3

Minor-Change-Type Product Development

Motorcycle Manufacturing Technology in China

This chapter discusses technological factors that have driven China's supplier system toward being an isolated type. First, the technological features of the development and production of small motorcycles is briefly overviewed by looking the experience of Japanese makers. Secondly, I illustrate the path of formation of technological capabilities of manufacturing firms in late-industrializing economies, which differs from the past experience of dominant firms in developed economies. Then I consider technological reasons that are likely to direct the former toward minor-change-type product development. This is followed by an empirical discussion of the current status of minor-change-type development in China's motorcycle industry based on an examination of the products actually developed and sold in the market.

I. Small Motorcycle Technology and Japanese Dominance in Asia

In the motorcycle industry, technological barriers to entry are not very high for indigenous manufacturers as the product technology is very mature and the size of each part small. Indigenous manufacturers even have potential advantages against foreign multinationals in their domestic market, since the product demand differs from country to country. However, as we saw in the previous chapter, Japanese motorcycle makers have overwhelming competitiveness in the world market outside of China. This section demonstrates the importance of "incremental technological innovation" in this industry and the organizational features of Japanese firms that have supported the achievement of their present dominant position.

1. Dominant Models and Their Adaptation to the Local Market

In the Asian market, there are "dominant models" developed by Honda; these models can more precisely be called "dominant engines" or "dominant mechanisms."[1] They include small motorcycles such as the C100, CG125, and GY6. These names are the original designations used by Honda as a design base when it was undertaking in-house development, and their commercial names vary from market to market in different countries (such as "Wave" in Thailand, "Supra" in Indonesia, and "Splendor" in India). Honda calls a group of products developed based on the C100 the "C100-line." The dominant model in Southeast Asia is the underbone-frame type within the C100-line, but the models put on the market in Thailand and Indonesia, for example, differ slightly in terms of maximum performance, specifications, and additional functions, though they share the same basic structure in frame, engine, and other important mechanisms. Due to differences of consumer preferences in terms of appearance, the use environment including road conditions, average driving hours, load weight, fuel quality, dust, and repair infrastructure, as well as public regulations concerning safety, exhaust emissions, and noise, which vary from one country to another, the products are not necessarily assembled from exactly the same parts, though they look similar to one another.[2]

The products and production technology used for the C100 and CG125 are so mature that even Honda's engineers describe them as "withered technology."[3] It has been approximately forty-five years since the C100 was developed for the impoverished Japanese market after World War II, while the CG125, developed for the markets of developing countries, has been on the market for thirty years, and the basic design has hardly changed during that time. The production of these models, designed in accordance with specifications from several decades ago, is relatively easy, as their structures are simple and accuracy requirements are not so strict.[4]

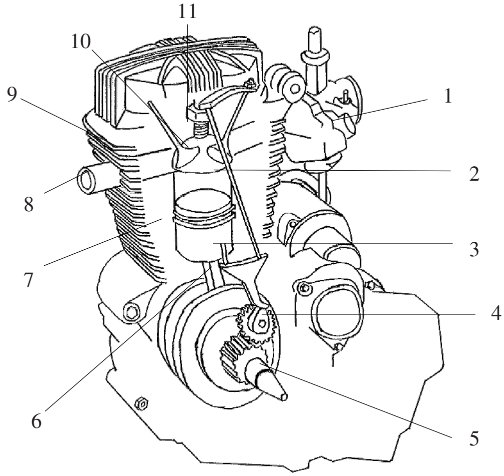
However, it is not an easy job even for Japanese rival makers to develop a brand-new engine with performance and cost levels equivalent to such standard models totally from scratch. As recognized by Honda's rivals, the CG125, in its original design phase, has excellent performance, quality, and usability. It is characterized by few failures, easy repairs, good fuel-efficiency, little vibration and noise, and can be produced cheaply because it requires a relatively small number of parts. Furthermore, through the process of mass production and after-sales "debugging" over an extended period, thoroughgoing improvements have been made. As a result, it is said to be an excellent engine in terms of cost performance.[5]

As shown by a vast past literature, such as Demizu (1991) and Oguri (1995), Japanese makers have strived to develop high-speed, high-performance, mid- to large-size products targeting motorcycle enthusiasts in developed countries, leading to great innovations in product and production technologies by using the state-of-the-art technologies they had accumulated, many of them derived from their racing experience. However, what we have witnessed in small motorcycles in the Asian market for many years is a competition of "incremental technological innovation" (Abernathy and Clark 1985) using matured technologies.

2. The Significance of Incremental Technological Innovation

The motorcycle is a machine product that makes use of incremental technological

Fig. 3-1. Name and Location of Selected Engine Parts (OHV-Type Engine)



1. Carburetor (air induction)
2. Combustion chamber
3. Piston
4. Cam
5. Crankshaft
6. Connecting rod
7. Cylinder
8. Exhaust pipe (leading to muffler)
9. Cylinder head
10. Valve
11. Spark plug

innovation as a key for better product performance and quality. Machines, as aggregations of moving parts,[6] consist of complex combinations of numerous parts that move in physical contact with one another. In particular, internal combustion engines operate under severe conditions of high-temperature combustion, high-speed rotation, and heavy load. As such, the well-organized adjustment of parts in the design phase is very important for ensuring that the product functions smoothly as an integrated entity.

Since human life is at stake, transport machines require a high degree of safety (quality, stability, durability, and strength). At the same time, they must clear regulations concerning exhaust emissions, noise, and other factors, while satisfying such sensory evaluations as drivability and comfort. Appearance is important, especially because motorcycles, unlike automobiles, are made up of many bare functional parts that are visible from the outside.

The development of a new model by a Japanese maker begins with the development of the engine, with the process continuing sequentially and incrementally for other parts.[7] For unit parts as well, the same design method is employed, focusing on certain core parts, while adjusting the mutual actions of the many components in an incremental manner. The maker is in charge of the total adjustment process.

For example, the joint between the crankshaft and the connecting rod is an important part, which experience massive loads as it converts the energy of combustion into rotating motion (see Figure 3-1 for a diagram of selected engine parts). The most appropriate configuration, processing accuracy and manner of heat treatment are minutely specified through repeated tests. The processing tolerance (permitted error range) is specified at the micrometer accuracy. Following the launch of mass production, the design is further modified in response to customers' complaints (analysis of complaints and discovery, reproduction, analysis, and solution of problems). This is done repeatedly for each important part.[8] As the production period lengthens, these improvements are gradually added into the product and technological knowledge and know-how is incrementally accumulated.[9]

And yet, this incremental accumulation does not occur as a natural process, but requires intentional organizational commitment. For instance, Japanese makers record and preserve cases of technological failures in the form of "prohibited-measures instruction manuals" (*kinte manyuaru*). These manuals are kept in their design room, and cannot be copied or taken out of the room; they are only available for reading and sharing by the development staff (Matsuura 2004).

Carrying out incremental technological innovation on a mature product is a low-key process, and does not involve any particularly high technological level. However, it creates great strength when it accumulates over a long period of time within an organization, and when experiences from the past are properly used.

3. Honda's Technological Capability and Integrated Production System

Since its foundation, Honda has persistently tried to accumulate a broad range of technologies involving whole products (including parts produced in-house and purchased parts alike). The above-mentioned incremental technological improvements are implemented through collaborations with suppliers, and in doing so, Honda does not depend totally on suppliers for the parts technology. Rather, it learns them itself, and often takes the leadership for the technological improvement of parts. A concrete case of this will be introduced in the next chapter.

What is important in this context is that this process has become the foundation not only of quality improvements, but also of major product changes. This was most dramatically observed in the successful development of the C100. This motorcycle was developed toward the end of the 1950s with each of the individual parts developed from scratch, based on a totally new concept for the purpose of cultivating a new segment, namely a small bike to be used for personal business and transportation. Until that time, motorcycles were being produced in Europe and elsewhere using a non–mass production craftsmanship system (Koerner 1995, p. 75). In Japan, small-scale makers emerged who made heavy use of purchased common parts just like in the bicycle industry (Ozeki 1993, p. 44). However, Honda, following the success of the C100, newly introduced a modern mass production system like the one for the automobile industry. Attempts were made to produce important parts in-house whenever possible, and to do this, specialized equipment was introduced on a massive scale and an integrated mass production system was established. The C100, with its quality and cost advantages, immediately came to dominate the market, and ever since, Honda has enjoyed a market share of around 60 percent in Japan. Small makers with poor technology and small capital bases rapidly withdrew from the market, and only four have remained, all with modern mass production capabilities.[10]

This is highly analogous to the product-life-cycle model, i.e., when a totally new product is born, many entrants initially manufacture the product in various specifications under a fluid production system. However, as the product technology matures, with the emergence of a dominant model, the production technology also matures, shifting the focus of competition to mass production and incremental technological innovation involving a few oligopolistic firms (Utterback and Abernathy 1975, pp. 641–42; Utterback and Surarez 1993, pp. 2–3).[11]

II. Formation of Technological Capability in Late-Industrializing Economies

1. Process of Technological Capability Formation among Latecomers

Generally speaking, the formation of technological capability in late-industrializing economies starts, first, by firms purchasing sets of technologies that have been already matured and standardized in developed economies and then making them "their own" by learning. Learning is widely recognized as the production and accumulation of firm-specific knowledge of their own in the process of using and adapting knowledge sets that are public and generic (Lall 1992; Ernst, Mytelka, and Ganiatsos 1998; Amsden 2001), and this is said to be accomplished by detecting and tracing the intellectual activities of the original firms in developed economies and adding ingenuity to them.[12] This "own" knowledge base, though narrow in scope and shallow initially, is believed to gradually broaden and deepen along with the accumulation of experience, and becomes the source of continuous rents for firms. Moreover, this upgrading proceeds from an easier stage to more complicated and risky stages of business, for example, as generally assumed by the past literature, as they move from a standardized manufacturing process to advanced process engineering and innovative product design, as if they "travelled backwards along the product life cycle, reversing the normal path" of the original firms of developed economies (Hobday 1995, p. 194).

In addition to internal knowledge accumulation, especially in an industry where "incremental innovation" matters, the sharing and mutual adjustment of external knowledge is also crucial. Through continuous cooperation with external firms, companies can share and accumulate specific knowledge internally.

However, acquiring firm-specific knowledge is by nature difficult and requires prolonged, continuous efforts. In reality, few manufacturing firms in latecomer economies undertake "proprietary innovation" (Amsden 2001, p. 2). In particular in China, in various industries, vast numbers of firms produce common standard products with very little differentiation, and harsh price competition has continued since the late 1990s, making it appear that there are obstacles preventing firms from accumulating specific knowledge for further differentiation.

2. Minor-Change-Type Development and "Homogenization Pressure"

In line with the above discussion, this study assumes that the path of upgrading of the product development capability of latecomers is a learning process that involves utilizing and discovering the original practitioners' development activities as firms move from minor-change-type to major-change-type development and, possibly, further to purely original innovations. In this subsection, first, the product development process of original firms in developed economies is described, and then, a model is proposed to show the path through which firms in late-industrializing economies upgrade their capability starting from minor-change-type development. Lastly, the internal factors in the late-industrializing economies that may delay or impede the accumulation of innovation capability and necessary knowledge are discussed.

At this juncture, let us assume that the product development process is an organized engineering effort to reduce risks by mobilizing expertise inside and outside the firm in the process of changing a highly risky plan into a final product.[13]

Generally, we can assume that the greater is the novelty of the product to be developed, the greater are the risks. The risks include the market risk, i.e., that the product may not sell, and the technology risk, i.e., that the product may not be technologically feasible. The dominant technology in developed countries, which has already received high evaluations in the market and has standardized production technology, inherently involves small risks for the recipient of the technology.

Adding original changes and engineering to the transferred product implies increased risk. Since firms in late-industrializing economies are in general vulnerable to both technology and market risks due to their weak knowledge base, they presumably can add only small novelties on the basis of the transferred products. However, as they repeatedly develop and accumulate knowledge, they presumably come to undertake more innovative development involving higher risks. When the added novelty is great, it constitutes major-change-type development, while minor-change-type development involves smaller or fewer novelties.

(1) Product Development in Developed Countries

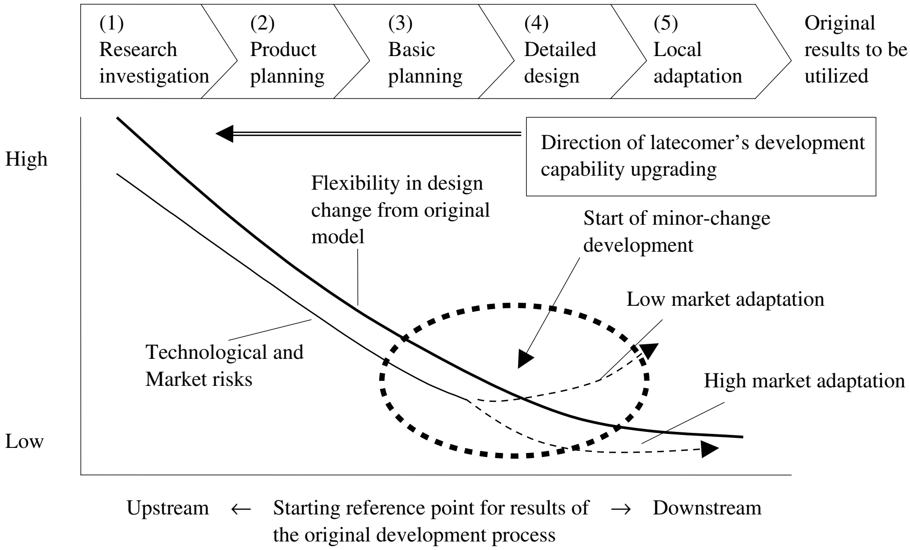
Generally, the product development process of makers in developed countries proceeds as follows:[14] (i) research: technological and market research; (ii) product planning: marketing, concept setting, basic specifications, appearance design, and profit forecasting; (iii) basic design planning: detailed specifications of the whole product, basic specifications for parts, prototype trials, experiments, and appraisals; (iv) mass product design (detailed design/drawings): mass production trials, design changes; (v) debugging: defection clearance after mass production and sales (improvement responding to user's complaints).

Starting with product planning in the development process, the specific functions, structure, and goal performance level of the product are established in the basic design phase. This is followed by the completion of the final design, which enables efficient mass production. During this period, production trials, experiments, appraisals, and design changes are repeated at the level of both individual parts and the final product. Some points requiring improvements are identified only after the product goes into commercial production and is actually used by consumers. The improvements based on this information are added to the detailed design so that they can be utilized in the future development process.

(2) Minor-Change-Type Development

Minor-change-type development means differentiation and market adaptation carried out in reference to mature dominant products, utilizing the results of the original

Fig. 3-2. Minor-Change-Type Development and the Learning Process of Latecomers



Source: Made by the author with reference to Monczka et al. (2000, Fig. 1.5).

firm's past development activities embodied in their products, with the addition of a firm's own ingenuity (Figure 3-2).

For example, a certain firm, beginning from a detailed mass product design purchased from a firm in a developed country, implements some design changes in accordance with the equipment and materials that are available to it. This involves using all the activities of the original firm up to the detailed design without change, and then promoting subsequent "market adaptations" using its own engineering capabilities. Since mature technology is applied almost as is, there is very small room for the addition of its own design changes, but the risk is low.

In addition, indigenous firms, by reverse engineering original models purchased on the market, can start developing their own products. This method involves reproducing the product by discovering and tracing the detailed design and production technology devised by the original firm by analyzing the whole product and each of the parts (Ge and Fujimoto 2005, pp. 88–91). In this case, the development process starts based on the (discovered) initial stage of "(4) Detailed design" or final development result of "(3) Basic planning" of the original firm (Figure 3-2). Compared with the purchase of detailed designs, there is greater leeway for design changes from the original model, while the market and production failure risks are greater.

In this study, the processes described above are called minor-change-type development. Many indigenous firms in developing countries, because of their poor risk-taking and engineering capabilities and their narrow scope of technological knowledge, are initially inclined toward minor-change-type development. Later, firms that have accumulated technological capabilities supposedly come to strive for major-change-type development, with the process starting based on the results of "(2) Product planning" or "(1) Research investigation" of the original firms (Figure 3-2).

(3) Heavy Dependence on External Parts and "Homogenization Pressure"

With minor-change-type development, both methods described above are possible, namely, acquiring the broadest possible scope of technologies of all the products, or acquiring technologies by reverse engineering only for limited parts of the product, and purchasing existing original parts (or similar parts) from the market and assembling them. In other words, this involves utilizing, both directly and heavily, external standardized knowledge in the form of purchased parts. Under the latter method, the product can be released on the market very quickly with little R&D cost. In fact, it was this method that allowed the rapid development of indigenous firms in the NIEs.[15] The problem with this method is that the leeway for differentiation from the original product or other minor-change rivals is extremely limited, so that it is highly likely that fierce price competition will take place among firms of homogeneous capability producing homogeneous products. However, as firms accumulate their "own" knowledge, they can expand the range of their own additional designs and may achieve differentiation from rivals.

This study takes note of the existence of "homogenization pressure," i.e. internal and external forces that discourage firms from accumulating firm-specific technological capabilities in order to differentiate themselves from rivals and to escape from price competition among homogeneous firms. In some industries such as motorcycles, "homogenization pressure" seems stronger in circumstances where there is scarce interfirm cooperation to upgrade not only themselves, but also other firms. This seems particularly true in an economy with rapid knowledge spillover and where the knowledge bases of firms tend to be homogeneous.[16]

For example, in an industry where fierce price competition can be expected, expectations of low profitability tend to encourage firms to suppress investment aimed at nurturing their own specific knowledge. Moreover, many suppliers, who can be assumed to have little grasp of future technological demand in the absence of communication with makers, may be blind about what type of future knowledge to nurture. They may then further try to strengthen their mass production capability for existing parts, which is likely to lead the competition as a whole to become more homogeneous and price-oriented.[17]

Further, as discussed in Chapter 1, the more a firm depends on the standard knowledge of external firms, the less it tries to cooperate with external firms to nurture new knowledge and share it with them. This is so because this external knowledge can be easily utilized by homogeneous rivals. Because of this, firms tend to concentrate all their efforts into nurturing their own capabilities.

In industries where "incremental innovations" and mutual adjustment among parts from various firms are significant, such as the motorcycle industry, this lack of incentives for cooperation is a significant disadvantage. For example, it is known that when a maker, which is supposed to have great knowledge of the whole product (integral knowledge), increases its component-specific knowledge through cooperative learning with a supplier, and when the supplier also acquires greater integral knowledge, both parties enjoy better efficiency and performance in product development.[18] However, in an industry without such mutual efforts, firms can not expect to enjoy these advantages.

As will be shown in the next section, the above situation prevails in the motorcycle industry in China. In addition, as seen in the previous chapter, for indigenous Chinese firms whose major users are in the low-end segment of the domestic market, major-change products may not be a major need. In terms of both supply (delayed capability upgrading) and demand, Chinese firms, facing discouragement from "homogenization pressure," may fail in efforts to step up from minor-change to major-change-type development competition.[19]

III. Minor-Change-Type Development in China's Motorcycle Industry

Product development in the Chinese motorcycle industry is a typical example of continuous minor-change-type development, with few signs of any movement toward major-change-type development. This section discusses the results and performance of product development in the industry. The organizations undertaking this development and their capabilities are discussed in Chapter 6 along with changes in recent years.

1. "Base Models" and Variations

(1) Rapid Increase in "New Products"

Let us look at the increase in the number of models using official data. The number of makers and models registered in 1988, according to the government's authorized list, was 87 and 232 (an average of 3 models per maker) respectively. These figures climbed to 118 and 971 (average 8) in 1995, 107 and 7,639 (average 71) in 1999, and to as many as 138 and 19,202 (average 139) in 2000.[20] The extraordinary surge in 2000 was due to a last minute rush of applications for registration before the introduction of a stricter production licensing system the following year (see Chapter 2). Even so, on the surface, the increase rate of "models" seems incredible, and the number is huge.

By contrast, the number of models sold in Japan by Japanese makers was just 182 as of 2002: 79 for Honda, 33 for Yamaha, 36 for Suzuki, and 34 for Kawasaki (IRC Co. 2003, pp. 42–54).[21]

In reality, nearly all the "models" that received production licenses in China are, with the notable exception of those produced with the formal cooperation of foreign makers, imitations of foreign models or models that incorporate some minor changes to them. Makers produce many minor derivative models internally, based on one original, and register them on the government's list as independent "models." Furthermore, many different makers do this based on the same original. As its result, there are a number of "models," but with little diversity.

TABLE 3-1

MAIN BASE MODELS AND ENGINES AND THEIR TECHNICAL SOURCES

Body	Engine	Engine/Body Type	Maker That First Introduced the Model Officially	Original Supplier	Type of Introduction	Year of Introduction
CD70	CD70	4 st., S, MC	Jialing Machinery Works	Honda	Technical cooperation	1983
C100	C100	4 st., S, UB	Luoyang Northern Ek Chor Motorcycle Co., Ltd.	Honda	Technical cooperation	1992
CG125	CG125	4 st., S, MC	Shanghai Ek Chor Motorcycle Co., Ltd.	Honda	Technical cooperation	1985
GL125	CB125S	4 st., S, MC	Guangzhou Motorcycle Group	Honda	Technical cooperation	1988
CB125T	CB125T	4 st., D, MC	Jialing-Honda Motor Co., Ltd.	Honda	Foreign joint venture	1993
CY50	CY50	2 st., S, SC	Jinan General Light Motorcycle Manufactory	Suzuki	Technical cooperation	1986
AX100	AX100	2 st., S, MC	Changchun Gasoline Engine Works, Jincheng Machinery Works	Suzuki	Technical cooperation	1985
GS125	GS125	4 st., S, MC	Jinan Qingqi Suzuki Motorcycle Co., Ltd.	Suzuki	Foreign joint venture	1992
GN125	GS125	4 st., S, MC	Grand River Motorcycle Co.	Suzuki	Technical cooperation	1992
V80	V80	2 st., S, UB	Jianshe Machine Tool Factory	Yamaha	Technical cooperation	1984
ZY125	4CW	4 st., S, SC	Zhuzhou Nanfang Yamaha Motorcycle Co. Ltd.	Yamaha	Foreign joint venture	1994
Haomai 125	GY6	4 st., S, SC	MCT Motorcycle Co., Ltd.	KYMCO[a] (Taiwan)	Technical cooperation	1993
ZH125	GY6	4 st., S, SC	Xiamen Xiashing Motorcycle Co., Ltd.	Sanyang[b] (Taiwan)	Foreign joint venture	1993

Sources: ZMGB (1995), QGSBW (2001), and interviews by the author.

Notes: 1. 4 st. = 4 strokes, 2 st. = 2 strokes, S = single cylinder, D = double cylinder, MC = motorcycle-type model, UB = underbone type, SC = scooter.
2. Name of the makers are those at the time they introduced the technology. Jialing Machinery Works and Jinan General Light Motorcycle Manufactory are the predecessors of Jialing and Qingqi, respectively.
3. The basic structures of the engines of the CD70 and C100 are almost the same.
4. Guangzhou Motorcycle started imitating the GL125 in 1984. It established Wuyang-Honda Motorcycle with Honda and started the production of the GL125 in 1992.

[a] Kwang Yang Motor Co., Ltd.
[b] Sanyang Motor Co., Ltd.

(2) Base Models

The models and engines used by most makers in China as bases for imitation and minor changes are referred to as “base models.” The main “base models” and their original technical sources are shown in Table 3-1.

There is no way statistically to grasp the extent to which the “base models” are shared. However, according to suppliers and others involved in the market,[22] there are more than ten different types of engines (along with integrated core structural mechanisms such as drive-related parts); those most frequently used as a basis for minor

TABLE 3-2

MODELS INTRODUCED FROM OVERSEAS OTHER THAN "BASE MODELS"

Maker	Model Number
Honda	CJ70, KW125, CD90, LEAD90, AME100, XL125, CHA125, SRC100, MCR125, M-Living125, CM125
Yamaha	YA90, DX100, ZR125, ZR150, ZY125, ZY125-T, YBR125, SR150, JYM200, JYM250, SRV
Suzuki	K50, SJ50, K90, AG50, SJ110, GF110, SJ125T, ES125, JC125, GX125, QS125, QS150, GSX250
Kawasaki	MAX100, KR250
Others	MONZA50 (Puch); K80 (Zundapp); CK50, CK125, JS125, KN125 (KYMCO); FOX600 (MV Augusta); SFERA80, TMR-703A (Piaggio); BYQ80, N100 (Unknown)

Sources: Same as Table 3-1.
Note: Names in parentheses are those of the makers who provided technologies.

change are the C100, CG125 (OHV),[23] and GY6.[24] It is widely said in the industry that, around 2000, engines based on the above three accounted for approximately half of the market.[25]

China actually introduced many models and engines from overseas in the past (Table 3-2). Many were culled out of the market, and even when they are still in production, the number is small.

(3) The Case of Jialing: Sharing of Base Models and Engines by the Entire Industry

For the 79 Honda vehicle models sold in Japan in 2002, there were 44 types of engines mounted, divided into 25 kinds by displacement ranging from 50 to 1,800 cc. For Yamaha, there were 33 body models and 28 engine types of 16 types by displacement (50–1,250 cc) (IRC Co. 2003, pp. 42–48). A simple calculation shows that there are 1–2 body models per engine type.

This hints at the development policy of the two makers. Specifically, when they develop a brand-new model, they also design a new engine specific to it. Furthermore, the engines are basically produced in-house. In other words, Honda would never make a vehicle using a Yamaha engine.

In contrast, as of 2001, Jialing had 11 engine models (of 8 categories, with displacements from 50–250 cc) for about 150 models of registered vehicles.[26]

Let us briefly look at how Jialing introduced its models and engines. It completed a localization model of a 50 cc moped in the early 1980s with technology introduced from Honda, and in 1983 introduced the CD70[27] from Honda. In subsequent years, based on the CD70, it developed new types with various displacements of 70 cc, 90 cc, 100 cc, and 110 cc. In the late 1980s, CB125S engine technology was introduced from Honda, and from it Jialing developed various bodies such as the CB125S, GL145, and XL125.[28] In the 1990s, it developed the GY6 by reverse engineering and 125 cc and 250 cc engines based on reference to the CB125T (twin-cylinder engine) introduced under a joint venture with Honda.[29] Essentially, the 150 or so models

TABLE 3-3

ENGINE PROCUREMENT STATUS, 1999

(%)

	Procurement Status	Ratio
1.	In-house engines used for all models	6.8
2.	In-house engines used for all models and also sold outside	3.0
3.	Purchased from outside for some models	43.6
4.	Purchased for some models, while selling in-house engines outside	18.8
5.	All engines purchased	27.8
	Total	100.0

Source: Bai, Xia, and Guo (2001, p. 145).
Note: The ratio, though not specified in the source, seems to have been calculated based on the number of firms rather than the number of product units.

developed by Jialing were indeed derivatives of the "base models," equipped with about 10 types (from 4 original sources) of engines.

In 2001, Jialing was purchasing engines for 50 cc mopeds from the outside, and was selling approximately 20 percent of its engines externally. Being equipped with one of the best engine factories in China, Jialing has a relatively strong preference for in-house production, and yet it shares its engines with other makers.

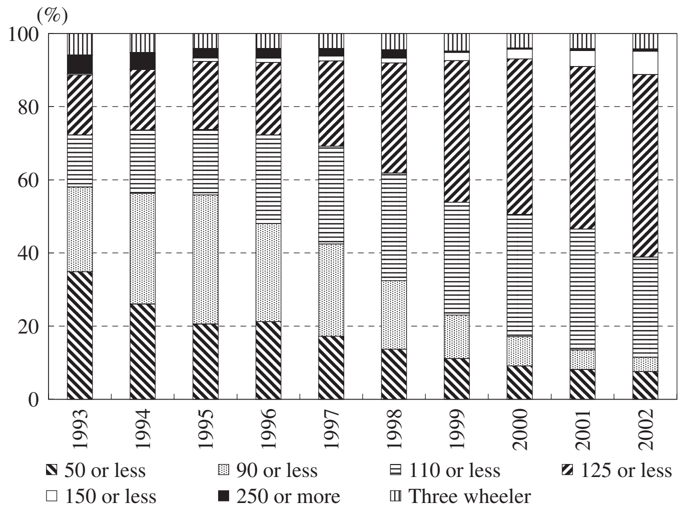
In fact in China toward the end of the 1990s, engines were routinely purchased. As indicated by Table 3-3, only 10 percent of the makers (total of items 1 and 2) were using in-house engines alone for finished vehicles, with an overwhelming majority using purchased engines. About 30 percent of makers did not produce in-house engines at all.[30]

(4) Convergence to Dominant Models

What is noteworthy from the 1990s onward is the trend for the entire market to converge toward a few dominant models. With regard to engines, the shares of the above three models (C100, CG125, and GY6) increased. Throughout the 1990s, the industry as a whole has gone through a "convergence to dominant models" in the sense that there was a consolidation of "base models" to be used as the basis of imitation and minor change.[31]

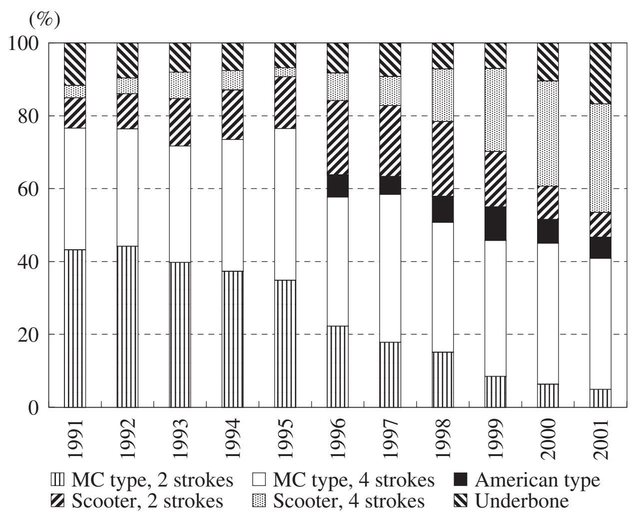
Statistical data support such an opinion. According to statistics on displacement and styling (Figures 3-3 and 3-4), in the first half of the 1990s, 110 cc or smaller (particularly 90 cc or smaller) horseback-type motorcycles (hereafter MC type) were prevalent. Among four-stroke types, the CD70, which was a specialty of Jialing, and its 90 cc derivative version were dominant and in two-stroke types, the AX100 was dominant. Meanwhile, in the latter half of the 1990s, three categories, namely, 125 cc or more, four-stroke, and scooters, sharply increased. The main models among them were the CG125-engine-loaded MC and GY6-loaded scooter. In 2000 and onwards, the underbone frame category increased, including mainly C100-related models primarily produced for export to Southeast Asia. In the meantime, the number of two-

Fig. 3-3. Motorcycles in China by Displacement (Unit Basis)



Sources: ZQGNB (various years).

Fig. 3-4. Motorcycles in China by Styling



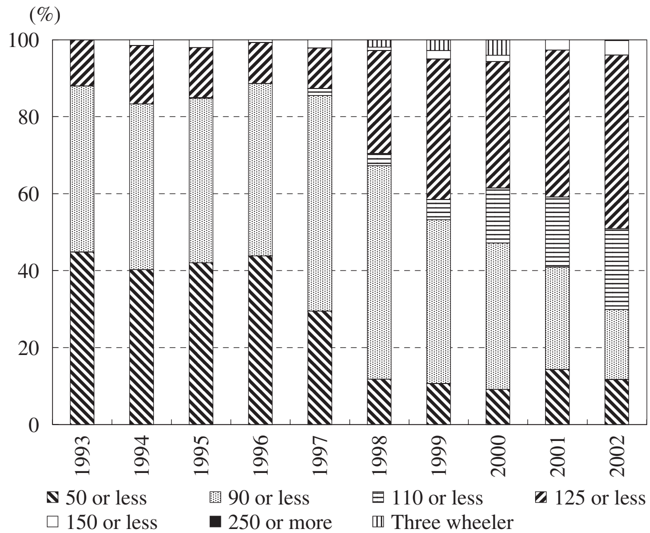
Sources: Documents of the Chongqing Motorcycle Institute.

stroke and 90 cc or smaller models plunged, with only a few remaining in 2002. This was presumably due to the change of demand, including that due to the tightening of environmental regulations (Chapter 2).

(5) Jialing and Qingqi Missed the Model Shift, Whereas Zongshen Succeeded

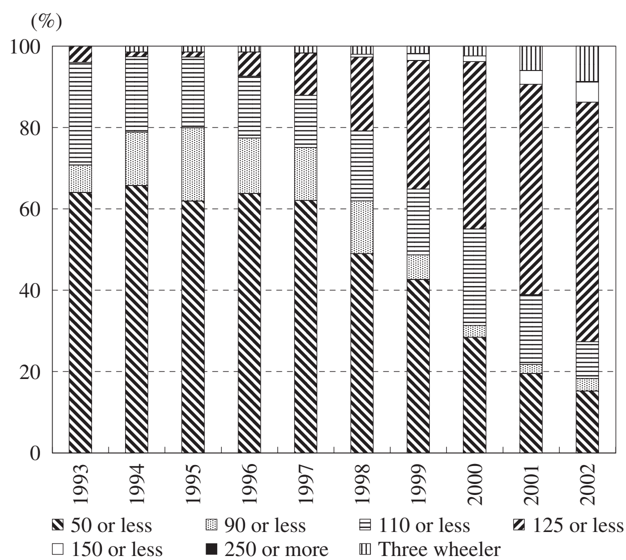
The statistics of Jialing, Qingqi, and Zongshen by displacement (Figures 3-5 through

Fig. 3-5. Jialing's Motocycles (Engines) by Displacement (cc)



Source: Same as Figure 3-3.

Fig. 3-6. Qingqi's Motorcycles (Engines) by Displacement (cc)

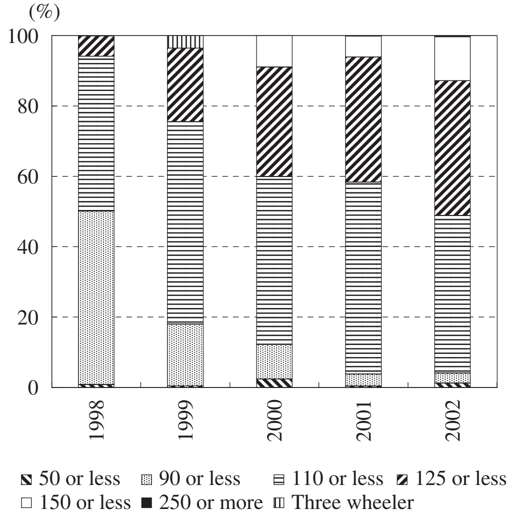


Source: Same as Figure 3-3.

3-7) reveal that their business results were directly linked with their response speed to the market's convergence to a few "base models."

In the first half of the 1990s, Jialing 90 cc models and Qingqi 50 cc models intro-

Fig. 3-7. Zongshen's Motorcycles (Engines) by Displacement (cc)



Source: Same as Figure 3-3.

duced from Honda and Suzuki, respectively, accounted for the majority of the products of these two firms, and this situation continued unchanged until 1997 and 1998. The deterioration of their business results were clearly due to the fact that while rushing toward the mass production of the models they had properly introduced, they failed to switch their major models by developing new products in the latter half of the 1990s, when the former became obsolete in the market. By contrast, Zongshen, while having a smaller number of models by displacement, improved its business results markedly by having its products converge to the well-selling C100 and 125 cc models. The effectiveness of the firm's development style—minor-change-type development involving the full utilization of standardized external parts—contributed to achieving this.

2. Degree of Minor Changes of Chinese Makers

While the bases for minor-change models have converged onto several dominant models, the scope and degree of "partial differentiation" from the "base models" has gradually increased in recent years. This process includes what can be called "configuration imitation" and "design changes with engineering." The latter, though based on the base model, involves the modification of performance, durability and cost of the products to the extent of the technologies available to the firm, thereby differentiating the product in accordance with the target user. This is the focus of analysis of this study.

There are two methods for making minor changes to motorcycles: changes in the combination of "unit parts" and changes of the "unit parts" themselves. In actuality, developing a model generally includes both methods. "Unit parts" are groups of parts categorized as those for the engine, carburetor, muffler, shock absorbers, frame, cowling (plastic cover), meters, etc.

An example of the former is loading a CG engine on a Suzuki GS-type body or changing the styling of a scooter simply by changing its cowling and lamp parts. These changes only make the product look novel and are relatively easy. Minor changes to the “unit parts” themselves are also common. For example, it is far more difficult to change the engine than the body and appearance parts. Various changes are made not only to enlarge the displacement by bore enlarging but also for various purposes such as reducing cost, improving (or downgrading) performance and adding (or reducing) functions.

For example, since using low-quality steel material for the crankshaft to reduce cost lowers durability accordingly, the maker might try to thicken the part that suffers from the increased load. Or to take another example, in designing a clutch gear with a given size, a firm can trade off differences in cost and performance by using either forged parts, which are more durable but costly, or steel-stamping parts that have simply been screwed on. Despite having the same appearance in terms of size, the difference in tolerance in the design leads to a difference in the quality of the die and the number of production process units, which in turn generates a difference in quality and cost. Some modifications are made to suit the target market, e.g., a kick starter can be changed to a cell starter or torque can be increased for use in mountainous and desert regions. In this way, engines and other functional parts with diverse price ranges were created throughout China.

In recent years, the degree of change has increased, and products integrating highly novel technologies patented in China have been launched, such as water-cooled rather than air-cooled engines, metal-plating cylinders and EFI (electronic-controlled fuel injection) systems. These launches were made after the makers acquired their own basic technology.

And yet, the makers have not gone far beyond the level of design changes and modifications based on the existing “base models.” The degree of minor changes has entered a phase where it includes not only extremely marginal ones but also some that can be claimed to be partially proprietary.

3. Mutual Coordination among Parts in China

The first section of this chapter discussed mutual adjustments among parts in the development of motorcycle products by Japanese firms and found that they develop products and parts in an incremental manner. What have indigenous Chinese firms done in this respect? Since they employ minor-change-type development using common base models among many firms, is there little need for mutual adjustment among makers and parts suppliers in undertaking minor changes, as can be seen with products such as personal computers, which are called “modular” products developed on a common design platform? It is necessary to confirm this point since it constitutes an important technological premise that affects the nature of the relationship between firms. In addition, it can help show the level of their technological capabilities and recent changes.

The conclusion is as follows. For parts that do not require either originality in appearance design and technology, or high accuracy and high quality, purchasing existing ready-made parts without any mutual adjustment is not unusual. However, core parts (engines in particular) that are important to performance and quality do require such mutual adjustments. The main target of this study is to analyze the latter and their suppliers.

(1) Combinations of Unit Parts

Let us first examine how each of the unit parts is designed and combined together. With 125 cc class vehicles, more than a hundred important parts (including unit parts), excluding standardized small parts such as screws and springs, are purchased from first-tier suppliers. Some of these parts are very standardized and others are highly customized. The former are purchased through highly spot-market-oriented transactions, and for the latter, specifications and technological requirements are presented to suppliers and through trial production and appraisal, the final detailed design is worked out.

As mentioned above, in development based on a "base model," for example, comparing "CG125" models produced by two firms, A and B, the physical dimension of the joint between parts is typically identical: for example, between the engine and muffler, engine and drive shaft, and frame and shock absorber. It is primarily the maker that sets the basic measurements of the "base model," and there is no reason for the supplier to change them, since keeping a common size makes it easier for various makers to use them. Further, as we have seen in the previous chapter, end users also want "compatibility" because it makes repairs easier. There are merits to each party to maintaining the original basic size.

Therefore, parts that have little mutual interaction with other parts in terms of function or performance, such as appearance parts like cowlings and lamps, and structurally independent parts like tires, meters, and shock absorbers, are often designed and developed by each supplier independently from the maker.[32] This is possible because small gaps in accuracy are not major obstacles at the time of assembly.

For engines, too, a pattern can be seen where an engine module supplier producing a "standard motorcycle engine," like Zongshen, undertakes independent development, while the maker who purchases the engine develops the rest to accommodate it. Zongshen and Lifan say that they maintain the original size of the joints between the engine and other parts as requested by the maker.

However, suppliers designing parts such as carburetors and mufflers, whose detailed design is determined in line with the engine, tailor them to the engine designated by the maker. In motorcycles based on a common base model, the dimensions of the joint with the engine of the carburetor and muffler retain a common size, but the features of the parts themselves (e.g., types of nozzles and airway configuration settings of the carburetor, and the shape of the internal metal pipe and surface process method for the muffler) all differ, depending on the performance requirements or internal structure of each engine.[33]

(2) Internal Components of Unit Parts

Mutual adjustment among parts can be seen more distinctly with components of units, such as the hundreds of engine parts that make up an engine (cylinder head, piston, crankshaft, clutch gear, engine case, etc.).

As we saw in Chapter 2, most of the parts of the CG125 engines produced by Loncin, Zongshen, and others once had a high degree of "compatibility," so that parts of any brand could be assembled for any common base model. This remains true even today for a majority of parts.

However, the necessity for compatibility among parts differs depending on the position with regard to the engine and the accuracy and quality required. Position-wise, parts related to combustion, air induction and exhaust (cylinder heads, cylinders, pistons, valve systems, etc.) tend to be designed specifically by each maker as they are directly linked to engine performance. In particular the design of the combustion chamber, which is made up of cylinders, cylinder heads, and pistons, is the greatest focal point of differentiation among suppliers.

Meanwhile, parts other than the combustion chamber, including drive-related parts such as the crankshaft and gears, are almost identical among suppliers. And yet, there can be differences from one maker to another. In an interview with firm *p*, a supplier specializing in crankshafts, I was told that the requirements of makers differed, configuration-wise, in terms of the length of the shaft, center of gravity, thickness of the connecting rod, etc. and process-wise, in terms of site, range, and plus/minus designation of tolerance requirement. This is because these specifications directly affect durability, drivability, vibration, noise, and other factors.

In addition, there are differences in production standards for quality control. For instance, firm *v* supplies identical cylinder heads to Zongshen (for domestic sales) and Sundiro Honda (export products to Japan). It can satisfy Zongshen's quality requirements, in boring five screw bolt holes, by applying a two-minute boring using a general bite, whereas to meet the standard of Sundiro Honda, a thoroughgoing five-minute boring is required, using a special bite.

Because of these many differences in the engine and other core parts, which are hard to identify on the surface but are important for production, it is not general practice for a supplier to provide multiple makers with identical parts for products which the makers want to use to differentiate themselves in terns of quality. This is why users purchase genuine parts for important elements, rather than using compatible repair parts, as we saw in the previous chapter. And at the same time, as we will see in the following chapters, this is why cooperative transactions have been observed between makers and suppliers, and in fact are becoming more and more prominent in recent years in this industry in China.

Summary

Because of their low capability to take technological and market risks, firms in late-industrializing economies tend to adopt minor-change-type development. Especially in China, the emergence of a large number of homogeneous competitors relying heavily on external common parts can trigger fierce price competition. Given such circumstances, it is assumed that firms are not encouraged to generate major changes, and that the upgrading speed of their development capability is slowed by the "homogenization pressure."

The empirical discussion of this chapter on the products developed by China's motorcycle makers and the technologies they use seems to support this assumption. It has revealed that development there is mostly minor-change-type, which was heavily dependent upon external standardized parts. The major-change-type development has not started yet in a full-fledged manner, and in fact, there is even a tendency to "converge to dominant models." This method of development is very different from the highly incremental manner of Japanese firms, and mutual adjustment among parts is not as prominent as among the Japanese counterparts. It is also true that the scope of Chinese firms' own engineering is being gradually enlarged and the necessity of mutual coordination has also increased recently. However, this upgrading does not seem to go beyond minor-change-type development.

This analysis is based on the products released in the market, i.e., the results of the development activities of Chinese firms. Chapter 6 will discuss the internal organizations that actually implement the development and technological accumulation therein, along with recent changes in these organizations.

Notes

1 Yamaha and Suzuki have also developed their own models, which have considerable market shares. When we say that Honda's model is "dominant," it has multiple meanings, including: (1) quantity-wise, it holds a large share; (2) Honda took the lead in development and diffusion and rival makers are benchmarking Honda's models in their development; and (3) as we see in China, most of the indigenous firms are using Honda's model as the base for minor changes.

2 Interview in Honda's production bases in Thailand and Indonesia (March 20, 2002 and September 24, 2004). Because of custom duties and local content requirements imposed by the governments, parts are manufactured and purchased locally whenever feasible. When a Japanese maker undertakes overseas production, it tries wherever possible to establish a local full-set-parts-supply network. The mutual supply of parts among their own overseas local bases is not actively practiced, though there are a few exceptions. In this respect, motorcycles are quite different from IT products and automobiles, whose parts are globally procured as a matter of course.

3 Interview at Honda's Kumamoto Factory (July 27, 2004).

4 Honda's engineers also recognize that, for such mature models, Chinese indigenous firms are perfectly capable of production alone. The same interview as above.

5 Interview with Yamaha's staff in charge of development. This does not mean that rival makers are unable to develop engines that are better than the C100 and CG125 in terms of performance or durability. Rather, it means that developing a product with a similar level of performance would require higher production costs if designed from scratch. There is also

an aspect in which Honda's gigantic production volume acts as a source of low cost. Honda's technological strength in small four-stroke engine derives from the historical fact that it has placed priority on, and accumulated experience in, four-stroke technologies ever since its foundation, whereas Yamaha and Suzuki until the beginning of the 1990s predominantly utilized two-stroke technologies. Also see Note 28 of Chapter 2.

6 It is said that a small motorcycle is made up of over 3,000 parts, if counted minutely, with several hundred in the engine alone.

7 For the decisive importance of the engine in the development process of whole vehicles, and difficulties involved in developing engines, see Shimizu (2000, pp. 319–20).

8 The incidence rate of complaints for Japanese makers is said to be about 5 per 1,000 units sold, not a negligible number. In Honda's motorcycle section, it is said that nearly U.S.$10 million was used annually to respond to those complaints in the 1980s.

9 The above statement is based on the report by Kanae Matsuura, a former development engineer at Honda (Matsuura 2004).

10 See Tomizuka (1996, pp. 169–70) and Ōtahara (2000). The integrated mass-production of the C100 in a modern factory does indeed mark an important turning point for the entire industry, but Honda's preference for integrated and in-house manufacturing, its full utilization of state-of-the-art equipment, emphasis on originality and efforts toward rationalization, have remained unchanged since the foundation of the company by Sōichirō Honda (Ōtahara 2000, p. 2.)

11 However, Honda's case differs from the model in the starting point of the cycle. When Honda developed the C100, motorcycle product technology was not in a fluid stage, but its basic structure and product technology was already fairly mature. What Honda did was carry out "major changes" on the basis of European motorcycles in order to adapt to a new market segment that had not emerged in Europe at the time.

12 The idea of the learning process as the discovery of the past intellectual activities of the original practitioners is based on Professor Fujimoto's interpretation of reverse engineering, which is presented in Ge and Fujimoto (2005). However, though Ge and Fujimoto developed the idea to distinguish learning by reverse engineering from configuration imitation (copying) without learning, this study focuses exclusively on the learning process and emphasizes the internal and external factors that slow down the pace of learning of latecomers.

13 See Knight (1985) and Note 2 of Chapter 1.

14 The statement that follows draws upon Asanuma (1997, p. 249), Clark and Fujimoto (1991, pp. 105–28), Buckley and Casson (1990, p. 55), and an interview at Yamaha Motor Co., Ltd.

15 See Gereffi (1994). Ernst, Mytelka, and Ganiatsos (1998), Kawakami (1998), and Suehiro (2000).

16 Considered as a typical case is China in the 1990s, where, among firms, important personnel were fairly mobile, and a stable corporate culture or "routine" had not yet been well established in the majority of firms (i.e., the degree of dependency on particular personnel as the source of rent was high), and where there was not yet sufficient legal authority to prevent the leakage of important business information.

17 Asanuma (1989) discovered that there are three types of suppliers involved in product development in the Japanese automobile industry: suppliers of marketed-goods-type parts, who promote development independently from the design of the maker; suppliers of "drawings approved" parts, who carry out detailed designs in accordance with the basic specifications of the maker; and suppliers of "drawings supplied" parts, who only engage in

production in accordance with the detailed designs of the maker. He analyzed cases where "drawings supplied" parts suppliers had been upgraded to "drawings approved" parts suppliers as their development capabilities improved (pp. 11–25). This happens when co-operative efforts between a maker and supplier take place as the supplier upgrades its capability and knowledge. However, considering the homogeneity among Chinese makers, it is assumed that Chinese suppliers, utilizing their own knowledge acquired independently, tend to develop "drawings approved" parts and marketed-goods-type parts separately from makers.

18 Takeishi (2001, 2002) verifies this for the case of the automobile industry. With regard to the importance of the sharing of integral (or architectural) knowledge and component-specific knowledge, this study is indebted to Takeishi's work. (See also Henderson and Clark [1990]). This study has learned from Ōtahara and Sugiyama (2005) which also take note of this point.

19 This idea is inspired by Ernst's "commodity trap" for NIEs firms. The "commodity trap" means that for latecomer firms, specializing in the narrow job of contracted production of the standardized dominant design and of minor-change-type production, relying upon the dominant firms of developed countries for core technologies delays their acquisition of a broad range of knowledge and technologies and impedes the upgrading of development capabilities (Ernst 2001, pp. 6–8).

20 The number of firms and models in 1988 is based on ZMGB (1995, p. 231). The numbers in 1995 and 1997 are from Cai et al. (1997, pp. 206–34), and Wang (1998, pp. 4–22), respectively, and those for 1999 and 2000 are based on an interview at Tianjin Motorcycle Technical Center.

21 The numbers are only those for the domestic market, and would be higher if the models for export were included. Yamaha produces 100 or more models in No. 1 Factory, the firm's main plant, with the number increasing to 400 if derivative models are included and to as many as 800–900 if one includes coloring as well (Interview at Yamaha Motor Co., Ltd.)

22 Interview with the distribution dealers and repairers referred to in Chapter 2.

23 The CG125 engine is a four-stroke single-cylinder engine developed in 1974 specifically for the developing countries. It cannot be used for high-speed driving, but the engine, having simple OHV (overhead valve) structure, which is easy to repair, has become a standard model in developing countries where the use environment is unfavorable and after-service is inadequate (http://www.honda.co.jp/50years-history/pdf/p198–201.pdf).

24 The four-stroke engine for 125 cc scooters. Honda's KCW125 (the commercial name in Japan is "Spacy") was modified by Taiwan's Kwang Yang Motor Co., Ltd. (KYMCO), under Honda's consultancy, and became a standard model called the GY6 which various Taiwan makers imitated and minor-changed. Apparently, vehicles of this model were imported from Taiwan by various manufacturers and traders, and spread mainly in the southern coastal regions of China.

25 According to fragmented descriptions from official documents, as of 2002, 16,000 models were registered, there were 256 models of a certain 125 cc model with exactly the same appearance; and a certain 125 cc engine was used in over 1,500 models (ZQGNB 2003 edition, p. 358). The latter is probably the CG125.

26 Interview with Jialing (August 31, 2001).

27 The CD70 belongs to the "C100-line," having basically the same structure as the C100 but with a different displacement.

28 The Chinese government prohibited multiple indigenous firms from introducing identical models from a foreign maker. Since the CG125 had already been introduced by another

firm, Jialing purchased from Honda the technology for the CB125S engine, as a part of the XL125 vehicle, which partly the structure of the CG125. However, the CB125S engine is different from the CG125, in having a valve structure equipped with an OHC (overhead cam) system. In the OHV (overhead valve) system, the revolving movement of the cam is conveyed to the valve by the metal bar's up-and-down motion, whereas with the OHC, it is directly conveyed by a chain, making it suitable for high-speed driving. However, it is vulnerable to breakdowns, such as chain slackening, in harsh driving environments, and it is not easy to repair. When there was not adequate repair infrastructure in place, it was hard for the model to spread.

29 Interview at Jialing and Zhang (1995, pp. 54–56). See also Note 7 of Chapter 5.

30 These 30 percent may well be considered as "odds and sods" makers in the third layer as described in Chapter 2.

31 The trend of the convergence toward certain "base models" is discussed by makers, administrators in charge of the industry and experts at institutions such as Tianjin Motorcycle Technical Center as a problem of "homogenization" (Xiang and Xian 2004, p. 12).

32 Typical examples are a number of independent cowling suppliers in Zhejiang Province (Interviews with firm *an*, *ao*, and *ap*). Hereafter, see Appendix for symbols of the firms when referring to firms interviewed.

33 Interviews with firm *c* and firm *k*.