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Productivity Growth and Technological Change in Chinese Industry

Gene Tidrick

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A Background Study
for
China: Long-Term Development Issues and Options

CHINA

Long-Term Development Issues and Options

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Abstract

This paper discusses the role of technology in intensive growth, which involves reducing costs, increasing productivity, and introducing new and better products. It makes estimates of total factor productivity growth for Chinese industry and analyzes such issues as what should be done about backward enterprises, how to choose between domestic and foreign technology, how to promote diffusion of technology, and how to improve incentives for innovation. A dominant theme is that the key to intensive growth in China lies not only in better access to modern technology, but also in systematic reforms that would generate incentives for enterprises to make sound investment decisions and pay constant attention to costs and product quality.

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PRODUCTIVITY GROWTH AND TECHNOLOGICAL CHANGE IN CHINESE INDUSTRY

Table of Contents

Page No.

1. INTRODUCTION

1.01 In the late 1970s, China's leaders concluded that China needed to undertake a major effort to upgrade technology. This decision was prompted by widespread dissatisfaction with the level of industrial technology which was mostly of 1950s and 1960s design, was often very inefficient in the use of energy or other inputs, and produced output of low quality or outmoded design. Improved technology in industry was seen as the key to shifting from extensive growth, based on accumulation of capital, to intensive growth, based on productivity change and improved product quality.

1.02 The decision to emphasize growth through productivity change was wise. Research on the sources of growth has shown that output growth is seldom entirely accounted for by increased inputs. A significant portion of output growth, especially in the most rapidly developing economies, is due to growth of total factor productivity (TFP), defined as the difference between the rates of growth of output and of the weighted average of inputs.1/ (See Table 1.) In Japan during the period 1960-73, for example, total factor inputs (the weighted average of capital and labor inputs) grew at 6.4 percent per year while output (value added) grew at 10.9 percent per year. The residual, or TFP growth, was 4.5 percent per year.2/

1/ When output is measured by GDP or value added, the relevant inputs are labor and capital (including land). When output is measured by gross output, material inputs are included along with labor and capital.

2/ Strictly speaking, the difference between the rate of growth of output and the rate of growth of inputs is the "residual." It differs slightly from the rate of growth of total factor productivity (defined as the ratio of output to inputs) because the residual includes both total factor productivity growth proper and the (normally relatively small) interaction between TFP growth and factor input growth. In conformity with normal practice, we will use the terms "residual" and "total factor productivity growth" interchangeably, although they are not in fact equivalent.

Table 1. GROWTH OF OUTPUT, INPUTS AND TOTAL FACTOR PRODUCTIVITY IN SELECTED COUNTRIES

	Period	Growth of value added	TFP Growth rate	TFP Share	Total Factor Input Growth rate	Total Factor Input Share	Growth of capital input	Growth of labor input	Capital income share	Labor income share
Developed Countries										
Belgium	1349-59	2.95	2.05	(69.5)	0.90	(30.5)	2.55	0.25	30.0	70.0
Canada	1947-60	5.20	3.50	(32.5)	1.70	(67.6)	6.80	1.10	42.0	58.0
	1960-73	5.10	1.80	(35.3)	3.30	(64.7)	4.90	2.00	44.9	55.1
Denmark	1950-62	3.51	1.64	(46.7)	1.87	(53.3)	3.84	1.21	25.0	75.0
France	1950-60	4.90	2.90	(59.5)	2.00	(40.4)	4.70	0.30	38.2	61.8
	1960-73	5.90	3.00	(50.8)	2.90	(49.2)	6.30	0.40	41.7	58.3
Germany, Fed. Rep.	1950-60	8.20	3.60	(56.3)	4.70	(43.0)	6.90	1.60	38.7	63.3
	1960-73	5.40	3.00	(55.6)	2.40	(44.4)	7.00	-0.70	40.1	59.9
Italy	1952-60	6.00	3.80	(62.8)	2.80	(37.5)	3.30	1.60	40.5	59.5
	1960-73	4.30	3.10	(64.6)	1.60	(35.4)	5.40	-0.70	38.3	61.7
Japan	1960-73	10.90	4.50	(41.3)	6.40	(53.7)	11.50	2.70	41.5	58.5
Netherlands	1951-60	5.00	2.30	(46.5)	2.70	(53.6)	4.00	1.40	47.0	53.0
	1960-73	5.60	2.60	(46.4)	3.00	(53.6)	6.60	0.30	42.9	57.1
Norway	1953-65	5.40	2.88	(53.3)	2.52	(46.7)	5.10	0.80	40.0	60.0
Sweden	1949-59	3.40	2.50	(73.5)	0.90	(26.5)	2.00	0.50	30.0	70.0
UK	1949-59	2.50	1.20	(48.0)	1.30	(52.0)	3.10	0.60	30.0	70.0
	1960-73	3.80	2.10	(55.3)	1.80	(44.7)	4.60	-	38.7	61.3
US	1947-60	3.70	1.40	(37.5)	2.30	(62.9)	4.00	1.40	39.3	60.7
	1960-73	4.30	1.30	(30.2)	3.00	(69.8)	4.00	2.20	41.4	58.6
Average		5.40	2.70	(49.0)	2.70	(51.0)	5.20	1.10	38.5	61.5
Developing Countries										
Argentina	1950-60	3.30	1.05	(31.8)	2.25	(68.2)	2.65	1.10	-	-
	1960-74	4.10	0.70	(17.1)	3.30	(82.9)	3.80	2.20	-	-
Brazil	1950-60	6.80	3.65	(53.7)	3.15	(46.3)	3.10	2.80	-	-
	1960-74	7.30	1.60	(21.9)	5.70	(73.1)	7.50	3.30	-	-
Chile	1950-60	3.50	0.85	(24.3)	2.65	(75.7)	2.60	2.50	-	-
	1960-74	4.40	1.20	(27.3)	3.20	(72.7)	4.20	1.90	-	-
Colombia	1950-60	4.60	0.95	(20.7)	3.65	(79.3)	4.25	2.75	-	-
	1960-74	5.60	2.10	(37.5)	3.50	(62.5)	3.90	2.80	-	-
Ecuador	1950-62	4.72	2.18	(46.2)	2.54	(53.8)	2.32	3.41	38.0	62.0
Greece	1951-65	6.90	2.39	(34.5)	4.52	(65.5)	7.10	2.30	40.0	60.0
Honduras	1950-62	4.52	1.40	(31.0)	3.12	(69.0)	3.65	2.93	25.0	74.0
Hong Kong	1955-60	8.25	2.40	(29.1)	5.85	(70.9)	4.68	6.63	40.0	60.0
	1960-70	9.10	4.28	(47.0)	4.32	(53.0)	7.60	2.97	40.0	60.0
India /a	1959/60 - 78/79	6.24	-0.18	(-2.9)	6.42	(102.9)	4.77	1.65	52.5	47.5
Ireland	1953-65	4.70	2.00	(42.6)	2.70	(57.4)	4.20	1.70	40.0	60.0
Israel	1952-58	9.80	3.90	(39.8)	5.90	(60.2)	11.20	3.20	30.0	70.0
	1950-65	11.00	3.40	(30.9)	7.60	(69.1)	13.10	5.00	30.0	70.0
Korea	1955-60	4.22	2.00	(47.4)	2.22	(52.6)	2.18	2.25	40.0	60.0
	1960-73	9.70	4.10	(42.3)	5.50	(57.7)	6.60	5.00	36.7	63.3
Mexico	1950-60	5.65	1.60	(28.3)	4.05	(71.7)	5.20	2.65	-	-
	1960-74	5.60	2.10	(37.5)	3.50	(62.5)	3.90	2.80	-	-
Peru	1950-60	4.50	-0.70	(-15.6)	5.20	(115.6)	7.65	2.70	-	-
	1960-70	5.30	1.50	(28.3)	3.90	(71.7)	4.40	2.70	-	-
Philippines	1947-65	5.75	2.50	(43.5)	3.25	(56.5)	-	-	-	-
Singapore	1972-80	8.00	-0.01	(-0.1)	8.01	(100.1)	9.48	5.52	61.1	38.9
Spain	1959-65	11.20	5.02	(44.3)	6.18	(55.2)	8.70	4.50	40.0	60.0
Turkey	1963-75	6.40	2.23	(34.8)	4.17	(65.2)	6.32	1.02	55.0	45.0
Venezuela	1950-60	7.85	2.15	(27.4)	5.70	(72.6)	7.20	3.70	-	-
	1960-74	5.10	0.60	(11.8)	4.40	(88.2)	4.50	3.30	-	-
Average		6.30	2.00	(31.0)	4.30	(69.0)	5.50	3.30	45.30	54.7
Centrally Planned Economies /a										
Bulgaria	1963-65	12.50	3.30	(26.4)	9.10	(73.6)	11.60	7.50	40.0	60.0
Czechoslovakia	1960-63	7.00	2.74	(39.1)	4.26	(60.0)	6.60	2.70	40.0	60.0
Hungary	1953-65	6.50	1.78	(27.4)	4.72	(72.6)	7.80	3.00	40.0	60.0
Poland	1961-65	6.60	2.20	(38.3)	4.40	(66.7)	5.30	3.00	40.0	60.0
Romania	1953-65	11.10	5.82	(47.9)	5.78	(52.1)	3.30	4.10	40.0	60.0
USSR	1950-62	6.30	1.32	(28.9)	4.48	(71.1)	-	-	-	-
Yugoslavia	1963-68	11.80	4.78	(40.5)	7.02	(59.5)	7.30	6.70	40.0	60.0
Average		8.20	2.50	(35.0)	4.79	(65.0)	8.80	4.50	40.0	60.0

/a Manufacturing only.

Source: Chenery, H.B. et al., Industrialization and Growth: A Comparative Study (forthcoming).

1.03 Calculations for China suggest that TFP in industry has essentially stagnated since 1957, after an increase during 1952-57. Table 2 shows that TFP in state-owned industry over the 26 years from 1957-83 declined by 0.2 percent or increased by 0.7 percent per year, depending on the weighting of labor and capital.[3/] This is broadly consistent with estimates from most other sources.[4/] The World Bank's first economic report estimated that TFP for all industry above the brigade level was basically stagnant from 1957-79 (World Bank 1983, Vol. II, pp. 115-116), either increasing or decreasing slightly depending on the weight given to labor and capital. Calculations by Rawski (1983) using alternative weights and base years and a different definition of capital show that TFP in state-owned industry declined in most subperiods between 1957 and 1981.

1.04 These calculations are crude and suffer from numerous conceptual and data problems. The choice of base years present an insoluble index number problem. Measurement of capital is also subject to a high degree of error. Working capital is excluded from the index of capital inputs in Table 2 because of lack of good data and no allowance was made for depreciation of fixed assets. Fixed assets are also valued at original prices. Since the price of capital goods went down during much of the period, this underesti-

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3/ In Table 1, labor's share ranges from 38.9 percent in Singapore to 74 percent in Honduras. Because of China's accounting and pricing system it is difficult to determine the appropriate weight for China. Table 2 assigns alternative weights of 40 percent and 60 percent to labor to test the range of likely variation.

4/ However, Shi Qingqi, Qin Baoting and Chen Jing (1984) calculated that TFP in state-owned industry grew by 1.82 percent per year from 1964-84 and by 2.84 percent from 1952-82. From Table 2, annual growth rates of the residual for 1965-83 and 1952-83 are 0.8 percent and 2.1 percent, respectively, where labor is weighted 60 percent and capital 40 percent. Their growth rates are higher because they used gross value of industrial output to measure output, a different capital stock measure, and a higher weight for labor.

Table 2. OUTPUT, INPUTS AND FACTOR PRODUCTIVITY IN CHINA'S STATE-OWNED INDUSTRY, 1952-82
Index (1957 = 100)

	1952	1957	1965	1978	1983
1. Net output	37.5	100	218.6	677.2	869.6
2. Labor input	68.2	100	165.5	406.6	474.9
3. Capital input	44.5	100	310.8	954.3	1,424.9
4. Total factor inputs (40% labor, 60% capital)	54.0	100	252.7	735.2	1,044.9
5. Total factor inputs (60% labor, 40% capital)	58.7	100	223.6	625.7	854.9
6. Labor productivity (1÷2)	55.0	100	132.1	166.6	183.1
7. Capital productivity (1÷3)	84.3	100	70.3	71.0	61.0
8. Total factor productivity (1÷4)	69.4	100	86.5	92.1	83.2
9. Total factor productivity (1÷5)	63.9	100	97.8	108.2	101.7

	Average annual growth rate (%)				
	1952-57	1957-65	1965-78	1978-83	1957-83
10. Output	21.1	10.3	9.1	5.1	8.7
11. Total factor inputs (40% labor, 60% capital)	13.7	11.7	8.3	6.3	8.9
12. Total factor inputs (60% labor, 40% capital)	11.8	10.0	7.9	5.2	8.0
13. Residual (10-11)	7.4	-1.4	0.8	-1.2	-0.2
14. Residual (10-12)	9.3	0.3	1.2	-0.1	0.7

Note: The index numbers of TFP (lines 8 & 9) are not wholly consistent with average annual TFP growth rates calculated by the residual method (lines 13 & 14). This is due to the interaction of factor weights and compound growth rates in the different methods of calculation. Neither method is more "correct;" the differences represent an index number problem. However, lines 13 & 14 should be used for comparisons with international data given in Table 1 because all calculations in Table 1 were based on the residual method.

Source: Statistical Yearbook of China 1984, pp. 13, 20, 29, 114, 194. Net output in constant prices was estimated by multiplying the ratio of net to gross output in current prices of all industry (pp. 20 & 29) by the index of gross output at comparable prices of state-owned industry (p. 194). Capital is the original value of fixed assets. Lines 4 & 5 present alternative estimates of total inputs, assuming different weights, and lines 8 & 9 present correspondingly different estimates of total factor productivity.

mates the increase in fixed assets and biases the capital productivity index upward. Finally, changes in aggregate productivity mask considerable differences in individual subsectors (see discussion below). A complete evaluation of productivity performance in Chinese industry would require data by subsector on gross output and inputs of materials and working capital, as well as labor and fixed assets.

1.05 In spite of these limitations, which are largely shared by estimates for other countries, the aggregate TFP index is a rough indicator of performance. And by this measure, China's performance has been extremely disappointing. Although Chinese industrial output growth has been high (8.7 percent per year during 1957-83), this growth has been achieved only through an equal or faster rate of growth of inputs. This has to change if China's industrial output growth is to be maintained. Without more efficient use of capital, energy, and other materials, it is highly unlikely that China could achieve the high rate of industrial growth needed to meet the target of quadrupling agricultural and industrial output by the year 2000.

2. LINKS BETWEEN TECHNOLOGY UPGRADING AND TFP GROWTH

2.01 A particularly disturbing feature of Chinese industrial performance during the past 25 years has been the relatively rapid growth of capital in comparison to both labor and output. The higher capital-labor ratio raised labor productivity (output per worker), but this was more than offset by a decline in capital productivity. China thus had the worst of both worlds--slow employment growth and a rising capital-output ratio. If this trend were to continue, China would be forced to choose between an ever-increasing investment rate or ever-decreasing growth rates of output and employment.

2.02 The high accumulation of capital was also disappointing in another respect. Rapid accumulation offers an opportunity to accelerate TFP growth by embodying improved technology in the growing capital stock. The failure of TFP to rise in spite of a high rate of investment could be interpreted as a failure to upgrade technology in the past 25 years.

2.03 There is some validity to this interpretation. During the 1950s, the Soviet Union helped establish new industries and upgrade technology with 156 major construction projects worth US$2.7 billion. With the termination of Soviet assistance in 1960 and continuing export restrictions by many Western countries, China concentrated on mastering the 1950s vintage Soviet technology, replicating it, and adapting it to Chinese conditions. Technology imports were limited to about US$280 million in the 1970s. Despite resumption of technology imports on a fairly large scale in the early 1970s,[5/] the level of Chinese technology continues to lag behind that in most advanced and many less developed countries. It is estimated that only 20 percent of China's present industrial technology is of 1960s and 1970s vintage while another 20-25 percent is backward but can still serve present needs. Of the remaining 55-60 percent, 35 percent urgently needs to be renovated or scrapped (because of excessive energy consumption, outmoded products, etc.) and 20-25 percent should be gradually scrapped (Ma Hong 1982). There is also abundant evidence from individual sectors of widespread use of old and inefficient equipment or production of low quality products.

5/ During 1970-77, China signed contracts in Japan, Western Europe, and the US for 26 projects totaling nearly US$4 billion, including several fertilizer, synthetic fiber, and petrochemical plants, as well as a steel mill and coal mining equipment. Even more contracts were signed from 1978, but some of these were subsequently canceled in the period of readjustment. See "China's Importation of Technology," Almanac of China's Economy 1981.

2.04 It is because of this dismal picture of technological backwardness that the Government has made upgrading technology the centerpiece of its long-term industrial strategy. The stated aim is to raise the technological level of all industry by the year 2000 to that of advanced countries in the late 1970s and early 1980s, while raising that of some industries to the same level as advanced countries at the end of the century.

2.05 Upgrading industrial technology is indeed essential if China is to increase productivity, but the level of technology in use is not the only determinant of TFP. The stagnation or decline of TFP is not entirely due to the failure to introduce more modern equipment after 1960, nor will future TFP growth be assured by introducing more advanced technology, for three reasons: some advanced technology may be inappropriate for a labor-abundant economy, China's absorptive capacity may be limited, and new technology is only one of many sources of productivity growth.

2.06 The latest vintage technology from advanced countries will not necessarily lower production costs (raise TFP) in China. Many innovations raise the productivity of some inputs, such as labor or energy, but have higher capital cost. The effect on production costs thus depends on input costs which differ in different countries.[6/] While it is likely that many of the older vintages in use in China need to be scrapped or upgraded, some old vintages--particularly those which have been modified for Chinese conditions--may still be the most productive.

2.07 This does not mean that the most appropriate technology is always the most labor-intensive or that China should eschew every change which raises

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6/ In all cases, China should compare not only production costs of using existing domestic equipment with costs using imported equipment embodying a newer technology, but also production costs when both the final product and the improved equipment are manufactured in China.

labor productivity. For any given level of output, an increase in labor productivity, by definition, means less employment. But an increase in labor productivity should be output-increasing rather than employment-reducing, provided that costs are reduced (TFP increases). If output of the product enjoying the increased labor (and total factor) productivity cannot rise, employment of the displaced workers may take time and will not be automatic. But proper policy should enable the additional surplus created by the fall in costs to be put to use to expand output and employment of other products in the same or other enterprises. It would be unfortunate and shortsighted to forego TFP increases in order to protect particular jobs because this would mean having to forego a major source of growth.[7/]

2.08 A second reason why the introduction of advanced technology will not assure future growth of TFP is that deficiencies in China's own technological capability may prevent absorption or digestion of the new techniques. China's success in digesting imported technology has been mixed. One study of large and medium-sized projects completed during 1980-82 concluded that "among the nine projects imported from foreign countries, six have poor economic results" (Ma Hong 1983). Another study of more than 30 major turnkey projects undertaken in the 1970s concluded that only one third of these projects met the three criteria of short construction periods, high utilization rates after

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7/ One policy change to encourage faster TFP growth would be to make the government rather than the enterprise responsible for supporting displaced workers until new productive employment can be found. Any proposed innovation should be preceded by thorough project analysis (see below) to ensure that it really does increase TFP and not needlessly reduce employment through substitution of capital for labor. In addition, research and development should be directed toward innovations which save capital or materials or substitute labor for these scarce inputs rather than initiating or taking over, without modification, innovations from advanced countries which are directed mainly at saving labor.

start of operation, and good operational results (Chen Huiqin 1981). Almost none of the complete plant projects met the construction schedule in the contracts; 11 were delayed for more than one year and some for three years. Of the 17 projects completed before 1978, only nine (comprising 32 percent of total foreign exchange costs) reached 90 percent of projected capacity by 1979 and six (absorbing more than half of total foreign exchange) reached less than 50 percent of capacity. Only about one quarter of the projects achieved good economic results, defined as projected increases in profits and taxes. The main successes were fertilizer and chemical plants. The principal problems encountered in other projects were availability of power, raw materials, or complementary domestic plant and equipment, as well as difficulties encountered in adapting the equipment to use domestic raw materials with different specifications. One lesson the Government drew from this experience was that more emphasis should be given to selective imports of equipment rather than whole plants and to imports of know-how rather than equipment. While this conclusion is broadly valid, the success of some complete plant imports suggests a need to analyze the reasons for success and failure in different sectors.[8/]

2.09 A more general conclusion, based on similar experience of other countries in absorbing foreign technology, is that technology is not something

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8/ One hypothesis could be that success is more likely in fertilizer and chemical industries because more of the technology or know-how is embodied in the equipment in these process industries than in other industries. Alternatively, organization and planning in the relevant ministries may have been superior. The success of transfer in chemicals is reflected in relatively fast TFP growth in that subsector (see below). It is worth noting that China not only mastered production technology in the large-scale nitrogen fertilizer plants imported in the 1970s, but achieved a large degree of investment capability as well. In new investments currently planned, China will purchase some know-how and specialized equipment from abroad, but will design the plants and manufacture about 75 percent of the equipment domestically.

which can be thoroughly codified in blueprints or embodied in capital equipment. It cannot therefore simply be transferred. Considerable effort and investment is needed to master any technology and to make adaptations in complementary production, in management, and in the technique itself (Dahlman and Westphal 1981). The importance of effort is also shown in other studies of technological progress. Improvements in productivity often come through experience in production, or "learning-by-doing." There is a learning curve following the introduction of a new product or process in which unit costs as a function of total cumulative production first fall steeply and then level off.[9/] Moving down the learning curve requires conscious effort, however. It does not happen automatically. Studies also show that radical innovations are less important than subsequent minor improvements in reducing costs of production (Enos 1958 and Rosenberg 1982, Chapter 1). In general, international experience shows that successful upgrading of technology, including absorption of technology from abroad, depends on systematic improvements in technological capability of individual enterprises and specialized agencies within each country.[10/] There is no quick technological fix to the problem of low productivity.

9/ See Arrow (1962) for the original concept. For another concept of learning, see Rosenberg (1982), Chapter 6, "Learning by Using."

10/ Westphal, Kim and Dahlman (1984), p. 6 define these capabilities as follows: "Technological capabilities are separable into three broad areas: production, investment, and innovation. The first capability is for operating productive facilities, the second is for expanding capacity and establishing new productive facilities, and the third is for developing technologies. Proficiency in production capability is reflected in technical (or x-) efficiency and in the ability to adapt operations to changing market circumstances. Proficiency in investment capability is reflected in project costs and in the ability to tailor project designs to suit the circumstances of the investment. Proficiency in innovation capability is reflected in the ability to develop technologies that are less costly and more effective."

2.10 The third and most important reason upgrading technology is insufficient to raise productivity is that the introduction of new techniques of production is not the only source of productivity growth. The measure of aggregate TFP captures the effects of: (i) reallocation of resources to higher (or lower) productivity sectors; (ii) changes in the skill and knowledge of labor, (iii) economies of scale, (iv) changes in the efficiency of use of existing technology; as well as (v) changes in the techniques of production.[11/]

2.11 The structure of Chinese industry has changed markedly over the past 25 years, but in the absence of value added data by subsector it is difficult to decompose changes in aggregate TFP into structural change and TFP changes within subsectors. Rawski's (1983) calculation of TFP change within selected subsectors for the period 1955-81 (Table 3) shows changes ranging from -23 percent in coal to +177 percent in electricity. Since average TFP growth within subsectors was positive, this suggests that high TFP in some subsectors may have been offset not only by decline in others but also by a shift in resources toward low-productivity subsectors. One caveat about this interpretation is that the basis of calculation differs between Tables 2 and 3. Table 3 covers a different period, including some years of high productivity growth before 1957; defines TFP as gross output divided by the weighted input of capital and labor; and gives a higher weight (70 percent) to labor. All of these tend to bias the measure of TFP upward. We cannot necessarily infer, therefore, that resources have been inefficiently allocated toward lower productivity sectors. However, Rawski's estimate that TFP increased by about 25 percent in Shanghai but decreased by 8 percent in the rest of the country

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11/ The division between these effects is rather arbitrary. Note that changes in skill, changes in efficiency, and changes in techniques of production could all be considered technological change, broadly defined as an improvement in the method for doing something.

from 1955 to 1981 suggests that part of the decline in aggregate TFP may be associated with the higher cost of expanding industry in relatively backward regions.12/

Table 3. GROWTH OF TOTAL FACTOR PRODUCTIVITY BY SUBSECTOR, 1955-81

Subsector	Index in 1981 (1955 = 100) Output	Inputs	TFP
Electricity	2,587.4	933.6	277.1
Chemicals	5,496.9	2,547.7	214.1
Coal	619.2	803.3	77.1
Building materials	1,304.1	553.7	235.5
Machine-building	2,408.5	2,593.5	92.9
Textiles	712.2	364.4	195.4
Paper	634.9	603.0	105.3

Source: Rawski (1983), p. 44.

2.12 The effect of changes in labor skills is equally hard to assess. Somewhat surprisingly, the downgrading and misallocation of technical expertise during the Cultural Revolution, as well as other policies of that period, had little measurable effect on TFP. The limited data available (see Table 2 of Rawski 1983) show little difference in performance during any period since 1957. However, educational policies during the Cultural Revolution will no doubt exact a cost in productivity until the end of the century. The shortage of well-trained technical personnel is already being felt and will become increasingly apparent as more of the older generation of engineers and technicians retire without adequate numbers of qualified and experienced replacements.

12/ These estimates are also upward-biased, for the same reasons as the subsectoral estimates.

2.13 Failure to exploit economies of scale and specialization have also denied China an important source of productivity growth and product improvement. In 1978 China produced 150,000 motor vehicles in 130 separate production enterprises in 26 provinces under the jurisdiction of several ministries. Even without the introduction of sophisticated transfer machines and other automated production techniques, consolidation of production could have a major impact on cost and quality of production through standardization of parts, longer production runs for individual parts, and introduction of more specialized machine tools. In industrialized countries the automobile industry is organized quite differently. A few very large-scale units product key parts and assemble vehicles while numerous (often small-scale) units produce components and provide specialized services.

2.14 The same contrast is apparent in many other industries. In 1982 China produced 190,000 refrigerators in 103 factories. Many of these imported technology from abroad, where a single factory often produces 1 million or more units.[13/] At present, production cannot meet domestic demand but in a few years China will undoubtedly be overproducing refrigerators in too many small-scale and inefficient factories. This has already happened in some consumer durable industries and is about to happen in bicycles and watches. In bicycles, an estimated 140 enterprises produced 24.2 million units in 1982. Industry experts claim that the break-even production point is about 300,000-500,000 units. Only 11 enterprises produce this number of bicycles.[14/] In watches, the cost of production fell 25 percent in China with each doubling of production scale. The average cost of production of all other watch producers

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13/ Information on refrigerators provided in briefing by State Economic Commission.

14/ Information on bicycles is from Liu Fengchang and Gong Jinglong (1983).

in China is 83 percent higher than that of the largest producer.[15/] In spite of the advantages of scale and impending oversupply, it has been difficult to control establishment of new small-scale factories. China's "small and comprehensive" production units inhibit economies of scale and specialization, both of which are important sources of cost reduction. The solution is not to organize production into large and comprehensive units, but to move toward larger-scale production in some cases while in others promoting specialized production in separate--often quite small-scale--enterprises.[16/]

2.15 The biggest potential productivity gain probably lies in changes in efficiency of use of existing technology. In China, as in many other countries, there is an enormous gap between the productivity of best-practice firms and the rest of an industry. This difference may depend on management and organization rather than superior equipment, i.e., it may be due to differences in what economists call x-efficiency or what we have previously referred to as production capability.[17/] Calculations of "frontier production functions" can be used to decompose TFP growth into technological progress (changes in the best-practice production frontier) and changes in technical or

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15/ See Byrd and Tidrick (1984), p. 91. Data are from State Economic Commission 1983. Economies of scale are estimated from a cross-section regression across enterprises for 1980.

16/ For products with high transport costs, such as coal or cement, small-scale production to serve local markets may be economic even if unit production costs are somewhat higher and for other products, such as clothing, there may be no economies of scale beyond a very small size.

17/ An enterprise is x-inefficient (sometimes called technically inefficient) if it uses more inputs per unit of output than the best-practice enterprise using the same production technique. X-inefficiency should be distinguished from allocative inefficiency, which results from using a higher cost technique of production, given input prices, but assuming production is x-inefficient. Both types of inefficiency lower TFP. For a detailed microeconomic study of the sources of relative TFP in the textile industry in Kenya and the Philippines, see Pack 1984.

x-efficiency. Estimates for Yugoslavia have shown that changes in x-efficiency dominated "technological progress" (as defined above) in relative importance. While technological progress was never negative, changes in x-efficiency were both positive and negative and the declines often more than offset technological progress in individual subsectors (Nishimizu and Page 1982). There are insufficient data to do similar calculations for China, but it is clear that widespread variations in x-efficiency exist.[18/]

2.16 For example, the Tianjin Watch Factory has more and better equipment and nearly as many workers as the Shanghai Watch Factory, yet it produces only 35 percent of Shanghai's volume at a 27 percent higher unit cost. These are two of the largest, oldest and best-managed watch factories in China. The gap between Shanghai and many new factories is much greater (State Economic Commission 1983b).[19/] In the sewing machine industry, costs of production for a particular model are nearly five times as great in the highest-cost enterprise as in the lowest (Table 4). Some of this disparity may be due to differences in technology rather than x-efficiency, but even among the five enterprises producing 124,000-135,000 units (and which probably have similar techniques of production), cost differentials range from one-fourth higher to more than double the low-cost producer within the group. Considerable scope thus exists for raising productivity and output through mastering existing technology--through diffusion of existing best-practice production methods throughout China.

18/ Although increases in x-efficiency may reflect improved technological capability, the fact that x-efficiency sometimes declines shows that upgrading technology is not synonymous with productivity growth.

19/ As noted earlier, many of the differences in costs in the watch industry are related to economies of scale in production. It is hard to distinguish scale effects from differences in x-efficiency, but both offer considerable scope for raising TFP.

Table 4. OUTPUT AND COST OF PRODUCTION OF JA 1-1 SEWING MACHINE BY ENTERPRISE

Output (10,000 units)	Cost per machine (year)
1.50	115.64
2.02	141.11
2.16	135.42
2.50	142.71
6.02	116.00
10.00	96.80
10.28	96.45
12.40	90.73
12.50	72.31
13.03	59.28
13.04	47.71
13.50	101.30
15.50	92.65
19.50	84.65
22.40	96.58
24.14	44.20
26.25	82.00
65.21	29.55
100.56/a	29.16/a

/a Includes production of both JA 1-1 and JA 2-1 models.

Source: State Economic Commission, Investigation and Research Office, "An Analysis of the Economic Efficiency of the Sewing Machine Industry in China," Jingji Diaocha, No. 1 (October 1983), p. 25.

2.18 Upgrading technology is not synonymous with productivity growth for another reason: the TFP measure has difficulty accounting for product quality changes. While TFP growth captures more than just the effect of technological change, it also fails to capture fully one important dimension of technological change--product innovation. For many manufactured products, it is extremely difficult to measure the change in output, and hence productivity, resulting from a quality improvement. For example, over the past 25 years there have been substantial improvements in the energy efficiency and other performance indicators of automobiles produced by the world's leading companies. Yet, in general, these quality improvements are neither counted as an increase in output nor a decrease in input--they do not show up in TFP measures.[20/] Indeed to the extent that quality improvements require additional inputs (or higher prices--hence reducing measured output volume) they may perversely show up as a decline in TFP. This is recognized as a problem in China where gross value of output in constant prices declined in some machinery plants after the Cultural Revolution, but "usable" output often increased. For this reason, the continued stagnation of TFP since the Cultural Revolution fails to measure improvements in economic performance.

2.19 In international comparisons the failure of TFP to measure the product innovation dimension of technological change means that China's performance has probably been worse than TFP comparison would indicate. While the rest of the world has shown substantial technological progress through product innovation which goes largely unmeasured in TFP, product innovation and quality improvement has been very slow in China.[21/] Many Chinese product designs have remained unchanged since their introduction. For example, the Liberation brand truck is based on a Soviet model which in turn is based on a US model from the 1930s. In other examples, Chinese machine tools are slower,

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20/ To the extent that product quality change reduced input consumption in another industry (e.g., more energy-efficient industrial boilers reduce energy consumption in user industries), this will show up in an increase in aggregate TFP. However, quality changes in final consumer goods are often not measured in TFP.

21/ Poor product quality is generally recognized as a problem in most socialist economies. This is reflected in the strong preference of consumers for imports of consumer goods when available and in the inability of the Soviet Union and most centrally planned East European countries to export manufactured goods except at a discount.

less precise and have a shorter life than machine tools in other countries; Chinese ball bearings last only one fifth to one half as long as the best of foreign ones; China still produces low-efficiency industrial boilers; and 40 percent of Chinese nitrogen fertilizer is still low-quality and unstable ammonium bicarbonate. Although some consumer product innovation in capitalist economies may be regarded as of limited social value, there is little doubt that China has been slow to upgrade quality of most products, including those which could bring substantial tangible and obvious benefits.

2.20 In summary, new technology is important but not as important as most people think. Experience in other countries shows that the cumulative effect of successive small innovations on both product cost and quality is greater than that of completely new products or processes and that average performance is more important than best-practice performance for overall growth and productivity. Thus while the rest of this paper will focus primarily on upgrading technology, it will also discuss the broader issue of reducing costs and improving product quality. A major theme will be that technology can most successfully be upgraded if constant attention is paid to efficiency and product quality. This has implications for the entire planning and incentive systems, as well as for the organization of research and development.

3. WHAT SHOULD BE DONE ABOUT BACKWARD ENTERPRISES?

3.01 China's technology is highly diverse. In nearly every industry, plants which are quite technologically advanced by world standards coexist with very old or specially adapted small-scale techniques of production rarely found in the rest of the world. This diversity partly reflects the deliberate policy of "walking on two legs" and is partly due to continued operation of old vintages of technology from investments of long ago. An industrial structure with a range of vintages is common. What is unusual in China is that old vintages tend to be kept in operation much longer than in other countries, and frequently reproduced in new investment. There is a long-standing debate about China's multilayered technology. Many see small-scale, labor-intensive industry (the second leg) as a creative and rational response to shortage of capital, poor transport and the availability of labor with little alternative employment. Others feel these plants are a drain on resources and should be closed down. Yet others see them as a necessary evil: they cannot be closed down because of the unemployment and shortages of goods this would create but they cannot be modernized because of a shortage of funds. What is the correct approach?

3.02 There is no categorical answer; each case must be examined on its own merits. The correct analytical approach is outlined below. However, such an investigation would almost certainly conclude that there are many small and backward enterprises which ought either to be reorganized or closed down. In a dynamic economy, under the surface appearance of steady and uniform growth there is considerable turmoil. Individual enterprises are constantly expanding, contracting, merging or closing down. There is an enterprise life cycle which, while not progressing inevitably from birth to maturity to death as in the biological life cycle, does involve both births and deaths of enterprises as well as differential growth, decline and mergers. Competition from progressive firms forces more backward enterprises either to match their advances or to face extinction. Technological progress is therefore necessarily, in Schumpeter's words, a process of "creative destruction." If backward firms are protected, they act as a drag on progressive enterprises. Backward enterprises take up economic "space"--materials, skilled labor, capital, and (most importantly) markets--which could be more productively taken over by progressive enterprises producing higher-quality products at lower cost.

3.03 In recent years the Government has closed down some loss-making enterprises which used excessive amounts of energy. This is a step in the right direction, but profitability is an inadequate guide to decisionmaking because prices at present do not reflect the real costs and benefits to the economy of either inputs or outputs. In certain highly profitable industries, such as consumer durables, backward and inefficient firms can still be profitable even though their costs may be much higher than the most advanced enterprises in the sector (see the examples of watches and sewing machines above) because prices are fixed much higher than they would be in a competitive market. In other industries, important inputs such as energy, capital, or land may be incorrectly priced or some enterprises may be favored by subsidies or tax remissions.[22/] In both cases, financially profitable enterprises may be operating at a social loss. Conversely, some loss-making enterprises may be socially profitable if, for example, their output price is controlled at a very low level.

3.04 How does one decide when an enterprise ought to be closed down? The decision should be based on economic cost-benefit analysis, just as for a completely new investment. The China Investment Bank has produced an Appraisal Manual for Industrial Credit Projects (1983) which adapts the well-developed methodology of project analysis to Chinese conditions. For investment in new plants, the method involves comparing the discounted present value of costs

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22/ For example, large mechanized coal mines are generally more financially profitable than small labor-intensive mines, but part of this is due to understated capital costs which favor large mines. Capital has been provided interest-free and depreciation rates are very low so that the financial cost of capital understates its economic cost to the national economy.

and benefits of alternative production techniques with all inputs and outputs valued at shadow prices.23/ If calculations show that it is cheaper to produce than to import, the techniques with highest net present value of benefits should be selected. As discussed above, this may or may not be the most advanced technique.

3.05 After an investment has been made and the plant is operating, the decision criterion changes. Suppose that a new and more efficient technique becomes available which would have been chosen if it had been available earlier and which will be chosen by enterprises expanding production or investing for the first time. Should the producer using the old technique scrap its old equipment and replace it with the new technique? Not necessarily, because once investment in the old technique has been made, its investment costs are sunk and are no longer relevant. The appropriate criterion for replacement decisions is: replace the old process by the new one if average total cost of production of the new process is less than average variable cost of the old technique.24/ The old technique is said to be "outmoded" if it would not be chosen for a new investment, but can still be used economically (cover average variable costs) in an existing plant. It is "obsolete" if it is uneconomic to continue using it in an existing plant, i.e., if its average variable costs exceed the average total costs of a new technique. Of course, it is also necessary to consider whether the old technique can be modified or upgraded to

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23/ Shadow prices measure opportunity costs (or foregone benefits). Traded outputs and inputs are valued at international prices and nontraded ones are valued by a somewhat more complicated process. For analysis of how to calculate shadow prices in China, see Helmers (1982) and Wood (1984).

24/ See Salter (1966). Variable costs are those costs, such as material costs, which grow with output. Fixed costs are those costs, such as the plant manager's salary, which do not vary with output. Variable costs plus fixed costs equal total costs.

improve its productivity and extend its economic life. The decision criterion for upgrading is similar to that for scrapping: upgrade if the average total cost of production after upgrading is less than the average variable cost without upgrading and also less than the average total cost of production using a completely new plant incorporating the new technique.

3.06 This implies that even in an optimally managed economy experiencing technological change embodied in new equipment, there will be differences in profitability among firms in the same industry which correspond to the vintage of their equipment. It should also be noted that just because a factory using old equipment is losing money, it does not necessarily mean that it should be shut down or its equipment replaced. Depreciation costs are not real economic costs; it will still be rational to use old equipment so long as the factory is able to cover its operating or variable costs (where both costs and output value are evaluated in shadow prices). However, if continually better equipment becomes available, a point will be reached at which the average total cost of production using the newest techniques will be lower than the average variable cost of the old technique. At that point, the old equipment should be scrapped even though it may not be physically worn out. The economic life and the physical life of equipment are not identical.

3.07 Scrapping may not be the only alternative, as the Government has recognized. It may make sense to replace old equipment in, say, Shanghai, but transfer this old equipment to producers in the interior. This possibility arises for two reasons. First, the scarcity of land, relatively high labor cost, and higher cost of pollution in Shanghai may make production using the old equipment uneconomic there while it is still economic elsewhere. Second, established producers in an existing industrial center may be capable of mastering a new technology whereas new producers may need to develop production capability by using older and simpler equipment. This is not necessarily the best solution however. New producers may also find using the new technology more economic. In this case, the old equipment may simply need to be scrapped.[25/]

3.08 Although cost and productivity differentials within subsector exist in all economies, the range of differentials in China is unusually large, partly because economically obsolete equipment continues to be used and outmoded or even obsolete equipment continues to be produced and incorporated into new investment projects. This happens because cost-benefit analysis is not applied to existing plants to analyze whether they should be scrapped. The analysis is not done for several reasons: there is a misconception that it is uneconomic to scrap machinery which is not physically worn out; the social costs of finding new employment for displaced workers is considered to be too great (and is often overestimated because "crowding out" of new firms is ignored); and there are insufficient incentives or pressures for enterprises or planners to replace obsolete equipment.

3.09 Lack of incentives is particularly important. Unprofitable enterprises are often subsidized either explicitly through tax concessions or subsidized input prices, or by mergers with more profitable enterprises. Provinces also sometimes protect their own high-cost enterprises by restricting sales of competing products from other provinces.

3.10 Enterprises are discouraged from selling or scrapping obsolete equipment by the virtual absence of a market for secondhand equipment. Fixed

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25/ It may also make sense to close down production of some products in Shanghai altogether and move production to less congested areas. Shanghai workers could then be reallocated to jobs in expanding industries more suited to the city. But managers, engineers and technicians may need to move away from Shanghai so that their skills can be used to develop the industry in a more favorable location.

asset charges would encourage enterprises to make good use, or get rid, of existing capital but these taxes are not universally or consistently applied. Since enterprises cannot easily dispose of assets which are not fully depreciated, they find it difficult to get rid of equipment even when they might like to.[26/] Many enterprises even keep old unused machinery rather than selling or scrapping it. This is very wasteful. The machinery takes up valuable space and has a high economic value which is not being tapped: sometimes for use in village industry but more often as scrap for the steel industry, which could save a lot of energy and upgrade product quality by using more scrap.

3.11 Finally, and most importantly, in many industries the output price is kept high in order both to generate large profit remittances and tax revenue for the government and to enable some of the more backward firms to earn a profit. This has three adverse effects. First, it enables obsolete techniques to remain profitable long after they should have been scrapped, thus

26/ It is for this reason that low depreciation rates may discourage modernization. Some Chinese economists argue that depreciation rates or the share of depreciation funds retained by the enterprise should be raised in order to give enterprises more funds for investment in modernization. However, it is doubtful whether enterprises should have more control over investment funds unless extensive price reform is also undertaken. Moreover, the need for modernization funds may not correspond to the present amount of fixed assets. However, it is desirable to set depreciation rates at a level which approximates the economic (rather than the physical) life of assets so that financial costs better reflect economic costs. Although it is difficult to predict the economic life of assets, there is little doubt that Chinese depreciation rates generally overstate it. A State Council regulation dated May 10, 1984 may make it easier to dispose of old equipment. It provides that "State-owned enterprises are authorized to rent out or transfer their surplus or idle fixed assets in exchange for some compensation, but when they rent out or transfer high-technology or sophisticated equipment under the management of the department in charge of the higher level, they must get its approval. The profits thus made must be used for technical transformation and the replacement of old equipment." See British Broadcasting Corporation (1984).

slowing technological change. Second, it ironically reduces government revenue since obsolete equipment is not replaced by more profitable techniques. Third, it encourages local governments to invest in small-scale or outmoded techniques which are financially profitable but economically inefficient. This is the main reason for the frequently cited problem of "blind development." In industry after industry, small-scale factories producing high-cost, low-quality products are established, usually outside the plan. This leads almost invariable to excess capacity. In bicycles, for example, a national conference determined that there should be a 57 plants producing 30 million bicycles by 1985, which was regarded as more than enough for national needs. Despite this plan, by 1983 there were 140 plants with a long-term capacity of 44 million bicycles. Famous brand products are still in short supply, but there is excess supply of low-quality products so that some plants have already had to stop production. Similar situations exist in numerous other industries.27/

4. THE ROLE OF PLANNING IN UPGRADING TECHNOLOGY

4.01 In order to accelerate technological upgrading, China needs to improve sector planning and project analysis. Although comprehensive annual planning at all levels of government is relatively well-developed, little attention has been given to long-term planning of individual industrial subsectors. In addition, planning of individual projects has often neglected the relevant sectoral considerations for both expansion and technical transforma-

27/ See Liu Fengchang and Gong Jinglong. See also Market Weekly (1983), which cites excess capacity in Liaoning Province in steel rolling, paint, rubber products, water meters, electric meters, and semiconductors.

tion investments. Sector planning is now needed in many sectors for three reasons: to provide an appropriate framework for analysis of indivdual projects, to map out an overall strategy for upgrading technology, and to take account of externalities and linkages of individual project decisions.

4.02 In both the objectives and detailed methods of sector planning, China could learn from Japan whose extraordinary success in catching up, or surpassing, the most advanced levels of technology probably owes a great deal to the leadership role of the Ministry of International Trade and Industry (MITI) in industrial sector planning (see Box A). The first lesson to be learned from Japan is the need to look at individual project proposals in the context of the entire national and international market and the plans of other producers. Departmentalism and regionalism in China lead to suboptimal project planning--investment proposals which may be rational for the bureau or region, but not for the country as a whole. For example, there were four iron and steel mills in Huangshi, Hubei Province in 1981, each under a different level of ownership and each having no links to the others. Each mill had separate investment plans to balance its capacity, even though integration of production facilities within the municipality could have improved balance at far less expense (Ding Hua 1981). With the same products being produced by many ministries and levels of authority and with each ministry, region and locality striving for self-sufficiency, China too frequently ends up with excessive numbers of small-scale and high-cost producers. Using steel as an example again, the central authorities are assuming that 29 provinces and municipalities will still be producing steel by the year 2000. No matter how successful China is in introducing the latest techniques of production from

Box A: LESSONS FROM JAPANESE INDUSTRIAL SECTOR PLANNING

A.1 Japan is not usually considered a planned economy, but in one field--industrial sector planning--it is often held up as a model for other countries. Several features of Japanese industrial sector planning are relevant even for centrally planned economies such as China.

A.2 In Japan, sector plans are drawn up before and generally dominate macro plans. Sector plans, whether for industry as a whole or individual subsectors, also have a longer time perspective than macro plans, in line with the requirements of different industries for meaningful planning horizons. The main actor in industrial planning is the Ministry of International Trade and Industry (MITI). MITI's plans are developed for individual subsectors in consultation with producers and are presented as "visions": flexible and adaptable ways of expressing broad common understandings about the present situation and future prospects, sectoral, or industrial. Common elements of all visions are an analysis of the present situation and problems, a comparison with advanced Western economies, an analysis of emerging trends, and a definition of Japanese development goals. Industrial development has been guided by visions for the industrial structure and for individual industries. In the 1950s and 1960s, emphasis was placed on changing the structure of industry in favor of industries with high income elasticity on the demand side and a relatively high rate of technological progress on the supply side. The favored industries during this period were chemicals and heavy industries. More recently, as Japan has caught up with advanced technology elsewhere and has become a leader in its own right, emphasis has shifted toward knowledge-intensive industries.

A.3 The ultimate aim of Japanese industrial policy has always been to establish internationally cost-competitive industries after a period of infant industry protection. Toward this end, MITI has sometimes strongly promoted mergers among small firms in order to obtain necessary economies of scale of production and in other cases has tried to promote competition among Japanese firms. MITI did not generally set distorted prices much above the international level as part of its planning or promotion efforts. On the contrary, subsidies have often been used to lower prices and widen the domestic market, in order to foster growth in industries which benefit from economies of scale (e.g., in the prewar automobile industry). The careful attention MITI has given to developing internationally fully competitive industries is often compared to the attention a mother gives a student preparing for an entrance examination; that is to say, MITI went to great lengths to help Japan's industries enter international competition.

A.4 Another reason for the success of Japan's industrial policy is that planning has not been mandatory. Enterprises themselves have borne the risks of failure and reaped the rewards of success. Some large enterprises (such as Sony and Honda) have stayed outside the MITI system, often pursuing strategies at odds with official objectives. Private automobile producers, for example, followed their own instincts and made automobiles one of Japan's leading exports despite MITI's initial decision not to support development of automobiles as an export industry. There have also been failures, of course. Sometimes both MITI and private producers have backed losers (e.g., petrochemicals, which became uncompetitive after oil price increases in the 1970s) and sometimes private producers alone tried but failed to develop industries which MITI did not want to back (e.g., commercial aircraft). Japan has thus had a flexible system of strategic planning that allows for mistakes and for experiments with alternative technological paths--a system in which competition and domestic as well as international--provides a strong incentive to seek out promising technological paths and retreat quickly from paths that lead nowhere.

NOTE: For a more complete discussion of Japanese planning, see Shinohara et al. (1983).

abroad in key steel plants, such a structure is bound to be inefficient and high-cost, with continuing imbalances in capacity, duplicate high-cost facilities, and high transport costs of raw materials and intermediate products.

4.03 Planning for upgrading technology in each subsector should begin with the same set of questions and issues addressed by MITI in its planning.

What is the present structure, level of technology and competitiveness of the industry compared to more advanced countries? What are long-term objectives for the industry? What structure and level of technology does this imply in 10-20 years? (Planning horizons will differ for different industries.) If the technology is relatively stable, planning is fairly straightforward. The steps are to: project market demand for the product, investigate alternative production techniques, and choose the most appropriate technique at projected input prices; decide how many plants of that type are needed, given economies of scale, transportation costs and the need for dispersion of industry on strategic or other grounds; and move through mergers and phased closings, expansions, and investment in technical transformation and capital construction toward the desired structure. Individual project analysis (both design and evaluation) would then be made within the sector planning framework. There are sophisticated sector planning models, such as those employing integer programming techniques,[28/] which can be used to analyze optimum location, scale and timing of investments in some sectors. In most cases, however, what is needed is a far simpler approach in which basic questions are asked within a broad enough framework to prevent suboptimization.

4.04 A second reason for improving sector planning is the need to make strategic choices--develop a long-term "vision" for each industry. China faces some unusual strategic choices. The normal sequence of developing technological capability in most countries is to develop first production capability, then investment capability, and finally innovation capability. China is virtually unique among developing countries in having a full range of industry, producing nearly every product from machinery to final products. Yet,

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28/ See, for example, Kendrick and Stoutjesdijk (1978).

China also needs to upgrade the level of technology in nearly every industry. Where does one break into this circle of low productivity? Should China import foreign technology to upgrade production capability for final consumer products or should attention first be given to upgrading technology in producer goods industries? In what industries should technology be obtained from abroad and in what industries should China try to upgrade technology through basic research? Should China forego production of some products altogether and rely on imports?

4.05 There is no generally applicable answer to these questions of strategic choice. Since China is a machinery producer, there is a presumption in favor of early upgrading in the production of general use machinery such as machine tools and boilers (see Box B). In general, however, issues of strategic choice are best approached on an industry-by-industry basis, viewing each industry as a vertically integrated entity from producer goods to intermediate components to final goods. For example, it may make sense in a relatively mature industry such as textiles to concentrate first on upgrading production capability in textile machinery. Improved domestically produced textile machinery could then be used to upgrade production capability in textile production. In a sector such as computers, the strategy of development would probably be quite different. If the goal were to increase the use of computers in the economy, it could be done most quickly by importing finished systems. The opposite extreme would be to develop everything domestically. The problem with the latter approach is that all parts of the equipment development program must be successful or the computer system will be unworkable. Moreover, by the time a complete domestically produced system had been developed it would be out of date because technology is developing rapidly elsewhere. Under these circumstances, a more effective approach is to concentrate

Box B: SECTOR PLANNING IN MACHINE TOOLS AND POWER STATION BOILERS

B.1 Planning for upgrading technology in machine tools and in boilers for power stations provides lessons in how sector planning should be approached and how it can be improved.

B.2 China's machine tool industry is a microcosm of the industrial sector. During the 1950s, the industry was based on Soviet technology, while during the 1960s and 1970s development depended upon the work of Chinese research and design institutes, internationally published literature, and occasional import of sample machine tools. This self-reliant strategy resulted in slow and very costly technological development. With the exception of a limited number of machine tools built through recently acquired technologies, current technology in the vast majority of machine tool manufacturing plants is about 20 years old. Old designs, combined with poor quality purchased components, inadequate manufacturing facilities and insufficient experience in production management result in products which, in addition to having a short life (5-7 years compared to 12-15 years in industrialized countries), are unreliable and not suitable for precision work.

B.3 The Ministry of Machine Building and the provincial governments that are in charge of most of the 121 main enterprises that account for the bulk of machine tools and accessories production have embarked on a program of modernization. In recent years, more than 20 collaboration agreements (mostly buy-back agreements) have been signed with advanced manufacturers in industrialized countries. In Shanghai, the Government asked the World Bank to help prepare and finance a comprehensive modernization plan for the Shanghai machine tool subsector.

B.4 Shanghai's machine tool factories and foundries are organized into two companies, the Shanghai Machine Tool Works (SMTW) and the Shanghai Machine Tool Company (SMTC), which together account for 10 percent of national output and about 20 percent of exports. The agreed approach to upgrading has several elements. First, existing operations will be rationalized. The product mix of individual factories will be changed to reduce or eliminate overlapping operations. Some foundries and factories will be closed down. Second, a modernization program will be carried out in several foundries, machine tool and accessories manufacturing plants, and in the research institutes of SMTW and SMTC. This program will be based upon feasibility studies to be carried out by foreign consultants in collaboration with domestic consultants and the companies. It may include imports of selected equipment and purchase of foreign licenses, as well as local investment. Third, a comprehensive training program for middle-level technicians and managers will be carried out in China and abroad. Fourth, modern management structures and systems will be introduced. SMTC, which has about 40 foundries and factories under its control, will be organized into four product divisions. New systems for quality control, financial control, market information gathering, production planning and inventory control may be introduced in both companies. Fifth, the existing program to upgrade the quality of critical components and materials will be strengthened. This includes raw materials such as sand, which is critical for the quality of castings and thus of the efficiency of machining operations.

B.5 This approach to technical transformation goes well beyond simply upgrading manufacturing processes and designs. It also identifies weaknesses in management, training, and supplies which can affect the overall quality and efficiency of production. Finally, it assesses the economic and financial, as well as the technological, implications of alternative investment proposals. A similar approach could be used to plan technical transformation of the rest of the machine tool sector, but for national planning purposes more national market information would be needed than was available for Shanghai.

B.6 The approach to upgrading technology in boilers for power stations presents an interesting contrast to machine tools. The Shanghai Boiler Factory (SBF) produces several types of boilers, including a 300 MW once-through type boiler for power stations. SBF was dissatisfied with the performance of its 300 MW boiler and has entered into an agreement with an American company to produce a drum-type 300 MW boiler. Under the agreement, the American company will provide the drum for three boilers while SBF manufactures most components according to a joint design. SBF has also sent 50 people to the US for one year's training. After the third set, SBF will manufacture everything itself, including the drum. This will require not only additional equipment in SBF, but also the construction of a new plant in Harbin to manufacture 200 mm steel plate.

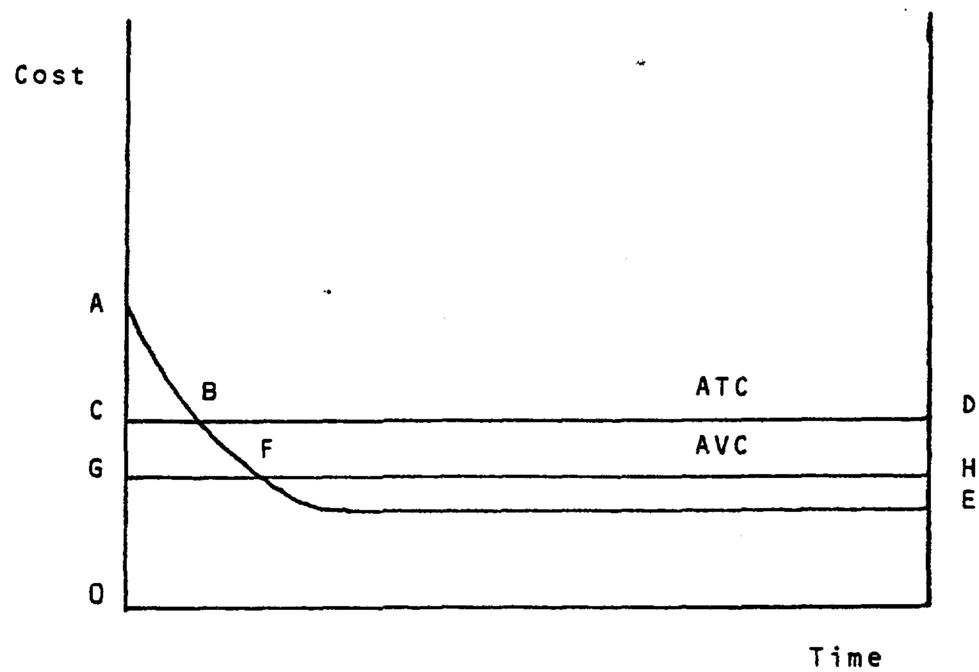
B.7 The approach by SBF and the Ministry of Machine Building (which did a feasibility study for the drum manufacturing project) was flawed, in that it failed to evaluate alternatives properly. One instance of this concerns the decision to undertake comprehensive domestic manufacturing of the drums for 300 MW boilers; there are many alternatives and it is not clear that these have been fully evaluated. One alternative would be for SBF to manufacture all the components of the 300 MW boiler but continue to import the drum. A second alternative would be to manufacture the drum in SBF, but use imported steel plate instead of constructing a new factory in Harbin for this purpose. A third alternative would be to upgrade the quality of the once-through 300 MW boiler (without a drum) which SBF has produced for ten years. The once-through boiler is potentially as energy-efficient and somewhat cheaper than the drum boiler. The main problem with using it is that better automatic controls must be introduced to be able to link up with improved generators and turbines. Thus, SBF had a choice between moving into production of a new type of boiler at enormous investment cost or of improving the control system of an existing boiler. This choice was recognized. In fact, SBF has concluded another agreement with the same American company to help upgrade their once-through boilers and will produce both once-through and drum-type 300 MW boilers in future. Parallel R&D on competing technologies is often justifiable, but full production development of both technologies may be uneconomic. Before proceeding to this final stage, a new evaluation of the alternatives facing SBF should be made in light of experience gained through development thus far.

efforts on developing production capability in certain key components and gradually broaden this base. In any critical intermediate good such as electronic components, the ultimate aim must be to produce a product which is competitive in price and quality. Otherwise, domestic user industries (such as electronic watches) will be burdened and unable to develop efficiently.

4.06 The third important function of sector planning is to take account of externalities and linkages of individual project decisions. The watch industry can be used to illustrate some of the issues. China mostly produces mechanical watches and its best factories produce these efficiently by world standards. A large domestic market and a modest export market for mechanical watches will probably continue to exist for many years. However, the rest of the world has largely shifted to production of electronic watches and production costs are falling. At present, China could only produce electronic watches cheaply by using imported electronic components because of the high price and low quality of domestic components. Should China continue to expand mechanical watch production or shift to production of electronic watches? If electronic watch production is chosen, should China replace existing mechanical watch production or only produce electronic watches for incremental demand? Should electronic watches use domestic or imported components?

4.07 Consider first the options facing an existing Chinese watch producer, as illustrated in Figure 1. The enterprise currently makes mechanical watches at average variable cost OG and wants to expand production. If the enterprise invests in new equipment it can produce the additional output at average total cost OC, where all costs are annualized. If the enterprise produces electronic watches, it will initially face high production costs OA because of inexperience with the new technology, but if it can master the new technology (overcome infant industry problems), it should follow a learning

Figure 1



curve AE. As drawn here, the average total cost of producing electronic watches ultimately falls below the average variable cost of producing mechanical watches. However, it is only economically justifiable to invest in electronic watch production for expansion if the extra cost of the infancy period (area ABC) is less than the extra benefit of electronic watch production after costs fall below OC (area BED). To justify replacing existing mechanical watch production with electronic watches, the criterion is even stricter: area AGF must be less than area FEH.29/

4.08 It may be desirable from a national point of view to introduce electronic watch production even though economic evaluation of electronic watch production for an individual enterprise shows that it does not pay. Suppose China is simultaneously trying to develop integrated circuits (ICs) as part of its strategy for upgrading the electronics industry. The enterprise may find it unprofitable to use domestic ICs based on present costs and part of its strategy for upgrading the electronics industry. The enterprise may find it unprofitable to use domestic ICs based on present costs and quality, while the domestic IC producer is dependent on a widening of user markets to be able to improve costs and quality through scale economies and learning by doing. Simultaneously, development of the two linked industries as part of an overall strategic plan may therefore permit mutually beneficial development which would be unlikely, or much slower, if these linkages were not recognized.30/ Moreover, a pioneer enterprise developing electronic watches might provide external benefits to later domestic producers who could have a steeper learning curve as a result of the pioneer firm's experience. Finally, the

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29/ In the project analysis all costs and benefits would have to be appropriately discounted. For simplicity, we have assumed here that the two watches could be sold at an identical price, but this would not necessarily be the case. Formal cost benefit analysis could take account of this complication.

30/ Of course, sequential development would also be possible. The electronic watch industry could be allowed to use imported ICs until the viability of electronic watch production was proven and a wide enough market was established to permit development of a competitive domestic IC industry. Rational sector planning would examine these alternatives. Even in this case, however, domestic watch producers might be reluctant to invest heavily in electronic watches for fear they would at some point be forced to use low-quality domestic inputs.

value of developing future technological options may be greater for the economy as a whole than for an individual enterprise. Technology in the world electronic watch industry is still improving and China would be chasing a moving target. Static economic evaluation by an enterprise might show that it is too risky to invest in electronic watch production since it might invest heavily in a particular production process which could soon be outmoded. But it may also speed future learning in the industry as a whole and enhance the possibility of catching up later to begin developing production capability now.[31/] Thus, because of the alternative technological paths which might be opened up for the economy as a whole by electronic watch production, it may make sense to pursue dual technological development for a time, with continued production of mechanical watches and experimental production of electronic watches. Because of the high risk and high externalities, sector planning should ensure that the industry neither switches completely out of mechanical watch production nor totally ignores electronic watch production.

4.09 It is difficult to quantify externalities or the benefits of alternative technological paths in formal cost-benefit analysis, but strategic sector planning should always begin with economic analysis and quantify technological factors to the extent possible. Although it may ultimately be necessary to make a less-than-rigorous, strategic evaluation of technological options, this does not mean that analysis should be suspended. Three examples of essentially nonanalytical thinking about upgrading technology in China are discussed below.

31/ However, it may also be possible--and cheaper--to wait until the world industry learning curve has begun to level off and then begin to try to catch up, skipping some of the stages gone through in other countries. This would differ by industry and should be part of the evaluation behind strategic planning.

4.10 First, it can be misleading to argue from analogy. For example, it is sometimes said that it is obviously better to spend more foreign currency to buy a hen to lay eggs than to use a large amount of foreign currency to buy eggs. Even in terms of the analogy, the conclusion is not at all obvious; it depends on how many eggs the hen lays, how much feed she consumes, and many other factors. More importantly, the analogy obscures the complexity of investment choice. The choice is not simply between importing a product and building a particular factory. There are also important choices to be made between different locations, techniques and scale of production.

4.11 Second, there is a common view that it would be desirable to modernize all of Chinese industry with the latest equipment but for the shortage of funds. As we have seen, it is not necessarily true that the latest technique is best for China either on economic grounds (abundant and cheap labor and expensive capital may make labor-intensive techniques more appropriate) or on technological grounds (China may not have the technological capability to assimilate some technologies at high rates of x-efficiency). Moreover, it pays to go on using outmoded (but not obsolete) techniques. In other words, upgrading technology is not simply a budgetary problem. It is a matter for economic and technological analysis.

4.12 Finally, product quality improvement is often cited as the reason for wanting to upgrade technology. Product improvement is indeed just as important as process improvement, but its costs and benefits must also be assessed. There are some product improvements which the government may feel are not worth making in China for social or political reasons. For example, how much value should be attached to the improved accuracy of timekeeping afforded by electronic watches as opposed to the production benefits? Similarly, how does the government view the proposal of a hearing aid producer who wanted to import Danish technology to improve the quality and appearance of hearing aids? The improved hearing aid would cost nearly four times as much to produce. Would such quality upgrading (and price increase) be socially desirable? As a general rule, the government will want to promote product quality improvement. In these cases it is usually possible to use world prices to evaluate rigorously the additional benefits of upgrading quality since higher quality products normally command higher prices in market economies.[32] But it is essential to analyze all the relevant options. For example, the efficiency of Chinese industrial boilers is low. This is not conclusive evidence that boiler production technology should be upgraded, however, for more efficient boilers can be purchased from abroad. Therefore, planning for the Chinese boiler industry should compare the costs and benefits of three options: continued production and use of existing models of Chinese boilers, production and use of improved models of Chinese boilers, and use of imported boilers. The benefit of using better boilers is a separate issue from the costs and benefits of producing them.

4.13 This section has stressed the benefits of sector planning, but it is necessary to be aware of the limits as well. The lessons of Japanese and other international experiences show that it is impossible to pick winners consistently. Although the government can help create a vision of future development which may become self-fulfilling, it is the efforts of producers which are the key to success. Producers have much more relevant experience of an industry than planners and it is important that some producers be permitted to follow their own vision when this conflicts with that of other producers or

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32/ If products are both higher in quality and lower in price, they will normally drive inferior products out of production in a market economy.

the government. Mistakes will inevitably be made, but successes are also more likely and mistakes are apt to be less costly and long-lived if final decisions regarding innovation are decentralized. In other words, it is generally best that planning for upgrading technology be indicative rather than directive, with respect to the details of upgrading. (However, directive planning would be appropriate to force closure or merger of uneconomic enterprises in industries with mature technology.) At the same time, the government can, and should, make more use of economic levers to ensure that decisions which conflict with the overall national interest are penalized. In brief, China should follow a two-pronged approach in upgrading technology: broader sector planning to combat departmentalism and regionalism and greater use of incentives to ensure the decentralized decisions are not inconsistent with the national interest.

5. THE MAKE OR BUY DECISION

5.01 Excessive self-reliance has undoubtedly slowed China's technological progress in the past. At the national level, overemphasis on self-reliance is reflected in the low share of capital equipment imports in gross domestic investment (5 percent in 1979). It is also reflected in China's past preference for developing known technologies through reverse engineering of imported equipment or through completely independent research and development, rather than through imports of technological know-how. For example, China designed its own basic oxygen furnace to make steel during the 1950s and 1960s even though it could have purchased the technology under license from an Austrian firm which originated the process. At the time, the price asked for the license appeared too high, but in retrospect it appears that, even though

China successfully developed the furnace in the end, it would have been cheaper and faster to have purchased the know-how. China's strategy of creating, and often recreating, technology contrasts sharply with the absorptive strategy of Japan which aimed to assimilate and adapt foreign technology as fast as possible. The absorptive strategy has many advantages for a technological latecomer striving to catch up with the rest of the world; if chosen wisely, imported or borrowed technology generally has lower risks, a shorter time lag, and a lower cost of acquisition.

5.02 The national drive for self-reliance is duplicated at every level of the economy. Individual ministries, provinces, localities, and even enterprises strive to become as self-sufficient as possible. This is manifested in the familiar phenomenon of "small but comprehensive" enterprises and the prevalence of enterprise machine shops. Most enterprises are eager to display machinery they have manufactured and products they have designed themselves. Although these accomplishments are impressive and show that China has a wealth of engineering and technical talent, excessive self-reliance is also extremely wasteful both of human and physical capital. Enterprise machine shops are chronically underutilized. This is one reason China has a larger stock of machine tools than the US or West Germany while producing only a fraction of the machinery output of those countries.[33/] Equally serious, the talent of China's technical personnel is being misused through wasteful duplication of effort and concentration on technically interesting but economically unproductive innovation. For example, one Chinese bicycle factory tried to copy alu-

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33/ China has an estimated 3 million installed machine tools compared to 2.63 million in the US and 1.25 million in West Germany. Chinese machinery output was about 20 percent of US and 25 percent of West German output in 1981. Data are from World Bank files.

minum components of a Japanese bicycle purchased in Hong Kong only to discover that the design would not sell and costs of production were too high. The factory sought no assistance from either foreign or other domestic companies and looked only at the technical feasibility of the design. The problem for China is how to channel the extensive talent and tremendous drive to innovate of Chinese technical personnel into more productive activities.

5.03 The issue is not whether China should upgrade technology through its own research or through imports. Studies in other countries have shown that the two are complementary. Countries (and enterprises) engaged in R&D can make more productive use of imported technology because they can unpackage the technology and be selective in importing, use the information developed from their own research to strengthen bargaining, use imports to strengthen their own research, and use their own R&D to adapt foreign technology to local conditions. The issues are: (a) the relationship and balance between imports and local technological effort; (b) mechanisms for identifying what innovations are needed; and (c) the implications of both of these for the location and organization of domestic R&D.

Relationship between Foreign and Local Technological Elements

5.04 Selectivity is the key to making the most of imports in upgrading technology. It is not necessary to choose, as China has frequently done in the past, between the extremes of importing turnkey plants or relying wholly on domestic R&D. Technology can be unpackaged and selected elements of technology imported; including licenses, designs, key equipment, and consultants for management, marketing, or engineering problems. Recent Chinese policy has stressed the need to import "software" know-how in addition to, or instead of, "hardware" or equipment.[34/] This is an important advance in technology policy because it recognizes explicitly that individual elements of technology can be traded and that equipment is not necessarily the most important element.

5.05 Import policy should remain flexible, however, and not insist on any particular mode of acquisition. It is less important how foreign technology is obtained than what is being obtained and why it is being acquired overseas. The appropriate mode of acquisition will depend on the objectives being pursued and the relative costs and benefits of foreign versus domestic sources. If the objective is to gain production capability in a radically new technology, a turnkey plant may still be the cheapest and most effective mode of acquisition. If the objective is to develop investment capability in producing better chemical equipment, it may be enough to purchase an overall design and certain specialized parts. The mode should be tailored to the objective and the choice between domestic and foreign elements of technology should be made in the same way as any project evaluation: start with a comparison of economic costs and benefits, using shadow prices, but then move beyond static cost comparisons to an evaluation of alternative technological paths. This involves looking several steps ahead into the future.

5.06 The "apprentice" pattern of technological development has proven effective both in China and other countries. Under this pattern, the first plant in an industry is built on a turnkey basis with substantial training of local staff and local participation in observation. On the basis of this experience, it is possible in subsequent projects to substitute domestic for foreign technological elements and to move from mastery of production capability to assimilation of investment capability. The Usiminas steel plant in

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34/ See, for example, Zhu Rongji (1984).

Brazil and numerous steel, chemical, and other companies in Korea have effectively used apprenticeship based on turnkey plants to upgrade local technological capability.[35/] China has also proven the value of the apprentice pattern in large-scale nitrogen fertilizer (see page 10) and in continuous casting of steel (see Box C).

5.07 Direct foreign investment (including joint ventures) may be the only way to obtain the very latest technology in some fields. In offshore oil drilling, for example, China had no alternative other than foreign investment. The disadvantages of this mode of acquisition are that the latest product or process design may not be the most appropriate for China and the foreign investor may operate as an enclave within the domestic economy rather than as an integral part of it. However, thorough judicious policy intervention, the foreign investor may be induced to provide important externalities through links to local suppliers. For example, many countries have used domestic content legislation to force automobile companies to make greater use of domestic suppliers and the assistance given to component manufacturers has enabled them to upgrade product quality and increase efficiency. The main danger of such an approach is that insufficient attention is given to ensuring that the domestic infant industries grow up to become internationally competitive. High prices in the protected domestic market may enable a foreign investor to make high profits while contributing little or nothing to net foreign exchange savings. Among the newly industrializing countries (NICs), Brazil and Mexico have relied heavily on foreign investment to promote industrial growth

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35/ See Dahlman and Fonseca (1978); Dahlman, Ross-Larson, and Westphal (1985); and Westphal, Kim and Dahlman (1984).

Box C: CONTINUOUS CASTING OF STEEL

C.1 Development of continuous casting in steel production offers an instructive example of how to open up a new technological path through selection of domestic and foreign technological elements. The Wuhan Iron and Steel Company (WISC) prepared design criteria and requirements for a continuous casting plant in 1970. The Government approached a West German firm to help build the plant and an agreement was signed in 1974. The agreement provided for the Germans to supply all the equipment and for the Chinese to construct the building, with collaboration in designing the building and erecting the plant. More than 200 people were sent to Germany for training. Construction began in August 1975, the plant was completed in October 1978 and trial operations were conducted for four months, followed by full-load acceptance tests. The plant was approved for operation by the state in 1980.

C.2 There were some initial problems with the control system, but German technicians were still in China and were responsible for solving these. The continuous casting unit was thus operating smoothly from early 1980. However, the plant reached only 50 percent of capacity in 1980, 60 percent in 1981, 66 percent in 1982, and 79 percent in 1983. The bottleneck was in the production of liquid steel due to a shortage of oxygen supply for the converters and poor quality refractory material which resulted in excessive downtime of the converters. These problems finally appear to have been solved by bringing in a manager from the Capital Iron and Steel Company in mid-1983. This illustrates the limitations of radical new technology in solving production problems. Attention to the mundane details of upgrading production capability in the better-known technology of steelmaking was as important in raising productivity as attaining production capability in the more radical innovation of continuous casting. Through an intelligent blending of foreign and domestic technological elements, WISC was able to master the continuous casting process, but this success was marred by slow mobilization of domestic expertise to solve production problems in the supposedly well-known steelmaking process.

C.3 The introduction of continuous casting was also successful in another way. China has used the experience of WISC to develop investment as well as production capability in continuous casting. The Echeng Steel Mill, a provincially run enterprise near Wuhan, is planning an investment in continuous casting in which the design work is being done by the Ministry of Metallurgy and the Wuhan Iron and Steel Design Institute on the basis of what has been learned in WISC. The equipment will be jointly manufactured by German and Chinese companies in China and will be entirely installed by a Chinese construction company which participated in the installation of two other billet casting units elsewhere in China. Training for the Echeng plant will be done in Chinese factories. Thus, through forward planning, China has been able to substitute increasingly more domestic for foreign technological elements in continuous casting. There may have been some trade-off between the development of investment capability and diffusion of continuous casting production, however (see Table 8 and discussion of diffusion of technology).

and acquisition of technology, while for Korea direct foreign investment has played a relatively minor role as it did for Japan. China has made relatively little use of direct foreign investment and has limited much of that to the special economic zones.36/ A case could be made for China being more receptive to foreign investment, less for the advanced technology it would bring, than for the demonstration effect of modern management techniques. The example and competition of a well-run foreign company could help identify the weak links in management, product design, material supply, etc. and thereby spur domestic firms (and the government) to undertake changes they might otherwise never consider. The argument is not to make direct foreign investment a major thrust of China's industrial strategy, but to provide selected close-up examples of the way modern industry is managed in more advanced countries.

5.08 In industries in which China already has substantial technological capability, licensing or purchase of technological assistance can fill in gaps in local knowledge and upgrade technology quickly. China has sharply increased the rate of use of licenses and other disembodied technology in the last few years (see Table 5), but the amount spent on these items is still relatively small compared with other countries. Licensing often covers only older technology and may carry restrictions on use, but it can help overcome

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36/ By the end of 1982, China had absorbed more than US$1.7 billion in direct foreign investment in 83 joint ventures, 792 cooperative management projects, 12 cooperative offshore oil exploration projects, 872 compensation trade projects and 34 independent foreign enterprises in special economic zones. By the end of 1983, there were 118 joint ventures, 1,047 cooperative management projects and 50 independent foreign enterprises in China. See Xinhua News Agency, in a report on an interview with Wei Yuming, Vice-Minister of Foreign Economic Relations and Trade (MFERT), Beijing, September 3, 1983, FBIS, September 9, 1983, p. K-12, and Xinhua News Agency, in a report on a speech by Cheng Fei, Advisor of MFERT, at the opening ceremony of an international economic-technical conference in Taiyuan, Shanxi Province, April 3, 1984.

critical shortcomings in domestic capability, as in components for machine tools (see Box B). Moreover, if the purpose of licensing is clearly defined, negotiations can often achieve an outcome which is satisfactory to both parties. It should be noted that even advanced countries find licensing an effective means of upgrading technology. Japan and the US, for example, have a large two-way trade in licenses. It should also be noted that technical assistance can substitute for licensing as well as fill in gaps in domestic capability. Many developing countries have hired foreign engineering firms to conduct R&D. When the Soviet Union was unable to get access to know-how for producing nylon, it hired the people used by Dupont to do its design and construction. China has followed a similar strategy in photographic film, hiring a retired employee of a leading film company as a consultant and buying machinery from the firms used by leading film producers.

Table 5. IMPORTS OF EMBODIED AND DISEMBODIED TECHNOLOGY, 1973-82
(Number of contracts)

Items	10-yr total	1973-78	1979-82	Last 4 yrs/ first 6 yrs
Complete sets of equipment	281	172	109	0.63
Licensed trade	157	18	139	7.72
Advisory service	15	3	12	4.00
Technological service	37	5	32	6.40
Cooperative production	31	-	31	-
Others	89	27	62	2.30
Total	610	225	385	1.71

Source: Beijing International Trade (1983).

5.09 Finally, "informal" means of acquiring foreign technology can also be important. Although reverse engineering of imported equipment can be inefficient 37/ and can never be used as the only means of acquiring technology, it can be effective in some industries (particularly simple mechanical industries). The Shanghai Bicycle Company has matched and even surpassed advanced European levels for some bicycle manufacturing equipment through reverse engineering or its own designs. The company imported a West German electric resistance welding machine in 1962 and through its own R&D has since tripled the machine's speed, essentially matching improvements which have taken place in Europe. The company also developed a rim-making machine based on a study of the technical literature starting in 1976. According to company sources, this machine is superior in most respects to comparable equipment produced by a leading French bicycle machinery manufacturer.

5.10 Other informal means of acquiring technology can be surprisingly important. A survey of 112 Korean exporting firms in 1976 showed that the most important sources of process technology, both domestic and foreign, were overwhelmingly informal (Table 6). Formal means (licensing, technical assistance and government-supported institutes) were important only 28 percent of the time. Informal means, particularly assistance from suppliers or buyers

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37/ Sometimes machinery simply cannot be copied without technical assistance or designs. A watch company for example tried to copy a Swiss testing machine by disassembling it and measuring the parts. They produced a workable machine, but when foreign exchange became available they imported another Swiss machine for use. Even when it is technically possible to reverse engineer foreign machinery, it may be uneconomic to do so. For example, the Shanghai Boiler Factory and Shanghai Number 3 Machine Tool Plant jointly designed a special deep-bore drill. The drill matches the technical quality of an imported product and may even have cost somewhat less, but it took several years to produce and will not be produced again. This illustrates the tendency to concentrate only on the technical rather than the economic aspects of innovation.

Table 6. RELATIVE IMPORTANCE OF SOURCES OF PROCESS TECHNOLOGY AMONG KOREAN EXPORTING FIRMS

Source	Percentage composition of responses indicating a source to be "important"
Domestic	
Licensing and technical assistance	3.0
Experience acquired by personnel through previous domestic employment	10.5
Suppliers of equipment or materials	4.8
Buyers of output	4.0
Subtotal	22.3
Government-supported institutes	9.0
Local know-how	18.9
Total Domestic	50.2
Foreign	
Licensing and technical assistance	16.0
Experience acquired by personnel through previous overseas employment	13.2
Suppliers of equipment or materials	10.7
Buyers of output	9.0
Total Foreign	48.9
Unidentifiable	0.9
Total	100.0

Source: Tabulated from a survey of 112 exporting firms conducted in 1976 by Pursell and Rhee. Reported in Westphal, Rhee and Pursell (1981), p. 40.

and hiring personnel with experience abroad or in domestic firms, were much more important. The two most important sources of information on product innovation (Table 6 refers to process innovation) were from buyers of output and overseas travel by staff.[38/] The role of overseas buyers in providing information on innovations is an important externality of exporting and partly explains why Korea, with its strong export orientation, has been able to upgrade technology quickly as well. China has also begun to engage in international subcontracting, to send both study tours and students abroad, and to try to attract back from overseas Chinese with technical or business experience. All of these international contacts should increase the flow of information into China.

5.11 In summary, the main lessons of how to acquire foreign technology are to be clear what the objective is, to tailor the mode to the objective, to be selective in choosing elements to make or buy, and to negotiate for terms of acquisition which help meet the objective. The scope for maneuvering within modes of technology transfer is perhaps as important as the differences between modes.[39/]

Identifying What Innovations are Needed

5.12 Discussion of sources of information about innovations leads naturally to the issue of how to identify what innovations are needed. In China, the philosophy has always been that central government agencies and ministries with their research institutes and superior resources can best determine what innovations are needed, though R&D proposals from below are

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38/ The relative importance of these sources were: foreign buyers, 26.2 percent; domestic buyers, 8.6 percent; and overseas travel, 19.9 percent. See Westphal, Rhee, and Pursell (1981), p. 43.

39/ The Chinese Government understands the use of negotiations very well. Recently the Government has stated that it will give preference when buying machinery to companies which have proved cooperative in providing know-how to China.

always entertained and in practice usually approved. Thus the State Science and Technology Commission has selected 38 key research projects and has identified several innovations which it hopes to popularize during the Sixth Five-Year Plan. Since there are economies of scale in information gathering, central agencies certainly can play an important role in informing bureaus, corporations, and enterprises about technological developments in the rest of the world and in progressive Chinese enterprises. In China's centrally planned economy, central agencies could usefully monitor costs and physical productivity of key processes and provide enterprises with feedback on their performance vis-a-vis best practice domestically and internationally.[40/]

5.13 There are several limitations, however, to top-down "technology-push" information flow. One of the main lessons of international experience is that bottom-up "need-pull" innovation is more likely to succeed than technology-push. A study of the distribution of major American innovations by source during 1953-73 showed that 60 percent of the ideas came from the same profit center that produced the innovation; about 20 percent from another profit center within the same enterprise; and 5 percent or less from universities and government laboratories (The Economist, June 26, 1982, p. 96). A European study also showed that over 70 percent of the main ideas for innovation came from within the innovating company and that by far the highest proportion of successful ideas came from commercial rather than technical staff (Table 7). The lesson is that market feedback is the most important mechanism for generating ideas on innovations.

5.14 The experience of several Chinese enterprises during the period of adjustment and reform confirms the importance of such feedback. For example,

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40/ A good example of the kind of process-by-process comparisons which can be made in the textile industry is given in Pack (1984).

the Qingdao Forging Machinery Plant changed its product mix and improved the lift mechanism on its presses only after it was made responsible for sales; several watch companies began recently to introduce ladies' watches and make design improvements; and a Wuhan television factory made one of its most important product improvements based on feedback from its repair staff. Market feedback appears to be an especially effective mechanism when responsibility for sales is combined with a shift to a buyer's market, for the enterprises actively seek out ideas for improvement.

Table 7. WHO CHOOSES WINNERS AND LOSERS IN EUROPEAN FIRMS

	Commercial		Technical	No. of	Failure rate
	Success	Failure	failure	cases	(Percentage)
Technical staff	8	19	4	31	74
Commercial staff	33	21	6	60	45
Top management	1	4	1	6	80+

Source: The Economist, June 26, 1982, p. 96. Based on data from the European Industrial Management Association.

5.15 User feedback has important implications in the special case of machinery manufacture. The machinery for process industries such as steel, cement and chemicals is most efficiently produced in large-scale manufacturing plants which have specialized equipment for metal forming and cutting and have developed technical skills in machine manufacturing. There is a similarity in the technique of manufacturing equipment for different process industries and it therefore is efficient to produce machinery for many different industries in large multipurpose machine plants in order to utilize fully highly specialized presses, milling machinery, etc. However, machinery manufacturers have no experience in using the machinery which they produce, whereas the producers of steel, cement and chemicals have special requirements of design but no expertise or specialized equipment or personnel for manufacturing machinery. Some mechanisms for interaction between machinery users and producers is therefore needed. The traditional system does not provide sufficient interaction. In that system, enterprises request equipment and if the request is approved, a machinery manufacturer is assigned to produce the equipment on the basis of its own design or that of a design institute. Users are, thus, often unable to convey their special requirements to machinery producers. This is one reason so many producers have designed or manufactured their own machinery. However, self-design and self-manufacture is not a satisfactory solution. What is needed is, first, direct contact between equipment users and suppliers and, second, specialized engineering consulting firms familiar with the process of manufacturing techniques in machinery industries to bridge the gap between users and suppliers. Above all, equipment users should have a choice of suppliers and designers. This should include the right to manufacture their own equipment, though there is likely to be less self-manufacture if enterprises can freely choose suppliers through direct contacts. The right of enterprises to make their own investment decisions should await more general reforms in pricing, but once investments have been approved, users should be allowed choice in procurement and direct contact with suppliers, including foreign suppliers, in cases where permission to import machinery has been given. During the readjustment period in 1981, much more freedom of choice was given to users but there is a tendency to restrict choice again now that markets have become tighter. Choice should again be expanded. The Government has also encouraged the development of domestic consulting firms. One form of additional support would be to establish twinning agreements with engineering consulting firms of industrialized countries. Chinese engineers working for prolonged periods in experienced overseas engineering firms could acquire the kind of expertise in advanced technology design to act as a bridge between process industries and machinery manufacturers.

Implications for R&D Organization

5.16 There is a growing awareness that the traditional organization of R&D in China puts too much emphasis on technology-push rather than responding to the demands of users for innovation. Consumer criticisms of the system include the following. The rate of utilization of research results in production is estimated to be only 10-30 percent. Research results handed over to production units are often incomplete. The prototypes handed over require much more development work before becoming operational than the production unit is capable of doing, but the research units regard their job as finished once a laboratory prototype has been developed. In addition, innovations often require new development in materials, components or ancillary machinery before they can be used. Since this may require the cooperation of other ministries, potentially beneficial innovations may not be easily integrated into production.

5.17 Several changes have been made in R&D policy and organization as a result of these defects. Research institutes have been encouraged to form closer links with production through contract research, technical assistance on a fee-paying basis, and joint research-production teams. A patent system is being introduced on the grounds that the incentive this creates for production of innovations outweighs the obstacles patents create to diffusion. Research institutes are also encouraged to become self-supporting through sale of services. Finally, pilot plants are being established in some industries to link research and production.

5.18 Most of these changes are potentially beneficial, but the effects will depend largely on the details of the schemes. Research-production associations have been tried in the USSR with indifferent effects on innovation; the tendency is to continue to separate activities of research institutes and production units despite nominal integration. Contract research and technical assistance has considerable potential for making research more responsive to needs of users. The danger, however, is that cooperation between enterprises and research institutes will be emphasized at the expense of cooperation between enterprises. Research institutes often do not have sufficient production experience to make an effective contribution. Moreover, research (particularly basic research) generates externalities which cannot always be captured by fee-paying users. Therefore, too few resources may be directed into research if all such work is put on a self-supporting basis.

5.19 A patent system can provide powerful incentives for R&D, but the experience of other countries suggests that close attention must be paid to the length and degree of patent protection. If patent protection is too weak, the threat of imitation or minor differentiation by competitors will deter R&D expenditure because firms will be unable to appropriate the benefits of an innovation. But if patents are too strong and wide, there may be a wasteful rush to get a patent first, followed by efforts to develop other, possibly inferior, innovations if other firms are blocked from using the patent (Nelson 1981). The main purpose of the new patent law is probably to promote transfer of technology from abroad rather than domestic research. Similar considerations of balance apply. Too weak a law will deter foreign firms from licensing patented processes or products while too strong protection will put them in a very strong bargaining position.

5.20 Pilot plants can be effective in linking research and production. A prominent feature of Japan's early industrialization strategy was to set up government-sponsored pilot plants which were turned over to private industry once they reached a certain level of efficiency. China has set up small-scale pilot plants for many products which have been since successfully scaled up for commercial production; one example is the production of benzene for use in polyester fiber. Research institutes have also set up full-scale production of some products. The Beijing Machine Tool Research Institute now assembles Japanese numerical control devices for sale to machine tool enterprises. The danger is that the stress of financial self-sufficiency will lead research institutes to become mere production units and to neglect research which has no immediate commercial payoff. The move toward commercially applicable R&D is commendable, but the main case for having R&D activities outside producing enterprises is that there are external benefits from R&D activities which cannot be entirely recovered by the originator through fees. It is essential, therefore, not to tip the balance too far toward R&D with an immediate commercial payoff. Research institutes should not be expected to be entirely self-supporting.

5.21 Recent policy changes have gone some way toward making reserach institutes more responsive to enterprise needs. However, consideration should be given to more extensive changes which would transfer much R&D away from research institutes toward enterprises. Most R&D expenditure in industrialized capitalist countries takes place within productive enterprises. Governments fund a large proportion of this research because they recognize that riskiness, externalities, and other factors would otherwise lead to too little R&D. But the locus of most publicly funded research is in enterprises in order to respond to user needs and take advantage of their production experience. Technology is not a good to be produced in a research institute and then simply handed over to factories for use. Assimilation and application of a new technology require considerable effort and adaptation on the part of the user. This implies, and the experience of other countries confirms, that there should be more emphasis on development of applied engineering capability at the enterprise level in order to be able to adapt and apply innovations introduced from research institutes, foreign source, or other enterprises in China.

6. DIFFUSION OF TECHNOLOGY

6.01 Diffusion is perhaps the weakest aspect of China's technology system. Innovations are introduced in a few enterprises but are often slow to spread to the rest of industry. Even in the steel industry, which is one of the best organized for spread of information, China has been rather slow to adopt energy-saving innovations such as continuous casting and conversion from open-hearth to oxygen steel production (Table 8).[41/] China has also lagged in converting cement production to the dry process (60 percent is still wet production), introducing high-efficiency boilers, and in upgrading quality or reducing costs to best-practice levels in numerous consumer durable industries, such as watches, bicycles and sewing machines. Diffusing best-practice techniques, including management techniques, already in use in China may be more critical to productivity growth than introducing more advanced technology into a few leading enterprises.

41/ China's percentage of open-hearth steel production (32 percent) was not much above that of the US, but the US steel industry is also one of the most backward among industrialized countries.

Table 8. INTERNATIONAL COMPARISON OF KEY INDICATORS IN STEEL PRODUCTION

1980 Steel production Market	Steel production by process, 1980 Oxygen (mln tons)	Open hearth (%)	Electric (%)	Thomas (%)	& other (%)	Continuous casting ratio (% of crude steel)	Energy consumption per ton of crude steel (gcal) /a 1976	1980
Developed Countries								
Japan	111.4	75.5	-	24.5	-	59.5	5.1	4.5
US	101.7	61.2	27.2	11.6	-	20.3	6.3	6.2
Germany, Fed. Rep.	43.8	78.4	6.7	19.9	-	46.0	5.6	5.2
Italy	26.5	45.3	1.7	53.1	-	50.1	4.4	4.2
France	23.2	81.9	0.9	15.9	1.3	41.3	6.0	5.7
UK	21.5*	60.1*	5.4*	34.4*	0.1*	16.9*	6.3	6.4*
Spain	12.7	45.8	5.0	49.2	-	36.7	-	4.4
Developing Countries								
Brazil	15.3	63.4	11.8	24.7	0.1	33.6	-	5.7
Romania	13.3	44.0	36.7	19.3	-	13.1	-	-
India	9.5	20.4	57.9	20.0	1.7	0.0	-	11.0 /b
South Africa	8.9*	64.7*	8.9*	24.2*	2.2*	49.3*	7.9	7.3*
Korea, Republic of	8.6	69.2	1.2	29.7	-	32.4	-	-
Mexico	7.1	37.0	20.8	42.2	-	29.7	-	-
Hungary	3.9	-	90.7	9.3	-	35.0	-	-
Yugoslavia	3.6	31.6	40.1	28.2	-	36.6	-	-
Egypt	0.8	-	-	-	-	-	-	9.5*
China								
Key plants	28.6 /c	-	-	-	-	-	-	8.4 /d
Total	37.1	48.8	32.0	19.2	-	6.6	-	9.1 /d

* 1979 data.

/a Energy consumption figures include casting and rolling.

/b Estimated specific energy consumption in integrated steel mills during the late 1970s ranged from 9.0 gcal per ton of steel (Bokaro Steel Plant) to 16.0 gcal per ton, with an average of about 12.5 gcal. The same source indicates that electric-arc furnace consumption plus steel rolling averages about 4.3 gcal/ton of steel (electricity converted at 3,000 kcal/kWh). Energy consumption per ton of steel is estimated at 9.0-9.5 gcal, but the authors are from the Bokaro Steel Plant, and their estimate appears to reflect conditions at their plant.

/c Estimate.

/d Figures represent "comparable energy consumption."

Source: World Bank, China: Long-Term Issues and Options, Annex C: Energy, 1985.

6.02 China's institutions and policies for the creation of diffusion of technology have followed the Soviet model. Most socialist countries have stressed the benefits of the free flow of knowledge and hence have generally tried to produce innovations in specialized research institutes which would then publicize the results and hand them over without charge to production units. Enterprises could also do their own research and introduce new techniques and products after approval; these innovations would likewise be diffused to other producers. As noted above, research institutes have had limited success in promoting industrial innovation and diffusion has also been relatively slow in China. Other socialist economies have had similar experiences, especially with diffusion.[42/] The Soviet Union and China have both recorded impressive technological achievements in areas in which the considerable resources of their R&D systems have been concentrated, but they have been less successful in diffusing a wide variety of improvements throughout industry. The reasons are mostly systemic and arise from the nature of technology noted previously. New technology cannot be assimilated without investment of human effort in understanding and adaptation. It, thus, cannot be transferred costlessly or without modification, and some incentives are accordingly required.

6.03 Some of the specific shortcomings of diffusion in China can be illustrated by three examples.

6.04 A Shanghai foundry producing small castings for machine tools successfully copied (achieving two thirds of the speed of) a Danish automatic molding process. This innovation was not diffused. Instead, a research

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42/ The classic study of technological diffusion in the Soviet Union is Amann, Cooper, and Davies (1978). See also Bergson (1983) and Poznanski (1985).

institute developed a similar machine some years later which was then made available to other foundries. The lesson is that while diffusion from the research institute occurred, there was little diffusion from enterprises. And even when innovations have been successfully diffused to subordinate units, there has been little communication with other ministries or regions producing similar products. In brief, innovations are rarely diffused horizontally. Within the compartmentalized vertical channels, information about new processes has mostly flowed downward.

6.05 A second example is drawn from the experience of the Shanghai Bicycle Company (SBC), which is not only one of the leading bicycle producers in China,[43/] but also the producer of a bicycle machinery factory which is advanced by world standards. However, SBC is not interested in producing bicycle machinery either for other plants in China or for export. The Shanghai Light Industry Bureau has set up a specialized bicycle machinery factory and it may use SBC designs, but it will have only minimal access to SBC specialists. Since much technological knowledge is tacit, that is, cannot be written out in manuals but rather is embodied in people, a separate specialized machinery producer is unlikely to be as proficient as SBC. It certainly is less likely to have the export potential of SBC. In a market economy, SBC would either spin off a specialized company to produce machinery, or its engineers would set up their own company or they would be hired away by the new producer, thus diffusing the technology of machinery production.

6.06 The third example is also from Shanghai. The Shanghai No. 6 Textile Mill has done an impressive job in developing computer monitoring of looms.

43/ Its Forever brand bicycles are in very high demand and must be rationed in the domestic market. It also exports bicycles to Sears, Roebuck & Co. in the US according to a design supplied by the buyer.

It achieved national recognition for its success and about 50 other textile producers in China have built or will build a similar system, many with the assistance of the No. 6 Mill. Thus, diffusion is occurring owing to the organization and communication within the Ministry of Textiles. The No. 6 Mill now has a more ambitious proposal to develop an online microprocessor control system. This will be done in cooperation with a research institute, but neither the enterprise nor the institute has anyone specially trained in microprocessors. Since it is difficult to hire an electronics engineer for the textile industry or to get support from the Ministry of Electronics, the enterprise and the research institute will rely mostly on training its own staff through seminars given by the city.

6.07 These examples suggest four main improvements to facilitate diffusion of technology. First, barriers to communication between ministries, regions and enterprises need to be broken down. The inability of the textile factory to tap the expertise of the Ministry of Electronics and the failure of the Ministry of Machine Building and of foundries outside Shanghai to learn of the casting innovation both illustrate this.

6.08 Second, better incentives are needed to encourage enterprises which innovate successfully to diffuse the innovations to other enterprises. Neither the Shanghai Bicycle Company nor the foundry which copied the foreign molding process had any incentive to spread this information. (In the next section we will address the even more important issues of the effect of incentives on the demand for innovation.)

6.09 Third, greater labor mobility would enhance diffusion. Hiring of experienced technicians and managers is perhaps the most important source of new knowledge for enterprises in most countries (see Table 6 above with reference to Korea). There is an optimal amount of labor mobility; too much mobility creates a disincentive for enterprises to invest in training. Moreover, Japan is a notable exception to the rule that mobility is an important source of new knowledge, at least in the large-scale manufacturing sector. The issue then becomes how to substitute for this means of diffusion. Japan apparently does it partly through the efforts of MITI to bring industry experts together to share experience and to develop a consensus on future development, and partly through the informal network of contacts among people who went to the same school or university but now work in different companies. But even in Japan there is far more flexibility with regard to hiring than in China so that textile enterprises, for example, can hire electronics engineering graduates if needed. There is little doubt that China would benefit from more flexible hiring procedures.

6.10 Fourth, and most important, China needs to encourage specialization. Specialized agents can mediate between producers and users of technology or provide missing technological elements. The importance of specialized agents as a link between machinery producers and users in process industries was discussed in a previous section. In the case of the textile mill above, consultants with expertise in electronics and some familiarity with textiles could probably provide a speedy and cost-effective alternative to training or to interministerial coordination. One advantage of specialized agents is that they have an incentive to speed diffusion, unlike competing enterprises which may wish to control it. Thus, it would be understandable if SBC did not want to assist other bicycle manufacturers through selling improved machinery to them. A specialized enterprise which spun off from SBC would have a strong interest in selling better equipment.

6.11 The Chinese Government has taken several measures recently which should improve prospects for diffusion. These include:

(a) Encouragement of joint ventures across administrative boundaries. For example, as part of the plans for cooperation within the Yangtze Delta zone, SBC has formed a joint venture with the Suzhou Bicycle Factory for associate production of the Forever brand bicycle. SBC will provide technical assistance to improve the quality of the Suzhou plant's main parts, as well as to several small component parts manufacturers. This should greatly expand the market share of the superior Forever brand at the expense of the lower-quality Suzhou bicycle, but without loss to the workers in the Suzhou factory.

(b) Some enterprises have been allowed to recruit staff through advertisements; individuals can apply for these jobs with permission from their present work units. Transfers are increasingly made on a temporary basis, as in the case of the manager sent from Capital Iron and Steel to Wuhan. There is thus some move toward greater mobility.

(c) Professional associations based on individual membership have been revived, thus encouraging engineers and scientists in different industries and fields to make contact.

(d) Patents, internal licensing of technology, and fees for travel assistance will be introduced. This should provide incentives for enterprises to diffuse innovations they have introduced. The results of these changes will need to be monitored, however, to ensure that a balance between incentives to produce and to diffuse technology is achieved.

(e) Creation of engineering (and economic) consulting companies. These can draw on expertise from several research institutes, universities and ministries. This is an important step in expanding specialized agents for technological development.

6.12 All of these changes are important and should be beneficial. What else should be done? One change which should be considered is to make it easier to create new enterprises and organizations which can specialize in the production of goods and services for technological advance. New firms providing special services are often among the most dynamic in developed countries. This is particularly true of the electronics sector in the US where very small firms have been in the vanguard of the "third industrial revolution." These need not be limited to high technology, however. It is quite common for special units providing services such as repair and maintenance to spin off from a parent firm to provide services on a contract basis, both to the parent and other firms. This is one reason firms in most industrialized capitalist countries, both large and small, are often less comprehensive than Chinese firms.[44/] Large Japanese firms often help set up trusted employees in business as specialized subcontractors. The specialization which results from this process of spinoff is one of the main vehicles of productivity growth. But specialization is also inherently risky, especially when small enterprises are set up to exploit an innovation. For this reason, there are high birth rates and high death rates in small enterprises. Only a small proportion evolve into very large and successful firms, a somewhat larger proportion remain small, and a lot fail or get taken over by larger firms. It is necessary to ensure that inefficient firms do fail in inherently risky ventures,

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44/ In Switzerland, watch companies do not have their own machine shops or provide all of their components as in China. In Japan, steel companies contract out many services, such as changing refractory linings in furnaces, which are done within Chinese enterprises. Some steel companies in less developed countries even contract for this difficult operation internationally.

but for this reason spinoffs are not well suited to organization as state enterprises. China should consider encouraging cooperatives or small private enterprises to undertake risky ventures and specialized activities. This would mean that cooperatives would have to cease being regarded as inferior forms of organization which provide a lot of employment and low-quality products. They would have to be given access to capital and material supplies and encouraged to sign contracts with state enterprises. To make the most of individual technical talents, permission to engage in part-time cooperative production using rented equipment from state enterprises could be allowed. Hungary is experimenting with such organizational innovations and individuals in China are now allowed to do consulting on this basis. The same principle might be applied to production of goods. With such encouragement, the individual and cooperative sector might make a far more significant contribution to technical advance and productivity growth than currently thought possible.

6.13 The other major change which needs to be made to speed up diffusion is to stimulate the demand of enterprises for innovations. This means that incentives affecting enterprises must change.

7. INCENTIVES FOR INNOVATION

7.01 Most discussion of technology upgrading in China and elsewhere focuses on the supply of new products and processes. However, the best system of technology-push will fail unless there is also demand for innovation by enterprises. This involves more than simply creating an abstract desire to introduce better products or the most advanced techniques of production. Managers and engineers of the best enterprises in all countries are always interested in upgrading technology in this sense and in China there is a wealth of talent and in much of industry a desire to innovate. The issue is how to channel this talent and energy in more productive directions--to prevent costly overemphasis on self-sufficiency, to encourage quality improvements which users want, and to force more attention to be paid to economic results rather than mere technological modernization. And for the large number of enterprises which rarely introduce innovations, the issue is how to force them into product improvement and cost reduction.

7.02 The planning and incentive system which existed in China before adjustment and reform was strongly biased against product innovation in several respects:

(a) The most important production targets handed down to enterprises were physical output or gross value of production. Targets for cost reduction and material use gave a small incentive for process innovation, but these targets were strictly secondary. Another secondary target for production quality was based on reaching a threshold quality standard for existing products; it did not reward upgrading product quality through innovation.

(b) Prices for all planned products were fixed. No differential existed for quality differences. Products of good reputation were often rationed while poorer quality products might be in excess supply. Major design changes might secure classification as a new product with a higher price, but as prices were set on an average cost basis, it was difficult to recover development costs. Since all profits were remitted to the state, this need not have in itself deterred innovation but it did nothing to encourage it.

(c) Marketing was handled entirely by other organizations. Enterprises had no responsibility for sales and were rewarded only on the basis of production. Intermediate goods were provided by an assigned supplier.

(d) There was a generalized shortage of all goods--a seller's market. This meant that almost any good produced found a buyer somewhere.

7.03 In brief, there were neither positive nor negative incentives for product innovation. The introduction of a new or improved product took resources away from other production and lowered gross output; the extra cost of production could not be offset by a price increase; and the marketing system neither rewarded innovation nor penalized poor quality since almost anything produced could be sold.

7.04 This pervasive excess demand did, however, create some incentive for process innovation. Since supplies were perenially short and machinery difficult to obtain, enterprises could benefit from material-saving innovations and could expand output if they could manufacture their own machinery. In practice, the search for cost-reducing innovation was generally outweighed by efforts to integrate backwards and obtain captive suppliers, but the shortage of machinery and controls on investment induced considerable self-manufacture of equipment. This tendency was reinforced by directives and campaigns stressing local self-sufficiency.

7.05 The program of adjustment and reform has affected enterprise incentives for innovation. The most important changes have been the following:

(a) A few changes were specifically aimed at increasing incentives to introduce new products. Rebates of the industrial and commercial tax are given for a limited period for designated new products. Price increases are also more frequently permitted for new or improved quality products. The new policy is to allow a "super price" for a "super quality" product. In addition, enterprises have in some cases been permitted to vary prices within a specified range. Finally, enterprises have been given a new product development fund based upon a percentage of profits or sales. This fund is supposed to be entirely devoted to development of new products, though in practice some funds are still diverted to other uses.

(b) At a broader level, the set of reforms giving greater emphasis to profits and to enterprise autonomy has created a better climate for innovation. Profit is now a more important target for many enterprises. Enterprises also pay taxes rather than remitting profit to the state and most enterprises can retain a portion of their after-tax profit, part of which can be used for worker bonuses or collective welfare payments. Thus worker benefits depend in part on enterprise performance.

(c) The link between worker benefits and enterprise performance is significant because of changes in the marketing system and in market conditions. These changes, which have often been overlooked, have been by far the most significant inducement to innovation in China. Since 1980, many Chinese enterprises (or at least companies) have been responsible for a portion of sales. Only part of output is guaranteed an outlet through planned purchases by commercial departments or the material supply network; the rest has to be sold directly to users. This change was coupled with other changes (reduced investment and a shift in emphasis toward light industry) which, at least for a time and in some industries such as machinery, created a buyer's rather than a seller's market. Enterprises have, therefore, had to pay attention to product quality and customer preferences in order to maintain sales and profits on which worker welfare depends. This has led to significant changes in product mix and an increase in product innovation in a number of industries.

7.06 The extent of the changes should not be overstated, however. Both profit retention and pricing reforms have been very limited and there has been an increasing tendency toward excess demand in most producer goods along with a corresponding tendency to reduce even the supplementary role of market regulation.

7.07 The results of the changes are also far from dramatic. Of 1982 investment in technical transformation, only 0.8 percent went into cost reduction (other than energy conservation) and only 4.0 percent into quality improvement compared with 39.5 percent for expanding production (State Statistical Bureau 1983, p. 362). In 1983, the cost of comparable products fell by only 0.2 percent compared to a target reduction of 2 percent (People's Daily, May 17, 1984).

7.08 Of course, the changes in incentives have had little time to work and some have not yet even been implemented. However, some of the disappointing results could have been anticipated from experience in the Soviet Union. Many of the recent experiments in China are similar to changes introduced in the Soviet Union and Eastern Europe. Experience in those countries suggests that the effect of these changes will be limited unless accompanied by more sweeping changes in enterprise incentives.[45/] Although China has experimented

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45/ At the aggregate level, TFP growth in all sectors in the Soviet Union has fallen steadily from 1.87 percent per year during 1950-60 to 1.51 percent per year during 1960-70 to 0.57 percent during 1968-78. See Bergson (1983), p. 40.

with new enterprise incentives under the program of adjustment and reform, other changes will be required to provide systematic and mutually reinforcing incentives for upgrading technology.

7.09 Analyses by both western and socialist scholars of attempts to improve the traditional administrative system of technology management in the Soviet Union and Eastern Europe are instructive for China. These studies 46/ emphasize that managers and workers are not rewarded for introducing new products or introducing new production processes to reduce costs. Special targets or bonuses for cost reduction or new products do little to offset the overwhelming importance attached to meeting quantitative production targets. In cases where profit targets are stressed or enterprises rewarded through profit retention, there is still only a weak incentive to innovate because enterprises can sell everything they produce without innovating. Moreover, distorted prices encourage enterprises to produce the wrong products or to use scarce inputs excessively. Increased price flexibility for new products may simply stimulate cosmetic product changes to justify price increases, thus generating inflation with little significant innovation.

7.10 In brief, increased rewards for innovation are insufficient. What is needed is a degree of punishment or risk for failing to innovate. In other words, enterprises should have some responsibility for losses as well as profits. As the Hungarian economist Janos Kornai has stressed, enterprises need to be faced with a "hard" rather than a "soft" budget constraint (Kornai (1980b). To be effective and equitable, responsibility for profit and loss should be accompanied by two additional changes. First, prices should be rationalized to ensure that profit and loss reflect cost efficiency and

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46/ Key references are Berliner (1976) and Kornai (1980a).

socially beneficial production. Second, seller's market conditions should be eliminated so that enterprises producing better or cheaper products will be rewarded by increased sales and profits and--equally important--so that enterprises which fail to produce better or cheaper products will be penalized. Under these conditions, there will be strong incentives for enterprises to innovate and to match best-practice production techniques throughout the country.

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