust storms into a regional economic framework; (2) measure the impacts of yellow-dust storms on Beijing's economy in 2000; and (3) discover possible policy implications of the quantitative analysis results. We selected Beijing for our case study because scholars have accumulated more information in this capital city than in any other region in China. As a metropolis with a dense population and fast-growing socioeconomic activities, it is probably more economically vulnerable to yellow-dust storms than other less-developed regions and is likely to be affected in more ways. Thus, it is a good starting place for further economic-impact analyses, either for Beijing or for any other region in China. Because scientific studies related to dust storms in 2000 are particularly plentiful during our research period, we selected that year as the time period of our study. Furthermore, because one dust storm usually lasts for only a few hours but several may occur in one day, analysts can have difficulty distinguishing successive occurrences, especially for their long-term effects. Consequently, we evaluate the total impacts of all occurrences of dust storms in 2000, instead of any single one. In addition, we had access only to a static 1999 input-output table for Beijing; we ignore those delayed impacts only apparent after one year.

We discuss in Section 2 the application of input-output techniques in evaluating the economic impacts of yellow-dust storms, and in Section 3 we briefly introduce the environmental-economic evaluation techniques that we adopt in order to integrate the manifold impacts into a regional economic framework. In Section 4, we employ these techniques and develop several other approaches to ascribe a money value to the direct impacts of yellow-dust storms, as data preparation for a regional input-output analysis. Using the results in Section 4 and our modified input-output table, in Section 5 we measure the total economic impacts of yellow-dust storms on Beijing's economy in 2000, from both demand and supply sides. We conclude with a sensitivity analysis in Section 6, along with discussion of our calculation results. Because this is a preliminary analysis with extremely limited data, the primary purpose of our study is to develop a conceptual model applying feasible methodologies, rather than to produce precise numerical results. Policy analysts may use and further improve our research framework to evaluate the comprehensive impacts more accurately, or to measure the economic impacts of other phenomena with similar properties.

2. Application of Input-Output Techniques for Socioeconomic-Impact Evaluation of Yellow-Dust Storms

The input-output technique is commonly used for economic-impact analyses because it incorporates detailed information on a sectoral basis, thus showing more accurate results in evaluating both tangible and intangible economic impacts on a regional level. We believe that such a sectoral perspective, compared with other available economic-impact evaluation techniques, may best clarify and systemize the manifold impacts of yellow-dust storms exhaustively and accurately.

Given that lessened demand from affected sectors (e.g., households) may diminish production in other sectors after dust storms, analysts may trace the demand-driven effects on a region's output by the changes in final demand. This traditional method, however, cannot capture all the economic impacts of dust storms, because some sectors apparently affected by dust storms may not change the demand from other industries. For example, outdoor vendors who sell newspapers or fruits need to make new orders for the next day's sale, instead of selling outdated goods held up due to dust storms; construction activities may be disrupted during a strong storm, although the amount of raw materials and utilities needed may not change for a year-long project; agricultural products may be damaged only after farmers have invested in the seeds, fertilizer, and other farming facilities, or even after the sowing season. Thus, these sectors may provide less to other sectors and, subsequently, less to the whole region. After identifying this aspect, we maintain that it is necessary to distinguish and evaluate the economic impacts caused by dust storms not only by demand-driven effects, but also by supply effects. Thus, we derive Equation (1), showing total inputs, which equal total outputs, as the sum of intermediate inputs and primary inputs (value added).

$$F^{T}X + V = X \qquad (1)$$

where:

F = the matrix of f_{ij} (= x_{ij}/x_i), or each element of the intermediate inputs divided by the row sum
X = the matrix of total output of every sector
V = a matrix representing the value added of every sector

Then, we can derive the total changes of regional inputs, or outputs, caused by supply effects through transforming Equation (1) into Equation (2). That is, economic impacts on the regional economy through supply effects can be determined by the product of the constant of $(I- F^{T})^{-1}$ and the changes in value added of the affected sectors.

$$X = (I- F^{T})^{-1}V; \text{ or, } \Delta X = (I - F^{T})^{-1}\Delta V \qquad (2)$$

where:

$(I - F^T)^{-1}$ is the Leontief inverse of the transpose of the F matrix
ΔX are the changes in total output
ΔV are the changes in value added
F, X, and V have the same meaning as shown in Equation (1)

The latest Beijing input-output table currently available is for 1999. Because the industrial structure in Beijing did not change dramatically from 1999 to 2000, we use the 1999 table for conducting regional economic-impact analyses in 2000. It is a single-region open table including 49 sectors, treating the household sector and other components of final demand as exogenous. The table has complete statistical information for intermediate and final demand transactions. Although it can provide us with basic requirements for input-output analysis, we make two important modifications: First, we aggregate the 49 sectors in the original table into 15, as it is impossible to determine the differences, presumably small, in impacts among 49 sectors, due to limited data and information. Because industries in some broad categories of sectors have similar consumption and production relationships and appear affected by dust storms in similar ways, we assume that such an aggregation (see Table A-1) does not compromise our calculation results, but it does simplify our analysis.

Second, we transform the open model into a partially closed one, treating households as endogenous to the regional economy. This approach is important because households are affected by dust storms in many ways, involving property loss, health impacts and corresponding increases in expenses, and so on. In addition, the household sector plays an important role as the supplier of labor; thus, it can induce reasonable ripple effects in a regional economy. Therefore, we use the partially closed

1999 Beijing 16-sector input-output table (see Table A-2) to quantify the economic impacts of dust storms from both demand and supply sides. To distinguish the partially closed matrices that we use throughout our study, we mark an asterisk after the symbols, such as A* and F*.

3. Integration of Environmental-Economic Evaluation Techniques

Because traditional input-output models normally do not capture non-economic or environmental aspects of yellow-dust storms, we have also incorporated environmental-economic evaluation methods into our economic analysis, mainly including dose-response analysis, as well as market-value and human-capital methods.

<u>Dose-Response Analysis.</u> Dose-response analysis is “a component of risk assessment that describes the quantitative relationship between the amount of exposure to a substance and the extent of toxic injury or disease caused by such a substance” (SRA, 2003). We use the findings of ECON Center for Economic Analysis (2000) on health impacts from pollution, and compile the research results by Aunan and Li (1999), the European Commission (EC, 1998), the World Health Organization (WHO, 1999), and the Asian Development Bank (ADB, 1996). Their results indicate that corresponding to every one-microgram increase in particulate matter of 10 microns or less (PM_{10}) per cubic meter in the atmosphere, in one year, from 0.003% to 0.02% more people exposed to it will make an emergency hospital visit and from 0.2% to 0.6% more workers will incur workday losses. Then, an analyst can estimate the number of people affected and corresponding workday losses by examining the change in the

concentration of PM_{10} during dust storms. We regard the increases in emergency visits as immediate impacts and the workday losses as delayed impacts.

Market-Value Method. As its name implies, the market-value method evaluates economic impacts by multiplying the losses in productivity by the market value. We adopt this approach to quantify the impacts of yellow-dust storms on agriculture, referring to the research findings of Chameides and his team that the high concentration of fine particles is “currently depressing optimal yields of about 70% of the crops grown in China by at least 5–30%” (1999: p.13626). Using the sectoral output as a substitute for the market value of the crops, we are able to proceed with our estimation.

Human-Capital Method. Analysts use the human-capital method to ascribe a money value to the health impacts on working people exposed to environmental pollution. Because yellow-dust storms usually involve little mortality, we adopt this method mainly for measuring the economic loss of workdays interrupted during dust storms. We first rely on dose-response functions to estimate the total number of workday losses; then, we multiply the result by the value that the workers would have produced per day if storms had not occurred, using Beijing’s Gross Domestic Product (GDP) per capita per day as a substitute.[3]

4. Identification and Evaluation of Direct Impacts of Yellow-Dust Storms

In addition to a few transportation statistics recorded in the *Beijing 2001 Yearbook* (Duan & Zhang, 2001, p. 364), we identified direct impacts mainly using data from newspapers compiled by *NFBC (2000)* and second-hand publications, such as the article by Zheng et al. (2000). The single occurrence of a dust storm with at least a skeleton of information for socioeconomic analysis is on April 6, 2000. All those records largely show immediately visible impacts that occur on the day of dust storms; we call them “immediate impacts.” There are other types of impacts that are revealed or even strengthened only after a certain period after the dust storms; we define them as “delayed impacts.” By this categorization, immediate and delayed impacts together add up to the direct impacts of yellow-dust storms.

Although we have the basis to measure immediate impacts of a single event (on April 6, 2000), we need to estimate immediate impacts of other occurrences of dust storms and all delayed impacts. To capture the comprehensive impacts of dust storms without limiting the analysis to those with concrete statistics, we have explored the following methods to make the estimations.

<u>Connecting Impacts of Yellow-Dust Storms with Meteorological Records.</u> Because socioeconomic data on the other dust storms (aside from the one on April 6) in Beijing in 2000 are incomplete, we try to connect the impacts of yellow-dust storms with meteorological records. Scientific studies show that dust storms can only occur with the co-existence of three factors—strong winds, source of sand, and thermally unstable air (see, for example, Gao et al., 2000; Zhu & Zhou, 2002). We accordingly assume that the higher the speed of wind velocity and the higher the concentration of particles (PM_{10}) during a dust storm, the more severe the socioeconomic impacts would be. With reference to our evaluation of the dust storm on April 6, 2000 on the basis of actual socioeconomic records, we can estimate the economic impacts of other dust-storm occurrences by comparing the environmental conditions recorded by Beijing Meteorological Bureau.

Balancing Positive Impacts with Negative Ones. In addition to the negative impacts caused by the high concentration of particulates and strong winds accompanying yellow-dust storms, scientists have suspected that there could be positive effects, such as decreases in pollutants of ozone (O_3), nitrogen oxide (NO_x), and sulfur dioxide (SO_2), which are absorbed by dust particles to an unspecified extent. Without adequate scientific support, we assume on the basis of field observations that the positive impacts of dust storms are not apparent in the immediate term; in the long run, negative impacts of PM_{10} play a dominant role[4], but they may be offset slightly by positive impacts. Given that the coefficients of dose-response functions are designed for evaluating the severity of pollution—that is, the higher the coefficient, the more severe the negative impacts—we have selected the mid value for the indicator of emergency visits and the lowest value for the indicator of workday losses. That is, there would be an increase in emergency visits of 0.011% of all population in one year and a 0.2% increase in workday losses per microgram increase of PM_{10} per cubic meter atmosphere.

Incorporation of Long-Term Effects of Yellow-Dust Storms. From the scientific literature, we find that in the long run, the dust particles primarily affect three sectors: agriculture, manufacturing, and households. To incorporate the impacts of the damage in agriculture, defects of sophisticated-equipment manufacturing, and workday losses of households, we locate some general findings on particulate pollution from the environmental literature and make some adjustments to take into account the positive impacts. We further adopt market-value method and dose-response analysis to ascribe a money value to these environmental impacts. Because many environmental impacts are not significant in one year and our input-output table available is only for a one-year period, we exclude the impacts existing after one year. In Table 1, we summarize the immediate and the delayed long-term impacts that we use in our case study in Beijing.

For all the six sectors examined (agriculture, manufacturing, construction, transportation, trade and catering services, and households), our estimated results show that dust storms in Beijing in 2000 may have resulted in a total direct impact of 2,195.1 million renminbi (RMB), or $264.5 million, one-quarter of which are caused by immediate impacts, while three-quarters are caused by delayed impacts (Table 2).

Regarding each individual sector examined, the manufacturing sector appears to have lost the most (855.3 million RMB), with the agriculture sector close behind (788.4 million RMB). In terms of both the absolute value and the percentage value (together 75% of the total direct impacts), these sectors show greatest losses from delayed impacts gradually generated throughout the year. Although being affected only during dust storms, trade and catering services along with construction sectors also undergo significant impacts (295.8 million RMB and 227.2 million RMB, respectively). The direct impacts on the transport sector (26.9 million RMB) are less significant compared to other affected sectors. In terms of the household sector, our estimation of both immediate impacts (0.5 million RMB) and delayed impacts (1.2 million RMB) in a one-year period appears to be small, because they comprise only part of many aspects of human health that can be evaluated with currently available data and methodology. These numerical results of direct economic impacts on an individual sector basis enable us to examine the inter-sectoral interactions by using the modified input-output model.

INSERT [Table 1] & [Table 2] ABOUT HERE

5. Input-Output Calculations and Analyses[5]

5.1 Calculations of Total Impacts Caused by Demand-Driven Effects

Following the common practice of evaluating total economic impacts by demand-driven analysis, we multiply the Leontief inverse of the direct requirement matrix, $(I-A^*)^{-1}$, by direct economic impacts (as a substitute for changes in final demand) on each sector. In absolute value, the manufacturing, agriculture, trade and catering services, household, and construction sectors are the sectors that experienced the greatest total impacts in Beijing (Table 3), comprising 90% of the total in the region as a whole. As a proportion of a sector's total output, however, the agriculture sector is the most severely affected (with a loss of 5.2% of its total output). Although our estimation of the impacts on the mining sector (61.9 million RMB) is not among the top ones, it is equivalent of 2.2% of its sectoral output—the second largest percentage rate among all sectors. The other sectors, almost evenly affected, show much less evident losses through demand-driven effects (0.1–0.4% of their sectoral output).

Overall, our calculations show that the total economic impacts caused by demand-driven effects are 4,032.3 million RMB ($485.8 million, 1.6% of Beijing's GDP in 2000), which includes direct impacts, indirect impacts on other sectors due to decreases in demand during and after production disruption, and induced impacts, as shown in the household sector.

INSERT [Table 3] ABOUT HERE

5.2 Calculation of Total Impacts Caused by Supply Effects

As demonstrated in Equation (2), we further evaluate the total economic impacts on a regional economy by changes in value added of each sector.[6] Our calculations (see Table 3) show that the total economic impacts caused by supply effects are 13,992.7 million RMB ($1,685.9 million), which is equal to 2.0% of Beijing's GDP in 2000. Compared to the impacts caused by demand-driven effects, Beijing's regional economy is affected more seriously through supply effects, in both absolute and percentage terms.

In absolute value, manufacturing and households are the top two sectors affected by dust storms, showing 5,317.8 million RMB and 2,424.3 million RMB (38.0% and 17.3% of the total economic impacts, respectively). When we examine the comparative value of each sector, the agriculture sector still shows the most serious internal economic impacts—6.2 % of its sector's output; the trade and catering services sector shows the second-greatest economic impacts caused by supply effects, while the mining sector does not show an impact ranking as high as with impacts caused by demand-driven effects.

When comparing the economic impacts on each sector caused by demand-driven effects and supply effects, we find that the agriculture sector consistently shows the most serious impacts, far exceeding those of other sectors. Other sectors are affected through inter-sector interaction very differently: some show larger losses through demand-driven effects, and some show the opposite. To study the underlying reasons for the differences in allocation of the indirect impacts among sectors, we conduct further linkage analyses below.

5.3 Linkage Analysis

On the basis of our modified Beijing 1999 input-output table, we calculate both backward and forward linkages of 16 sectors. With only one exception, the forward linkages of each sector are all higher than its backward linkages; the average of the forward linkages is 5.451, about 3.5 times the average of the backward linkage (1.565). This shows that dust storms may affect the regional economy more heavily through forward linkages than through backward linkages. Furthermore, almost all sectors with high forward linkages (namely, agriculture, manufacturing, transportation, trade and catering services, and households) were all directly affected by dust storms. This causes the total economic impacts on Beijing's regional economy to be significantly higher than are direct economic impacts.

We found that the two sectors with the highest backward linkages were the manufacturing sector (2.136) and the construction sector (2.022). They are also the only two sectors with backward linkages above 2.0, being 1.4 and 1.3 times the average, respectively. This implies that decreases in demand in the manufacturing and construction sectors, compared to all the other sectors, may result in the greatest losses to Beijing's regional economy; in contrast, increases in investment in these sectors may have the greatest potential power to augment the regional economy by requiring large quantities of goods and services from other sectors. Because yellow-dust storms do not involve large-scale remediation and mitigation activities afterwards, we infer that their impacts would not create a new round of investment activities on the manufacturing or the construction sectors, as generally happens after earthquakes and tornados. Thus, all the losses may be permanent, and the regional economy may not easily recover to its original level. From this perspective, the most effective and critical means to reduce the negative impacts of yellow-dust storms would be by focusing on prevention, in order to mitigate the impacts before they happen.

6. Sensitivity Analysis and Further Discussion

Acknowledging that our quantitative analyses involve a considerable number of estimates, we conduct a sensitivity analysis in order to determine a range of the total economic impacts. With different estimates, we find that the delayed impacts are always more serious than the immediate impacts: the lowest estimate of delayed impacts is still higher than the upper estimate of immediate impacts. Moreover, the range of delayed impacts is much broader than is that of immediate impacts, presenting the vast uncertainties for delayed impacts of dust storms. Through inter-sector analyses, we estimate that the total economic impacts caused by demand-driven effects range from 1.0% to 2.3% of Beijing's GDP in 2000. The range of the total economic impacts caused by supply effects is much larger: the difference is 5.5% of Beijing's GDP in 2000 (from 2.9% to 8.4%). That is, changes of input variables would produce a much larger range of effects through the supply side than through the demand side.

Because demand-driven effects and supply effects are substantially intertwined, the total economic impacts on Beijing's regional economy are not the sum of these two. Although we acknowledge that additional studies are necessary to determine the upper bound, it is safe to infer that the total economic impacts of the yellow-dust storm in Beijing in 2000 are greater than 2.9% of Beijing's GDP that year (the higher value of the lower estimates of economic impacts caused by demand and supply effects).

Although economic sectors are affected by dust storms differently through different mechanisms and at different temporal magnitude, we demonstrate in our analysis that the economic impacts on agriculture, construction, and manufacturing, as well as other sectors, can be very costly, although they may not be immediately apparent. Accordingly, we suggest that billions of dollars of annual investment in dust storm control should not be limited to reforestation, as is the current situation in China. The Chinese government should also encourage research on prevention measures, such as how to improve the technology to protect crops and sophisticated equipment from particulates, and how to depress the elevated dust from open construction sites. Such prevention measures may help avoid potentially high costs.

To conclude, we want to stress that the goal of this study is not to provide precise figures for policymakers' investment decisions, and we acknowledge that our study may incorporate some biases, such as the constraints of a single-region, one-year study and the narrow perspective on human activities. We regard it as a starting point for an integrated economic-impact analysis across disciplines and a reference for other analysts to verify and improve. With a sound research framework, analysts can subsequently, with additional data, improve both the research methodology and the data inputs, thereby enhancing the accuracy of the numerical results.

Table 1 Economic Impacts of Yellow-Dust Storms in Beijing in 2000 to be Evaluated

Sub-categorization	Affected sectors	Recorded/estimated impacts	Evidence/source	Evaluation method
Immediate impacts	Construction	Nearly 60 million square meters of construction sites shut down.	Zheng et al., 2000	Market-value approach
	Transportation	1. Air –Transportation 48 flights were cancelled, 9 flights returned, 52 landing flights were transferred, and altogether 129 flights delayed. 2. Road Transportation An increase in road accidents of 20-30% over normal conditions.	Duan & Zhang, 2001, p. 364	
	Trade	Outdoor vendors closed business much earlier than usual.	*China Youth Daily,* April 7, 2000. Quoted from NFBC (2000) *Focus on Dust Storm. P.16*	
	Households	Emergency hospital visits increased for eye infections.	*China Economic Daily*, April 7, 2000. Quoted from NFBC (2000) *Focus on Dust Storm. pp.12-13.*	Dose-response analyses
Delayed Impacts	Agriculture	High concentrations of particulates depressed optimal yields of about 70% of the crops grown in Beijing by 5%.	Adjusted based on the findings of Chameides et al. (1999).	Market-value approach

	Manufacturing	Particulates may have caused 1% decrease in product yield of sophisticated-equipment manufacturing.	Only one article (Peng, 2000) presented a numerical analysis, which briefly mentioned that less than 5% of product defects are caused by human and environmental effects. Taking account of possible positive effects caused by decreases in O_3, NO_x, and SO_2 after dust storms, we assume that particulates do not significantly increase product defects and only lead to a 1% decrease in product yield.	Market-value approach
	Households	There was a 0.2% increase in workday losses per $\mu g/m^3$ of $PM_{10.}$	Lower value selected from dose-response functions.	Dose-response analyses

Table 2. Summary of Direct Impacts of Yellow-Dust Storms in Beijing in 2000

Affected sectors	Immediate impacts	Delayed impacts	Total direct impacts	Percentage of total direct impacts
	Thousand RMB			%
Agriculture	N.A.	788,412	788,412	35.9
Manufacturing	N.A.	855,268	855,268	39.0
Construction	227,174	N.A.	227,174	10.4
Transportation	26,898	N.A.	26,898	1.2
Trade and Catering Services	295,802	N.A.	295,802	13.5
Households	460	1,185	1,645	0.0
Total	550,334 ($66.3 million)	1,644,865 ($198.2 million)	2,195,119 ($264.5 million)	100.0

N.A.: not applicable.

Table 3 Total Impacts of Yellow-Dust Storms on Each Sector of Beijing in 2000

No.	Sector	Sectoral output in 1999	Impacts caused by demand-driven effects			Impacts caused by supply effects		
			Total impacts	Impacts/ total	Impacts/ sectoral output	Total impacts	Impacts/ total	Impacts/ sectoral output
	Unit	Million	Million RMB	%	%	Million	%	%
1	Agriculture	18,208.9	946.8	23.5	5.2	1,136.7	8.1	6.2
2	Mining	2,844.3	61.9	1.5	2.2	29.4	0.2	1.0
3	Manufactur	246,847.4	1,681.7	41.7	0.7	5,317.8	38.0	2.2
4	ElecGasW	11,224.9	34.4	0.9	0.3	96.3	0.7	0.9
5	Constructio	66,445.0	230.7	5.7	0.3	1,404.9	10.0	2.1
6	TransStora	27,306.6	114.5	2.8	0.4	407.5	2.9	1.5
7	Trade	25,153.5	445.8	11.1	1.8	711.6	5.1	2.8
8	Finance	62,022.3	86.3	2.1	0.1	695.9	5.0	1.1
9	RealEstate	6,032.3	7.3	0.2	0.1	112.0	0.8	1.9
10	Social	34,408.7	62.2	1.5	0.2	616.1	4.4	1.8
11	HealthSpor	6,677.6	1.2	0.0	0.0	156.2	1.1	2.3
12	EduCulture	16,491.5	9.7	0.2	0.1	311.7	2.2	1.9
13	Science	24,682.2	38.4	1.0	0.2	278.9	2.0	1.1
14	Geology	636.7	0.6	0.0	0.1	11.4	0.1	1.8
15	GovOthers	12,690.3	24.6	0.6	0.2	282.0	2.0	2.2
16	Household	137,118.4	286.1	7.1	0.2	2,424.3	17.3	1.8
	Total	698,790.5 ($84,191.6 million)	4,032.3 ($485.8 million)	100.0	1.6*	13,992.7 ($1,685.9 million	100.0	2.0*

Notes: 1. US $/ RMB = 8.3, in 2000 value. 2. Numbers with "*" are percentage of total economic impacts/gross domestic product (GDP) in Beijing in 2000.

APPENDIX

Table A-1 Aggregation of Sectors in the 1999 Beijing Input-Output Table

No	15-sector aggregation	Abbreviation	Corresponding 49-sector aggregation
1	Farming, Forestry, Animal Husbandry, and Fishery	Agriculture	1. Agriculture, 2. Forestry, 3. Fishery, 47. Services for farming, forestry, animal husbandry and fishery
2	Mining	Mining	4. Coal-selection, 5. Gasoline and natural gas extraction, 6. Metal mineral mining, 7. Non-metal ore extraction
3	Manufacturing	Manufacturing	8. Food production and cigarettes, 9. Textiles, 10. Clothing, leather, fur and other fiber production, 11. Wood processing and furniture manufacturing, 12. Papermaking and education-equipment manufacturing, 13. Petroleum and coke-making, 14. Chemistry, 15. Non-metal mineral products manufacturing, 16. Metal smelting and manufacturing, 17. Metal-products manufacturing, 18. Machinery, 19. Transportation-utility manufacturing, 20. Electric-equipment manufacturing, 21. Electronic and communications manufacturing, 22. Equipment and meter manufacturing, 23. Machinery repairing, 24. Other manufacturing, 25. Waste materials
4	Electricity, Gas, Water Production and Supply	ElecGasWater	26. Electric power supply, 27. Steam and hot water supply, 28. Gas supply, 29. Water supply
5	Construction	Construction	30. Construction
6	Transportation, Storage, Post and Telecommunications	Transport StoragePostTele	31. Water transportation, 32. Other transportation and warehouse, 33. Post and telecommunications, 36. Water passenger transportation, 37. Other passenger
7	Wholesale, Retail Trade and Catering Services	Trade	34. Commerical, 35. Catering trade
8	Finance and Insurance	Finance	38. Finance and insurance

9	Real Estate Trade	Real Estate	39. Real estate trade
10	Social Services	Social	40. Public utilities, 41. Residential services, 42. Other social services
11	Health Care, Sports, and Social Welfare	HealthSports Welfare	43. Health care, sports and social welfare
12	Education, Culture, Art, Radio, Film and Television	EduCulture	44. Education, culture, arts, radio, film and television
13	Scientific Research and Polytechnical Services	Science	45. Scientific research, 46. Polytechnic services
14	Geological Prospecting and Water Conservancy	Geology	48. Geological prospecting and water conservancy
15	Government Agencies, Party Agencies, Social Organizations, and Others	GovOthers	49. Administrative agencies and others

Source: The 1999 Beijing 49-sector input-output table was provided by Professor Xikang Chen at the Institute of System Science at Chinese Academy of Sciences in Beijing, in March 2002.

Table A-2 1999 Beijing 16-Sector Partially Closed Transaction Table

		PURCHASING SECTORS															
	No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Agriculture	Mining	Manufacturing	Electricity	Construction	Transportation	Trade	Finance	Real Estate	Social Service	Health	Education	Science	Geology	Government	Household
PRODUCING SECTORS	1	353986	117	716311	1	1	2	56500	0	1026	2160	1781	18	181	0	0	606300
	2	5287	33975	108023	55860	109415	2051	3833	0	7858	16762	1519	3277	4176	497	2414	54681
	3	251010	35987	121481	155358	329247	738218	407477	884620	69584	641060	275109	145956	282027	7618	179382	355263
	4	28450	9719	310965	19896	30016	30605	54047	69026	19256	76373	6620	13483	29924	1034	16467	392602
	5	499	156	11261	2970	912	8271	10932	26142	7321	158999	4609	2333	6232	191	13052	0
	6	28211	7267	102419	46094	317658	250390	116781	206826	22472	137573	14618	168125	65751	1755	141235	173059
	7	144046	7980	155923	50731	438019	126045	71377	196203	21369	110898	60464	25108	34132	1676	47707	109957
	8	11057	9780	967392	41873	65662	274566	127618	107286	209039	76091	1462	54301	21311	6923	174943	992849
	9	0	450	22261	39	1174	4319	38800	283043	5872	21202	1370	804	3178	26	6590	56775
	10	3875	16590	550466	9938	288664	70926	153570	812010	34456	405819	4597	39388	68971	4154	54541	227744
	11	157	99	3373	218	1653	4448	1550	1096	577	20085	11586	6769	12690	25	6610	102752
	12	1695	870	36549	4070	18634	17337	28708	157890	1730	25191	3129	215775	120284	1907	36795	289242
	13	3865	1470	493742	42787	151747	15425	87515	14478	5494	48472	311	81172	196047	3508	11478	0
	14	340	3848	0	0	0	0	0	0	0	1889	0	0	0	1607	0	0
	15	59201	28	2842	92	98653	28820	0	24665	3050	192056	10472	1979	15214	1851	11003	5610
	16	52012	49106	219537	120820	102241	492893	103556	293956	285501	135619	384215	102237	722011	33150	913646	373260

Note: The 16th row and column are modified by the author, based on the open 1999 Beijing input-output table.
Unit: Ten thousand RMB.

NOTES

1. Because the origin of dust particles in China is mainly yellow-sand covered deserts, scientists interchangeably use the terms of "yellow-dust storms" and "dust storms" in the case of China.

2. Source: China Dust Storm Net. http://www.duststorm.com.cn/script/ReadNews.asp?NewsID=204&BigClassID=23&SmallClassID=72.

3. Source: BMSB, 2001a.

4. This assumption is supported by the World Bank report "Clear Water, Blue Skies" (1997), which indicates that health costs of PM_{10} emissions made up 83% of environmental costs in China.

5. Given that most regional input-output tables in the United States use region-to-region inputs for the intermediate transactions, we originally assumed that the Beijing table was constructed in the same way. A comment by one of the reviewers caused us to inquire more deeply into this issue, and we discovered that the Beijing intermediate inputs represent both regional inputs and inputs from outside the region. Given that the method to remove the imports and the available data would involve more time than we had and would be only an extremely rough approximation, we decided not to make any adjustment to the table. Given that a considerable portion of inputs in Beijing may be imported from other regions, some of the estimates, therefore, are probably larger than they would be if the inputs represented only local Beijing inputs.

6. Source: BMSB, 2001b.

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