Analysis of the General Aviation Jet Industry: Competition, Concentration, and Forecasts With an Eye on Labor Markets

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This paper examines the global production and delivery of business jets, focusing on trends and shifts in industry concentration using the Herfindahl-Hirschman Index (HHI). After analyzing the concentration trend, we use ARIMA models to forecast production and industry structure through 2026 and estimate the impact of changing concentration on employment. Although estimates indicate increasing concentration in the large jet sector, a potential increase in deliveries and growing GDP could offset the higher HHI. The findings offer valuable information for policymakers and analysts interested in capital-intensive industries while contributing to broader discussions on market competition and labor dynamics.

Keyword: Herfindahl-Hirschman Index (HHI), labor market, general aviation

INTRODUCTION

The impact of mergers on labor markets often receives insufficient attention in antitrust enforcement, which typically prioritizes consumer welfare standards by assessing the adverse impacts of anti-competitive practices on consumers. This study aims to fill the gap by quantifying the level of market concentration over time and its subsequent impact on labor within the specific subsector of general aviation manufacturing, commonly called business jets. We focus on the business jet sector within the general aircraft market due to the changing buyers' interest in the jet segment, which represents the bulk of the revenues within the industry.

The business jet industry is characterized by its complexity, with various firms producing a wide range of jet sizes that cater to different market segments. Some manufacturers produce jets across the small and large categories, while others specialize in only specific sizes. Moreover, some of these firms are conglomerates (i.e., operating in multiple industries). Understanding competition within the business jet industry requires an in-depth analysis of market concentration, which we have conducted using the Herfindahl-Hirschman Index (HHI). The HHI is a popular metric that assesses market concentration by squaring the market shares of each firm (i.e., the market share is implicitly multiplied by 100 to remove the decimal point, so a 20 percent market share, or 0.20, would be 20 and when squared would be 400) and summing the results. A higher HHI indicates a more concentrated market dominated by fewer firms, whereas a lower HHI suggests a more competitive landscape with numerous firms holding relatively small shares. According to the United States Department of Justice and Federal Trade Commission Antitrust

Guidelines: "…Markets with an HHI greater than 1,800 are highly concentrated, and a change of more than 100 points is considered a significant increase..." (U.S. DOJ and FTC, 2023).

Our analysis maps out industry concentration by creating sub-industries for small, medium, and large jet production. Using the highly detailed dataset, we created from publicly available information on general aviation aircraft deliveries from 1985 to 2023, we calculate HHI for the entire business jet industry and its sub-segments. We are able to track the HHI over time, whereas most studies only capture the HHI as a snapshot at one or two points in time. By comparing year-over-year changes in HHI and integrating production data with nonlinear forecasting models, we project production trends through 2026. These forecasts highlight key dynamics in the industry, particularly the slight change in concentration, which have important implications for employment within the aerospace sector.

History and Background

The size classifications depicted within the history, background, and analysis are based on standardized segments defined by the Subcommittee on Business Aviation of the Transportation Research Board (TRB). This subcommittee meets biannually to review industry trends and develop a consensus forecast. As of May 2024, the TRB has established seven distinct size classifications (excluding airliners).

The business aviation industry has experienced significant evolution since its early years, marked by the entry of new competitors and the exit of established manufacturers. In the late 1970s and early 1980s, five major manufacturers—Bombardier, Cessna, Dassault, Gulfstream, and Hawker—dominated the market with smaller jets with limited passenger capacities and ranges. These early jets were designed primarily to meet the needs of smaller businesses and individual owners. As demand grew, the business jet industry focused on larger aircraft, driven by improved cabin comfort, reliability, safety, range, and efficiency.

Over time, the business jet market has been shaped by economic cycles, mergers, and acquisitions as new entrants and established companies sought to capitalize on profit opportunities. One of the most notable industry consolidations occurred when Textron Inc. acquired Hawker Beechcraft, merging it with Cessna to create Textron Aviation, a key player in small and midsize jet segments. While some mergers seemed to bring new life to straining companies, others, like Eclipse Aviation, a manufacturer that aimed to revolutionize the very light jet (VLJ) market with an initial price target of only $1.5 million, failed to survive the economic challenges of the Great Recession, filing for bankruptcy in 2008.

Despite these challenges, new entrants have found success in the market. For instance, Embraer, initially known for producing larger regional and commercial jets, entered the business jet market in 2002. A Brazilian company with operations in Melbourne, Florida, Embraer initially focused on the midsize sector but quickly expanded its offerings to smaller segments by 2009 and 2015. Honda followed in 2015, introducing the HondaJet, a Class I aircraft (introductory class) with a distinctive over-the-wing engine design that enhanced aerodynamic efficiency and reduced cabin noise. Pilatus, which was known for its rugged PC-12 turboprop, entered the business jet market in 2018 with the PC-24, a Class II jet capable of operating from short, unpaved runways, offering versatility not typically seen in business jets.

In Table 1, the small jet segment reached its highest concentration in 2002, with an HHI value of 4,460, and has since declined, reaching a low of 1,901 by 2020. The small jet segment is more sensitive to economic cycles and was impacted heavily by the Great Recession. The segment eventually recovered from the recession, and new firms entered the segment, which diversified the competition.

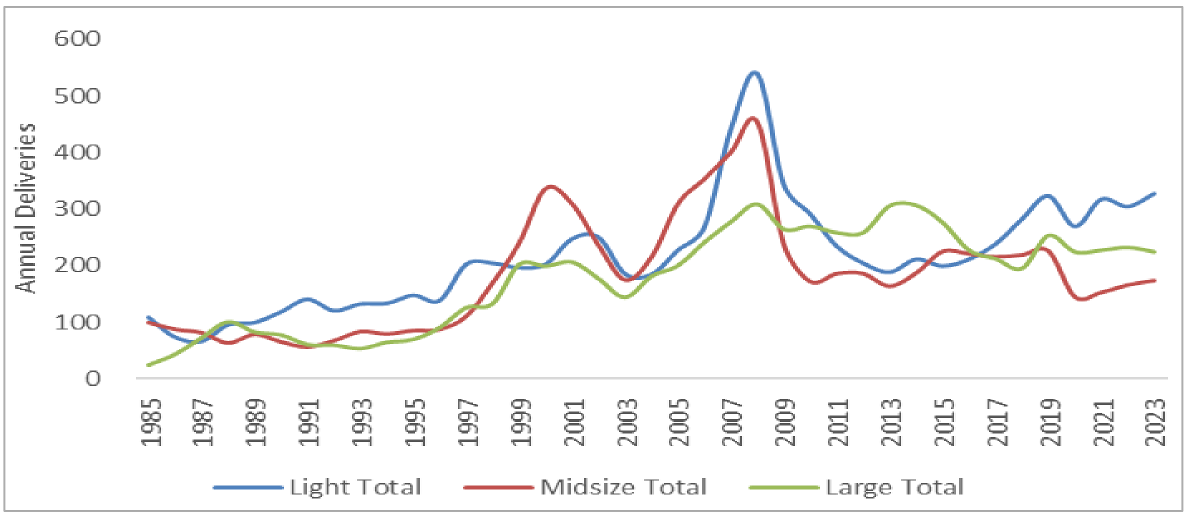
In contrast, the large jet segment has remained more concentrated throughout the period. The HHI for large jets peaked at 5,392 in 1985 and gradually decreased to 3,335 by 2009, yet it has remained consistently above 3,000 throughout most of the period. This level of concentration highlights the dominance of a few key manufacturers, driven by the higher barriers to entry in the large jet market. Large business jet production is costly and mainly serves corporate clients with steady demand, so it has stayed relatively stable even during economic downturns compared with the small jet segment of the market.

Across the entire business jet industry, the HHI fluctuated between 2,833 in 2002 and 1,550 in 2020, as competition in the small jet market increased while the large jet market remained relatively stable. This variation in concentration shows how the different segments have shaped the industry's overall structure.

The number of firms producing jets has also shown notable trends. In the small jet segment, the number of manufacturers increased from five firms in 1985 to eight firms in 2023, reflecting the more competitive nature of this market. Alternatively, the large jet segment was continually dominated by three or four firms producing large jets over the same period. This contrast reflects the significant capital and technological barriers required to compete in the large jet segment.

As shown in Figure 1, the jet deliveries by size also support these observations. Light jets peaked in 2008, with over 400 units delivered, but saw a sharp decline following the Great Recession. However, deliveries have since stabilized, showing moderate recovery in recent years. The midsize jet segment followed a similar pattern, peaking in the late 2000s, with deliveries stabilizing at around 200 units annually. Meanwhile, large jets have demonstrated more consistent delivery rates, peaking at around 300 units in 2008, with less fluctuation during economic downturns.

FIGURE 1
BUSINESS JET DELIVERIES BY SIZE



The historical data reveals a clear distinction between the dynamics of the small and large jet markets. The small jet segment has become more competitive, with more firms entering the market and deliveries fluctuating due to economic cycles. In contrast, the large jet market has remained more concentrated, with relatively stable demand from corporate buyers and high barriers to entry, maintaining a limited number of manufacturers.

The industry's capital-intensive nature benefits companies with significant financial resources and established reputations, often deterring new competitors from entering the market. However, as the market has evolved, even well-established manufacturers have had to adapt to market concentration and demand fluctuations across small and large jet segments.

LITERATURE REVIEW

The business jet manufacturing industry, like much of the broader aerospace and aviation sectors, operates within a highly concentrated market structure. This concentration is particularly evident among a small number of large firms that dominate design, manufacturing, and sales while managing a broad network of suppliers and subcontractors. The Herfindahl-Hirschman Index (HHI), a common metric used to measure market concentration, indicates that higher HHI values correspond to more concentrated markets dominated by fewer firms. For example, it is more useful in this industry than four-firm concentration ratios because these measures do not capture the dominance of the firms with the greatest market share. For example, an industry with four firms would have a four-firm concentration ratio of 100 percent if the firms had 50, 30, 15, and 5 percent of the market, respectively. The HHI would be $60^2 + 25^2 + 10^2 + 5^2 = 4,625$ (i.e., 3,600 + 900 + 100 + 25 = 4625). Whereas, if each firm had an equal share of that market (i.e., 25 percent each), the HHI would be 2500 (i.e., 25^2 each, which is 625 * 4 = 2,500). The HHI captures concentration dynamics, whereas less sophisticated metrics may not. Market concentration has important implications for competition, innovation, and employment trends in the general aviation jet industry.

Past research has shown that industries with higher levels of concentration, such as aircraft manufacturing, tend to favor incumbent firms due to high barriers to entry, steep learning curves, and significant capital requirements. These firms can leverage economies of scale, extensive supplier networks, and technological advantages to maintain their market positions, making it difficult for new entrants to compete. As a result, these oligopolistic structures often lead to reduced competition and innovation, particularly in capital-intensive industries where the cost of entry is prohibitively high (Kleiner et al., 2002). We might add economies of scope to Kleiner's list in the production and sale of jet aircraft.

The distinction between large and small jets in general aviation is particularly significant due to stark differences in production costs, market prices, and target customers. Large jets, typically have purchase prices greater than $20 million up to approximately $81 million, cater to a niche market of affluent individuals and corporations, while smaller jets, priced between $3 million to $20 million, appeal to a broader audience (Bjtonline, 2024). Segmenting the industry based on jet size facilitates a more nuanced understanding of competition, as the factors influencing market concentration can vary considerably between these two segments. This detailed examination of size-based segmentation contributes to a deeper comprehension of the competitive landscape and its implications for labor in the business jet industry.

The impact of market concentration on employment is widely studied in the economics literature. Higher concentration, as measured by HHI, tends to reduce employment growth. This reduction occurs because dominant firms can often streamline operations and reduce labor costs through technological efficiencies and economies of scale, thereby requiring fewer workers to maintain or even increase production levels. This trend aligns with the economic theory of monopsony power, where firms that dominate a market have the ability to suppress wages and limit employment due to a lack of competition for labor (Kleiner et al., 2002).

Further reinforcing these findings, a study in 2021 found that labor market concentration, measured by the HHI, leads to a 3.2% reduction in hires and a 0.5% decrease in workers' hourly wages for every 10% increase in concentration (Marinescu et al., 2021). One could suggest that these findings would also apply to general aviation manufacturing, where consolidation would limit employment opportunities and reduce workers' bargaining power, leading to wage stagnation. Dominant firms can gain greater control over both wages and the volume of labor they employ as market concentration increases.

Leadership also plays a significant role in shaping outcomes during periods of merger and acquisition activity in highly concentrated industries. For example, the 2014 merger of Cessna Aircraft Company and Beechcraft Corporation, which formed Textron Aviation, highlights the critical importance of leadership during major industry consolidations. This merger created the world's largest general aviation company, necessitating the integration of two large organizations under a unified vision (Robert Evenson et al., 2020). Leadership during this process required innovation, collaboration, and strategic foresight to integrate systems and develop a competent workforce capable of sustaining the demands of the rapidly growing market (Kleiner et al., 2002). The success of such mergers depends on the ability of leaders to navigate complex organizational changes while maintaining market share and operational efficiency. Effective leadership is critical in maintaining market competitiveness, particularly in an industry that continues to consolidate for reasons such as growth stimulation, elimination of competition, and diversification of business interests.

The impact of economic cycles on market concentration has also been a focus of research, particularly in industries like aircraft manufacturing, which are highly sensitive to macroeconomic trends. During periods of economic growth, market concentration tends to decrease as new firms enter the market to take advantage of rising demand. However, during economic downturns, smaller firms often struggle to survive, leading to increased concentration as larger, more established firms acquire or outlast competitors. For example, during the Great Recession of 2008, smaller aircraft manufacturers like Eclipse Aviation faced bankruptcy, while larger firms like Textron and Bombardier were able to weather the economic challenges and maintain their dominance in the market (Marinescu et al., 2021). This cyclical pattern of consolidation during downturns reflects the vulnerability of smaller firms in capital-intensive industries and highlights how economic conditions influence the structure of the business jet market.

Market concentration not only affects employment but also has significant implications for innovation and production capacity in the aircraft manufacturing industry. Capital-intensive industries like aircraft manufacturing have long development cycles and high costs. Stagnation in technological advancement can happen when the industry has long development cycles and a lack of competitive pressure. Alternatively, companies can streamline their supply chains and manufacturing capabilities when they merge, resulting in more efficient production processes. The tension between the benefits of efficiency and the drawbacks of reduced innovation is a key issue in understanding the broader impact of market concentration on the business jet industry.

As concentration in the market increases, a ripple effect also impacts sub-industries that support aircraft manufacturing. The effects impact machine shops, component suppliers, and metalworking firms that provide essential parts for aircraft production. Smaller suppliers often need more pressure to reduce prices and meet stricter production deadlines, which can lead to limited growth and further job losses. Smaller suppliers are particularly vulnerable to shifts in demand from dominant aircraft manufacturers, as their survival is often dependent on a few large contracts. When aircraft production levels fluctuate due to market consolidation or economic downturns, these suppliers may be forced to downsize or close altogether. Thus, the consolidation of market power at the top of the supply chain has a cascading effect on the smaller firms that support aircraft production, further reinforcing the negative employment effects of market concentration (Kleiner et al., 2002).

Overall, the existing body of literature provides a comprehensive view of the dynamics of market concentration in the business jet manufacturing industry and its broader economic impacts. Studies consistently show that increasing market concentration, measured by the HHI, leads to reduced employment growth, stagnant wages, and diminished innovation. Sub-industries are also impacted, which leaves them stagnant with job losses. Industry consolidation and structure should be monitored as market conditions evolve.

DATA AND METHODOLOGY

This analysis utilizes data on aircraft deliveries and labor trends within the business aviation sector. Aircraft shipment data on new deliveries is collected from the General Aviation Manufacturers Association (GAMA, 2024). The General Aviation Manufacturers Association (GAMA) is widely recognized within the industry as the official source for historical delivery numbers from member organizations. Although the data is reported quarterly, we rely on annual figures because many manufacturers report their numbers on an annual basis. This approach ensures consistency across all manufacturers analyzed in this study.

The labor data within this paper focuses on employment within the Aircraft Manufacturing sector in the United States. This dataset is derived from the U.S. Bureau of Labor Statistics and sourced from the Federal Reserve Economic Data (FRED) database. The data is indexed to 2017 (Index 2017=100) and provided on an annual frequency without seasonal adjustments.

By leveraging these key datasets, the analysis examines changes in market concentration and production trends over time, forming a basis for evaluating how industry dynamics influence workforce and production decisions.

The analysis uses data on the Herfindahl-Hirschman Index (HHI) for the entire business jet industry and the segments producing large and small jets, covering the period from 1985 to 2023. By evaluating year-over-year variations in HHI, the analysis highlights how industry dynamics, such as the entry and exit of manufacturers, influence labor forces and production decisions. The variation in HHI forms a foundation for understanding how industry concentration and shifts in production affect the long-term market structure, which is central to this study’s forecasting models. The HHI is calculated as follows:

$$HHI = \sum_{i=1}^{n} s_i^2 \quad (1)$$

where s_i is the market share of firm *i*, and *n* is the total number of firms within the market. This index ranges from 0 to 10,000, with higher values indicating a more concentrated market.

We segment the market based on size classifications defined by the Subcommittee on Business Aviation of the Transportation Research Board (TRB). To simplify these classifications, they are grouped into two broad categories: small aircraft (Sizes I through IV) and large aircraft (Sizes V through VII). Some manufacturers produce jets across all different sizes, while others specialize in certain size categories. By segmenting the industry in this way, we capture nuances in competition and production trends that might be overlooked when analyzing the entire market.

We use Autoregressive Integrated Moving Average (ARIMA) models to forecast the size classifications for each manufacturer. The ARIMA (p,d,q) model is defined by three parameters: p, d, and q. The parameter p represents the number of autoregressive (AR) terms, which capture the relationship between the dependent variable and lagged values of that dependent variable. The term d indicates differencing, the number of times the series must be differenced to achieve stationarity. Finally, *q* denotes the number of moving average (MA) terms, which is the relationship between an observation and a lagged error term. The three components allow ARIMA models to forecast trends in aircraft size classifications based on historical data, with each model tailored to the specific characteristics of the respective manufacturer's production. Moreover, ARIMA models allow researchers to foresee possible turning points that many forecasts simply cannot do. For a time series *Yt*, the ARIMA(*p*, *d*, *q*) model is defined by the following equation:

$$Y_t = \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \ldots + \emptyset_p Y_{t-p} + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-q} + \varepsilon_t \quad (2)$$

where *Yt* represents the differenced time series (adjusted for differencing order d) at time *t*. The coefficients ϕ_i correspond to the autoregressive (AR) terms, which capture the relationship between the current observation and a specified number of lagged observations. The parameter *p* defines how many of these lagged observations are included in the model; for instance, if *p*=1, only the immediately preceding value is used in forecasting the current value. The term *d* denotes the differencing order, which is the number of times the series needs to be differenced to become stationary, thereby stabilizing the mean and variance over time. The coefficient term θ_j, the moving average (MA) term, captures the influence of prior forecast errors on the current observation. The number of lags of the forecast error term is the parameter *q* within the model. The parameter *q* indicates the number of lagged forecast errors included in the model. The coefficient ϵt symbolizes the white noise error term at time *t*.

To estimate the impact of industry concentration on the aircraft manufacturing workforce, we utilize a regression model highlighting the role of the Herfindahl-Hirschman Index (HHI). We also include a vector of additional variables that may economically impact employment within the industry. The model is represented as follows:

$$ChgWorkforce = \alpha + \gamma(HHI_{t-1}) + \beta X_t + \varepsilon_t, \quad (3)$$

where α is the intercept, capturing the baseline level of workforce change, γ represents the coefficient for the HHI in the industry, indicating the influence of market concentration on workforce adjustments. Time is represented by *t*, which ranges from zero in 1985 (i.e., the first year in our sample) to 41 in 2026, the last year for which we forecast any variables. The vector βX_t represents other relevant variables that influence workforce adjustments collectively, and finally, the error term is denoted by ε_t. This structure emphasizes the effect of industry concentration as a primary driver of employment trends while accounting for the combined influence of other selected economic factors. The organization of the model in this manner captures the influence market concentration has on changes in the labor force associated with the business jet manufacturing industry.

RESULTS

The ARIMA models provide a forward-looking analysis of how the industry seems most likely to evolve from 2024 to 2026 based on the patterns the historical data reveals. We began by conducting the Dickey-Fuller test to ensure the data was stationary. The results indicated that most models required first differencing, allowing us to remove trends and stabilize the data over time.

During the modeling process, we examined the significance of the autoregressive (AR) and moving average (MA) terms to ensure their meaningful contribution to the model's predictive power. We also verified that the models' residuals were white noise, ensuring no further patterns remained in the data. Additionally, the Wntestq error test was used to confirm model robustness. Importantly, we did not rely solely on statistical selection criteria such as the Akaike Information Criterion (AIC) or Bayesian Information Criterion (BIC). We also factored in industry-specific constraints, including the understanding that aircraft manufacturing requires long lead times and strategic planning, so large swings in deliveries within a short period would be unrealistic. Models that projected such swings were adjusted to reflect the practical limits of production capabilities.

The ARIMA models in Table 1 offer valuable insights into the differing production dynamics between small and large jets. Small jets (Sizes I and II), with lower p and q values, exhibit simpler autocorrelation and moving average processes, indicating more frequent fluctuations in demand. These fluctuations are driven by smaller businesses and individual buyers, whose purchasing behavior is likely to be more sensitive to economic conditions and probably differs somewhat compared with the decision-making of larger corporations with respect to purchasing more considerable capital assets. Additionally, the small jet market is seeing an increasing number of entrants, which introduces further volatility. The simpler ARIMA models, such as (1,1,0) and (1,1,1), suggest that shifts in demand happen quickly, with short-lived effects. This reactive nature of the small jet market allows production cycles to adjust rapidly, aligning with this segment's competitive and dynamic environment.

TABLE 1
ARIMA MODELS BY SIZE CLASSIFICATION

Size Classification	ARIMA Model (p,d,q)
I	(1,1,0) to (2,1,3)
II	(1,1,0) to (2,1,2)
II	(2,1,0) to (2,1,3)
IV	(1,1,1) to (2,1,2)
V	(1,1,1) to (3,1,2)
VI	(1,1,1) to (2,1,3)
VII	(2,1,2) to (2,1,3)

In contrast, the ARIMA models for large jets (Sizes V to VII) show higher p and q values (i.e., longer time spans influencing deliveries), such as (2,1,3), reflecting greater complexity in production cycles. While the number of overall deliveries of large jets is more stable, the larger magnitude of internal specifications within the ARIMA models reflects the influence of longer-lasting trends (and shocks) on large jet deliveries. The production of large jets is characterized by extended lead times, strategic resource allocation, and persistent patterns in demand. Corporate clients are the main buyers of large jets (excluding fractional shares), providing a steadier flow of orders than small jets. However, manufacturing large jets requires more complex adjustments. New model introductions and the long-term production process add to these complexities, reflected in the ARIMA models' higher p and q values.

These patterns suggest that small jets experience short-term volatility as demand rapidly adjusts to changing market conditions. On the other hand, large jet production faces long-term complexities, where stable deliveries mask the more intricate production planning and resource management required to sustain consistent output.

The ARIMA models in Table 2 highlight the forecasted trends for different manufacturers across the defined size classifications. The variation in ARIMA parameters among manufacturers reflects differences in production volumes, market demand, and strategic focus.

TABLE 2
ARIMA MODELS

Manufacturer	Size Classification	ARIMA Model (p,d,q)
BOM	III	(2,1,0)
BOM	IV	(2,1,2)
BOM	V	(3,1,2)
BOM	VII	(2,1,3)
CES	I	(2,1,0)
CES	II	(1,1,1)
CES	III	(2,1,0)
CES	IV	(2,1,2)
CIR	I	(1,1,0)
DAS	I	(1,1,1)
DAS	V	(1,1,2)
DAS	VI	(1,1,1)
DAS	VII	(1,1,2)
EMB	I	(2,1,1)
EMB	II	(1,1,0)
EMB	IV	(2,1,2)
EMB	V	(1,1,1)
GLF	IV	(1,1,1)
GLF	VI	(2,1,3)
GLF	VII	(2,1,3)
HON	I	(1,1,3)
PIL	I	(1,1,1)

The models in Table 3 complement the prior analysis by examining the impact of aircraft deliveries, real GDP, and HHI concentration levels on employment within the aircraft manufacturing industry. Using the percentage change in aircraft manufacturing employment *(%Chg Workforce*) as the dependent variable, we developed two regression models to forecast short-term employment using *Total Deliveries* and percentage change in real GDP *(%Chg RGDP* Lagged one period *(L1))* as the core explanatory variables. The second model extends the first by introducing the Herfindahl-Hirschman Index (*HHI* Lagged one period (*L1*)) to account for the effects of market concentration. Variance Inflation Factor (VIF) tests were conducted to check for multicollinearity. The VIF results confirmed that multicollinearity was not a significant concern in either model, ensuring that the relationships between variables were reliable and distinct.

TABLE 3
DEPENDENT VARIABLE: PERCENT CHANGE IN AVIATION MANUFACTURING WORKFORCE: OLS REGRESSION WITHOUT AND WITH HHI

	Model 1: Without HHI	Model 2: With HHI
Total Deliveries	0.000081***	0.0000458*
	(0.000)	(0.000)
% Chg RGDP L1	0.847**	0.964**
	(0.370)	(0.382)
HHI Industry L1		-0.000063***
		(0.000)
Constant	-0.081***	0.078
	(0.021)	(0.063)
N	36	36
R^2	0.206	0.366

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In the first model, *Total Deliveries* has a positive and statistically significant impact on employment, with a coefficient of 0.000081 (p < 0.01), suggesting that increased aircraft deliveries lead to greater employment. Similarly, *%Chg RGDP L1* has a significant positive effect on employment, with a coefficient of 0.847 (p < 0.05), indicating that economic growth from the prior period contributes to current employment levels. The model's R^2 of 0.206 indicated that 20.6% of the variation in employment was explained by variation in these two factors.

The second model adds *HHI L1*, the lagged Herfindahl-Hirschman Index, to capture the effect of market concentration. Compared with the model without the HHI, introducing *HHI L1* slightly reduces the effect of *Total Deliveries* on employment, with a coefficient of 0.0000458 (p < 0.10). The positive coefficient in each model is consistent with *a priori* expectations. The effect of *% Chg RGDP L1* increased slightly to 0.964 (p < 0.05), reinforcing the finding that economic growth from the previous period drives employment gains. Labor markets are notorious for lagging other economic indicators as employers likely resist the temptation to lay off workers at the first sign of an economic downturn for fear of losing a well-trained and experienced workforce. Similarly, they are likely to use overtime and other factors before recruiting, screening, hiring, and training skilled workers as the industry/economy appears to be poised for expansion. Most notably, *HHI L1* has a significant negative impact on employment, with a coefficient of -0.000063 (p < 0.01), suggesting that increased market concentration leads to reductions in employment. As indicated before, cost saving and efficiency gains are commonly associated with larger firms consolidating market share. The R^2 for this model was 0.366, indicating that the combination of variation in total deliveries, lagged GDP, and market concentration explained 36.6% of the variation in employment.

The results from both models provide valuable insights into how total deliveries and economic growth influence employment in the aircraft manufacturing sector while highlighting market concentration's dampening effect on workforce levels. The improvement in R^2 from Model 1 to Model 2 suggests that market concentration plays a vital role in explaining employment variation, with concentrated markets potentially reducing labor needs as firms grow more efficient. The VIF tests confirmed that multicollinearity was not a significant factor, further strengthening the validity of the models and the relationships between the variables.

Using Model 2, we estimate the change in employment in the aircraft manufacturing industry through 2026. The forecast for total deliveries derives from industry ARIMA estimates, with projections of 730, 746, and 752 units for the years 2024, 2025, and 2026, respectively. The real GDP growth forecast derives from the Federal Reserve's projection of 2% growth for the next two years, following a growth rate of 2.54% in 2023 (*Summary of Economic Projections*, 2024). The HHI values, reflecting market concentration, are 1625 for 2023, with an estimated value of 1636 and 1612 for 2024 and 2025, respectively. These nonlinear forecasts using ARIMA models do not forecast major turning points (i.e., trends reversing in the near term). Table 4 reflects historical deliveries and HHI values, along with projected deliveries with associated HHI.

TABLE 4
FIRMS, DELIVERIES, HERFINDAHL HERSCHMAN INDEX – ACTUAL AND FORECAST

Year	Firms Producing Small Jets	Firms Producing Large Jets	Total Firms Producing Jets	Small Deliveries	Large Deliveries	Total Deliveries	HHI Small Jet MFG	HHI Large Jet MFG	HHI Industry
1985	5	2	5	208	25	233	2933	5392	2591
1986	5	3	5	161	44	205	2556	4514	2160
1987	5	3	5	148	73	221	2957	3582	2109
1988	5	3	5	159	101	260	2879	3783	2038
1989	5	3	5	178	83	261	3017	3828	2206
1990	5	3	5	184	78	262	3609	3609	2472
1991	5	3	5	197	61	258	3853	3658	2733
1992	5	3	5	188	60	248	3768	3550	2612
1993	5	3	5	216	54	270	3691	3909	2800
1994	5	3	5	213	65	278	3939	3392	2797
1995	5	3	5	233	70	303	3464	3371	2516
1996	5	3	5	226	91	317	3843	3353	2513
1997	5	3	5	313	126	439	3932	3425	2514
1998	5	3	5	374	133	507	3603	3573	2488
1999	5	3	5	436	202	638	3508	3367	2401
2000	5	3	5	538	199	737	3307	3382	2447
2001	5	3	5	556	206	762	3759	3350	2621
2002	5	4	6	486	177	663	4460	3072	2833
2003	5	4	6	360	144	504	3864	2869	2427
2004	5	4	6	399	181	580	3283	2926	2173
2005	5	4	6	536	200	736	3316	2882	2347
2006	6	4	7	621	241	862	3410	2837	2375
2007	7	4	8	841	277	1118	2927	2752	2101
2008	7	4	7	992	308	1300	2960	2830	2134
2009	6	4	7	581	264	845	3216	2972	2106
2010	5	4	6	463	269	732	2673	3111	1812
2011	5	4	6	420	258	678	2839	3161	2032
2012	5	4	6	390	258	648	3110	2969	2101
2013	6	4	6	352	305	657	2804	3103	2102
2014	6	4	6	398	306	704	2721	3284	2152
2015	7	4	7	424	276	700	2795	3392	2197
2016	8	4	8	432	227	659	2767	3299	2045
2017	8	4	8	454	212	666	2463	3333	1855
2018	8	4	8	501	195	696	2184	3662	1742
2019	8	4	8	549	253	802	2152	3369	1667
2020	8	4	8	414	224	638	1901	3381	1550
2021	8	4	8	470	227	697	2104	3459	1581
2022	7	4	8	470	232	702	2282	3264	1677
2023	8	4	9	501	224	725	2070	3345	1625
2024				502	228	730	1669	3348	1636
2025				516	230	746	1612	3382	1612
2026				517	235	752	1648	3400	1627

*Excludes Eclipse

Applying these projections to Model 2, we estimate the following changes in employment in the aircraft manufacturing sector: an estimated 3.33% increase by the end of 2024, a 2.81.% increase in 2025 and a 2.99% increase in 2026. These estimates suggest a general rise for all sectors of general aviation jet manufacturing employment over the next three years, driven by increasing total deliveries and moderate

GDP growth. However, the slight increase for HHI, on average, suggests a slightly dampening effect on employment growth related to this industry.

DISCUSSION

Our novel approach to mapping industry concentration by segmenting the market into different jet size classifications highlights significant differences in market behavior. The ARIMA models reveal key insights into the contrasting dynamics of the small and large jet segments. The small jet market is highly reactive, with demand driven by competitive pressures, frequent new entrants, and external economic conditions. Manufacturers in this segment must remain agile, adjusting production capacity quickly to meet fluctuating demand. Compared with the ARIMA models for large business jets, the relative simplicity of the ARIMA models for smaller jets, with lower p and q values, aligns with the market's more predictable production cycle. The broader customer base, which includes smaller businesses and individual owners, contributes to this steady but variable demand. However, this market's increasing competition raises several possibilities, including potentially less profitability for firms in the industry, oversaturation, and innovation, potentially leading some to exit the industry.

In contrast, the large jet market faces longer, more complex production cycles driven by longer lead times and strategic planning requirements. The ARIMA models for large jets have larger p and q values, reflecting the complexity of managing production schedules in response to corporate demand. Large jets require substantial capital investment, and the volatility in demand from high-net-worth individuals and corporate buyers adds to the challenge. Nevertheless, the relative stability in delivery numbers shows the resilience of the large jet market, which has experienced steady demand even during economic downturns. However, the concentration in this segment raises questions about long-term competition, with fewer players dominating the market and potentially stifling innovation.

The employment forecast models complement the ARIMA insights by focusing on the relationship between economic factors and workforce trends. In both models, Total Deliveries and Lagged Percentage Change in Real GDP (L1 %Chg RGDP) emerge as significant factors in forecasting employment in the aircraft manufacturing sector. The positive impact of total deliveries on employment demonstrates a positive relationship between production output and labor needs, while the influence of lagged GDP growth highlights the broader economic environment's delayed but lasting effect on employment. However, the second model, which introduces the Herfindahl-Hirschman Index (HHI L1) as a measure of market concentration, reveals the importance of how industry concentration influences employment. As market concentration increases, employment tends to decrease, likely due to cost-saving and efficiency gains as dominant firms consolidate their market share and optimize their production processes. In highly concentrated markets, such as the large jet segment, the dominance of a few players may lead to job reductions despite steady production levels, as fewer firms may be able to operate with greater efficiency.

The forecasts derived from these models suggest slow and steady employment growth in the business jet industry over the next three years. The expected employment growth will likely be driven by increased production, but the potential for consolidation could mitigate these gains in certain sectors. Consolidation within the large jet sector would not appear likely without further technological advancements due to the small number of established competitors. In contrast, while the small jet sector also has well-established companies, the larger number of competitors increases the likelihood of consolidation in that market. Moreover, if past mergers, acquisitions, entry, and exit of firms manufacturing light jet aircraft are any indication of the future, then we cannot rule out changes in the concentration related to manufacturing light jet aircraft.

IMPLICATIONS AND CONCLUSION

For manufacturers, particularly those involved in small jet production, the more competitive and volatile market may provide growth opportunities, but there are also risks of oversaturation. Manufacturers in this segment have exhibited adaptability to shifting demand and competition. By contrast, facilities focused on large jets may face fewer competitors but will face navigating the complexities of production planning and long-term investment cycles, as highlighted by the ARIMA models.

As the industry looks ahead to 2026, balancing the opportunities presented by rising demand with the structural challenges posed by market concentration and competitive pressures could be challenging. These findings highlight the critical role of production levels, economic growth, and market concentration in shaping workforce trends and market behavior. Stakeholders, including satellite machine shops in the aircraft manufacturing sector, would be wise to recognize the complexity of these factors, especially as they make strategic decisions about future investments and capacity planning. Additionally, further insight into the growth and impact of fractional operators on the industry is an avenue that could be pursued further. Moreover, external factors such as elections, changing regulations, and ongoing conflicts in other countries, among others, could significantly impact these findings in this global market.

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