Chapter 14

CHANGING PRIVATE AND PUBLIC ROLES IN TECHNOLOGICAL DEVELOPMENT: LESSONS FROM THE CHILEAN FRUIT SECTOR

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Technical change is widely accepted to be the basis of sustained agricultural progress. Since private investors can capture only a small part of the benefits of many types of research, given the public-good nature of much of the knowledge so produced, public intervention is warranted. Although intervention does not require public research, it is usually suggested that most agricultural research should take place in public institutions. Much work has gone into strengthening "public" research institutions in the less-developed world. In recent years, however, evidence is growing that private agricultural research and development (R&D) is more important than previously expected, e.g., Trigo and Piniero (1981), Evenson and Evenson (1983), Pray (1987) and Pray and Echeverría (1991). This evidence suggests need for understanding the determinants of private agricultural R&D activities, for understanding how private and public activities relate and for more explicit attention to coordinating them.

This chapter analyzes the R&D roles of the public and private sectors in the growth of the Chilean fruit industry. Chilean temperate fruit exports grew at a compound rate of nearly 20 percent annually during the past 18 years, from about US$40 million in 1974 to nearly US$1 billion in 1991 (in 1991 US$). An important aspect of this unusual success was the rapidity with which Chileans were able to transfer, adapt and extend fruit technologies, initially developed for California and other fruit growing regions, to Chile. Moreover, and surprisingly so, although the public sector was responsible during the 1960s for developing the scientific expertise and the technological base that initiated the fruit sector’s growth, the private sector was the motivating force for the substantial, varied and broadly diffused technological advances which occurred after 1974 and which have been directly associated with Chile’s expansion into international markets.

The prominent early role of the public sector was consistent with expectations. The shift to the private sector was not. Moreover, the increase in private research activity within the fruit sector seems to have been an exception even in Chile, where public research expenditures in agriculture have greatly dominated private expenditures during the past four decades. The World Bank (1991) calculates that the National Agricultural Research Institute (INIA) accounted for the bulk of total expenditures, ranging between 73 and 88 percent from 1970-90. In 1990, total agricultural research amounted to about US$19 million and, of this, private research amounted to only US$200,000. However, the private-sector figures clearly exclude the research and development activities, whether formal or informal, of private firms in
the fruit sector. The private activity documented in this chapter will suggest that persistence is required to quantify private R&D efforts in agriculture in order to report them on a basis comparable with those of the public sector.

But why was the private sector motivated to undertake so much technological learning after 1974, how did it accomplish it and why did the public sector reduce its activity? Was this shift in sectoral roles desirable? Are the roles likely to shift again and, if so, in what ways? What implications does the Chilean experience have for technological policy in other countries?

Technological advances in the Chilean fruit sector were achieved mainly in orchard management and post-harvest technologies, which had a largely public-good nature. Thus, patents and breeders' rights legislation played little role in determining who carried out research and developing activities. This chapter argues that the shift in the sectoral locus of technological activity was caused mainly by changes in price relationships and in industry structure, which increased the returns to private R&D, greatly increasing the amount of private activity. My explanation of Chilean fruit technology development fits closely with the analytical framework proposed by Pray and Echeverría (1991) to explain the level of private agricultural research and development. Although the first version of this chapter was written independently, this version benefits from their insights.

The high adaptability of foreign technology and the relatively simple, well understood and thus low-cost nature of the research required to achieve technological advances in Chile facilitated private activity. Government policy after 1974 also specifically discouraged public-sector fruit research, with positive and negative implications to be discussed.

After 1974, a military government implemented extensive domestic economic reforms, opening the Chilean economy to foreign trade and removing many economic distortions. Fruit production became much more profitable and with it, the profitability of private fruit-related R&D. Market structure also played an important role in making private R&D profitable, especially the monopolistic imperfections which allowed fruit exporters to capture a greater share of research benefits. Such imperfections were largely caused by the "immature" condition of the fruit industry. These imperfections were otherwise undesirable and the higher private research activity they induced was not necessarily optimal.

As the Chilean fruit industry grows and matures, product and factor prices are becoming less favorable, market imperfections are diminishing and the research issues confronting the industry are becoming more complex and costly. These changes will systematically reduce the returns to private fruit-related R&D. To ensure that the socially profitable amount of fruit-related R&D is achieved, increased public intervention will be needed. Since private firms should continue to have an advantage in R&D activities at the more applied end of the technology spectrum, coordination between private and public R&D activity should become a central element in technology policy (Evenson 1983, Pray and Echeverría 1991). The importance of maintaining a well functioning market to guide and motivate private-sector activity also warrants emphasis.

Following this introduction, section 14.1 provides a brief background, section 14.2 discusses the public sector's early crucial role in developing scientific expertise and basic infrastructure, section 14.3
points to the effect of market and institutional reforms, section 14.4 analyzes the processes used to transfer, adapt and extend important foreign technologies, section 14.5 analyzes the research incentives facing different private actors, section 14.6 discusses the effect of private-public sector interaction on the research undertaken, section 14.7 suggests the private sector research was temporarily quasi-optimal during the fruit boom and section 14.8 offers conclusions and draws lessons for technological policy in Chile and other countries.

14.1 BACKGROUND

Chile sporadically exported fresh fruit to the United States and other Latin American countries during the first half of this century. Exports began to grow steadily during the 1960s, stagnated from 1972–74 and then grew more rapidly after 1974 (Figure 14.1). The area planted to commercial orchards rose from about 65,000 ha in 1965 to 190,000 ha in 1990 (Figure 14.2), while fruit production rose from about 0.5 Mt to 2 Mt (Figure 14.3). Fresh fruit exports also rose as a proportion of fruit output, from about 10 to more than 50 percent. An additional 25 percent is now exported in processed form (juices, pulps, frozen and dried fruit), adding US$200 million. The fruit sector now produces 20 percent of agricultural output and employs 25 percent of agricultural labor.

[Figures 14.1, 14.2, 14.3]

Seasonal complementarity has facilitated Chile’s success. As a result of its southern hemisphere location, Chile’s main fruit harvest occurs during October–April, and its exports arrive in northern hemisphere markets when little fresh temperate fruit is domestically supplied. Chile also has exceptional natural conditions, including a range of excellent climates, fine soils, good water and a relative absence of major pests and diseases. Chile’s ports are located close to growing areas, allowing fast and low-cost transport. Chilean farm labor is inexpensive.

Chile competes with other southern hemisphere countries, primarily Australia, Argentina, New Zealand and South Africa, which traditionally had substantially greater shares of this market than Chile. The exports of those countries have grown much less rapidly. Chile has become the major fresh temperate fruit exporter in the southern hemisphere, accounting for more than 50 percent of the total. Exports from other countries were constrained by several factors: phytosanitary barriers (the Mediterranean fruit fly in Argentina), poor economic policy (Argentina), political barriers (South Africa) and geographical/climatic limitations (New Zealand, Australia and South Africa). These factors—some natural and some created by domestic policies—allowed Chile to acquire a virtual monopoly on table grape exports to the United States (more than 95 percent of total U.S. imports). In other fruits and in other regions, Chile’s exports had a smaller, but nonetheless rapidly growing share.

Chile based its early expansion on the export of table grapes, primarily to the United States. Grapes still account for more than half of Chile’s fruit exports, which remain concentrated in the United

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States and Europe, but Chile has steadily expanded its exports of other fruits and diversified its markets. Foreign demand has increased rapidly as foreign consumers shifted toward fresh, natural, more nutritious foods and as year-round fruit availability and improved fruit quality induced higher consumption. Technological change in Chile has been aimed as much at improving fruit quality as at reducing production costs and emphasis on quality has increased through time, precisely as a means of stimulating foreign demand. Many California producers encouraged and assisted Chilean fruit development, expecting that fruit availability during the winter would induce new habits leading to higher consumption of domestic fruit as well. Clavier (1991) presents evidence that this has occurred. Nonetheless, some California producers successfully pushed for changes in the U.S. Grape Marketing Order which imposed minimum quality standards and time limit on the Chilean imports during the Spring. These restrictions encouraged quality improvements in Chilean grapes.

14.2 THE CRUCIAL EARLY ROLE OF THE PUBLIC SECTOR

A qualitative change in the fruit industry occurred in the 1960s when the government instructed the National Development Corporation (CORFO) to design and implement a national Fruit Plan. Some of Chile’s best young agronomists and fruit experts were recruited to CORFO, where they elaborated this plan between 1962 and 1965. Implementation began in 1966, including (a) a cadaster of existing fruit orchards, which determined the area planted to different varieties and estimated future output, (b) analysis of potential demand in foreign markets and elaboration of production goals, (c) introduction and screening of new varieties, mainly from California, (d) establishment of nurseries to propagate disease-free plants, (e) construction of four cold storage facilities at strategic locations to improve post-harvest care, (f) phytosanitary inspection of exported fruit, (g) establishment of favorable credit lines for orchard investments and working capital and (h) “drawback” payments for fruit exports.

Nearly simultaneously, in 1965, a ten-year program (Convenio) was established between the University of California and the University of Chile to permit technical cooperation and improve graduate training. The Convenio, which was encouraged by the Alliance for Progress, was financed largely by The Ford Foundation. Fruit production was selected as an emphasis because Chile was believed to have a comparative advantage in fruit production. California had a similar climate and substantial scientific expertise. Numerous Chilean students and faculty received graduate training at the University of California, mainly at the Davis campus, while University of California faculty taught and undertook fruit research in Chile. The Convenio enabled the University of Chile to establish a first-rate faculty in the fruit-related sciences, to update the curricula of its teaching programs and to begin modern fruit research. Spillover effects strengthened government agencies and other universities. The ties established between academics in Chile and California also greatly facilitated technological transfer thereafter.

In 1964, Chile established INIA to replace the research division of the Ministry of Agriculture. INIA’s semi-autonomous nature allowed it to pay higher salaries and thus attract and maintain mor
skilled researchers and gave it greater flexibility in carrying out research. INIA initiated a fruit research program in the late 1960s.

The accomplishments of the 1960s were significant. Although much of the planning and infrastructure investment was crude by today's standards, Chile developed the scientific personnel and knowledge to achieve technological transfer; identified and began to plant new varieties suitable for foreign markets, especially the United States; improved orchard and post-harvest management; upgraded fruit research and teaching; developed the infrastructure necessary to export fruit to foreign markets; and altered government policy to increase the profitability of fruit production and export. The bulk of these developments was carried out by the public sector. In response, area planted and yields began to rise. Exports grew by nine percent annually from 1962-70. A core of modern fruit producers and several fruit export companies emerged and gained familiarity with foreign markets. Chilean firms, which previously shipped fruit on all-purpose liners plying south-north trade routes, achieved the volume needed to charter special fruit cargo ships. Improved fruit handling, better cold storage management and ship scheduling and reduced transit time, allowed fruit to reach foreign consumers in better condition (CEPAL 1990).

14.3 ECONOMIC POLICY CHANGES SET THE STAGE

Significant growth in fruit exports occurred in the 1960s despite the disruptive nature of major economic and social reforms carried out in Chile's rural sector. Implementation of land reform between 1965 and 1970 resulted in the expropriation of nearly 20 percent of all agricultural land (in productive value). Although farms with commercial fruit orchards were usually spared expropriation, uncertainty inhibited private investment and the government had too little capital to initiate fruit investments on expropriated land. Rural labor unionization and pro-strike laws introduced in the same period made labor use more costly and more risky. Other barriers to fruit development remained important throughout this period, such as import quotas and high tariffs, slow and inefficient transport and port handling and bureaucratic red tape. That the fruit industry progressed so much within such a context indicated its great potential.

Conditions for fruit production worsened during the early 1970s when a Marxist government implemented economic policies that led to higher inflation, currency overvaluation, goods shortages and black markets. Uncertainty rose. The government imposed foreign exchange controls, including an unfavorable rate for fruit exports, land reform was extended, political confrontation increased and economic and political events became more chaotic. Although fruit exports declined, newly planted orchards matured and the industry continued to gain experience.

In 1973, a military coup imposed an authoritarian government that quickly moved to liberalize markets and reduce government intervention (e.g., Ramos 1983, Edwards and Edwards 1987). Land reform ended. These policy reforms made fruit production more profitable and secure. A sharp peso devaluation in 1974 significantly increased the domestic equivalent of foreign fruit prices. Quota
restrictions on imported inputs were relaxed and, beginning in 1976, import tariffs were quickly cut from an average of 96 percent to a uniform level of 10 percent. Export procedures were also streamlined. Rural labor unions were effectively proscribed and labor could be fired at will. Real wages fell significantly, reducing labor costs. The policies described had high short-run costs, including high unemployment and a worsening distribution of income, particularly in agriculture (Jarvis 1985). Policy error caused two sharp economic contractions (e.g., Ramos 1984, Edwards and Edwards 1987), which delayed economic growth for a decade. The military government was guilty of serious human rights violations and general political repression. Still, the policy reforms of the military government led, in the longer run, to a more efficient economic structure that is now producing more rapid growth in GNP and higher employment. Real wages have begun to rise. Primary reliance on the market as an allocation mechanism is widely accepted today in Chile.

Fruit production became dramatically more profitable after these changes. For example, relatively accomplished table grape growers earned US$10,000 to US$15,000 net income per ha in the mid-1970s. Land, if not already owned, cost only about US$1,000 per ha and planting (including vine support structures) cost about US$3,000 per ha. Annual maintenance costs from planting to maturity were about US$1,000 per ha; production occurred in the fourth year. Total investment costs were easily recovered in the first year of production. Table grapes were highly profitable, but kiwis were even more so. Kiwis were introduced to Chile from New Zealand in the early 1980s. After an investment similar in magnitude to that required for table grapes, one of the pioneering producers reports having netted more than $150,000 per ha in the first year of production. This was an example of the exceptional returns to innovation.

Profits declined from this heady level as output rose, but remained high. Real foreign prices increased in the late 1970s. This increase was temporarily offset at the producer level by an appreciation in Chile's real exchange rate. Chile then sharply devalued again in 1982, causing still-higher domestic prices and stimulating fruit investments. Only in the late 1980s did foreign prices weaken and the Chilean currency appreciate again (Jarvis 1991). Even then the more efficient producers continued to earn attractive profits. Estimates of the real rate of return expected by a good, but not exceptional producer over the investment life of an orchard from the late 1970s to the late 1980s generally ranged from 25 to 50 percent. A variety of Chilean trade journals during the past 15 years have published estimates of the return to different types of fruit investments under varying conditions.

In response to such high profitability, investors sought land on which to plant fruit. Aided by the previous land reform, a dynamic land market emerged. Prospective fruit investors had easy access to land after decades in which such access had been difficult (Bauer 1975). The bulk of the previously expropriated land had been sold to rural laborers on long-term credit. Many of these land reform beneficiaries, who were short on capital and expertise, sold their parcels as land prices rose. Harsh government policy toward the beneficiaries encouraged such sales (Jarvis 1985). Numerous large farms, which had been partly reconstituted when land reform was ended, were also subdivided and sold, either
as their owners sought capital to intensify production or because the owners, aging or exhausted from the battle over land reform, chose to exit.

The area planted to grapes grew more than 10 percent annually from 1975–85. Output followed, initially as the orchards planted in the late 1960s matured and subsequently as large new investments came into production. Yields also rose and fruit quality improved.

Fruit exports had increased significantly during the 1960s, but that increase had occurred without a large change in the total area planted. Since prior exports were small, exports could grow rapidly as new area came into production, as yields rose and as existing output was diverted from the domestic market. After 1974, however, the evolution of fruit area planted and production both followed the "logistic" pattern commonly observed in the diffusion of new technologies (Figures 14.2 and 14.3). This pattern suggests that the high profits available after 1974 caused a qualitatively different type of fruit expansion.

14.4 THE TRANSFER, ADAPTATION AND EXTENSION OF FOREIGN TECHNOLOGY

Fruit is a highly perishable crop and its value is strongly related to fruit quality. The production, packing, fumigation, cooling, storage and transport of fresh fruit is a complex, demanding process requiring timely, precise execution of many tasks and the coordination of numerous agents. The risk associated with fruit production and marketing was unusually high in Chile, given the high concentration of total sales in foreign markets thousands of miles distant, which required that fruit be kept stored in cold storage for long periods.

To increase production, expand foreign sales and reduce risk, Chile improved technology at all levels of the production and marketing chain. Important advances took place in domestic transport, port operation, international shipping, banking and telecommunications as well as in all aspects of fruit production, packing and cold storage (CEPAL 1990). A sense of the different types of technological advances achieved and the channels used, can be given by discussing several of the more important technologies involving the production and post-harvest care of table grapes, Chile’s most important fruit export.

First, a significant proportion of table grapes rotted in transit abroad as a result of infections such as Botrytis cinnerea, a fungus prevalent in orchards. Botrytis can be controlled by gassing with SO₂, but one treatment was insufficient for a long voyage and it was impossible to gas on ships because SO₂ use leads to damage of steel. In 1969, a CORFO official encountered experiments in California with small pads that released SO₂ gradually in response to rising humidity. If a box of fruit was encased in a plastic bag, the low, but continuous dose of SO₂ could control botrytis for a longer period and fruit humidity was conserved in the process. Since California fruit generally was stored for shorter periods, the technology was of less commercial interest there. CORFO carried out experiments in Chile and a Chilean exporter, David del Curto, observed the results. The next year Del Curto shipped all of his table grapes
with SO\textsubscript{2} pads. Chilean firms obtained the license to produce the pads, improved their design and fruit loss to botrytis was reduced, increasing returns and reducing risk.

Second, U.S. regulation required the fumigation of Chilean grapes with methyl bromide to ensure against the introduction of insect pests, especially the Mediterranean fruit fly. Fumigation was initially carried out at U.S. ports under quarantine. As import volume increased, there was insufficient capacity to fumigate without long delays. U.S. and Chilean officials agreed to move fumigation to Chile. Initially done in Chilean ports—where delays were also often long, Chile's National Institute of Technology (INTEC) incorporated fumigation into the cooling tunnel (a variant of California technology) as the temperature was brought down to zero degrees, speeding transit and allowing for continuous cold storage until sale.

Third, because early season grapes received premium prices, Chilean producers planted grapes increasingly to the north, in warmer climates. The lack of water in northern desert regions limited production to river valleys. Chilean producers developed sophisticated drip irrigation systems to expand planted area higher up on the surrounding hills. Much of this technology was imported, but significant adaptation was carried out in Chile.

Fourth, Chilean grape varieties were seeded, thin-skinned and prone to damage and rot during packing and storage. They were also unfamiliar to and unappreciated by U.S. consumers. Chilean varieties were replaced by California seedless varieties (e.g., Thompson, Flame and Red Seedless). Growers had to identify appropriate production areas and management practices. For example, a major problem with seedless varieties is the irregularity of the bunch, including small, round grapes, compared to the regular bunches of longer, larger grapes preferred by the U.S. consumer. Chile adapted technologies developed in California such as the timely application of chemical growth regulators and changes in pruning, thinning, irrigation and fertilization techniques to achieve the desired bunch shape and grape size, shape and color. The Chilean grapes exported in the early 1970s averaged about 12 mm each, while those exported today have a 17 mm minimum standard and many exceed 20 mm. The scientific principles underlying the advances described were well understood when the California varieties were introduced to Chile, but techniques fitting Chilean conditions had to be developed and then learned by farmers and their workers.

These four examples suggest the varied channels used to transfer and develop fruit technology. Each example involved adapting foreign technology. The first was identified by the public sector, but further developed by Chile's private sector. The second was designed by a public research corporation, working in close cooperation with fruit exporters, and Chilean and U.S. officials. The third was designed by fruit producers themselves, with help from domestic and foreign irrigation specialists. The fourth, and by far the most important, consisted of many small, interrelated adjustments. It too was carried out by the private sector, i.e., the technical divisions of fruit exporter, chemical companies and fruit producers. Although such technological advance was of a type for which public research would normally play the primary role, that sector played a clearly secondary role. University researchers and their students participated in this research, but their work was usually financed by private firms and the
results were kept confidential for a significant period. Even this work thus had more a private than a public character.

Foreign technology generally worked well in Chile. Chile based its development on the internationally available menu of plants, screened them for performance, selected the best for each local production environment and then fine-tuned production and post-harvest technology. Due to the variety of environmental niches, considerable adaptive research was warranted to fit imported technologies to local conditions. Relatively small technological refinements, often specific to a single crop and region, offered a significant increase in producer profits.

Chilean conditions did differ from those in California in two important respects. First, Chile faced greater transit times from farm to consumer. While most fruit harvested in California reached consumers in about a week, Chilean fruit required three to five weeks to reach consumers, during which time undesirable physiological changes in the fruit were more likely. Chileans thus eventually selected a number of Californian varieties other than those used most frequently in California (e.g., a different variety of Thompson Seedless grape, which travelled better than the variety used in California), harvested fruit at different stages of maturity and implemented more sophisticated post-harvest technologies. Second, Chilean labor cost much less, about one-tenth as much. Labor use can greatly affect fruit quality. Thus, Chilean technologies became more labor-intensive, with a focus on preparing fruit to be more attractive to the consumer and to maintain quality during storage.

14.5 HOW AND WHY THE PRIVATE SECTOR ACHIEVED SO MUCH TECHNOLOGICAL LEARNING

The main force behind technological progress was the quest for high profits. Export firms played the major role. The largest exporters benefited from a number of market imperfections which encouraged them to take on tasks that might have been left to other actors under different conditions. These firms enjoyed preferential access to capital, economies of scale, asymmetric information regarding the relationship between fruit technology and fruit prices in foreign markets, lower transactions costs when providing growers multiple services, and monopsony power.

David del Curto, perhaps the most visionary and entrepreneurial of the exporters, played a particularly significant role in establishing a competitive strategy. Recognizing the high profits available in fruit marketing, Del Curto set out in the mid-1970s to convince Chilean farmers that fruit production was good business. He sponsored technical talks to growers up and down the countryside by foreign fruit specialists that he brought to Chile, as well as by domestic fruit specialists. He offered growers technical assistance to plan, plant, manage and harvest fruit, provided long-term investment capital (most of which he obtained from abroad, given the capital shortage in Chile) and signed profitable contracts for the fruit to be harvested, including attractive cash advances for working capital. The major remaining obstacle to fruit expansion was the shortage of capital. After financial reforms were introduced in 1975, real short-run interest rates for agricultural loans, historically negative, rose to 65 percent. Long-term credit
was unavailable from financial institutions. As long-term bank credit became available in the late 1970s, real long-run interest rates for fruit investments remained in the range of 14 to 20 percent. Fruit exporters obtained access to cheaper credits through foreign banks, sometimes assisted by foreign receivers who were making large profits from selling Chilean fruit.

A prospective grower could thus obtain nearly everything needed from Del Curto, reducing the transactions costs and the risk inherent in entering fruit production, but did pay a price. Exporters earned a commission on fruit exports sold, received payment for a variety of inputs and services provided growers (including technical assistance, finance, chemical inputs, materials used in fruit packing, cold storage and domestic and international freight) and—for a substantial period—"took a piece of the action" on final sales.

This competitive strategy was quickly copied by other major export firms. Firms competed as much by offering growers better technology and technical assistance—a scarce resource of crucial importance to many producers who were just learning the ropes of fruit production—as by offering a higher price. Most fruit producers took up the enterprise in the past 18 years. The regular fruit cadastres carried out since 1965 indicate that there were about 8,000 fruit producing units in 1965 compared with about 14,000 in 1992. Moreover, few producers in 1965 had modern technical skills and most produced only for the less-demanding domestic market. To compete, exporters hired technical staff and established technical divisions (generally within the rubric of "quality control"). They attracted outstanding fruit professionals from the universities, CORFO, INIA and the Ministry of Agriculture, and also paid attractive consulting fees to those fruit experts remaining in the public sector. They hired foreign fruit experts to provide expertise missing in Chile, and even contracted out research to foreign universities. Exporters rapidly snapped up the best Chilean university graduates specializing in fruit-related sciences, and sent staff on trips abroad, primarily to California, in search of new technologies which might improve the competitive advantage of the firm. Although Chilean exporters enjoyed substantial interaction with foreign receivers, including many technological suggestions, all of the major export firms were Chilean owned until the late 1970s. Two foreign-owned export firms were then created, partly to take advantage of special market access to the Middle East and Europe. In the 1980s, several multinational firms purchased several large Chilean fruit exporters which had fallen on hard times. It does not appear that the technological practices of foreign and domestic exporters have been distinct.

Exporters were able to capture a significant part of the benefits from the development and diffusion of new production and post-harvest technologies, and thus had considerable incentive to pursue them. Increased volume led to higher earnings on inputs sold, freight and commissions, and higher prices were also likely to bring gain. The value of research would rise further if the exporter produced part of the fruit that it marketed. Anecdotal evidence suggests that the largest 10 exporters (and their owners, as individual producers) own 10 to 20 percent of total fruit area. Although other producers export their own fruit, most do not handle the fruit of others.

The exporter generally acted as agent for the producer, who retained fruit ownership until sale and received the residual proceeds after costs, including commissions. Since the exporter had much
better information than producers about market conditions, exporters could appropriate part of any price increase achieved by a new technology simply by declaring a different sale price. The producer received information only through the exporter or informal sources such as conversations with other producers regarding the prices they received. Since prices depend strongly on fruit condition at the time of sale—which is not necessarily correlated with condition at the time of shipment, and since the price of fruit of a given condition can vary significantly within the same market from hour to hour and across markets at any point in time, it was difficult for producers to verify sales information provided by exporters. The known high margins enjoyed by export firms encouraged many producers to integrate vertically. They invested in packing plants and formed their own export firms in an effort to reduce costs and obtain better sale prices. Sales concentration ratios have decreased, although the largest 10 exporters still account for about 70 percent of total exports. As a result of increased competition, farmer experience, and efforts by farmers to systematically pool market information, sales transactions are becoming more "transparent" in recent years.

Large exporters also could more easily identify where research would be profitable, particularly to the extent that it permitted production of new varieties, extended the season of existing varieties, or improved fruit quality. Exporters directly observed both the relation between price and fruit quality in foreign markets, and also the changes that took place in fruit physiology throughout the production and marketing cycle. They could relate the changes that took place in storage, which producers did not see, to prior production and harvest decisions. Exporters also employed professionals familiar with modern fruit science, who knew that technological advances could be obtained through rather simple applied research.

Given the ease of disseminating techniques, the knowledge developed through research was quickly diffused through the fruit sector. Many growers sold output through two or more exporters, both to draw on the technical expertise of each and also to obtain a more competitive price. With regular visits by technicians from two or more different exporters (plus, often, a privately contracted agronomist), any new technology of significant importance was likely to be known and widely used within a year or two. Nonetheless, a significant technological lead could justify the relatively low costs of much research. To the extent that an increased supply of improved quality fruit caused lower wholesale prices, U.S. consumers benefitted both from the transfer of California technologies to Chile and also from the Chilean research required to adapt them. Jarvis and Clavier (1991) suggest, using a partial equilibrium total surplus framework, that U.S. welfare was increased more than Chilean welfare by Chilean fruit development.

Exporters charged a commission (usually 8 percent) on the FOB price; the FOB price was approximately equal to the wholesale price in foreign markets, less international freight charges. During the period of most rapid fruit sector growth, exporters were able to declare a lower sales price to producers than actually received, thus effectively charging an additional, unrecognized commission which could vary across producers and with the sale price. Exporters also leased space on fruit cargo ships (or established their own shipping lines), which they then sold at a profit to producers, and sold producers
a wide variety of other production inputs (e.g., technical assistance, fertilizer, growth hormones, packing house materials, domestic freight and finance).

By developing improved production and post-harvest technology, the firm increased the volume handled and improved the prices of the fruit it sold, ceteris paribus. First, the volume handled by the firm increased as farm yields increased, as the exportable proportion of its producers' fruit increased and as additional producers were attracted because of its ability to offer them improved financial results, i.e., higher yields, better quality fruit and a better unit price. Second, the absolute value of the exporter's commission rose approximately proportionately with the foreign wholesale price, which was closely related to fruit quality on arrival. Rough calculations suggest that the export firm directly captured about 10 percent of any wholesale price increase (in foreign countries) brought about by improved technology. Since the wholesale price was more than twice the producer price, and since the exporter handled the fruit of many producers, an individual exporter handled up to about 10 million boxes annually in the mid 1980s. A box commonly sold at a wholesale price of about US$15, but could easily vary US$5 around this level. This gain could be significant.

Improved technology worked to reduce foreign prices to the extent that it increased total fruit output. Chile had a near monopoly on grape sales in the U.S. winter market, supplied a substantial fraction of winter fruit in other markets, and did not face an perfectly elastic export demand curve (Clavier 1991, Jarvis 1991). However, at the level of the individual export firm, any tendency for new technology to decrease price through rising output seems to have been offset by the competitive advantage technology provided vis-à-vis other firms. Indeed, even at the aggregate level, foreign prices did not significantly decline until the late 1980s. Not surprisingly, exporters concentrated on expanding the supply of fruit until the early 1980s. As volume began to rise more rapidly, concern over market saturation increased and exporters began to focus on achieving higher quality fruit to spur demand.

Farmers generated technology mainly through learning by doing, "a by-product of production activity rather than of explicitly assigned R&D programs." High profits doubtlessly focused farmers' attention in a way that led to a more rapid rate of learning. The quote is from Teitel (1984) in reference to technological change in Latin America manufacturing activity. The "newness" of Chilean fruit producers probably facilitated technological progress since new entrants generally lacked technological preconceptions and accepted the need for professional assistance, but it also restricted the amount of technological generation achieved by farmers. An important distinction should be made between farmers' learning to implement the new technologies which they adopted, which was considerable, and their development of new technologies, which was much less. Many continued to adjust and refine the technologies they adopted as they and their workers gained experience, but most producers had insufficient expertise to undertake any type of formal R&D and insufficient volume to have made such investment profitable in any event.

There is an important core who have produced fruit for 25 years or more, but most of Chile's fruit producers took up fruit production in the relatively recent past. Many were even new to farming, being urban residents attracted by the fruit boom. At least originally, these "new" fruit farmers accepted
technology as it was communicated to them (or directly to their employees). Many hired administrators to manage their day-to-day operations, and relied on consulting agronomists or fruit exporters for technical assistance. Some obtained technological information from domestic seminars and short courses, or sent their administrators and middle-level technical employees to similar training courses. A growing number of farmers travelled abroad in search of new technologies and some even sent their administrators abroad to learn techniques at first hand, recognizing the tacitness of much technology (Nelson 1987, 1990).

All of these activities improved on-farm productivity, though most are better characterized as knowledge acquisition than knowledge generation. However, a few producers, usually resident owners having a hands-on, scientific approach, systematically refined their production system to the point where their products are of extremely high quality and their costs are quite low by international standards. Even here it is difficult to judge whether some fundamental aspect of the technology or simply its management improved, but some of this represents an improvement in usable technology (Evenson 1983). Such advances have increased productivity on individual farms. However, because Chilean farmers do not usually share technical or commercial information with one another, such advances have not spread widely. The learning achieved by individual farmers has spread mainly when independent technical advisors have observed and communicated it to others. The technology transfer groups initiated by INIA in the 1980s, discussed later, also had positive effects.

Each of the large international chemical companies and their Chilean distributors—producers of fertilizers, pesticides and growth hormones—developed substantial technical departments to undertake formal trials to demonstrate their products’ effectiveness, to formulate recommended applications and to obtain domestic licensing. Like the fruit export firms, they hired university faculty and INIA staff to help design and evaluate some trials. Although such efforts have been more narrowly focused, they have also contributed to advances in "usable" technology.

14.6 PUBLIC RESEARCH AND PUBLIC-PRIVATE INTERACTION SINCE 1974

Despite the rapid growth of fruit output and the increased demand for improved fruit technology after 1974, public research in the fruit sciences has certainly increased little and may even have declined. Research was restricted both by the withdrawal of skilled expertise—which was bid away to the private sector and also by a reduction in government support for research and development. Given the demand driven nature of the fruit boom, it is not surprising that the private sector began to bid scientific expertise away from the public sector as soon as the boom began. The government facilitated this shift of human resources by cutting public-sector budgets in the mid-1970s, with further cuts to university and INIA budgets in 1980 (World Bank 1991). The government also granted university faculty increased latitude to seek outside income. Finally, and somewhat paradoxically, INIA researchers were instructed not to utilize public funds for research on the major fruit varieties being exported.
The shift in government research policy was part of a generalized effort to encourage private as opposed to public activity, mainly driven by ideology. The military government cut university budgets believing that many students and faculty had leftist political leanings. It also argued that in an era of fiscal stringency public funds should be spent on primary and secondary rather than on university education. However, the government hoped to encourage public researchers to forge closer ties with the private sector, expecting that such ties would lead to better utilization of researcher’s talents and to greater private-sector support for fruit research. Indeed, in explaining the shift in INIA priorities, policy makers argued that producers rather than the public should pay for fruit research since it would primarily benefit the producers.

These policies did contribute to a shift in resources from the public to the private sector, with mixed effects on fruit research. Although nearly all MS and PhD degree holders were employed in the public sector prior to 1974, it is estimated that only one-third are so employed in 1992. A survey of Chilean fruit scientists undertaken to determine the evolution of their employment and research activities during the past three decades indicates a continuing shift toward the private sector and toward "private" activities among public-sector employees. Figure 14.4 depicts the shift in sectoral allocation of human resources in a stylized manner. There was a substantial increase in the growth of such degree holders in the 1960s and early 1970s, but few Chileans began graduate training in the fruit-related sciences in the late 1970s or the 1980s. The universities and INIA paid low salaries, lacked research funds, offered little institutional reward for research accomplishments and few fellowships were available to finance graduate work abroad. The best students went directly to the private sector, which offered rapid advancement, responsibility and high pay.

[Figure 14.4]

Much of the scientific expertise that made its way to the private sector worked in areas other than research. However, the broader presence of such expertise enabled the sector to appreciate the potential gains from research and led it to establish an institutional framework to achieve these gains. The private sector had lower transactions costs in some aspects of the knowledge generation process, mainly related to the private character of information which often allowed it to identify specific problems, seek practical solutions and diffuse the results more rapidly and effectively than the public sector could have done, even had the latter been more fully funded. Moreover, individuals with scientific expertise were highly productive in other areas, such as in the promotion of fruit production, providing technical assistance and in marketing and administration. The Fundacion Chile, established in 1977 to identify and develop new business ventures in Chile, is a quasi-private institution (Meissner 1989). The Fundacion Chile does not engage in research, but employs several well qualified fruit experts and has made important contributions to the fruit industry, including the introduction of several types of berries and a quality control program for fruit exports.
Those fruit specialists who remained in public institutions also reallocated their time, dedicating more to "private-sector" activities, e.g., offering short courses, providing technical assistance and consulting on private research—for a fee, as well as in starting and managing their own orchards. As university salaries were low, some 25 to 30 percent of those available in the private sector for persons with similar qualifications, the pressure to seek outside income was great.

The increased contact between university faculty and the private sector did broaden faculty expertise, increase their ability to understand the practical needs of farmers and exporters and enable them to communicate knowledge of a more practical and timely value to students. The number of students specializing in fruit-related sciences increased greatly and the availability of well trained graduates played an important role in industry expansion. Teaching is considered the main responsibility of university faculties. Research is deemed desirable to the extent that it improves university teaching (World Bank 1991). However, the amount and character of public-sector research also changed. In the universities, faculty probably spent less total time on research as their other activities increased. Supervision of student theses required for the Ing. Agr. degree absorbed significant faculty time and became an important source of research output (Table 14.1). Nonetheless, faculty generally shifted their research even more toward highly applied issues of short-run importance, often carried out on a contract basis for the private sector. World Bank (1991, p. 20) notes that "agricultural faculties do not attempt to set (research) priorities because they are extremely dependent on opportunities for external funding for projects."

Fruit exporters and chemical companies contracted university faculty and INIA staff to undertake applied research on specific problems and facilitated student research by suggesting topics to thesis advisors, arranging for on-farm trials and paying many research costs. Although private sector support resulted in additional research, probably of higher commercial value, it gave a growing part of shrinking public research a largely private character, since the results of such research were usually kept confidential or were published with a considerable lag. And, as research expertise was used to solve problems of private value, there was less available to address those socially profitable problems that the private sector did not find profitable.

Due to mandated priorities, INIA staff participated only marginally in the development of the technologies that were so important to Chile's success, though INIA did successfully introduce blueberries and several other minor fruits into fruit growing areas south of the central valley. For example, only in 1989 did INIA initiate a grape research program.

Chile had no national extension service when the fruit boom began and no such service was ever developed, leaving the private sector almost wholly responsible for diffusing information about new technologies and management techniques. In the early 1980s, INIA did implement an extension program to assist larger producers in identifying and transferring technology (GTT) and this program had a positive effect on the fruit farms involved. This effort consisted of using INIA staff to organize farmers into cooperative groups of about 10 farmers each, who then hired a private agronomist to assist them implement improved production and management techniques. About 700 medium to large producers were
affected. The effort introduced few truly new technologies, but is widely credited with increasing the diffusion of existing technologies and improving their utilization. The program largely ceased in 1990 when INIA was instructed to give priority to smaller farmers cultivating other crops. The National Institute for Agricultural Development (INDAP), which was charged with providing technical assistance and credit to small farmers (after 1978, land-reform beneficiaries were gradually included), had no specific fruit development program though it financed some fruit investments, with mixed results. Relatively few small farmers and land-reform beneficiaries became successful fruit producers. Most such beneficiaries were poorly educated and required significantly greater assistance in identifying and implementing the technologies required for the production of high quality fruit than did larger farmers. While many larger farmers also were initially ignorant about fruit production, the latter were able to identify and contract fruit experts who could provide them the needed expertise. Most small farmers could not and generally lacked the commercial sophistication to interact effectively with input suppliers, banks and fruit exporters. Small farm size was also a disadvantage as economies of scale in fruit production are important. Whatever their inherent disadvantages as fruit producers, small farmers received next to no assistance from the public sector.

14.7 THE TEMPORARY QUASI-OPTIMALITY OF PRIVATE RESEARCH

Guided by an extreme faith in the free market, the military government cut support for public-sector fruit research. According to conventional wisdom, total investment in fruit research should have fallen well short of the optimal. In Chile, however, the high profitability of fruit production, the relatively low cost and certainty of much of the applied research needed to improve fruit technology in Chile and the market imperfections that increased private appropriability research benefits, made private investment in the development of fruit technology unusually profitable. As a result, I conjecture that the research and development undertaken by the private sector was socially quasi-optimal for a time. Griliches (1958) noted that private returns to research could be sufficiently high to make public intervention unwarranted.

This conjecture can be illustrated with reference to Figure 14.5. Following Spence (1984) and Perrin (Chapter 27), a process-technological advance provides value insofar as its application permits future cost reductions in production. The present value of the future stream of cost reductions is a measure of the benefits of a particular technological advance. There is similarly a present value for investment costs.

[Figure 14.5]

Figure 14.5(a) portrays a number of potentially socially profitable fruit research projects, \( k_{s} \), for exportational purposes, each having identical net present social value as given by the difference between
the present value of future benefits, B, and costs, C. However, these projects differ in the private appropriability of their benefits. Line A indicates the present value of the appropriable benefits for a private investor, descending from projects whose output is a purely private good to those whose output is a purely public good. Individual private investors will undertake only k_p projects. The remaining projects, k_s - k_p, will be undertaken only if private appropriability can be increased, if multiple potential private beneficiaries can develop mechanisms to share investment costs, or if public intervention occurs.

In Chile, the unusually high profitability of fruit production shifted the benefits line upwards to B', the adaptive nature of research shifted the costs line downwards to C' and the market imperfections that allowed fruit exporters to appropriate a higher proportion of research benefits shifted the appropriability locus to A', as shown in Figure 14.5(b). As a result, the private sector undertook such a high proportion of the socially profitable research and development that, even assuming that the public sector undertook little of the remaining research, k_s - k_p, the social loss was not great.

Whether this is true depends on a number of difficult judgments regarding what the private and public sectors actually achieved versus what they might have achieved ideally given the resources available and good arguments can surely be made on both sides. Conversations with producers, exporters and public-sector researchers do suggest, however, a seemingly important list of problems that have not been undertaken to date. Most of these problems have solutions that cannot be achieved by simply adapting foreign technology. For example, Chilean fruit producers suffer significant losses from pests, diseases and plant nutritional problems whose economic effects in other countries are smaller. These problems have not been the focus of research abroad, and there is little technology to transfer. Chile might contract out some of this research to research institutions abroad, but there seems to be no inherent reason to believe that it would be more economical to do so. Moreover, efficient solution of these issues will require a systemic approach and that requires an important component of local research.

Sustainability is also becoming an important issue, and solutions to the problems appearing will require more basic research and also an important local component. Sustainability problems include salinization of the soil in Chile's northern regions, where there is insufficient water for leaching, soil compaction in table grape orchards in Aconcagua, and the gradual build-up of pesticide residues in several areas. Finally, research on plant genetics and fruit breeding is a complex and expensive area in which Chile is just starting research. Chile has been able to import fruit varieties from other areas, and will probably be able to continue importing varieties from California, given the apparent complementarity between the two regions. However, other Southern Hemisphere countries are likely to try to restrict

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1 In the graphical representation employed by Perrin (Chapter 27), research projects are ranked along a curve in terms of the present value of the socially useful knowledge they create, from highly valuable to no value. Knowledge has the characteristics of a public good. Once created, the costs of excluding others from using the knowledge is high; the cost of making it available to others is low and it is non-rival in consumption. It therefore is assumed that a private investor is unable to appropriate a fixed amount of the social benefits available. Some socially profitable research projects thus offer no private gains and will not be undertaken unless public intervention occurs.
Chilean use of any new varieties they develop, and seem to hope to use the development of new varieties as a means to gain market share. To compete, Chile may need to invest more in this area. Locally developed varieties also could offer inherent benefits even if foreign varieties were fully available. Since fruit breeding is costly, it appears that such research will require public intervention.

Research also may have been biased toward the needs of large as opposed to smaller farms and a strengthened public extension system probably would have improved the returns of the small farmers who attempted to produce fresh fruit, thus spreading the benefits of the fruit boom. Such extension, or the enforcement of existing regulations, might also have improved the application of pesticides, reducing contamination of workers and rural residents. Additional public research and diffusion might have allowed Chilean farmers to avoid some of the investment and management errors that the fruit sector has manifested in recent years. Numerous producers planted varieties that were unsuited to their farm's climate, or which turned out to have little commercial value. Much of this was due inadequate farmer planning, but private research often was carried out within an informal scientific framework, was sometimes ill designed, implemented and evaluated, and led to incorrect recommendations.

The research process doubtlessly could have been more efficient. Still, the observed errors and the unfinished research agenda may reflect less inefficiency than first appears. Significant error was to be expected in any industry offering such high incentive to take risk, so that error per se is not necessarily an indication of too little public investment. Stories are told of Chilean growers who obtained and planted new varieties still undergoing evaluation in the US and that had still not been released. Significant profits were sometimes earned from these ventures, but losses were also common.

Many of the research problems now becoming prominent may not have been priority concerns a decade ago. Research expertise also had a high opportunity cost and it is difficult to determine how well the public sector would have performed had it been given more of Chile's scarce resources. There is no assurance that reallocating scientists from the private to the public sector would have greatly increased social welfare.

Whatever its past validity, I do not think the same argument can be made for the longer run. As fruit prices fall, as an increasing proportion of research must deal with more basic problems (as noted above)—not simply the adaptation of foreign technology—and as market imperfections diminish, an increasing proportion of the socially profitable research projects will not be privately profitable. Market conditions are changing, and my conversations with exporters and producers in mid-1992 suggested that private investment in research is declining. The situation in Chile is shifting back towards that depicted in Figure 14.5(a). It seems essential that public-sector research capacity be increased if important research is not to be left undone.

Chile has the expertise required to borrow and adapt technologies where highly applied research is adequate, but it has limited capacity to solve the more complex problems that will be of long-run importance in maintaining its competitive position vis-a-vis other southern hemisphere fruit exporters. Some basic research has been done in recent years, partly stimulated by the funding opportunities provided by the National Fund for Scientific and Technological Research (FONDECYT). FONDECYT
provided funds amounting to nearly US$1 million in 1989 to support agricultural research, but only about US$65,000 of this was allocated to fruit research (World Bank 1991).

The failure to develop this capacity is an area in which the greatest argument can be made for insufficient prior public action. There was too little public investment in research facilities and advanced training in fruit science and too little attention to issues of long-run importance, particularly the creation of an institutional framework that would allow effective public-private interaction in the future.

The dynamic changes in the locus of research activity bring benefits and impose costs. Chile was able to shift resources toward the private sector, but in doing so it weakened the development of its public sector. It now needs to shift or create new resources. However, it seems unlikely that the public sector will be able to develop the needed research capacity without private-sector support. The government is unlikely to allocate greater funds to public research on fruit unless there is strong pressure from private firms. Moreover, from a practical viewpoint, the public sector is unlikely to perform the needed research role unless it receives a great deal of cooperation, in terms of information and advice, from public firms.

Unfortunately, no private-sector initiatives to encourage additional public fruit research are evident. The private sector has little recognition that a greater public research contribution will be needed in the future. It senses that private sector has been the active force in the recent past, has little belief that the public sector could do as good a job and thus sees little reason to seek a change.

This situation has been encouraged by past policy, which forwent any effort to coordinate fruit research (World Bank 1991). The Ministry of Agriculture has no link with the agricultural faculties of the universities (World Bank 1991). The Ministry of Education is responsible for setting teaching and research priorities in Chilean universities. The government's principal research initiative was the creation of several competitive funding programs, including FONDECYT, which grants research funds to individuals and the Fund for Productive Development (FDP), renamed the Fund for Technology (FONTEC) in 1991, which supports technological innovation by industry. Total funding is relatively small, amounting to about US$1 million 1990 and funding for fruit research is minuscule.

Chile, of course, cannot capture all the benefits of its own fruit research, whether private or public. Chile's research shifts the supply curve of Chilean fruit and, since international demand for Chilean fruit is not perfectly elastic, international consumers will capture some of the benefits from research. Chilean producers could even lose from research if foreign demand is sufficiently inelastic. Nonetheless, if Chile has monopoly power in trade, the first best policy is an export tax on fruit, not a "tax" on research. If there is monopoly power in trade, the shadow price of fruit exports is lower than the market price and profitability calculations based on the latter will call for too much research. Even public sector interventions might favor too much research if public technocrats respond to market rather than shadow prices in setting research priorities. Levying an export tax could send (appropriate) signals to reduce both private and public research. Nonetheless, I suspect that Chile's monopoly power in trade is declining, not growing. Moreover, if an optimal export tax were to be applied, I suspect that more rather than less public research will be profitable in the future. Whether this speculation is true or not,
the question of monopoly power in trade only reinforces the importance of public-private coordination in research policy.

14.8 CONCLUSIONS

The private sector was largely responsible for the substantial, varied and broadly diffused technological advances that occurred in the fruit sector after 1974, including improvements in orchard management and post-harvest techniques. Since only a small proportion of the social value of such techniques would normally have been privately captured, economists would not expect that the private sector would invest the resources needed to produce such technological advances. During the Chilean fruit boom, the profitability of many technological advances was so high relative to their cost that the private sector solved them relatively quickly. Export firms played the major role because, given market imperfections, mainly due to a still immature market structure in the rapidly growing fruit industry, export firms were able to capture significant benefits from research and development activities. The advances achieved allowed Chile to greatly improve the quality of the fruit sold in foreign markets, a crucial factor in the rapid growth of Chilean exports.

Extensive trade and market reforms occurring after 1974 played a crucial role in setting the conditions for private activity. Economic reforms gave rise to higher profitability, stimulated entrepreneurial activity and improved factor use. Among the most important reforms were setting an adequate real exchange rate, removing quantitative import restrictions and reducing import tariffs and creating a more competitive rural labor market. Land reform, insofar as it transformed archaic land tenure structures, created an active land market that facilitated entry into fruit production by more efficient, entrepreneurial and technologically modern producers. Opening the economy led to a sharp increase in the rate of domestic learning, with export-led growth an important modernizing influence. Indeed, it has been said that the Chilean fruit industry stimulated the growth of other export industries; other Chileans concluded that "if those 'huasos' (farmers) are capable of selling their products abroad, then surely we are as well."

It must be emphasized that the public sector was responsible during the 1960s for developing the scientific expertise and the technological base that was crucial to the acceleration of fruit export growth after 1974. Nonetheless, the research capacity of the public sector, including the universities and the national agricultural research system (INIA), may have declined after 1974 and certainly increased little despite the rapid growth of fruit output and the increased demand for improved fruit technology. In part, skilled expertise was bid away from the public research sector to undertake tasks in the private sector, given the high wages that the latter was willing to pay. The government facilitated this process by passing new regulations that allowed public staff to engage in substantial consulting. Paradoxically, the government also sharply cut salaries and research budgets in the universities and INIA and, even, prohibited research by INIA on the major fruits being exported. This shift was part of a generalized effort to encourage private as opposed to public economic action, with a strong ideological bias. The
decreased public research capacity probably did not greatly slow fruit expansion, but it may have increased investment and management costs and was a factor limiting the benefits of fruit production to better educated and economically more sophisticated growers. More importantly, the public sector's capacity has not grown in keeping with the industry, nor with the probable demands it will face in the future. Chile currently has the research expertise to borrow and adapt technologies where highly applied research is adequate, but has limited capacity to undertake more basic research needed for the solution of more complex problems of long-run importance.

The experience of the Chilean fruit sector suggests that the private sector in less-developed countries may generate greater amounts of agricultural technology than is generally suspected, though this case clearly involved a number of unusually favorable conditions. The experience also illustrates how the nature of private and public efforts and the links between them, depends on the prevailing characteristics of product and factor markets. Market characteristics may change over time and place. In Chile, the profitability of fruit production is declining, the export sector is becoming more competitive and research needs are shifting toward more basic, more complex, and more costly efforts. As a result, the private sector should find research less profitable in the future and the proportion of socially profitable research that will require public intervention if it is to occur will doubtlessly increase. Most probably, the need for public intervention will increase absolutely. Judgments regarding the appropriate amount of research, private and public, ought to take into account Chile's monopoly power in trade, if any.

Because Chile has so improved its fruit quality and caused, via rising exports, a decline in international fruit prices, other countries interested in fruit development will face conditions less favorable to private research and development than those which occurred in Chile. To compete, these countries will have to begin at a technologically more advanced level and, because of the prospect of lower private profits, their technological development will probably have to depend more on public-sector research. Nonetheless, they would be wise to explicitly encourage private research and development activities in coordination with public activities.

Coordination between private and public sectors is increasingly recognized to be an important aspect of technology planning, given that public and private research activities are expected to be distinct and complementary (Evenson 1983) and coordination appears more important if the public-private division of research activities responds in significant and predictable fashion to market conditions.

14.9 REFERENCES


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Table 14.1  *Changing number and composition of university theses submitted in partial fulfillment of Ing. Agr. degree*

<table>
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<tr>
<th>Period</th>
<th>Total theses</th>
<th>Fruit-oriented theses (number)</th>
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<td></td>
<td>General fruit</td>
<td>Berries</td>
<td>Table grapes</td>
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<td>10</td>
<td>43</td>
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<td>1981–85</td>
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<td>1986–90</td>
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<th>Period</th>
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<tr>
<td>1986–90</td>
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Figure 14.1. Fresh fruit export value (million US$).

Source: Data from CIREN-CORFO, INE
Figure 14.2. Fruit area planted (hectares).

Source: DEP, CIREN-CORFO, INE
Figure 14.3. Chile fruit production (tons).

Source: DEP, from CIRED-CORFO, INE
Figure 14.4. Time Allocation of Fruit Science Expertise in Chile

1974

Public Sector

E

C

T

R

1992

E

C

T

R

(private)

(public)

Private Sector

E

M

C

T

R

= research (in the public sector, research can have a predominantly private or public character. C = technical assistance and advising. E = entrepreneurship. M = marketing and administration. T = teaching. Fruit scientists are defined to include foreign trained MAs and Ph.Ds in fruit related sciences, plus holders of the domestic Ingeniero Agronomo degree who have been or are employed in formal research activities.

Source: Author’s survey and estimation.
Figure 14.5. Determinants of Private-Sector Fruit Research

(a) Normal Situation

(b) Chilean Fruit Sector, 1975-1990