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ECON 332

21 December 2022

Aircraft Manufacturing

 When the Wright Brothers aircraft took to the skies in 1903, they had little idea of the innovations and industries that would subsequently be developed from their seemingly short flight. Now, over a hundred years later, people can fly at supersonic speeds, and the entire world has become increasingly more connected through people’s ability to travel through flight. Not only is society more connected, but economic forces have made it affordable for a common person to travel internationally for discretionary reasons. Today the passenger aircraft manufacturing industry plays a crucial role in connecting the world.

 Passenger aircraft manufacturing has an extensive history over a relatively short period of time. Following advancements in the mass production of aircraft for WWII, passenger aircraft began being produced at a mass scale. In 1958 Boeing delivered the 707, which is considered to be the first modern passenger jet aircraft (Curran, Andrew). Airbus became the first manufacturer to develop a twin-engine wide-body aircraft, the A300, the first passenger aircraft that eliminated the flight engineer position the A310, and the first “fly by wire” aircraft, the A320. Historically there have been many other aircraft manufacturers, most notably McDonnell-Douglas, which was ultimately acquired by Boeing. Today the four largest aircraft manufacturers, Boeing, Airbus, Bombardier, and Embraer, are products of considerable consolidation of other aircraft manufacturing companies (Aerospace Industry). While these four firms have a considerable hold on the market, with China’s growing middle-class Chinese aircraft manufacturers are expected to have a considerable role in the future aircraft market. China has strategically made decisions to increase its influence in the aviation industry, such as being the first country to ground the B737 Max in 2019 before the FAA ordered the aircraft to be grounded. While a seemingly minuscule event, it helped prove the Civil Aviation Administration of China’s legitimacy over the FAA by grounding the aircraft first (Wendover Productions).

 The vertical boundaries of aircraft production are considerably extensive, from gathering the raw materials to the aircraft eventually ending up at the gate for a passenger flight. The Airbus A380 consists of parts manufactured in many countries around the world. There are several upstream industries from the final assembly plant. Although Airbus manufactures the airframe, most of the components are manufactured at specific plants and are then transported to an Airbus final assembly plant. Many components are outsourced to another manufacturer in an upstream industry, most notably the jet engines, which are manufactured by Rolls Royce. The A380 undergoes final assembly in Toulouse, France. However, for example, the wings are manufactured in Whales and are transported to Toulouse. In order to move the wings from Whales to France, Airbus employs a series of ships and road convoys to move the wings along with other components to Toulouse. There are many upstream industries from the wing manufacturing plant in Whales. The immediately upstream industry is the factory where the metal used to manufacture the wings is produced. After the aircraft is assembled, it is ready for delivery. The industry that is immediately downstream of the final assembly is the airline that has purchased the aircraft (Pande, Pranjal). There are many employees performing many different tasks to build the aircraft. In the factories, large lifts are employed to assist in moving the large components of the aircraft around the factory. At Boeing’s primary factory in Everett, Washington, employees who have worked at the factory for years joke that they often still get lost at the factory due to its enormous size.

 The horizontal boundaries of commercial passenger aircraft are a narrowly defined industry. A commercial passenger aircraft is an aircraft that is manufactured with the primary purpose of transporting paying passengers that is operated by an airline that has some type of commercial operating certificate. The Minnesotan aircraft manufacturer Cirrus is not considered to be operating in the passenger aircraft industry as it primarily manufactures piston engine airplanes targeted towards general aviation pilots. Similarly, Lockheed Martin is not considered to be operating in the passenger aircraft industry currently because its aircraft are primarily targeted toward military operations. While Boeing, Airbus, Embraer, and Bombardier may be the largest producers of passenger aircraft. There are other competitors operating in this space. Most notably, the turboprop manufacturer ATR. Although ATR does not manufacture jet aircraft, it operates within the horizontal boundaries of commercial passenger aircraft because it is a major competitor to Bombardier’s turboprop passenger aircraft (Loh, Chris). Boeing and Airbus have developed a presence in some form in most aviation markets around the world. As a result of the global presence of aviation, the passenger aircraft manufacturing industry competes with international geographic boundaries. Boeing and Airbus have further attempted to compete with each other globally by setting up final completion factories in major aviation markets. One of the most notable examples of this is Boeing’s and Airbus’s decision to open final assembly plants in China, which is a growing aviation market (Wendover Productions).

 A key metric of output is how many aircraft orders the company receives and how many it fulfills, also known as deliveries (Loh, Chris). Airlines often will order their aircraft in large quantities to take advantage of competitive offers and will take delivery of their aircraft a few years after the order is placed. Since the time between order and delivery can be a significant period of time. Airlines will often either change or completely cancel an aircraft order. An example of this is Delta Airlines, through its merger with Northwest Airlines, inherited a B787 aircraft order. Since Delta did not need the B787, Delta canceled its B787 order (Singh, Jay). Boeing and Airbus will often continue to produce an aircraft until their orders decline, and the production ceases once the last plane is delivered. Recently Boeing has announced plans to end the production of its iconic 747 aircraft due to declining orders, and Airbus has decided to discontinue its A380 program (Pallini, Thomas).

 The airplane manufacturing industry demand is generally considered to be more inelastic. There are many factors in this market that make it considerably different from traditional markets. The airlines have tremendous negotiating power, especially budget airlines that order mass quantities. While the high amounts of negotiating power from the airlines does suggest more elastic demand. Aircraft manufacturing is still considered to be more inelastic because when airlines need planes, they need planes, and the price isn’t as big of a holdup as something such as the delivery date. While there are exceptions, airlines generally like fleets that have all of one brand of aircraft, especially when considering long-term aircraft replacement. Airlines with cost-sensitive customers, such as budget airlines, are especially concerned with maintaining the same aircraft type to ensure consistent training and maintenance needs. Airbus aircraft benefit from high levels of consistency in flying experience between small aircraft and large long-haul aircraft. Airbus also benefits from having common type ratings for its A330 and A350 aircraft. This means that a pilot who is examined by the FAA and given a rating to fly the A330 does not need to receive as extensive of additional training to fly the A350, saving airlines time and money. A study by the Federal Trade Commission in 2005 that studied the aircraft purchases by airlines from 1978-1997 found a price elasticity of demand of approximately -0.75, which is a higher PED than previous studies have calculated. This study was unique in that it included used aircraft. It is theorized that because this study included the used aircraft market (which demand for is likely more elastic than the new aircraft industry), this caused the PED to be higher than in previous studies while still inelastic (Smith, Loren).

The demand for airlines to place orders for aircraft is primarily shifted based on forecasted demand. One of the issues that airlines face is a long waiting period between when the aircraft order is placed and when it is fulfilled. While during the start of the COVID pandemic, most airlines were grounding their fleets, airlines were simultaneously attempting to prepare for the redeployment of the aircraft. It is likely that air travel, in general, will continue to grow. However, what the specific needs of an airline are from an aircraft manufacturer is rather debatable. Additionally, airlines often consider their need to replace aircraft in their fleet due to age. Delta has recently retired its 747 fleet, and it was replaced by the A350 (Hayward, Justin).

 The airplane manufacturing industry has many complementary industries supported by airplane manufacturing. One of the most notable industries is maintenance. Most large airlines perform their own maintenance or outsource it to a company that will perform it. Delta, for example, runs Delta TechOps, which services not just Delta aircraft but aircraft of all airlines (Delta Techops). Similarly, Lufthansa runs Lufthansa Technik. Airplanes inevitably need parts and routine inspections to comply with FAA certifications. The airplane manufacturing industry also supports the complementary good of flight training. In the United States, when receiving a private pilot’s certificate (the basic level “pilots license”), to fly for an airline like Delta, one has to obtain an Airline Transport Pilot certificate, and because Delta flies all jet aircraft all of Delta’s planes require a type rating specific to that aircraft. When pilots are hired at Delta, they already have their ATP; however, they do not necessarily have a type rating for the specific aircraft they will be flying. Delta has its own flight simulators and trains its pilots. However, many smaller airlines, such as the Canadian airline Air North, outsource their training to another company, such as a competing airline. Air North, for example, outsources its simulator training to Canadian North Airlines.

 The highest costs for building an airplane are the costs associated with designing and certification of the aircraft. The reason the costs associated with designing a new aircraft can be rather expensive is because this process can take a long time, and there are many steps toward getting an aircraft certified. When designing an aircraft, airlines have two basic options: develop a new “clean sheet” design or develop a new variant of an existing aircraft. In the case of Boeing’s B787, it was a brand-new clean-sheet design. While the Boeing 777X is a new variant of an existing Boeing aircraft, the 777. The time it takes for Boeing or Airbus to develop its aircraft greatly influences its final sticker price. One of the ways airlines can gain a discount on a new aircraft is to be a launch customer. This can be risky for the airline as the aircraft has not yet proven itself, but it can offer a financial incentive. Aside from the indirect costs of design and development, the most expensive comport of an airplane is its engines. Boeing and Airbus purchase engines typically from General Electric, Pratt and Whitney, Rolls Royce, and Safran. The third most expensive component is the onboard avionics (Why Are Planes So Expensive to Make?).

 The aircraft manufacturing industry benefits heavily from both economies of scale and economies of scope. Economies of scale have helped Boeing and Airbus significantly ward off competitors. The relatively new emerging Chinese aircraft manufacturer COMAC will struggle against Airbus and Boeing’s economies of scale cost advantage (Petrosyan, Grant). Boeing and Airbus benefit from economies of scale because of the high fixed costs associated with entering this market. Before an aircraft can be delivered to an airline, research and development, as well as manufacturing and certification of the aircraft, incur a high sunk cost for Boeing and Airbus. As a result of this high fixed cost, the average total cost decreases substantially as more aircraft are produced. Boeing and Airbus benefit substantially from economies of scope by producing different types of aircraft with different missions together rather than separately. With regards to passenger aircraft, Airbus produces its A320 family, which is meant to serve short to medium-haul flights alongside its A350, which will be Airbus’s flagship aircraft (after production of the A380 concludes) which is meant primarily for either high-density short-haul routes or long-haul flights. Boeing benefits from economies of scope by producing its military aircraft alongside its passenger aircraft. Many costs of these aircraft types can be shared between them, especially research and development, which can help drive down the cost of producing both aircraft. Bombardier and Embraer experience economies of scope by producing business jets alongside commercial passenger jets. Embraer and Bombardier benefit financially because they are essentially selling the same aircraft but to two different types of customers requiring substantially different missions of the aircraft. It is cheaper to produce them together because they can share manufacturing space, as well as the designs for the planes themselves (Economies of Scale and Scope).

 Currently, the four largest manufacturers in the commercial passenger aircraft market are Airbus, Boeing, Bombardier, and Embraer. While these four firms are the dominant players in the global aircraft market, and arguably Airbus and Boeing are the only dominant players, there are several other firms that manufacture commercial passenger aircraft. For example, the typically associated with general aviation manufacturers Cessna and Piper do manufacture aircraft that can be used for commercial operations. Additionally, there are several foreign aircraft manufacturers, such as ATR, Tupolev, Ilyushin, Antonov, COMAC, and Sukhoi, that manufacture commercial passenger aircraft. However, except for ATR, these firms have yet to establish a substantial global presence outside their home country and region. While these firms do technically compete with the four largest firms, their competition is rather unsubstantial. Given that these firms do not compete with the four largest in a meaningful way, the inability to easily find worldwide total aircraft deliveries of all passenger aircraft manufacturers, and because Airbus, Boeing, and Embraer account for 97.8% of the global passenger aircraft market (Bombardier was excluded from this statistic), the four largest manufacturers will be assumed to have complete total market share. To study the market shares of the four largest firms, the number of deliveries will be used for the fiscal year of 2021 (Global Commercial Aircraft Market Analysis/Growth Opportunities Report 2022). During 2021 Airbus made 611 aircraft deliveries, Boeing made 340 deliveries, Bombardier made 120 deliveries, and Embraer made 141 deliveries (Salas, Erick Burgueño).

 In the fiscal year of 2021, Airbus had the largest market share at 50%, Boeing had the second largest market share at 28%, Embraer had the 3rd largest market share at 12%, and Bombardier had the lowest market share at 10% (Salas, Erick Burgueño).

Herfindahl-Hirschman Index:

 $HHI=[(0.5)^{2}+(0.28)^{2}+(0.12)^{2}+(0.10)^{2}]×10000$

HHI = 3528

m-firm concentration ratio:

 $C\_{m}=\left(0.5+0.28+0.12+0.10\right)$

$$C\_{m}=1$$

As can be seen, by the high HHI and a m-firm concentration ratio of 1, this is a highly concentrated industry. However, it should be noted that a more accurate HHI and m-firm concentration ratio would be slightly lower due to the simplifying assumption that Airbus, Boeing, Embraer, and Bombardier have complete market control, which is not entirely true.

Historically Boeing has been the more dominant firm over Airbus. However, because of the grounding of the B737 Max, Boeing had substantially fewer aircraft deliveries during 2021. Additionally, all of these firms are recovering from the decrease in aircraft demand due to the COVID-19 pandemic. Throughout history, these four manufacturers have not been the dominant forces. For example, historically, McDonnell-Douglas, Fokker, Lockheed, and De Haviland have been significant players in this market. Additionally, Airbus is a relatively recent competitor to Boeing, and Bombardier and Embraer are relatively new entrants to the aviation market. The current four largest manufacturers have largely received their current market share due to industry consolidation through the merging of companies such as Boeing and McDonnell-Douglas (additionally, McDonnell-Douglas itself is a result of a merger between McDonnell Aircraft and Douglas Aircraft). Additionally, many historical competitors have exited the passenger aircraft market, most notably Lockheed, which today has merged with Martin Aircraft under the new name of Lockheed-Martin and is a prominent manufacturer of military aircraft. A likely contributor to this industry consolidation is that firms can take advantage of economies of scale through one company, ultimately producing more aircraft by purchasing another aircraft company. Lockheed attributes its exit from the passenger aircraft market due to the company’s inability to break even on its L-1011 Tristar aircraft, which was a highly technologically advanced aircraft at the time (Shifrin, Carole).

 The oligopoly market structure best describes this industry. This is because there are relatively few players in this industry with immense bargaining power. Some industry analysts could argue that a duopoly would better represent this market because Airbus and Boeing are the most considerable competitors. However, Embraer and Bombardier do still play a substantial role in the global aviation market. Many airlines have a comparably sized fleet of Bombardier and Embraer aircraft to their Boeing and Airbus fleet, and this is because Boeing and Airbus do not manufacture jets that are targeted toward the regional jet market. The aircraft manufacturing industry is not described by perfect competition because there are few sellers and the barriers to entry are high. The high upfront fixed costs, such as capital investments required and FAA regulation fees, substantially prevent new entrants.

 Historically Boeing has been rather consolidated to its plant in Everett, Washington. However, today parts are made at several different plants and are ultimately brought to a final assembly site. Both Boeing and Airbus have strategically opened final assembly plants in key markets for their aircraft. For example, Boeing and Airbus have final assembly plants in China, which is a key market, and Airbus has a final assembly site in Mobile, Alabama, to compete effectively with Boeing. Aircraft manufacturers likely have a cost structure that includes high amounts of fixed costs and relatively small variable costs in comparison. Due to the physical size of the final product, Boeing and Airbus are producing; a substantially large facility is required to manufacture an aircraft. Large, expensive equipment such as lifts are required to move the various parts of the aircraft to assemble it. Additionally, in order to even have a product to sell, Boeing and Airbus, at a minimum, need to do research and development to conceptualize an aircraft to sell, resulting in a high sunk cost. Airlines are often willing to sign purchase agreements when the aircraft is just on the drawing board before an expensive investment has been made in building an airworthy prototype and conducting a test flight. This can be seen by United Airlines commitment to purchase a conceptual supersonic aircraft from Boom Supersonic and their commitment to purchase an electric passenger aircraft from Heart Aerospace (Boom – United Goes Supersonic). These aircraft are a highly experimental concept that will have substantial engineering challenges to overcome before they can even take a test flight. While Airbus and Boeing do incur substantial variable costs for producing each additional aircraft, most of the cost structure associated with an aircraft is a fixed cost.

 Throughout a relatively short amount of time, the passenger aircraft industry has, in many ways, rapidly changed and has stayed the same. Despite there being relatively little competition in the passenger aircraft market, manufacturers compete heavily for long-term customers and have advanced aircraft such that flying commercially is more accessible for the average person. With current engineering pursuits of economical supersonic flight and electric flight, the world will continue to become more physically connected.

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