Energy and Environmental Impacts of Chinese Rural Vehicles[1]

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More than 3 million Chinese rural vehicles (CRVs) were produced in 2002, three times the number of conventional passenger cars. These small, simple, indigenous vehicles are widely used in small cities and rural areas but are virtually unknown outside China. CRVs provide huge benefits in terms of mobility and economic development, but they are also highly energy inefficient and polluting. CRVs now consume about one-fourth of the diesel fuel in China. Increasing government regulation (mostly for emissions and safety) is having profound effects on the industry, with uncertain implications for the sale and globalization of rural vehicle technology.

In 1994, the Chinese government designated the automotive industry a "pillar" of economic development. In the Tenth Five-Year Plan (2000–2005), the government established a goal of widespread car ownership, and since then, intense efforts have been made to engage the international automotive industry (Gallagher, 2003; NRC et al., 2003). As a result, passenger car output has been increasing rapidly, from 0.6 million in 2000 to 1.06 million in 2002 (China National Bureau of Statistics, 2004).

In striking contrast, and virtually ignored, is the even larger number of small

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three-wheel (3-w) and four-wheel (4-w) vehicles manufactured by domestic Chinese companies for use in small cities and rural areas. With virtually no governmental financial support, the production of these CRVs first exceeded 3 million per year in 1999 and reached an estimated 20 to 22 million in 2001 (China Automotive Technology and Research Center, 2000; Chinese Government Website, 2003a). The implications of these vehicles are huge—in terms of safety, energy use, air pollution, noise pollution, greenhouse gas emissions, and rural development. The English language literature provides very little information about CRVs (indeed, there is no accepted English name for them), and even in Chinese, information is sparse.

HISTORY OF CHINESE RURAL VEHICLES

The CRV industry arose as a result of early efforts by the Communist government to boost rural development. The small enterprises that emerged and flourished were largely independent of national and provincial governments. Although they were at a disadvantage because they received little (if any) financial support from government at any level, they benefited from being subject to few regulations and little intervention. The sales history of the CRV industry is shown in Figure 1.

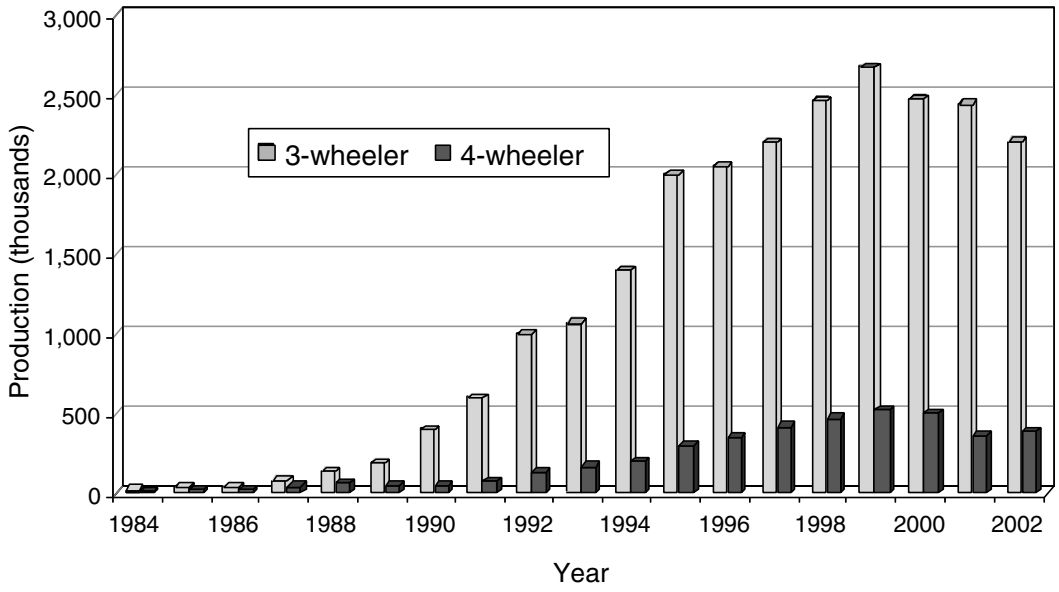

FIGURE 1 CRV production (in thousands), 1984–2002. Sources: Data through 1998 are from GM (1999); data for 1999–2000 are from Chinese Automotive Technology and Research Center (2000); data for 2001–2002 are from China Machinery Economic Information (2003).

As the CRV industry matures, it is also consolidating. In just one year, from 2001 to 2002, the number of registered CRV manufacturers dropped from 204 to 120, although it is believed that many manufacturers are still in business but no longer registered. In any case, the market share of the 10 largest manufacturers is increasing. In that same year, the top 10 3-w manufacturers increased their share from 59.5 percent to 65 percent, and the top 10 4-w manufacturers increased their share from 93 percent to 96 percent of the market. Two companies, Shifeng and Juli, accounted for 61 percent of the 3-w CRV market.

The government appears to favor consolidation in the CRV industry, as well as in the automotive industry, as a means of creating companies with greater resources and greater capabilities to develop and adopt advanced technologies, including emissions-control technologies (Harwit, 1995). The large number of companies in the CRV industry, ranging from small backyard shops to large industrial enterprises, is indicative of the traditionally low entry barriers in terms of capital investment and government licensing and rules. Price competition is severe, with strong downward pressure, and, until recently, companies had few incentives to invest in advanced technologies, especially for reduced emissions and other features that do not add much to consumer-perceived utility.

The new emission standards and policies being adopted by the central government will undoubtedly lead to further consolidations and the disappearance of small CRV manufacturers that produce poor quality vehicles and have no research and development (R&D) capabilities. In early 2003, Yanmar Co., Ltd., a Japanese company specializing in diesel engines, and Shandong Shifeng Group Co., Ltd., established a joint venture to produce and market single-cylinder diesel engines that comply with new CRV emission regulations. It remains to be seen how this collaboration will affect the health of the industry, the creation of a supplier industry, and industry responsiveness to the low end of the market.

The CRV industry is at a crossroads. As government regulation and intervention increase, as companies gain access to improved technologies (through internal R&D and transfer from others), and as the industry consolidates into fewer and larger companies, one would expect product quality to improve. Yanmar's penetration into the Chinese single-cylinder diesel-engine industry, the core of the 3-w CRV industry, is indicative of the changes in the configuration of the industry and the expectation of higher quality vehicles (Yanmar Co. Ltd., 2003).

DESCRIPTION OF CHINESE RURAL VEHICLES

CRVs are used mostly to transport goods. Powered by diesel engines, they are smaller and slower than conventional cars and trucks, and they use technology developed in China. Officially, the Chinese government treats the CRV industry as part of the farm machinery industry, rather than the automotive industry (defined by an official government standard, Technical Requirements on Safety for CRVs (GB18320-2001)). For a more detailed description that

reconciles evolving technology with changing government rules and definitions, see Sperling et al. (2004).

CRVs range from simple 3-wheelers with one-cylinder diesel engines on a motorcycle-like frame that cost about $300 (Figure 2) to sophisticated, small, truck-like 4-wheelers that cost more than $5,000 (Figure 3). About 80 percent of the 22 million CRVs are powered by single-cylinder diesel engines originally designed for stationary agricultural machinery (China Agricultural Resources

FIGURE 2 Typical 3-w CRV. Source: Juli Company, 2003.

FIGURE 3 Sophisticated 4-w CRV. Source: Juli Company, 2003.

Network, 2003). These one-cylinder engines are very inefficient, especially in mobile applications, and emit large amounts of pollutants.

The preference for single-cylinder diesel engines is based on technology, economics, and policy. Diesel fuel is less prone to explode and burn than gasoline and is, therefore, safer. Diesel engines are also easier to maintain and can operate satisfactorily on poor quality fuels. With minimal mechanical skills, a farmer can repair a faulty injection pump, the principal source of diesel engine problems. In contrast, common maintenance problems with gasoline engines are related to carburetors and ignition systems, which require considerably more skill to repair.

Diesel engines are also easier to manufacture. In the 1970s and early 1980s, the only available small engines were single-cylinder diesel engines, which were widely used for walking tractors. Professor Liu (professor emeritus, Tsinghua University) has said, "Farmers themselves can even produce single-cylinder diesel engines. When CRVs became popular, many counties had their own single-cylinder diesel engine factories. One province could have tens of such factories."

Perhaps the most important factor in their popularity has been low fuel costs. Diesel engines use less fuel than gasoline engines because they are 20 to 30 percent more fuel efficient. In addition, the price of diesel fuel in rural China was one-third to one-half the price of gasoline until the 1980s. Since policies were changed in the mid-1980s, however, gasoline and diesel prices have been more comparable (CRSTA, 1982).

ENERGY USE

As a result of increased motorization, Chinese petroleum consumption has increased rapidly since 1990 (Figure 4). Increases in gasoline consumption reflect rising automobile use in urban areas and motorcycle use in urban and rural areas. Increases in the consumption of diesel fuel and other middle distillates are partly attributable to increasing diesel consumption in rural areas, including consumption by CRVs.

Unfortunately, it is difficult to determine the portion of energy use attributable to CRVs because reliable, detailed analyses are not available. Therefore, our estimates are based on fragmented information from the literature and our own knowledge of CRVs. We have reconciled bottom-up data based on the estimated number of vehicles and top-down data based on aggregate national estimates.

According to a study done by Xunying Yang (2001), total diesel fuel consumption in China in 2000 was 69.5 million tons (see Table 1), or 21.6 billion gallons. In his study, highway transportation accounted for 24 percent of total diesel fuel use, and CRV use accounted for 21 percent. Total gasoline consumption in China in 2000 was 35 million tons, or 12.5 billion gallons (CCCT, 2003).

Another study of oil consumption conducted by the China Petrochemical Consulting Corporation arrived at similar estimates for energy use by CRVs (although the assumptions and methods were not provided) (Ke and Shang, 2000).

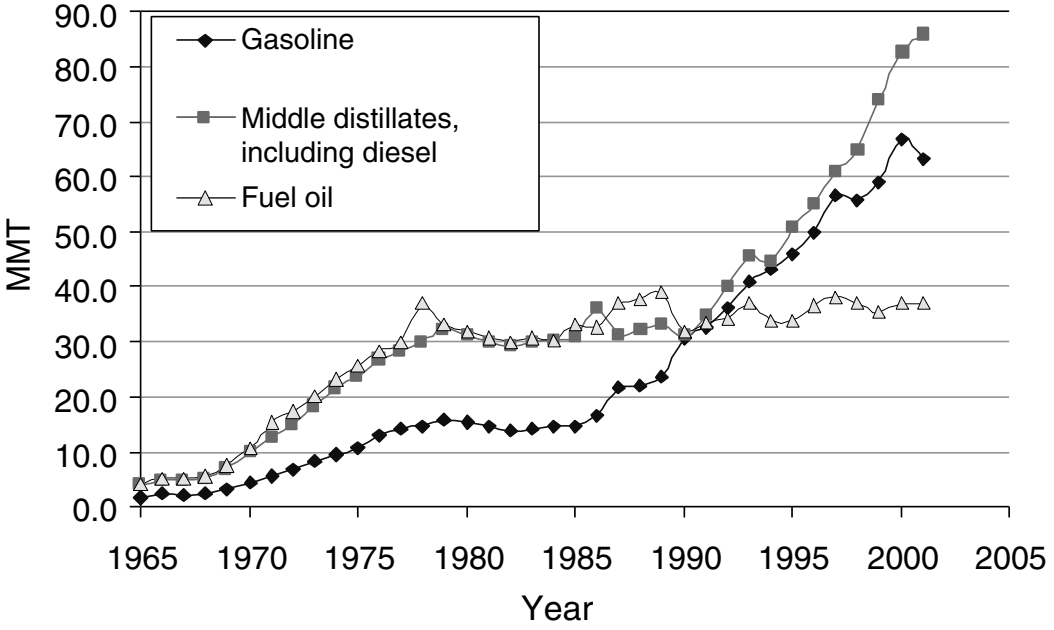

FIGURE 4 Chinese oil consumption in million metric tons (MMT), 1965–2004. Source: BP, 2003.

TABLE 1 Diesel Fuel Consumption in China (in millions of metric tons, MMT)

User	1996	1997	1998	1999	2000
Highway transportation	8.21	8.95	10.09	13.64	16.86
Light vehicle	1.16	1.57	2.02	1.93	1.83
Medium vehicle	5.55	5.60	5.95	8.18	10.10
Heavy vehicle	1.50	1.78	2.12	3.53	4.93
CRV	9.28	10.74	13.25	13.19	14.43
Railway	4.50	4.60	4.80	5.00	5.20
Marine	3.50	3.60	3.80	4.00	4.20
Agriculture	12.00	12.40	13.70	15.00	16.00
Fishing	5.70	6.00	6.10	6.30	6.50
Electricity	4.50	5.00	4.50	4.10	3.80
Others	2.50	2.50	2.50	2.50	2.50
Total	50.19	53.79	58.74	63.73	69.49

Source: Yang, 2001.

This study provided estimates for 1997 and forecasts for 2000 and 2005. The forecasts for the nonmilitary consumption of diesel fuel in 2000 was 26.6 million metric tons (MMT), somewhat lower than the 31.29 MMT estimated by Yang (Yang's estimate may include military transportation). In any case, the figures for

diesel consumption by CRVs for 2000 were similar in the two studies: 14.28 MMT and 14.43 MMT.

For a bottom-up estimation of fuel use by CRVs, we relied on interviews with CRV users, fuel economy data provided by CRV makers (Sperling et al., 2004), expert opinion by Professor Liu, previous CRV regulations, and data on the numbers and composition of the CRV fleet. The parameters for the calculations for 2000 include: fuel economy of 2.8 liters per vehicle-ton per 100 km; average CRV weight (without payload) of 1.0 ton; average payloads of 0.5–1 ton; useful lives of six years for 3-w and single-cylinder 4-w CRVs and nine years for multicylinder 4-w CRVs; accumulated kilometers of travel of 120,000 km for 3-w and single-cylinder 4-w CRVs and 250,000 km for multicylinder 4-w CRVs; and a total vehicle fleet of 19 million CRVs.

Our estimate of diesel consumption by CRVs in 2000 is 19.03 MMT, if vehicles weigh 2 tons (including payload), or 14.27 MMT if they weigh 1.5 tons. The latter figure is close to those of the two studies cited above. Based on our analysis, the two aggregate studies based their estimates on company fuel economy data and the 0.5 ton payload. But based on the high frequency of overloading, we believe that 19.03 MMT is a more reasonable estimate. This would represent about 25 percent of total diesel consumption in China in 2000, equivalent to almost 50 percent of all of the gasoline consumed in the country.

EMISSIONS

Even less is known about CRV emissions than about CRV fuel consumption. Clearly, though, CRVs are high emitters of smoke and pollution. Even when new, these primitive single-cylinder diesel engines emit clouds of black smoke, particularly under heavy load and at low RPM, conditions frequently encountered because overloading is common and the vehicles have three-speed gearboxes.

No data are available on the contribution of CRVs to total pollution, but rough calculations and assumptions suggest that the total amount may be similar to the amount from conventional vehicles. This conclusion is based on the following information and estimates. First, one government document asserts that "CRVs in China are powered by diesels and their emissions per unit of energy are on average twice that of trucks" (Ji, 2003). The situation may be even worse for 3-w CRVs. Second, we combined that assertion with statistics indicating that 88 percent of the 2.8 million CRVs produced in 2001 were single-cylinder CRVs and that more than 60 percent of single-cylinder 3-w CRVs and about 30 percent of multicylinder 4-w CRVs cannot meet the emissions requirements of GB 18322-2002, Limits and Measurement Methods for Smoke at Free Acceleration from CRVs (Ji, 2003). Based on these assumptions, we estimate that the contribution of CRVs to air pollution in China is equivalent to that of all other motor vehicles combined.

Although CRVs are more widely dispersed than cars, in small towns where

CRVs are allowed and agricultural trade is active, CRV emissions are likely to have a large impact on local air quality. This pollution is damaging not only to human health, but also to agricultural production. Recent studies have suggested that air pollution in China in the form of ground-level ozone (Aunan et al., 2000) and atmospheric aerosols (Chameides et al., 1999) can substantially reduce crop yields. Nitrogen oxides (NO_x), a principal pollutant from diesel engines, is a major source of ozone; and small airborne particles, also from diesel engines, are a major source of aerosols, which can absorb sunlight and contribute to regional haze.

The Chinese government is beginning to pursue more aggressive policies to reduce emissions from motor vehicles. In 2002, the government announced that by 2004 diesel trucks must meet standards equivalent to Euro 2 standards (which took effect in the European Union in 1996) (China Environment News, 2003) and that CRVs must meet the equivalent of Euro 1 standards by 2005 (effective in the European Union in 1993) (Xu, 2003). At the same time, the government adopted rules and tests for CRV emissions, known as GB 18322-2002, Limits and Measurement Methods for Smoke at Free Acceleration from CRVs (Chinese Government Website, 2003b).

There is some uncertainty about the enforcement of these rules. On one large CRV maker's website, the only emission attribute specified for 3-w and 4-w CRVs is for visible smoke (Juli Company, 2003). No mention is made of other emissions, such as hydrocarbons, NO_x, carbon monoxide, and invisible particulate matter. From this, we concluded that only visible smoke is being regulated for CRVs.

The national emission law, GB 18322-2002, delegates some authority to provincial governments: "Smoke limits for CRV driving in developed urban areas can be determined by provincial governments." We are not certain about the interpretation of this provision, but apparently it is the legal basis for local governments to adopt their own policies regarding CRV use. Indeed, in many cities, diesel vehicles of all types are allowed only during the night (e.g., 9 p.m. to 6 a.m.); in others, CRV owners may purchase special license plates that allow them to enter the city. In cities where CRVs are allowed, the licenses and registrations are controlled and can be very expensive.

Even though emissions rules are lax for the CRV industry, they still present a substantial challenge for CRV manufacturers. Although we do not know how this will play out, the standards certainly put pressure on CRV companies to consolidate to support R&D on engines and emissions, as well as to seek investment and expertise from international carmakers and parts suppliers. Indeed, as the recent joint venture between the largest CRV company (Shifeng) and an international manufacturer of diesel engines (Yanmar) indicates, that process has already begun.

CONCLUSIONS

Developing countries rarely have the capabilities to design and mass produce functional vehicles at low cost without significant foreign assistance and public subsidy. Yet that is precisely what happened in China. The good news is that CRVs have been a boon to rural development in China. The downside is their high energy use and air pollution.

Chinese governments are now intervening to improve CRV technology. But these interventions are seen by the CRV industry as a mixed blessing. On the one hand, stricter requirements for safety, emissions, and vehicle quality will no doubt lead to better vehicles and will accelerate the weeding out of undercapitalized companies with weak technical capabilities. The companies that survive will be better able to compete in the world market. On the other hand, it remains to be seen whether or not the industry will serve the low-cost rural markets as well as it has and whether or not competing governmental interests will create an even more uncertain and risky financial and market environment for CRV makers.

In any case, the future of the CRV industry will play an important role, not only in China, but also potentially worldwide. CRVs have been central to rural development in China and could play an equally positive role in other developing countries. But the CRVs being built today are inefficient users of petroleum and large emitters of pollution and greenhouse gases.

Therefore, the future of CRVs is largely in the hands of the Chinese government. Will the government clamp down on the negative attributes of CRVs with more stringent rules and more aggressive enforcement? Or will it create incentives for their proliferation? The government must consider how to balance the benefits of rural development with the benefits of safety, energy, and environmental standards. The government must find a way to develop effective industrial policy to mitigate the negatives and promote the benefits of CRVs. The debate would be greatly helped by more research on costs and benefits and on the effectiveness of various industrial policy strategies and policy instruments.

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