Transportation Technology and The Rising Share of U.S. Perishable Food Trade

William Coyle, William Hall, and Nicole Ballenger[1]

Abstract: By reducing delivery times, maintaining product quality, and reducing shipping costs, advances in transportation technology have greatly facilitated trade of perishable food products. Advances in transportation technology are partly responsible for shifts in the composition of U.S. agricultural trade from bulk commodities to non-bulk items, including perishable products.

Introduction

The more-than-decade-long shift in the composition of U.S. agricultural exports from bulk commodities (*e.g.*, wheat and soybeans) to nonbulk items, including perishable products (*e.g.*, meats and fruit) (fig. D-1) is primarily explained by income growth and trade liberalizing measures in the high- and middle-income markets of East Asia, North America, and the European Union (EU). Advances in transportation technology also help to explain this shift, particularly in the rise of perishable product exports. Perishable products now account for about 20 percent of total U.S. food and agricultural exports, and an even larger share of imports.

Advances in transportation technology have made it possible for shippers to deliver perishable products to purchasers thousands of miles away with no substantial loss in freshness and quality and at lower and lower costs. These lower transportation costs have a similar effect on trade as a tariff cut: reducing transaction costs or the wedge between the product price in the exporting and importing countries, thus stimulating trade (see box "Adoption of Transportation Technologies Has Similar Impact on Trade as a Tariff Cut").

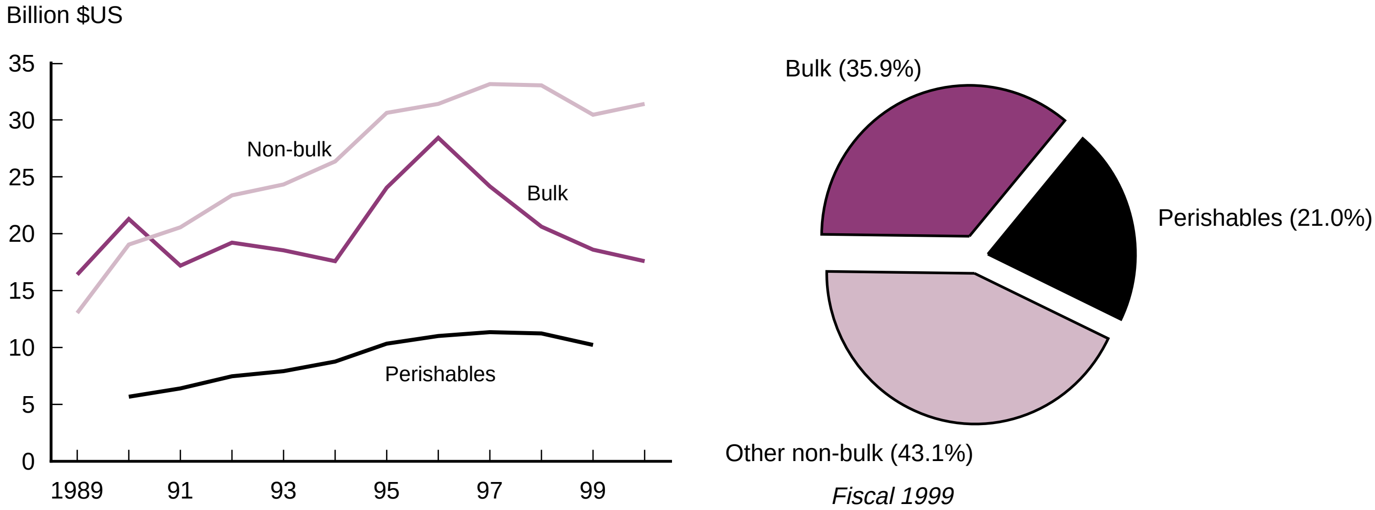
For many producers, marketing perishable products abroad was largely infeasible or prohibitively expensive until new technologies were developed in the past 30 years. Packaging innovations, fruit and vegetable coatings, bioengineering[2], and other techniques that reduce deterioration of food products have helped shippers extend the marketing reach of U.S. perishable products. In addition, new technologies in transport are gradually opening the ocean and overland trades to a host of perishable products. As a result, U.S. exports of horticultural and livestock products now can travel greater distances than before (fig. D-2).

Markets for U.S. perishable products are concentrated in high- and middle-income East Asian countries, North America, and to a lesser extent in Europe. Today, beef and pork produced in the U.S. Midwest are chilled or frozen in regional packinghouses, moved overland to Mexico or to West Coast ports, and shipped by sea to Japan and South Korea. Fresh broccoli goes by ship from California to Japan, and fresh cherries travel the ocean from Washington State. Perishable products, as fragile as avocados, lettuce, mangoes, and nectarines, are increasingly transported by sea to Asia and Europe from the United States and to the United States from suppliers like Mexico and Chile.

[1] William Coyle is an agricultural economist in the Market and Trade Economics Division and Nicole Ballenger is the Assistant Administrator, Economic Research Service, USDA. William Hall is a partner in the Seaport Group, a consulting firm specializing in port planning and logistics analysis.

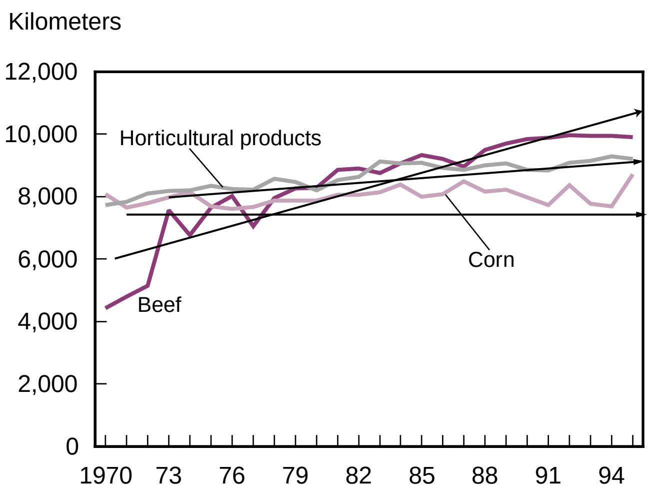
[2] Some products are engineered to have a longer shelf life such as the 10 to 14 day shelf life of the FreshWorld Farms Endless Summer tomato.

Figure D-1
U.S. non-bulks surpass bulk exports since 1991



Source: FATUS, fiscal years.

Figure D-2
Weighted mean distance for U.S. beef, horticultural products, and corn exports



Note: Data excludes the nearby markets of Canada and Mexico.

Source: Wang, Zhi, Bill Coyle, Mark Gehlhar, and Tom Vollrath. "The Impact of Distance on U.S. Agricultural Exports: An Econometric Analysis," in Technological Changes in the Transportation Sector--Effect on U.S. Food and Agricultural Trade, A Proceedings. Economic Research Service, USDA. Misc. Pub. 1566, Sep. 2000.

Trans-ocean transportation costs are still higher for many perishable products than for raw agricultural products like cotton or nonperishable products like nuts and raisins (fig.D- 3). However, new developments in ocean shipping have made it possible to preserve the quality of perishables during transport and still bring down transportation costs.

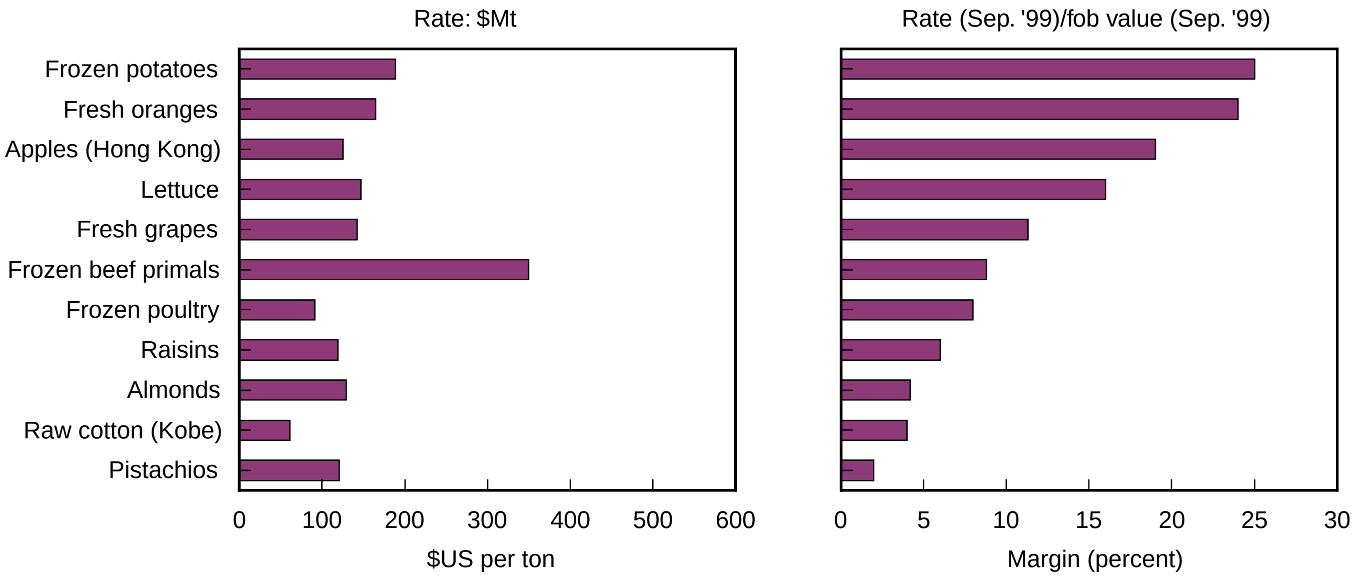
In addition, satellite technologies, particularly global positioning systems (GPS), which are becoming increasingly available and less expensive, enable shippers to track their cargo around the world electronically. Other electronic technologies enable shippers and carriers to monitor quality, reduce risk (and costs) of liability claims, and shorten cargo delivery time. Profitability in perishable product trade will likely increase further as ocean shipping technologies continue to adapt to the special requirements of different horticultural and livestock products.

U.S. exports of perishable products increased from $3.5 billion in FY 1989 to $10.3 billion in FY 1999. Meats accounted for about half of these exports in FY 1999 and fresh fruit and vegetables about one-fourth. Consumers in the United States and U.S. trading partners have benefited from improving transportation technology, as the United States imported $13.1 billion of perishable products in FY 1999, with horticultural products (including fresh vegetables, fruit and juice, bananas, cut flowers, and nursery stock) accounting for about 60 percent (fig. D-4).

Reducing Shipping Costs

Loading and unloading have always accounted for a relatively large share of total transportation costs (fig. D-5); thus the longer the journey, the lower the per-mileage transportation costs, other variables remaining constant (fig. D-6). The use of containers has radically reduced these front and back end costs. Port workers

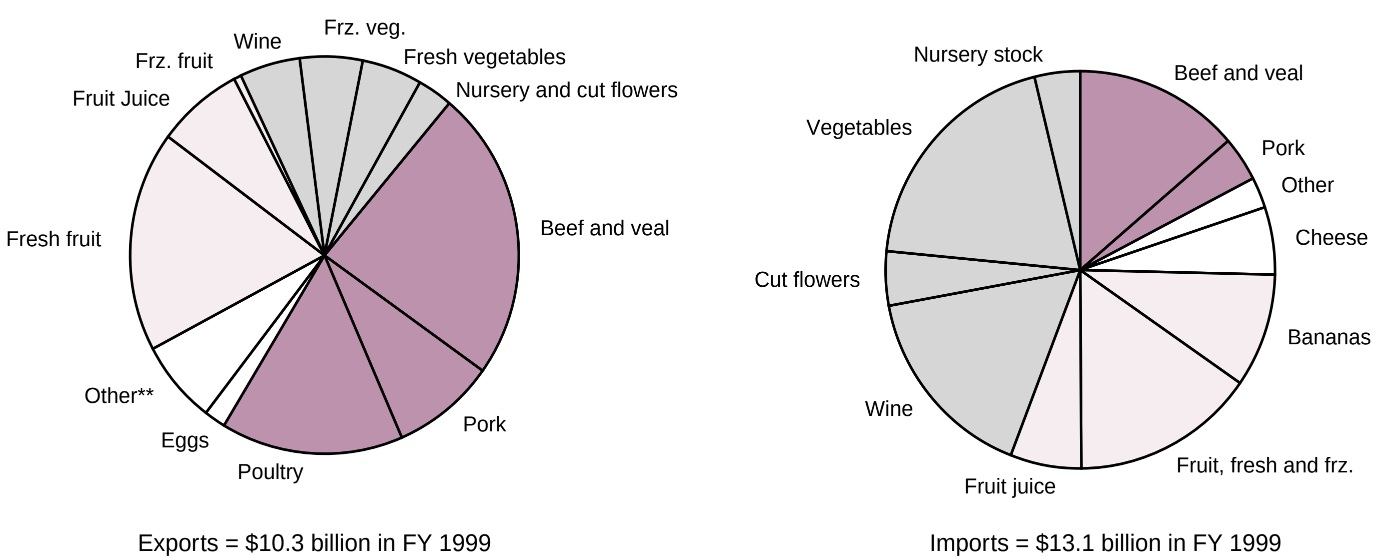
Figure D-3
Shipping margins higher for horticultural products



Source: Shipping rates for selected commodities from L.A./L.B./Oakland to Tokyo, Japan; Agricultural Marketing Service, Ocean Rate Bulletins, Sep. 1999.

Note: Apples are for Hong Kong; container and per ton shipping rates are for June 1999; shipping as a share of the commodity's fob value is based on export unit values for Sep. 1999.

Figure D-4
U.S. trade of perishable products



**--dairy products and bull semen.
Source: FATUS.

Figure D-5

Shipping costs and times

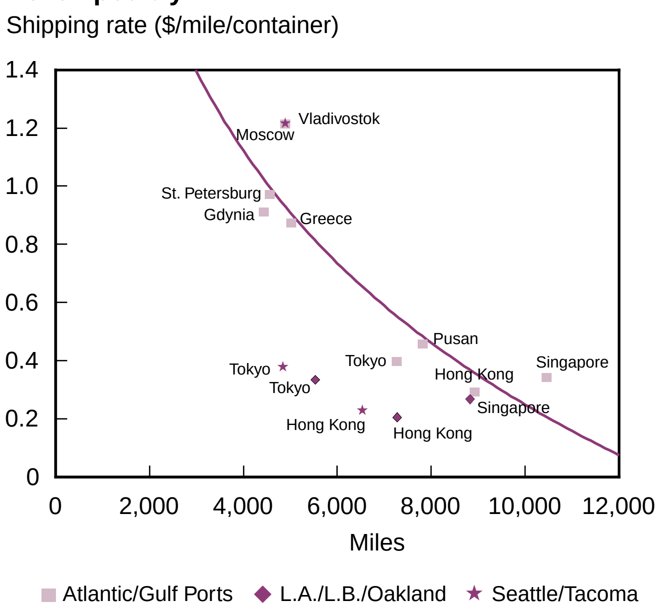
Sequence	Time (Hrs)	Cost (US$)
Moving container from loading ramp to storage	1	80
Container waiting for pick up after stuffing	48	12
Loading container on road trailer	1	62
Road transport to port terminal	33	360
Waiting for admission to port terminal	2	
Transfer from road trailer to stack		80
Waiting in stack	146	40
Unstacking and transfer to terminal trailer		88
Transfer/loading onto ship		240
Containership travel time (New York-Rotterdam)	154	1,840
Transfer/unloading off ship	1	192
Transfer to stack		60
Waiting in stack	106	30
Transfer from stack to road trailer		60
Clearance and inspection	2	10
Road transport, port terminal to inland depot	14	220
Unloading container at inland depot		40
Storage in inland depot	30	
Moving container to consignee	2	40
Total	540	3,454

Loading and unloading costs are relatively large and fixed regardless of the length of the journey

Source: Cost of operations and time for shipping a 40' container; in APEC's *Congestion Points Study, Phase III, Best Practices Manual and Technical Report, Volume 2 Sea Transport,* Feb. 1997, p 105.

Figure D-6

Shipping rates for container loads of frozen poultry



Source: Agricultural Marketing Service, Ocean Rate Bulletin for Frozen Poultry, October 30, 1998.

now handle standardized containers filled with cargo, rather than handling the cargo itself (see box “Inventing the Container”). Containerization has also led to a significant change in global shipping practices known as intermodalism, moving goods by linking together two or more modes of transportation (*e.g.* rail, truck, air, and ocean).

Containerization is recognized as a major contributor to the steady reduction in world transportation costs since the 1950s. For perishable products, however, the increased speed of handling and reduced transport costs with containerization were not sufficient. Ocean transport of cooled and frozen cargo received a substantial boost with the development of mobile refrigerated containers called “reefers” in the 1960s.

Reefers, like regular containers, are 20-foot or 40-foot boxes with their own refrigeration units. Reefer containers use ship-generated power for climate control and can be carried alongside standard containers on general-purpose containerships. This allows for perishables to be integrated into larger flows of general cargo and to benefit from the scale economies inherent in container transport. It is an advantage that has challenged the competitiveness of conventional, dedicated refrigerated cargo ships that lack this flexibility.

The reefer share of refrigerated cargo is about 44 percent and accounts for about 22 million tons of cargo annually. Deep-freeze and dedicated refrigerated vessels—accounting for 28 million tons, or 56 percent—are important for palletized chilled fruit, particularly bananas, apples, peaches, pears, grapes, kiwifruit, and citrus, but the reefer container trade is growing more rapidly and is considered better suited for carrying these fruit as well as produce needing more careful handling, like asparagus.

Increasingly efficient and accurate cooling systems for some time have allowed refrigerated carriers to maintain temperatures with great accuracy (plus or minus a quarter degree Celsius). More recently, however, controlled atmosphere (CA) technologies added refinements that have extended the shelf life of perishable products and thus expanded the types of perishables that can be shipped in reefers without spoilage.

CA technologies allow operators to lower the respiration rate of produce by monitoring and adjusting oxygen, carbon dioxide, and nitrogen levels within a refrigerated container. In this way, CA can slow ripening, retard discoloration, and maintain freshness of perishables like lettuce, asparagus, peaches, mangoes, and avocados that would not have survived well during ordinary refrigerated ocean transport. Not all CA systems are the same: some especially sophisticated ones are combined with systems to maintain relative humidity, a crucial factor for some produce such as grapes, stone fruit, and broccoli; and controlling levels of ethylene, a naturally occurring gas that accelerates the ripening process in fresh fruits and vegetables.

In addition, remote reefer monitoring systems can transmit and collect performance information electronically so that physical checks are not required while the reefer is stacked in the hold or by the dock. The remote system may also activate an alarm, helping minimize losses when problems arise at sea or in the container yard.

Developments in Vessel Technology

Accompanying advances in containerization have been changes in container ship technology and in the abilities of world ports to serve those ships. Container vessels are being built larger and larger, making them more competitive with traditional refrigerated vessels.

In the 1970s, container ships on the world's major trade routes were built to carry an average of about 2,500 TEU's (twenty-foot equivalent unit—standard containers with exterior dimensions measuring 20 feet by 8 feet by 8 feet). New vessels deployed on major routes are often 5,000-6,000 TEU's, too wide to fit through the Panama Canal (about 4,800 TEU's maximum). Per-container vessel operating costs are about 50 percent lower for a 5,000-TEU ship when compared with a 2,500-TEU-vessel (Bill Hall, Seaport Consultants; input into Ballenger/Coyle article in AO, 1999).

The largest container ships now in service, such as the Sovereign Maersk, are estimated by industry analysts to have a capacity upwards of 6,600 TEU's, which includes space for over 800 refrigerated TEU's. The refrigerated capacity alone makes the gigantic Sovereign Maersk equivalent to a medium-sized conventional refrigerated carrier. A number of vessels of this size are on order and are expected to become more common. Ships with capacities of 15,000 TEU's or more are said to be technically feasible (JOC, 6-5-00).

The challenge of facing radically larger ships, however, is to increase capacity while maintaining stability and safety, particularly important for ships carrying tall stacks of containers. New hull shapes and ballasting systems promise to improve stability at sea, while bow thrusters will make these large vessels more maneuverable in port than their smaller predecessors. Very large containerships may also require advances in propulsion and propeller technology that remain to be fully developed and tested.

These larger and larger ships, while lowering the cost of transportation, would be limited by the capacity of ports that service them. They would be constrained by harbor depths and the capacity of loading and unloading equipment. They—like the largest container ships of today—would be too large to pass through the Panama Canal. A new service pattern could emerge with these giant ships traveling along an east-west route between large transhipment ports, which would be fed by smaller north-south feeder lines.

Container ships are dominating the perishable trade between North America, East Asia, and Europe, though conventional refrigerated vessels can serve

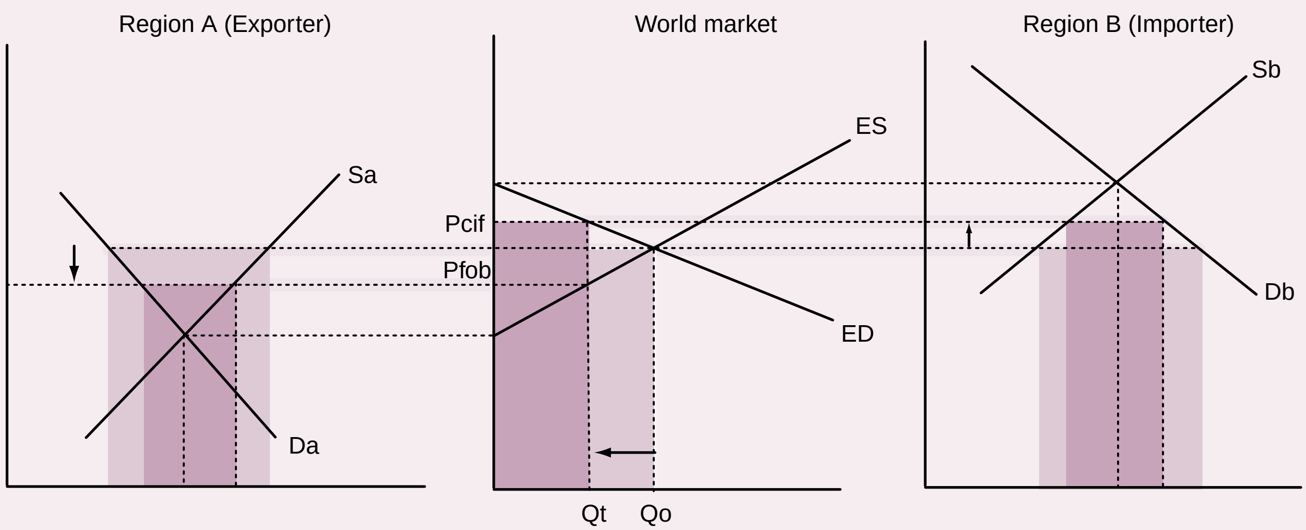
Adoption of Transportation Technologies Has Similar Impact on Trade as a Tariff Cut

Overcoming distance has always been an important issue in marketing agricultural products, but agricultural economists have examined the role of distance only occasionally (Thompson, 1981). International trade economists have long ignored distance until recently as described by Paul Krugman:

> The analysis of international trade makes virtually no use of insights from economic geography or location theory. We normally model countries as dimensionless points within which factors of production can be instantly and costlessly moved from one activity to another, and even trade among countries is usually given a sort of spaceless representation in which transport costs are zero for all goods that can be traded. (Paul Krugman, *Geography of Trade, 1996*)

Transportation costs represent a wedge between the exporter's fob price and the importer's cif price and act as a tariff; when taken into account, it lowers the exporter's price, raises the importer's price, and reduces the quantity traded (fig. D-7). The darkened areas represent the new equilibrium with the inclusion of transportation costs. When transportation costs are included, one can see how the quantity traded on world markets contracts from Qo to Qt. Alternatively,

Figure D-7
Spatial equilibrium model with and without transport costs



Qt = traded quantity with transport costs
Qo = traded quantity without transport costs
Pfob = exporter's fob price
Pcif = importer's cif price

Source: Gehlhar, Mark. "Incorporating Transportation Costs into International Trade Models: Theory and Application" in Technological Changes in the Transportation Sector--Effect on U.S. Food and Agricultural Trade, A Proceedings. Misc. Pub. No. 1566. Economic Research Service, USDA. Sep. 2000.

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smaller ports, especially in the developing world, that are still unable to handle large container vessels and lack the specialized cranes and storage yards needed to support them. Conventional refrigerated ships may have a brighter future in these smaller trades, especially where competition from container vessels has not increased. Ports in some producing areas throughout the developing world have been developing perishable-oriented container terminals. Fruit exporting companies have been among the leaders in

Continued from page 36

one can also see how the reduction of the transportation margin, the difference between Pcif and Pfob, would expand the quantity traded. The top graph in figure D-8 is the same as the middle graph in figure D-7. The level of transportation services (Qs) is derived from the level of trade (Qt) (fig. D-8). Technological change as well as other factors shift out the supply of transport services, reducing transportation costs, and thus expanding trade (fig. D-9).

A key distinguishing characteristic of many food and agricultural products is perishability, which requires refrigeration and prompt delivery to consumers to assure quality. The adoption of modern technologies has facilitated trade of many high-value agricultural products in recent years by shifting out the supply of transport services and lowering costs.

There are also constraints, such as environmental restrictions on refrigerants and inadequate infrastructure that can lead to an inward shift in the supply, or a rise in the cost of transport services.

Figure D-8
Link between world trade and market for shipping services

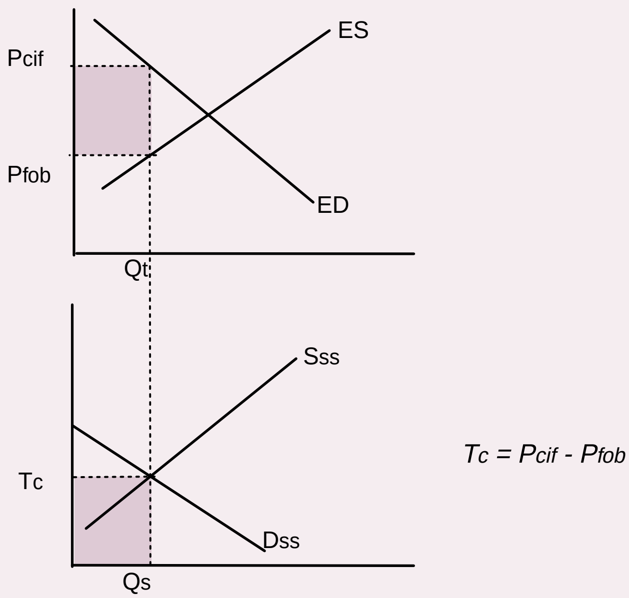

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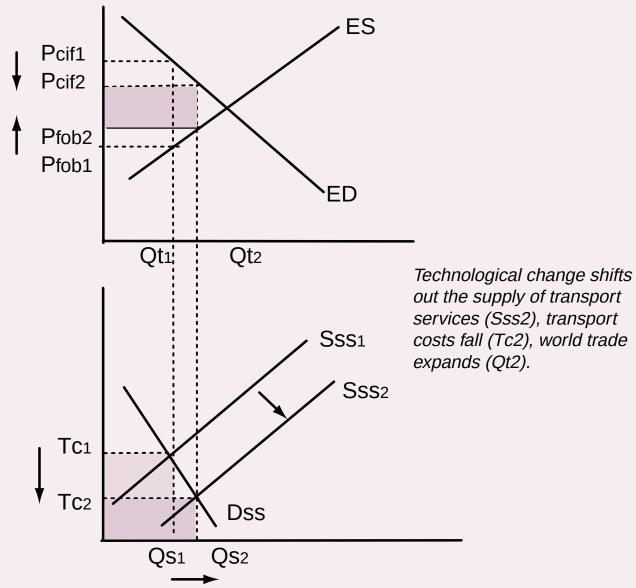
Figure D-9
Impact of technological change on shipping rates and trade



Source: Gehlhar, Mark. "Incorporating Transportation Costs into International Trade Models: Theory and Application" in Technological Changes in the Transportation Sector--Effect on U.S. Food and Agricultural Trade, A Proceedings. Misc. Pub. No. 1566. Economic Research Service, USDA. Sep. 2000.

this process. For example, in late 1999 Dole took delivery of two 2,000 TEU refrigerated containerships for operations between Chile, the Caribbean and the eastern United States. These vessels are as large as the containerships active in the trans-Atlantic and trans-Pacific trades of two decades ago.

At the same time, the conventional refrigerated shipping industry is not standing still. New ship designs allow more rapid loading and discharge, with forklifts moving throughout the holds. Onboard cooling plants have become highly efficient. The industry is concentrating into fewer and larger firms to increase efficiency, and vessel pooling arrangements help companies utilize capacity more effectively. Some refrigerated carriers can now carry loads of containers on deck, and operators are increasingly using their refrigerated vessels to carry other cargoes, such as autos and palletized machinery, on a seasonal basis, which helps even out earnings for carriers. Conventional refrigerated ships can still be effective, especially at smaller ports, although competition from container ships is increasing.

Inventing the Container

Malcolm McLean, founder of Sea-Land, the largest U.S.-based ocean carrier, made a major contribution to the technology of perishable product shipping (Allen 1994). In 1937, he waited on a dock in Hoboken, New Jersey with a ship-bound truckload of North Carolina cotton. For hours he observed the complicated, labor-intensive process of goods being unloaded from trucks, moved onto the ship, and juggled into their proper places in the hold. As the story goes, he wondered why his truck trailer could not simply be lifted up and placed on the deck of the ship without its contents being touched.

McLean made his idea a reality in 1956 when he purchased a small tanker company, adapted the ships to carry trailers, and launched the Ideal X from Port Newark in the New York harbor. When he later converted from conventional truck trailers to specially engineered steel boxes that could be stacked several layers deep inside the hold, he had launched the era of the cargo container. In 1966, one of his new container ships crossed the Atlantic to Rotterdam, launching the first trans-Atlantic and later trans-Pacific containerized shipping service.

Significantly faster ships may also be on the horizon. Ships are being developed that will travel as fast as 40 knots, about twice the speed of standard vessels. There are significant problems to be overcome, but if solved these ships would perform a North Atlantic transit in about 3-and-a-half days and door-to-door delivery from the U.S. Midwest to Central Europe in 7 days, compared with the typical 14-28 days (Journal of Commerce, 6-29-00). They would occupy a market niche between ocean and air shipping for long-distance movements. These “fast ships”, once perfected, would probably target perishables as an ideal market segment.

In summary, it now appears that container ships will continue to take market share from conventional refrigerated ships, although these will likely persist in certain trades and niche markets. We can expect containerships to continue to grow in size, which should decrease unit costs further. More distantly, a new type of fast ship may appear that could significantly impact shipment of high unit-value commodities—such as perishables.

How many ports worldwide have the necessary infrastructure and links to international markets to handle large volumes of reefer container trade? Although there are many “containerports,” container traffic and traffic growth are clearly concentrated around the largest few. Of the top 100 containerports in 1999, 15 accounted for about 50 percent of all container throughput (*www.cargosystems.net*).

By far the largest throughput is handled at ports in Singapore and Hong Kong (each with 10 percent of 1999 container throughput), followed by Kaoshiung in Taiwan and Rotterdam in the Netherlands, each with less than half the volume of the largest two ports. In the United States, the five leading container ports (Long Beach, Los Angles, New York/New Jersey, San Juan, and Oakland) together accounted for about 9 percent of world container throughput (*www.cargosystems.net*). Although these figures mean little in terms of the ability of other ports to respond to growing consumer demand for perishable products, they do suggest a challenge to the diversification of perishable product trade beyond major, high-income markets.

Environmental Challenges

Despite tremendous progress in adapting shipping technology to the marketing of perishables, there remain significant constraints to the expansion of perishable product trade. Some constraints derive from economic and environmental issues associated with the technologies.

First, controlled atmosphere (CA) technologies, particularly some of the more complex systems, are expensive for carriers to adopt and install. Although continued technological refinements and developments and increasing competition among manufacturers of CA systems are bringing investment costs down, much of the CA reefer trade is seasonal (timed, for example, to the fruit harvest) and therefore particularly vulnerable to income swings. The reefer business can be very profitable because of the high value of the cargo, but some industry analysts believe that the CA reefer trade, while continuing to grow, will remain a niche market.

Some questions also remain as to how international environmental agreements and national environmental regulations will affect the availability of economical and environmentally friendly refrigerants for reefer systems. Chlorofluorocarbon compounds (CFC's), the predominant refrigerants used in reefer containers, are being phased out under the terms of the 1990 Montreal Protocol international treaty because of their damaging effect on the ozone layer.

The most popular replacements for CFC's are hydrochlorofluorocarbon compounds (HCFC's) which have limited ozone depletion potential. However, HCFC's are expected to be phased out in favor of hydrofluorocarbons (HFC's) which have zero ozone depletion potential but some global warming potential. The Kyoto Agreement on climate change, while not presently ratified, suggests the possibility of bans or caps on these "greenhouse" gases. If the proposed restrictions on HFC's become a reality, refrigerated shipping will face serious challenges in finding acceptable substitutes.

Hydrocarbons, such as propane or butane, are a possibility, but have come under scrutiny due to their flammability; they have been banned by the Environmental Protection Agency (EPA) for nearly all refrigeration uses. Ammonia systems using cooled brine, which were common before the adoption of Freon (a CFC) in the late 1970s, may be adapted to address environmental concerns. Although new ammonia-brine systems are attractive, ammonia is hazardous and brine is quite corrosive and difficult to pump. Liquid nitrogen systems have also been developed. These new systems are still in the development stages and it is agreed that more work is needed in order completely to replace existing refrigeration systems.

Future Challenges

Perhaps most critical to expansion of perishable trade are infrastructure, institutional and information linkages to make ocean shipping of perishable products not only technologically feasible but also efficient and profitable for all players along the supply chain. Reefer container trade requires that ports on both ends provide sufficient crane capacity, adequate storage space, and ready access to highway and rail systems designed for container traffic. Efficient inspection and customs services by government agencies, as well as port-to-market distribution systems, are critical since most fresh produce must arrive on store shelves within 24 hours of unloading.

Advances in information technologies have been critical in spurring the growth of perishable traffic. This ranges from on-ship remote container monitoring to precise inventory management systems linking producers, shipping companies, and the major supermarket chains and other large customers. Many industry observers maintain that since container shipping is now a mature technology, the greatest future challenges are in the areas of alternative refrigeration systems and in discovering ways to more efficiently manage the supply and inventory chain from production sources to supermarket.

What lies behind the rapid growth in U.S. exports of perishable products over the past 10 years? The general decline in trade barriers, such as tariffs and import quotas, and worldwide income growth play major roles. But the contribution made by advances in transportation technology, particularly in ocean shipping, tends to be ignored. These advances have extended the marketing reach of U.S. perishable high-value products to distant markets by reducing delivery times, maintaining product quality, and reducing costs.

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This article is based on an updated version of Ballenger, Nicole, Bill Coyle, William Hall (Seaport Consultants), Brian McGregor (AMS), and Roy Hawkins. "Transportation Technology Eases the Journey for Perishables Going Abroad," *Agricultural Outlook*, January-February 1999.

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