

**Pump Set Clusters in China: Explaining the Organization of the Industry
that Revolutionized Asian Agriculture**

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ABSTRACT

This paper studies the pump set industry in rural China that has led to the widespread diffusion of inexpensive and readily repairable pumping technology in countries such as Bangladesh, Pakistan and Vietnam. To do so, we first describe the rise of China's pump set industry, which includes hundreds of small family-owned enterprises that are doing business in a manufacturing cluster that is located in a single small town in south China. We then discuss the advantages and disadvantages associated with this type of industrial structure. We conclude by examining the dynamics of the industry that have emerged during that past decade and speculate on future developments of China's pump set industry and the ways that it may continue to support the further expansion of food production in Asia.

Keywords: Pump set industry; Industry cluster; Rural China; Southeast Asia

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Introduction

The most important development in Asian agriculture during the past 40 years has been the Green Revolution (Pingali, Hossain and Gerpacio, 1997). However, the Green Revolution did not affect all countries the same. For example, while rice yields in India and Indonesia increased by more than 1.5 percent during late 1960s and 1970s (and after), those in Bangladesh and Pakistan grew more slowly during the same period (Food and Agriculture Organization of the United Nations, 2007). The Green Revolution was clearly missing in parts of South and Southeast Asia in the 1960s and 1970s. However, beginning in the mid-1980s, something changed. Rice production in Bangladesh suddenly accelerated, increasing by 2.6 percent annually between 1985 and 2000 (Food and Agriculture Organization of the United Nations, 2007). Bangladesh, once a large importer of rice, almost achieved 100 percent self sufficiency in the 1990s (Baffes and Gautam, 1996). The same thing happened in Pakistan.

In search for what happened in the 1980s that was missing in earlier phase of the Green Revolution, researchers have found that the rapid diffusion of pumping technology was behind the delayed take off of rice production in the 1980s and 1990s (Barker and Molle, 2004; Dawe, 2005; Molle, Shah and Barker, 2003). In Bangladesh, the total number of shallow tubewells increased from 45,000 in the early 1980s to more than 800,000 by the end of 1990s (Ministry of Agriculture Bangladesh, 2001). The number of small pumps used in these tubewells grew even more rapidly. More significantly, most of these small pumps were privately owned as relatively reliable and readily repairable pumps became affordable for small farmers. Between 1980 and 2000 tubewell irrigation increased from 15 to 71 percent of irrigated area and surface water

irrigation using low lift pumps accounted for another 15 percent (Bangladesh Bureau of Statistics, 2003). The diffusion of pumping technology also revolutionized access to water in other Asian countries (Dawe, 2005; Kikuch, et al., 2002). For example, between 1980 and 2000 the number of pumps in Vietnam increased from less than 30,000 to more than 800,000 (Barker and Molle, 2004). The number of pumps in Sri Lanka rose to more than 100,000 from almost zero.

While researchers have documented the expansion of pumping technology adoption and studied its impact on crop production, few have studied where these small pumps came from. In fact, there were other pumps available in the 1960s and 1970s. In the case of Bangladesh, for example, there were pumps from both India and Japan (Embassy of Bangladesh, 2007). However, these pumps were not always appropriate for use in the poor, undeveloped countryside. Pumps from India were heavy, difficult to move around and unreliable. Pumps from Japan were lighter and more reliable but also were more expensive than farmers could afford. Additionally, it was not easy to repair Japanese pumps. If they broke down, often they had to be shipped back to Japan for repairs, which was expensive and time-consuming.

So why is it that small, affordable pump sets were quite rare in the 1970s and then suddenly there was a veritable explosion of growth in the 1980s? Two changes over the past two decades may explain the rapid diffusion of cheap pumping technology in some nations. First, many South and Southeast Asian countries changed their trade policies and opened up their markets to the import of pumps and engines. For example, the government of Bangladesh began to liberalize agricultural input markets and deregulate the import of irrigation equipment in the mid 1980s (World Bank, 1999). Vietnam liberalized its markets significantly between the 1970s and 1980s as part of the Doi Moi reform program (Pingali and Xuan, 1992). Trade liberalization also has taken place in Pakistan since the late 1980s (Social Policy and Development Centre,

2006). With these changes in trade policies, falling tariffs contributed greatly to lower prices of and easier access to imported irrigation equipment.

Second, market forces in the global pump set industry may be responsible for an additional, and perhaps even greater, downward shift in the price and availability of appropriate pumping technology. In particular, one of the most important forces appears to be the emergence of China as a major pump producer and exporter in the 1980s. The expansion of irrigated acreage in rural China that began in the 1960s stimulated the development of China's agricultural pump set industry. During the beginning phases, the industry tended to focus on larger pump sets that were used by communes, factories and municipalities. It was not until decollectivization in the early 1980s and the subsequent reduction in the size of China's farms (Lin, 1992) that there was a shift in the demand for smaller pumps. However, although all pump manufacturers were initially state owned, the rapid change in demand was not met by the unresponsive state sector. The industrial reforms allowed small-scale, profit-oriented manufacturers to appear (Oi, 1999). When this happened, the production of small pump sets rose rapidly and the cost of manufacturing pumps and engines in China fell. The number of pumps used inside China for agriculture increased steadily from zero before the late 1970s to more than 16 million in 2000 (Figure 1). During this time, China's manufacturing capacity rose so fast that it began to export pump sets in the early 1980s. Moreover, although China has exported pump sets before 1985, the amount of export only started to increase rapidly after 1986, which coincided with the time when rice production started to rise rapidly in some of the Asia countries (Figure 2).¹ Between 1986 and 1989, the total amount of export increased by more than four and half times.²

¹The dollar amount of the total export includes both the export of agricultural pumps and pumps used in other sectors (industrial or residential). This is because China Customs was using Standard International Trade Classification (SITC) before 1993. The SITC classification system classifies pumps according to their types (reciprocating pumps, centrifugal pumps or rotary pumps), but it does not further classify each type of pumps

The rise of China as a pump exporter together with changes in the trade policy led to the increasing *availability* of affordable and readily repairable pumping technology globally. Because of its comparative advantage in producing light, industrial products, and due to favorable foreign exchange policies, China was able to move into international markets soon after the liberalization of the agricultural input markets in South and Southeast Asia. Between 1993 and 2007, the export of Agricultural pump sets from China to most Asia countries has increased rapidly. The value of the total import of Chinese pump sets has increased by more than six times in Sri Lanka and more than 10 times in Bangladesh, VietNam and the Philippines (Figure 3). Today Chinese pump sets dominates the market for mechanized irrigation pumps in Bangladesh and other South Asian countries (International Development Enterprises and Winrock International, 2002; Kabir and Ahmmed, 2005). Pump sets from China also have become common in Vietnam and Sri Lanka (Barker and Molle, 2004; 2005).

More importantly, the inexpensive small pump sets from China have made pumping technology *affordable* to poor farmers in developing countries and given them a tool that is readily repairable. Most of the small pump sets sell for less than \$10. In Pakistan where pump subsidies were removed and free import of Chinese pumps was allowed, pumps were sold for 35 to 40 percent less than in India, where Chinese pumps were still not available (Water policy briefing Series, 2002). These pumps, although not of superior quality, were still “*reasonably reliable*” for the purpose of shallow tubewell irrigation and low lift surface water irrigation. Of equal relevance, because of their less sophisticated nature, they were also much more *repairable*.

according to their usages (agricultural, residential or industrial). As a result, we can only see the trend of the total export of all types of pumps in the 1980s. After 1993, China Customs adopted the Harmonized Commodity Description and Coding system (HS), which classifies commodities according their types as well as usages. Because of this, we are able to obtain the data that describe the trend of the export of agricultural pumps (Figure 3).

² The currency in this paper is in US dollars. Chinese currency, yuan, is converted into US dollar using an exchange rate of US\$1= 8 Yuan.

In fact, the rise of the pump repair industry in Bangladesh—which arose after the large inflow of China’s pumps—has been noted to be an important factor is triggering broader rural development. Researchers in India have suggested that removing the pump tariff altogether would be one of the best ways to deliver pumps faster to poor communities in India.

Surprisingly, even though the pump set industry in China has contributed so significantly to food production growth in South and Southeast Asia, almost nothing is known in academic circles about this industry. To our knowledge, there is no study that documents the rise of and the current status of this source of small pumps and engines and why it has been able to produce such a reasonably reliable and readily repairable product at such an affordable price.

The overall goal of this paper is to increase our understanding of the small pump set industry in China. To meet the overall goal, the paper pursues three specific objectives. First, we describe the nature of the small pump set industry and explain the organization of the industry in China. Second, we examine the factors that have contributed to and those that have limited its development and success as the suppliers of pumps to China’s markets as well as to other countries. Finally, we speculate on the future of the pump set industry and its potential to support the continuing growth of food production in Asia.

In order to achieve our objectives, we will focus on the Daxi pump set industry cluster. Inside China, Daxi is undisputedly the leader of small pump set manufacturing. Daxi town is located in Zhejiang Province, a coastal province in eastern China that has been undergoing rapid industrial development over the past 25 years (Figure 4). Pump manufacturing in Daxi started in the late 1970s and has grown rapidly since then.³ The Daxi pump set industry has been extremely

³ In fact, the pump set industry in Daxi was not the first site of the industry. Originally, there was another center of China’s pump set industry in Fu’an city of Fujian Province. Pump manufacturing in Fu’an actually started ten years earlier than that in Daxi. However, over the years, Daxi’s manufacturers have out-competed those in Fu’an.

successful. In 2002 the title, “Hometown of China’s Small Water Pumps,” was conferred on Daxi by the China Pump Set Industry Association.

Unfortunately, during the time in which we have been studying Daxi, we have encountered a systematic lack of statistical data. The nature of the industry—tens of thousands of small, unregulated, family-run firms—has made it difficult for the government’s statistical bureau and/or the local government to collect data on these enterprises. A large share of the pump enterprises in Daxi are small factories that can best be characterized as backyard-like, self-employed firms. These small enterprises operate on an informal basis. Many business owners in Daxi do not register their enterprises with either the local bureau of industry or the local chamber of commerce. Officials from the township government told us that many of the smallest enterprises paid no taxes. If they borrowed money for financing any part of their operations, it was typically from relatives or friends on a handshake. Since these enterprises are outside the formal system of regulation, industrial management and finance, it has been difficult for the local government to keep record of them. In fact, there is not even a complete list of the Daxi enterprises.

In order to learn about the Daxi pump set industry, we made multiple field trips to Daxi between December 2003 and March 2004.⁴ During our field trips, we interviewed the owners and managers of nearly 50 factories. The factories that we interviewed spanned the spectrum from extremely small parts producers to the largest assembly enterprises in Daxi. Most information in this paper comes from the interviews and observations we made during the field trips.

⁴ We also visited Fu’an to have a complete picture of the small pump set industry in China.

The Features of the Pump Set Industry in Daxi

The Features of the Pumps and Engines Produced in Daxi

Small-scale electric pump sets are a common product that is used by agricultural producers and rural consumers in many Asian countries and elsewhere in the world. The pump set consists of two major components, a pump unit and an electric engine (Diagram 1). Although they come in many sizes, pump sets produced in Daxi are mostly powered by engines that are less than eight kilowatts. Although lacking in horsepower, these types of pump sets are light enough to be lifted and moved by a single individual. On average, pump sets weigh between 10 to 15 kilograms and are about the size of small electric home generators that are commonly found in the US or other developed countries.

Because of their compact nature and because they are self-contained units (each pump set unit contains both a pump and an engine), pump sets have many uses in developing countries. Farmers use them for different irrigation operations. In some cases pumps are used to lift water out of canals or rivers for irrigating field crops. In other cases, they are used to deliver water from canals to plots that grow horticultural crops in home gardens and greenhouses. Typically, farmers place the pump unit on the bank of the river or the edge of the shallow well. The pump operator puts an intake hose the water source. After being connected to an electrical power source, the pump draws water and pushes it out to the field through an outtake hose.

The pumps manufactured in Daxi are highly homogeneous and based on simple technology. Almost all factories are producing centrifugal or submersible pumps. The pumps and engines manufactured by the different factories are similar in terms of size and shape. Although relatively simple in design, they are often appropriate for their use since the simple functions that these pumps serve do not require a sophisticated technology.

The procedure used in manufacturing these small water pumps also is simple. The manufacturing of pumps is mostly labor-intensive. In fact, local manufacturers designed the earliest pump sets simply by reverse engineering pumps bought from outside of Daxi. At an early stage of the development of the industry (1980s), none of the enterprises branded their products. These undifferentiated and unbranded products were almost indistinguishable to an outside consumer.

The Features of the Industry in Daxi

Clustering of a Large Number of Enterprises. The most poignant characteristic of the pump set industry in Daxi is that it is made up of thousands of pump-related enterprises. An enterprise can be classified as one of two major types of enterprises: a pump set assembly plant or a parts supplier. Parts suppliers produce the parts or intermediate inputs that are needed to assemble the pump sets. Assembly plants purchase parts from parts suppliers and then use them to produce the final product, pump sets. It is estimated that there are about 800 pump assembly plants and more than 1,000 parts suppliers in Daxi (Chen, 2004; Wang, Chen and Chen, 2003).

The sheer number of pump enterprises is immediately visible as we drove into Daxi on our first field trip. From the time we entered the outskirts of the town, buildings with signs and posters indicating that the establishment housed a pump assembly plant or part supplier lined both sides of the street. Along the two-kilometer main street, almost 90 percent of the stores sold pumps or pump-related parts. There were some other small shops—grocery stores, pharmacies and clothes shops. However, even some of the convenience stores would have a shelf of daily goods for sale in the front and a pump part manufacturing facility in the back of the store or on the second floor.

Close Physical Proximity of Enterprises. Since Daxi is only a small town of 129 square kilometers, another distinctive characteristic of Daxi is that almost all enterprises are located in close physical proximity to one another. The assembly plants and parts suppliers form a veritable cluster of enterprises. Almost all of the enterprises are located inside Daxi's town center. During our field trips, the managers of the pump assembly plants that we interviewed told us that they could purchase any given part of their pump sets and not have to travel more than 30 minutes. Indeed, we accompanied an assembler as he was buying parts to complete an order of pumps and he was able to walk to the three parts suppliers. In making his purchases (he bought a box of bearings, a crate of rotors and 10 plastic casings), our interviewee was never more than 200 meters away from his own plant. The three transactions took less than 45 minutes. Literally, every partner and competitor of every enterprise is a neighbor. When asked about the process of ordering and purchasing parts, the owner of one assembly plant put it best, "Purchasing supplies is just like going to grocery stores; they are just around the corner and there are lots of options to choose from."

High Degree of Specialization. The enterprises in the Daxi cluster are highly specialized. Typically, each enterprise specializes in producing one particular pump or engine part or providing a single type of service. As shown in Diagram 1, manufacturing a pump set requires many parts. During our field trips, simply by looking at the names of the stores along the main street in Daxi, we identified factories that produce each of the parts of a pump set: Old Chen's Stator Factory, Lucky Rotor Company, Daxi Capacitor, Wang and Sons Enamel-insulated Wire Enterprise. Looking down the first three lanes and alleys of the west side of town, we could see factories that produced the rest of the parts: pump cases, impellers, bearings, valves and seals.

There were even enterprises that produced specialty screws and other hardware for the different types of Daxi pump sets.

Producing pump sets also requires the use of a number of different services. There are businesses that specialize in providing each of these pump-related services. In particular, grouped on the road that radiates out from the township government complex in the center of the town were enterprises that designed pumps, inspected product quality, booked transport logistics or provided marketing information.

Small Scale. Given the extraordinarily large number of pump enterprises that clustered into such a small town, it is not surprising that most of the factories are small. Most of the 800 assembly plants are producing in a space that is smaller than one fifth of a hectare. The parts suppliers are even smaller. In fact, some parts suppliers do not even have a dedicated factory building-structure. Many small enterprises are producing in the backyards of their houses. On the main street, many of the houses are three-story houses and the first two floors are workshops for production. The family and some of its workers live on the third floor.

In such a small space, of course, enterprises have little need for large labor forces and/or large volumes of capital. Although we do not have systematic data on Daxi, we did collect detailed information on 159 small enterprises in Zhejiang during the 2000 China Rural Survey (CRS).⁵ These businesses are much like those found in Daxi. According to the 2000 CRS, most of the China's self-employed, rural enterprises have fewer than 10 employees (Table 1a). On average, each business hires two wage-earning laborers. In addition, more than 40 percent of

⁵ The businesses in the survey were randomly selected from a set of 5 counties, 10 townships and 20 villages. The counties, towns, village and household form a small, but representative sample of Zhejiang Province. After ranking all of Zhejiang's counties by per capita income, one county was chosen from each of the income percentiles (that is one from the poorest 20 percent of the counties; one from the second poorest (20-40 percentile); one from the middle income counties (40-60 percentile); one from the second richest (60-80 percentile); and one from the richest (top 20 percent of Zhejiang counties). A similar procedure was used to choose two towns in each county (choosing one from the richest half of each county's towns and one from the poorest) and to choose villages in each town.

these self-employed businesses have assets of less than \$650 (or about 5,000 yuan in Chinese currency, Table 1b). Therefore, assuming that many of the Daxi enterprises (with the exception of some of the larger ones discussed below) are much like those in the rest of our Zhejiang sample, these enterprises—rather than being called micro-enterprises—might best be characterized as “nano-enterprises.”

Family-owned Nature. One of the unique features about the enterprises in Daxi is that none of the firms is state-owned; 100 percent of the firms are family owned and operated businesses. Even the largest enterprises are owned and controlled by a single family. This is similar to the findings of Cai et al. (2007) that studied the overriding preeminence of the family enterprise in Zhejiang. Even when the enterprise has corporatized, most enterprises only have family members as shareholders. Family members also make most of the decisions on production, investment, salaries, hiring, firing and enterprise reorganization. Typically, the father of the family (that is, the household head) is the enterprise head; his wife, sons and daughters manage different aspects of the enterprise.

Personal business relationships. Most enterprises in Daxi have developed close personal business relationships with one another. Most business owners are local residents. They know each other personally. Indeed, in one part of Daxi Township that was known for producing pump cases, a large share of the business owners had the same surnames. They are part of an extended family. Even if they are not close relatives, a large share of the owners of factories or service providing firms were close acquaintances that had grown up together. In many cases, we found that competing suppliers or close collaborators were classmates in school. Most poignantly, during our field trips, it became clear to us that each business owner that we interviewed knew most other enterprises well. When we randomly pointed to a firm across the street or referenced

an enterprise down the road, the interviewee could almost always tell us who was the manager, what type of pump or parts they produced and more importantly, what it was like to do business with them.

Because of this, and because almost all of the key components were produced locally in Daxi, most assembly plants purchased their parts from their neighbors, friends and relatives. Most orders could be placed by a phone call or during an evening stroll down the street or alley. Parts suppliers frequently allowed assembly plants to buy on credit. To finalize the supplier credit arrangement, however, there was almost never more than an implicit agreement that the supplier would be paid as soon as the assembler was paid.

While this pump set cluster in Daxi is almost assuredly unique in the pump set manufacturing sector worldwide, clustering is not unique in China. In China, clusters have emerged in many other industries. There is a large motor cycle cluster in Chongqing that is made up of more than 200 assemblers and more than 1,000 parts suppliers (Hu, 2003). In southern Jiangsu, there are printed-circuit board clusters that have emerged in the midst of a number of other industrial clusters (Sonobe and Otsuka, 2006).

The pump set industry in Daxi also shares characteristics with industrial clusters in other countries.⁶ For example, the shoe industry in Rio Grande do Sul in Brazil is a super cluster of more than 1,200 shoe manufacturers and hundreds of supporting enterprises (Schmitz, 1995). In India a knitwear industrial cluster in Tiruppur has more than 800 small knitted cotton textiles factories (Chari, 2000). There are clusters of auto parts supply firms in Thailand (Lecler, 2002).

Despite the commonality of clusters in other parts of China and worldwide, it is arguable that Zhejiang Province, the home of Daxi, is one of the largest centers of industrial clustering in

⁶ Industrial clusters are defined as concentrations of a large number of enterprises in a single local area and the development of a system of supporting industries that specialize in providing inputs or services (Gordon and McCann, 2000; Porter, 1990).

world (Zhang, 1999). For example, in Zhili town (literally translated as “weaving town” in Chinese), a place near Daxi, a clothing manufacturing cluster has formed in which all the factories are only producing simply designed cheap pillow cases and children’s clothes (Sonobe, Hu and Otsuka, 2002). Within Wenzhou city, several clusters have formed that produce low-voltage electric appliances, and cigarette lighters (Sonobe, Hu and Otsuka, 2004). A footwear industrial cluster consisting of over 4,000 shoemaking factories, 200 leather enterprises, 380 footwear sole enterprises, 200 footwear machine manufacturers, 168 footwear laces factories and other footwear-related industries also is in Zhejiang province (Huang, Zhang and Zhu, 2007).

Advantages of the Pump Set Industry Cluster in Daxi

The clustering of a large number of small, highly specialized and family-owned enterprises that are physically close to each other has brought a range of advantages. Some of these advantages have been identified by Marshall (1920): the formation of labor markets; information spillovers among enterprises; and the division and specialization of labor among enterprises. These advantages have allowed easy entry and exit of the industry and rapid expansion of production in its early stages. In addition, there are also several other advantages that fit the reality of Daxi: most players are farmers who have little formal training in engineering, management or marketing. In this section, we analyze some of the factors that have allowed the industry to grow since early 1980s.

Advantages that Facilitate Entry and Exit of Firms as well as Expansion of Production

Availability of Labor in Local Labor Force. The clustering of a large number of enterprises in Daxi has created a rich pool of affordable labor. According to the Wenling Bureau

of Investment (2005), the local population is far too small to satisfy the demand for labor of all of the factories. However, the employment opportunities offered by the numerous enterprises in the pump set cluster have attracted a large number of migrants from nearby provinces. Migrants now account for more than 40 percent of the population. The constant flow of unskilled migrants also generates an affordable supply of workers since migrants are willing to work for a wage that is far below what most local residents would accept. The average wage of an unskilled worker in Daxi is about \$3.50 per day. When we asked any of the local residents what they expected to earn, it was always \$10 per day or more. Access to reliable supplies of low cost labor has significantly reduced costs of hiring labor for enterprises that are already in the industry.

With access to such a large pool of labor, search costs are also much lower. When asked how they hire new workers, managers and owners told us that they can usually find new workers within a couple of hours. Because there is such a high concentration of factories, each of which has its own workers, there is always a large cohort of labor looking for work at any given time. A manager in search of a worker can simply ask his current employees or a neighboring manager if they knew whether anyone was looking for a job. According to our interviews, it was not unusual that by the time they came back to their factory (after making the inquiries) that one or more prospective workers would be there waiting for an interview. At the very longest, the manager would have to wait until the next day. If a manager were looking for a worker at the end of a workday, he and his workers would ask around that evening. By the next day, there would usually be many prospective workers lined up waiting at the plant in the morning.

Rapid Spread of Technology and Marketing Information. The close physical proximity of enterprises facilitates the exchange of information and technology. The exchange of information, however, was not orchestrated by any government bureau. From our interviews it is clear that

even if an enterprise did not want to share information, it was difficult, if not impossible, to keep secrets in Daxi. Daxi enterprises often imitated the new designs of products brought from the large state-owned factories from nearby metropolitan areas such as Shanghai and Hangzhou. As soon as any new product began to sell well, it was almost immediately (“within several days,” according to one small enterprise owner) copied by a large number of competing enterprises. The same thing happened when a plant received a new order from a new part of the country or from a new overseas market. Every other plant owner would know who was scaling up and within days or even hours everyone in Daxi would know about the new market or new marketing channel. The rapid spread of information among the enterprises enabled the firms to procure market information and product knowledge without the need to invest heavily in research and development (R&D) or marketing.

Low Initial Capital Investment. Access to hundreds of parts suppliers also significantly reduced the initial capital investment required to start an assembly plant. An assembly plant could purchase all the material inputs needed for manufacturing pumps locally. Instead of investing a great deal in equipment to be able to manufacture parts on its own, an assembly plant only needed to finance a stock of inventory. There also was no need to invest in building marketing channels because each assembly plant could use local sales agents. Each plant only needed a minimum amount of capital. During our interviews, several pioneers in the industry told us that they initially only needed to invest a few hundred dollars for renting a room and for hiring several workers to start their businesses.

Low Production Costs. In addition to the easy access to the large pool of low cost labor, access to hundreds of parts suppliers also lowered production costs significantly. Most obviously, the production of one single product lowered the cost of producing each part through economies

of scale. In addition, competition among parts suppliers lowered prices of the material inputs. During our interviews, owners of the assembly plants told us that when they purchased parts, one common strategy was to negotiate with several suppliers at the same time. The fierce competition among parts suppliers induced the parts supplier as a group to lower their prices. Being close to parts suppliers also reduced transportation, inventory and other logistic costs.

Low Transaction Costs. The close personal relationships among Daxi enterprises formed business relationships that greatly decreased transaction costs. Since people knew each other, they could interact with each other with trust. With these localized circles of trust, almost 100 percent of the transactions among enterprises in Daxi were carried out without a written contract. One of the most obvious manifestations of this trust is that while there are thousands of factories and service enterprises in Daxi, in the phone book there is not one listing for a lawyer. In nearly 50 interviews, not one owner/manager said that they had any serious conflict that went unresolved. If there were major conflicts, even though there were no legal procedures, the punishment of the party that was at fault was that they would lose their reputation and it would become difficult if not impossible to do business with others in Daxi. Because reputation in such a setting is so important, one manager told us that no one would ever do anything to endanger ones reputation (implying this was the reason that there were so few unresolved conflicts).

Competitive and Cooperative Relationships. In such an environment, although most of the assembly plants are competitors (as are parts suppliers at another level), enterprises also cooperated from time to time. For example, when we were in Daxi, one small enterprise secured an order for more than 1,000 pump sets. This order needed to be finished in less than one month. There was no way that the firm could have built that many pump sets in the time available. Therefore, the enterprise owner sub-contracted different parts of the order to other small

assembly plants. The manager told us that usually the other party would reciprocate later — either by giving an order back or by lending him workers if needed. These low transaction costs and the competitive cooperation that distinguished business relationships in Daxi have helped many enterprises develop in their early stages.

Flexibility. Being small in size in many cases also makes enterprises more flexible and more adaptable to changes in market conditions. Entering or exiting the industry was easy for a small enterprise since it required little capital investment to enter and there were few sunk costs to consider when exiting. The small nature of the firms also made it easy for firms to adjust their levels of production. For example, when market demand was high, as seen above, assembly plants sometimes sub-contracted a share of their orders to other assembly plants. Being small, these factories could start production on short notice.

Advantages That Fits the Reality of Daxi.

In addition to the advantages that made it easy for firms in Daxi to enter, exit and expand production efficiently, there were a number of facets of the cluster that facilitated the industry's rapid growth by making it easy for individuals—especially those in this relatively backward area of China—to develop their businesses. Before entering the business, most plant owners were either farmers or working as migrant workers; few plant owners/managers had any advanced training or formal vocational education. Prior to the 1980s, literally none had had any experience in running a business. Hence, in such a case, the simpler business was, the better.

Ease of the Organization of Production. Also of great importance was the high degree of specialization that lowered the requirement on organization skills—which could be important to manufacturers in such a setting. Since Daxi contained the entire spectrum of parts suppliers, each

enterprise typically only had to produce a single product (either the assembled pump set or a one of the parts that made up the pump set). Since there was such a high degree of specialization, the production process for each was also simple from an engineering point of view. For example, there was almost no need to hire different types of specialized workers to produce the different parts. Additionally, small enterprises did not require extremely complex management skills to organize production activities.

The Simple Nature of Technology. Small water pump manufacturing, although labor-intensive, does not require lots of skills or technical knowledge. The low technical content in the manufacturing process of pumps makes it relatively easy for new comers—usually rural residents from surrounding areas—to enter the industry. When there are technological changes, they can also be easily adopted by enterprises. This was the case in Daxi. In interviews after interviews, we were told that although at first the manufacturing process seemed difficult to the new operator/manager, they all recounted how they had quickly been able to master the skills involved.

Low Requirements for Marketing. The production of undifferentiated products also made it easier to target consumers and required less sophisticated (and less expensive) marketing. There was no need to conduct marketing research to develop or hold niche markets. With such products, retail buyers cared most about price. There were few expectations about other characteristics of the product, such as a manufacturer guarantee or the convenience of use. The homogeneity of products also enabled all the enterprises in the industry to compete as a whole with enterprises outside the cluster.

Strong Incentives. Although we raise this last, it is not the least important of the features of Daxi's pump set cluster. The nature of Daxi's family businesses provided the key figures in

each firm with strong incentives to work hard and make careful and timely decisions. In their paper on family enterprises in China, Cai et al.(2007) argue that a significant share of China's rise as a manufacturing giant is attributable to family enterprises. When managers and key employees are members of the family that owns the enterprise, there is a gain in productivity because each will face good incentives since they are claimants of part of the enterprise's earning residual and require relatively little monitoring.

The industrial strategy of clustering in the pump set industry in Daxi—at least at this stage of development—has succeeded. Thousands of parts suppliers and pump assemblers have produced literally millions of small and cheap pumps. On average, Daxi pumps were and continue to be about 30 percent cheaper than similar pumps produced in other parts of China. This low price has made the pump set industry highly competitive in the domestic market. Pumps produced in Daxi account for more than half of the market share in the domestic small pump market (Zhu, 2002). Daxi almost certainly exported more of these small pumps than any other single (or cluster of) factories from the rest of the world. Because of this, to an extent never possible before, these cheap small pumps offered an affordable irrigation option for farmers from developing countries—inside and outside of China. As the owners and managers of the Daxi pump set assembly plants that we interviewed told us, their products were exported to many Southeast/South Asian countries. The value of the exported pump sets was more than \$30 million per year in the early 2000s. Because of the pumps and engines imported from China, the rice economies in many countries of Southeast and South Asia have developed rapidly over the past two decades (Barker and Molle, 2004).

Disadvantages of the Pump Set Industry Cluster in Daxi

In this section, we examine the factors that limit the further development of the industry. As discussed in the previous section, the organization of the Daxi pump set industry was quite successful in its earlier stages of development. Its success depended in part on a number of the features of the pump set technology and the organization of the industry in Daxi. However, for a number of reasons, Daxi also faced (and continues to face) a number of disadvantages. Although these disadvantages may not have posed a high enough barrier to limit Daxi's growth in the earlier stages of the development, it is possible that in the longer run, some of these disadvantages could restrict the growth of the industry. Ironically, as we will see, some of the factors that bestowed some of the advantages on the industry in its earlier phases have the potential of becoming a disadvantage as the industry matures and as China develops.

Weak Intellectual Property Rights Protection and Limited R&D Investment

Despite the advantages that enterprises enjoy from the clustering of enterprises, the structure of the industry has generated strong disincentives to invest in R&D. During our interviews we sought out the owners and managers of enterprises that were considered to be leaders in the industry because they had taken initiatives in developing new products or investing in differentiating their current products. All of these innovators told us the same story. As soon as their enterprises developed a new way of manufacturing or assembling a pump set or in any way made changes to differentiate their products from those of their competitors, innovations were almost instantaneously imitated by their neighbors. In many cases the innovators told us that copying their new product was often started before it was even introduced onto the market.

Given the nature of the cluster, there were many ways that technology passed from one enterprise to another—most of them simple and direct, since the imitating enterprises was often just next door. Sometimes information leaked out through exchanges of workers. Sometimes information got out accidentally through usual daily interactions. In one case the wife of an innovator passed the new breakthrough to a competitor (the nephew of the innovator) after an hour of evening gossip with the nephew's wife.

Although the high degree of specialization made the entry into the industry easy since it reduced the required level of initial capital investment (as well as production costs), the reliance on a large number of parts suppliers outside an enterprise (which was called outsourcing in Daxi), also increased the probability that any new technological innovation would be stolen. New technologies were often passed on by those involved in the design service sector. In the creation of pump sets, one of the most technical steps is the design and manufacture of the molds for some of the key parts (such as the impellor). The mold determines the shape of the parts, and is one of the key determinants of quality. When a pump assembly plant designs a pump, it must hire an enterprise to design molds for key parts that the parts supplier can use to manufacture the parts. Few assembly plants have the capacity to develop molds by themselves. Consequently, even innovative assembly plants needed to provide information on the new technologies to designers and mold developers. Even though the assembly plant pleaded with the mold designers to keep the design secret, according to the assemblers, new secrets were never secrets for long. In many cases the interviewees said that the leaks could have only come from the design enterprise. Sometimes design employees sold the design to a competitor assembly plant. In other cases assembly plant bribed a design company engineer to leak the new product. Whatever the channel, design enterprises were notoriously porous.

As a result of the poor protection of technology, there was little motivation for enterprises to invest seriously in refining the manufacturing process or upgrading the quality of a pump set as a way to gain a competitive edge in the market. Even in times when a change was made to improve the pump set and the change was protected, imitators were able to mimic the outside of the pump. This made it difficult for buyers of pump sets to distinguish between the old and new styles of pumps. Leading enterprises would quickly lose their chances to charge a price premium for the improved product. Because buyers could not tell which product was better, demand for improved products grew sluggishly if at all.

Few measures could be taken to protect a brand. In some cases, enterprises even suffered losses when they tried to take action against the imitation from other factories. For example, Jinlong (or Golden Dragon) Water Pump Factory—one of the earliest innovators in terms of creating materials that made their pumps last longer and perform more reliably—had to change its brand name every several years. The problem was that as soon as it started making above normal profits on its new variety of pump sets, scores of small assembly plants began manufacturing gold colored pump sets with dragon patterns on the outside of the pump. When orders began to fall and complaints rose from buyers that thought they were buying the premium pump sets, the enterprise changed its name to Crocodile. Within months, numerous small assembly plants were painting their pump sets green and changed the dragon pattern to crocodile patterns. In 2001 the enterprise changed its name again to Pump King. Each change of name, according to the owner, cost the enterprises tens of thousands of dollars and a lot of effort. In addition, each time the enterprise changed its brand, they lost some of their old customers because the customers could not locate them any more.

Poor Quality Control

Outsourcing also impinged on quality. In the process of outsourcing, since it was difficult for the pump assembly plant to monitor the production process of parts, an enterprise lost much of the control on the quality of the parts. Because of competitive pressures, parts suppliers were always looking for a way to shave fractions of pennies off their cost bases and would often compromise quality if they could get away with it. A pump made with low quality parts, of course, would be low quality itself. During our interviews, we heard repeatedly the complaints from the pump assembly factories about the reliability of their parts suppliers.

General Lack of Management Expertise

Although the family-owned nature of enterprises provided strong incentives, it also brought with it limitations. A family's members do not always have the range of skills needed to run a complex enterprise. In several of our interviews, we were told that the greatest limitation to expanding the size and profitability of the enterprise was that there was no member of the family that understood a specific aspect of the business: e.g., engineering, financing or management or marketing. Hiring professional managers did not work well, partly due to the family-owned nature of the enterprises. Because families in the area are tightly knit, managers that were hired often felt like outsiders and believed that they were not treated fairly. Family business owners complained that if they invested a lot in a manager, which made him/her competent in the industry, because of the low start up costs, in many cases the manager would take the technology and skills of the family business and start up a competitive enterprise. They would often also steal workers and customers.

Vulnerability to Market Shocks and Lack of Access to Bank Loans

Being small, although flexible, also imposed costs. Above all, the small size of Daxi enterprise made them vulnerable to unexpected changes in market conditions. Ups and downs in the market easily forced enterprises out of business. For example, during our field visits, we learned that quite a few small pump assembly plants went out of business because the price of copper (the key input in producing insulated wires) rose significantly. Furthermore, the small size of many of the enterprises limited their ability to expand production or upgrade quality. Small enterprises were less likely to invest in longer term projects that may have been risky in the short term. Additionally, the small size of enterprises also diminished the chance of the enterprise to apply for and receive bank loans. As a result, enterprises often did not have enough capital to invest in upgrading equipment or hiring more or higher skilled workers. As a result, most small enterprises stayed small for most of the past two decades.

Low Value-Added and Low Quality Products

Because of the limitations on the ability to expand production and/or upgrade the quality of the product, most enterprises have stayed small and continued to manufacture simple and undifferentiated pump sets. Simple technology has made it difficult to create a high value-added product. The fierce competition has driven profit margins down to returns to land, labor and capital. The homogeneity of products has meant that every pump enterprise was competing in the exact same market. In order to increase their profit margins (or according the many interviewees “to keep from losing money”), many assembly plants and parts factories have opted to use inferior materials for inputs and parts. The enterprises have not (or could not) invest in maintaining their equipment. Most factories were still using old machines even though the precision of the equipment had deteriorated over time. Several of the factories that we visited had

eliminated all testing of their assembled pumps before putting them in the market. Quality, according to our interviews, had declined sharply.

Because of the extreme cost pressures, the pump assemblers were not able to respond to the needs of their customers. Partly due to the low quality of their products, no pump assembly plant in Daxi offered after-sale service. Warranty programs have been discontinued. The township government official told us that the industry's low quality had become a barrier to its further development. He said plain and simply: Although inexpensive, "Daxi pump sets have become a symbol for inferior quality manufacturing." The Zhejiang Province Bureau of Technical Supervision branded Daxi with the name "Zhejiang Province Regional Quality Problem" town. In some sense, part of the industry is in a low-level equilibrium trap: low profits led to low quality; low quality limited profitability; weak intellectual property protection reduced the willingness of enterprises to invest in further development of new designs and/or new plants with old designs.⁷

The Dynamics of the Development of the Industry

Despite the early success that was in a large part fueled by a number of special advantages that were inherent to Daxi and those involved with the industry, as seen in the previous section the remaining disadvantages may be putting the future of the industrial cluster are in doubt. However, it is possible that a new dynamic is emerging. In the midst of this race to

⁷ Although low quality has increasingly become a problem in the further development of the industry in the twenty first century, it does not discredit the contributions of the small pumps in the past. These pumps, although not superior in their qualities, are "*reasonably reliable*" for the purpose of shallow tube well irrigation or low lift surface water irrigation. These simple functions do not have high requirement on the quality of irrigation equipment. Partly due to the fact that they were relatively low quality (when compared to pumps from Japan), were *affordable*. Even relatively poor farmers in developing nations, such as Bangladesh and Vietnam, were able to access enough capital to buy the pumps. Many of the small pump sets sold for less than \$10. Because of the low prices, almost all the small pumps were privately owned. Furthermore, because of their less sophisticated nature, they were also much more *repairable*.

the bottom, a group of elite firms has emerged. The four largest and most prominent of these are SHIMGE, Dayuan, Dafu and Taifu. These elite firms have adopted and continued to develop new strategies to expand their production and upgrade the quality of their products. The development of these elite firms can be divided into two phases: the quantity expansion phase before 1998 and the quality upgrade phase after 1998. In fact, this trend of quality-upgrading may be seen to be emerging in the later development stages of the development of other industrial clusters in rural China (Sonobe, et al., 2004).

The new dynamic in the pump set industry in Daxi must be looked at in two phases. Before 1998, the elite firms focused on increasing their production capacity by investing in equipment and facilities and reforming production processes. For example, Dayuan invested more than \$1.3 million in purchasing equipment and buildings. In fact, in order to expand his production capacity, the owner of Dayuan used the profits from his transportation business in Guangzhou to finance his investment. The elite firms also invested in the creation of more streamline assembly lines, which enhanced their production efficiency and reduced their labor costs. After making such investments, the production capacity of these elite firms rose. For example, the production of Taifu increased from only 500 pumps in 1985 to more than 10,000 annually in the early 1990s.

With the larger production capacity, the elite firms gradually began the process of vertically integrating their operations. Whereas in the past they used to purchase all of their parts from surrounding parts suppliers, the elite firms have now begun to produce more of their own parts—especially the key ones. The firms also found that although perhaps their costs have risen, when they produce their own parts, they were able to control the quality more closely and guard their technology better.

Although the elite firms started to reform their businesses in the early 1990s, significant changes to the industry did not take place until after 1998 when the Daxi township government started a quality rectification plan that was supported initially by the central government. Although this action was not targeted at Daxi specifically, most firms in the pump set industry were hit hard. The action started with a class of pumps called submersible pumps. As the name suggests, the entire pump set is placed fully in water during operations and is supposed to be completely waterproof. Because of a number of accidents caused by the use of low quality products, the government began to crack down on the “quality problem.” Production licenses became mandatory before a firm was allowed to produce submersible pumps. The township government put in a lot of effort in implementing and monitoring the licensing regulation. Many enterprises had to stop production for a while or even exit the industry because they could not reach the quality standards specified in the approval of production licenses. New firms also found it much more difficult to enter the industry than before. The number of pump enterprises assembling submersible pumps fell by more than half during this period. The growth of many enterprises has been stagnant since then.

The quality rectification, however, did not impose negative effects on elite firms like Dafu and SHIMGE since they were able to meet the requirements necessary to receive a production licenses. They also learned other lessons. For example, we were told during interviews that the rectification campaign increased their awareness of the importance of quality. For the first time since the mid 1980s, the elite firms began to invest heavily in quality inspection and the equipment that they needed to maintain quality. Quality control facilities are crucial in helping manufacturers of metallurgy products control product quality. For example, the investment into equipment by one of the elite firms was less than \$26,000 in 1989. By the late

1990s, the firm increased expenditures to more than \$0.8 million. Since so few firms originally inspected the quality of their products, there was not any one skilled in the execution of inspection tasks. Therefore, elite firms had to train their own technicians to operate and maintain the quality-inspecting equipment.

After upgrading the quality of their products, the elite firms began to signal the superior quality of their products by getting their products certified. Most elite firms obtained national certificates such as *Zhejiang Province Famous Trademarks* or *Zhejiang Province Excellent Products Certificate*. These certificates are issued by quasi-government bureaus whose objective is to promote higher quality manufacturing in China. Some elite firms even obtained quality certificates that are internationally recognized. SHIMGE, Taifu and Duyuan are all now ISO9001 and ISO9002 certified. SHIMGE also introduced an environmental management system that helps it meet the ISO14001 standard.

With the new and safer environment, the elite firms also started to invest again in R&D. The firms realized that as long as their products were based on simple and easily adoptable technology, they could be easily copied and would never be able to be sold as high value-added commodities. The best way to prevent imitation, according to the manager of one of the firms, was to produce products that were technically more difficult. To do so, these elite firms began to hire their own engineers and technicians from colleges and research institutes such as Hangzhou Machine and Electric Research Institute and Nanjing Technology University. They also hired employees with particular skills away from large State-owned enterprises. According to the manager of SHIMGE, out of their 600 employees, more than 150 are well-trained technicians. Recently there has been a trend to hire even more expertise. In 2004, SHIMGE hired an engineering professor, Dr. Lin, from Jiangsu University, who is the leading researcher in pump

technology. Dr. Lin comes to SHIMGE's Daxi factory and works on developing new technology several times each year.

The investment in R&D has paid off for the elite firms. With its high-profile R&D team, SHIMGE became the leading producer of larger pumps that are used for deeper wells, a market in which there has been less competition and higher profits. They also produced the first Screw Pump, a type of pump that can be used to extract water from more than 80 meters below the ground surface. The Screw Pump is more energy efficient. Deep water submersibles and Screw Pumps are much more difficult to copy than the smaller pumps sets that can be only used in shallow wells or for use in lifting surface water. In fact, during our field trips, we saw only a few enterprises that produced and sold these products.

Furthermore, as the quality of the product rose, the elite firms started to develop new marketing strategies, including branding and advertising. To differentiate their products from those in the traditional segment of the industry, the elite firms have begun to mark each part of their pump with their trademark. These firms began to advertise on local agricultural and rural radio stations. They have begun to put up billboards on highway. Two firms have contracted with a national advertiser and have begun to pay for commercials that air nationally and internationally. For example, Dayuan spent \$430,000 on advertising on China's central TV station (CCTV), about 60 percent of which was on the national channel, CCTV1 and the rest on the international channel, CCTV4.

The importance of the changes of strategy and new directions of the industry can be seen clearly by the relative performance of the elite and undifferentiated firms. The elite firms that had the business foresight to upgrade the quality of their products have continued to grow. For example, SHIMGE only produced around 7,000 pump sets annually in 1989. After the rapid

expansion since 2000, they have been producing more than 500,000 units annually. When SHIMGE was first established in 1989, they purchased 100 percent of the parts from outside parts suppliers. The share of outsourced parts fell to 20 percent in 1995. Today, SHIMGE produces 100 percent of their parts internally. The production capacity of Taifu increased from 500 pumps in the late 1980s to more than half million units in 2003.

In contrast, we have interviewed several enterprises that started the same time as the elite firms but have stayed small. These firms invariably have only been able to produce low quality pumps during the past 20 years. In fact, one of the interviewees, the owner of Changhong (Long Rainbow) told us that the owner of SHIMGE had advised him more than a decade ago to adopt SHIMGE's strategy to upgrade his firm's quality. He did not follow the advice. He now laments the fact that it is too late that that he missed the best opportunities.

Clearly, there is a revolution going on with the rise of the elite large firms and the reduction in the number of small enterprises. During our last visit, many small firms recognized that their industry was going through a transformation. Smaller firms were hoping that their businesses could last another 10 years. Medium to large firms were looking for ways to expand and join the elite firms. The largest firms were hoping that they could move out of their old cluster-bound, low-level equilibrium trap. They were planning new strategies to modernize further and keep their competitive edge. It is clear that the race is not over.

Conclusion

Without the access to cheap pumping technology, farmers in South and Southeast Asia would not have been able to take advantage of the miracles of the Green Revolution. In this paper we have traced the origins of the small pump sets that revolutionized Asia's agriculture. Our analysis has taken us back to both the geographical source of the pump sets and their economic beginnings. Specifically, we have documented the story of how China became the supplier of the developing world's small pump sets. From the rice paddies of a Socialist country in the 1960s and 1970s that restricted private entrepreneurship or any pursuit of profits to one of the world's most unfettered, capitalistic industrial clusters in the reform era, China has been able to supply the missing link for many farmers that needed a source of power to lift water from wells, canals and rivers to irrigate their crops at an affordable price.

There are several lessons that may be worth studying. First, when left to itself, a country with a motivated, entrepreneurial population can organize its own industry that can supply key products that are in demand. The formation of industrial clusters, including that for pump sets, were not directed by any government agency but emerged on their own. In doing so, the economic activity took advantage of the features of the local economy and its actors that gave it a competitive edge. Hundreds of small firms clustered together so they could tap the economies of scale of large factories while not needing the capital input, risk coping institutions or industrial organization that often act as a barrier for developing countries that are trying to industrialize. While there were some preconditions in China that may not make it replicable all over the world (e.g., sources of liquidity and a minimum level of technological expertise), in many parts of the world these conditions do apply. When allowed to emerge and not strangled by government

officials, China has shown that small rural firms that become competitive can make inroads into world markets while at the same time provide employment and profits for the domestic economy.

Second, it has also become clear, that in the longer run such simple forms of technologies also have a number of disadvantages. While close interaction among firms facilitates the flow of information, inputs and managerial skills, it also can retard investment in R&D and discourage the development of quality products and higher value added manufacturing and services. If this goes unchecked, industrial clusters run the risk of entering a “race to the bottom.” It is perhaps at this point in the development of industries that governments may want to encourage the development of branding and research. If effective ways are created, it has been shown that out of the same industrial forces that created the intense competition among micro-firms, large, respectable firms with coherent strategies for R&D, quality improvement and branding can emerge.

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Table 1a. Employment Distribution of Self Employed Enterprises in Zhejiang Province ^a

(Year 2000)		
Number of labor	Number of Enterprises	Percentage
1	102	64.15%
2	31	19.50%
3	12	7.55%
4	3	1.89%
5	2	1.26%
8 and above 8	9	5.67%
Total	159	100%

^a The survey was conducted in late 2000 and collected information on the year 2000. Six provinces are selected, one in each of China's "major zones": Hebei, Shaanxi, Liaoning, **Zhejiang**, Sichuan, Hubei. In each province, we selected five counties from each province, each randomly selected from each income quintile. In each county, we selected two townships. In each township, we selected one village randomly selected within each 20 households randomly selected in each

Table 1b. Joint Distribution of Total Asset and Liability Self Employed Enterprises in Zhejiang Province (Year 2000)

		Liability		Total
		≤ \$650	> \$650	Percentage
Total	≤ \$650	40.8%	1.3%	42.1%
Asset	> \$650	37.5%	20.4%	57.9%
Total	Percentage	78.3%	21.7%	100%

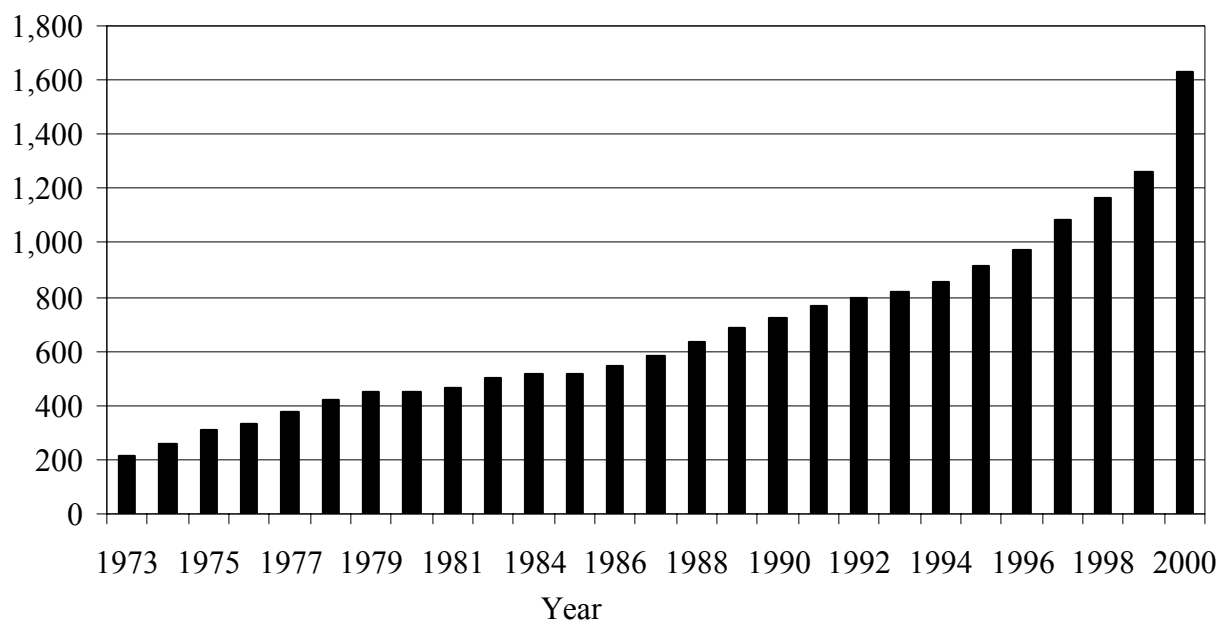


**Figure 1. Number of pumps for agricultural use in China
(Unit: 10,000)**

Source: China Agricultural Machinery Statistical Yearbook

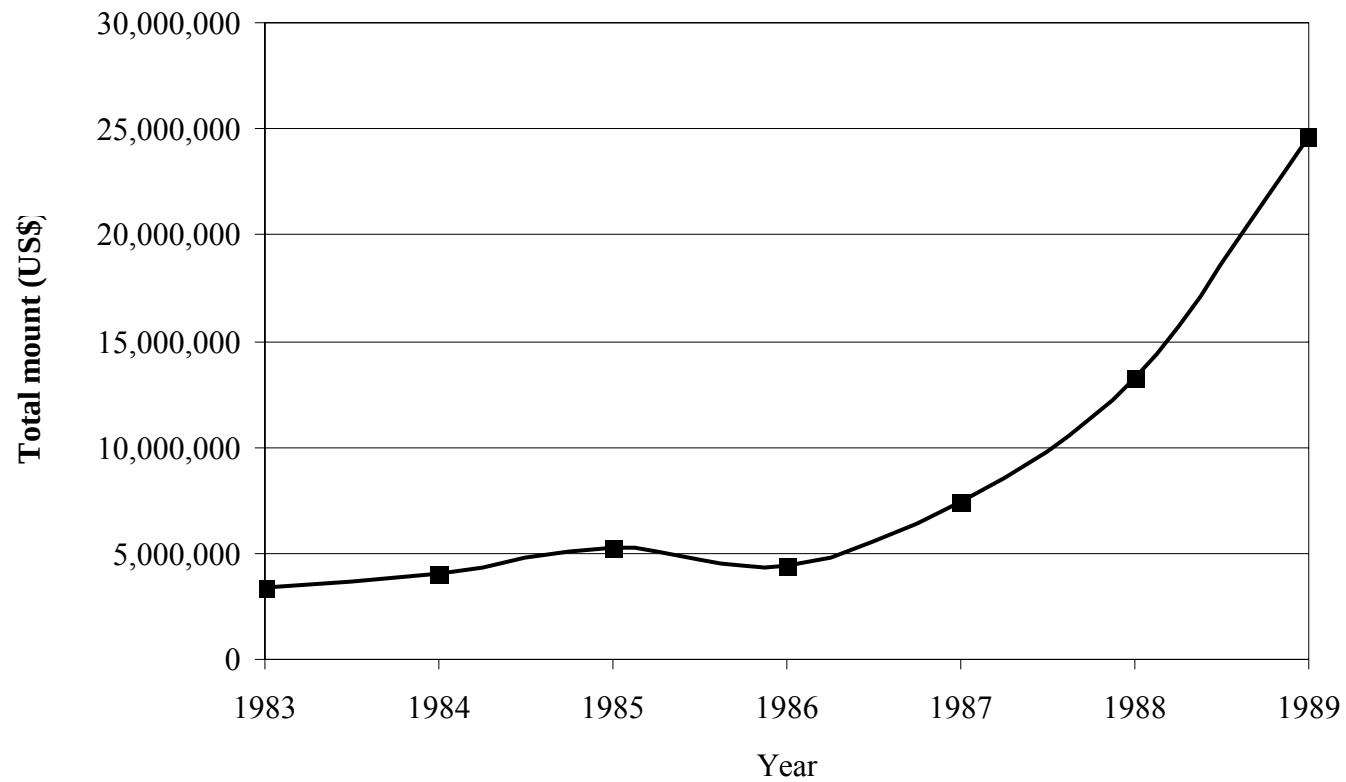


Figure 2. Total value export of pumps in dollar amount between 1983 and 1989

Note: Dollar amounts are adjusted using consumer price index.

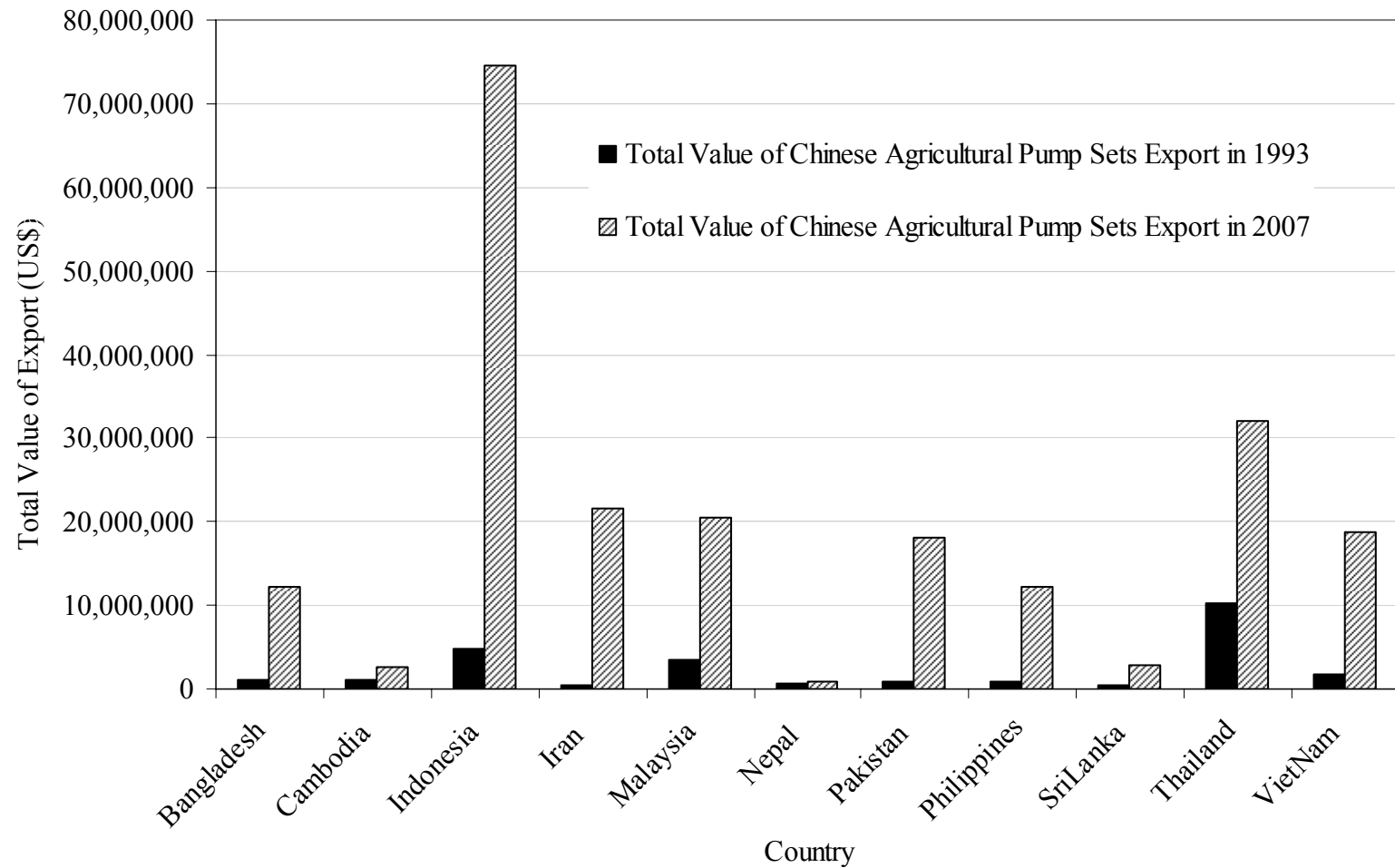


Figure 3. Total value of Chinese agricultural pump sets export in 1993 and 2007

Note: The value of export in 2007 does not include export in December 2007 since the data was not available at the time. Dollar amounts are adjusted using consumer price index.

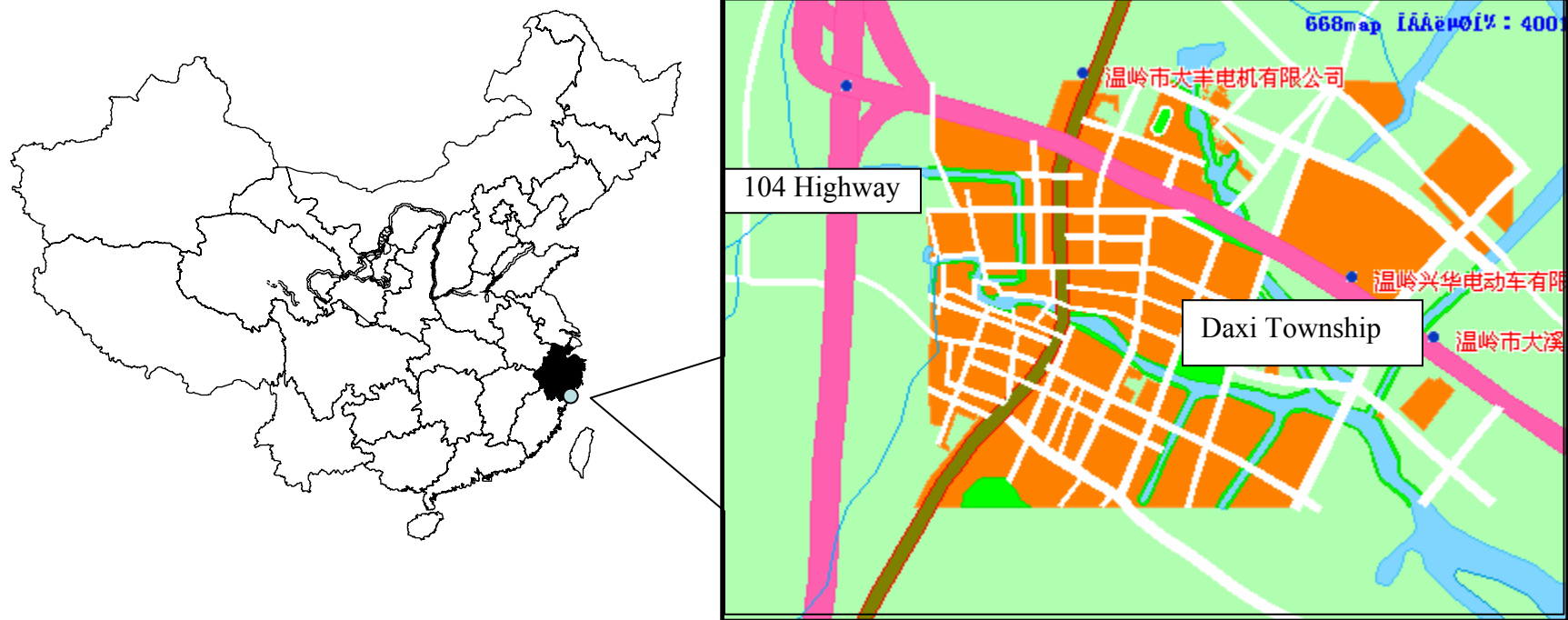
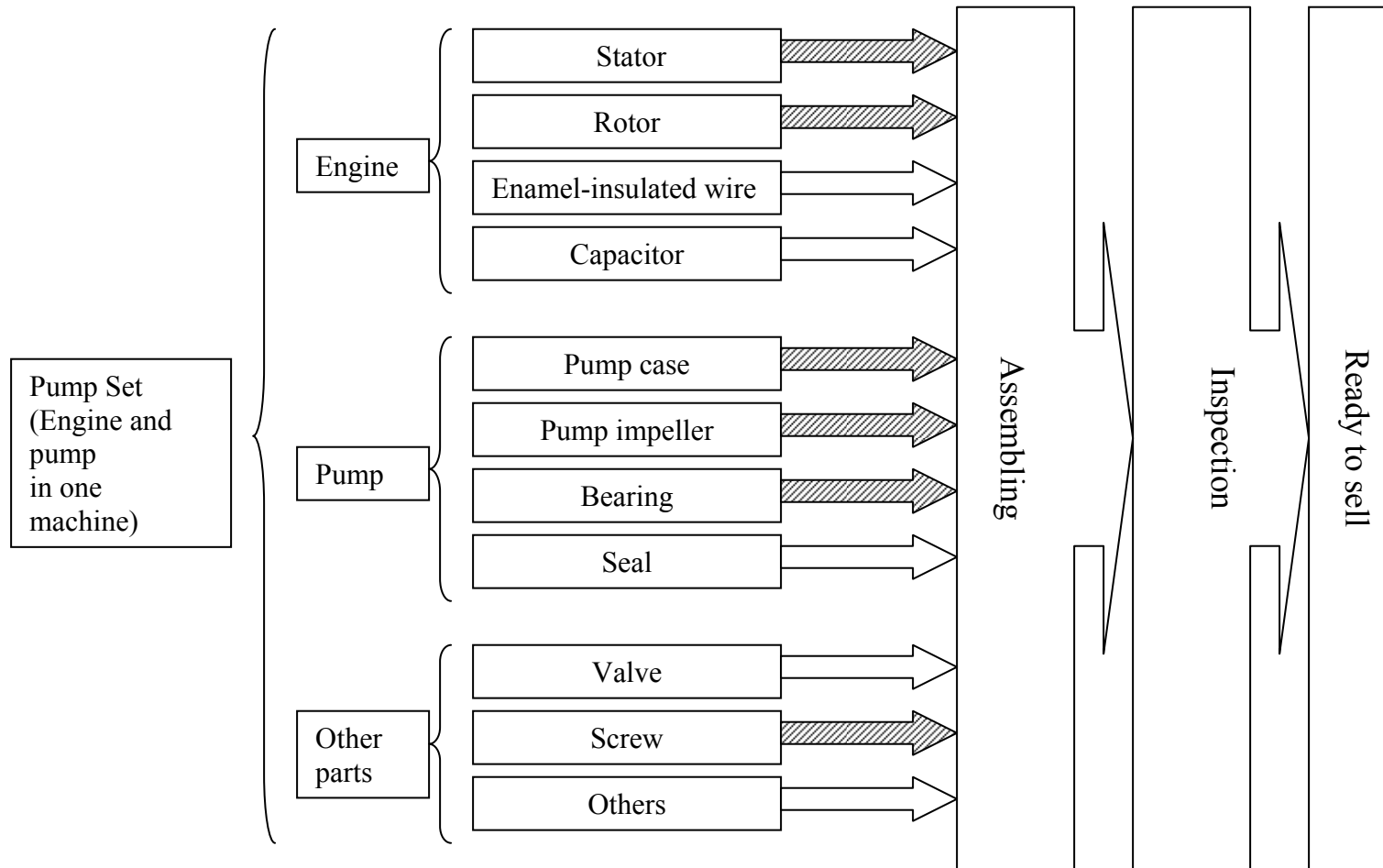


Figure 4. Location of Daxi Township

Diagram 1. Parts of a typical pump



The processing procedures for the parts marked with

