Impact of Technology on Stakeholders of Commercial Air Transportation: Airlines, Manufacturers, and the Public

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ABSTRACT

OVER the past twenty years, the commercial air transportation industry has benefitted from many advances in technology. Most of these new technologies have worked to reduce the cost of air travel, primarily through reductions in fuel consumption. Figure 1 shows how fuel efficiency in available seat miles (ASM) per gallon has improved as compared to fuel prices. Other changes like increased range, reduced crew requirements, and reduced prices have simultaneously made air travel cheaper and more available. It is therefore of interest to understand how these changes have affected the welfare of the air transportation industry. This paper will utilize historical industry profits and average aircraft characteristics to attempt to quantify the effect of technology utilization on three stakeholder groups: aircraft manufacturers, airlines, and the public.

Data on average aircraft characteristics is drawn from the Bureau of Transportation Statistics TranStats database[1,2,3], which provides quarterly data on passenger miles flown for every airline and each aircraft type. Combining this information with manufacturer specifications for each aircraft, we may construct a “characteristic aircraft” using a combination of all aircraft weighted by the total passenger miles flown by each model. The aircraft characteristics considered are: maximum range, useful payload, maximum takeoff weight, zero fuel weight, operating empty weight, fuel capacity, passenger capacity, fuel efficiency in nautical miles per gallon, max speed, required flight crew, and list price at introduction.

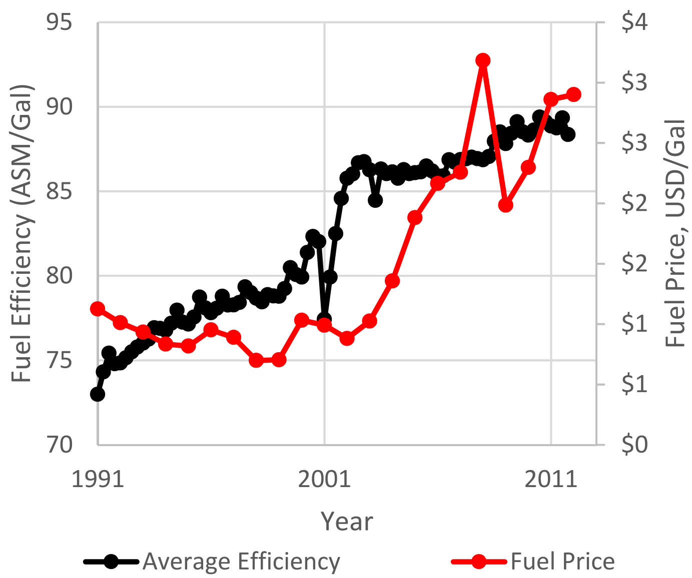

Figure 1. Annual jet fuel prices and average aircraft efficiency

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Quarterly profits for both airlines and manufacturers are used as a measure of their respective welfare. The TranStats database provides these quarterly profits for each airline, while manufacturer profits are acquired from each manufacturer's published quarterly reports[4,5]. To quantify public welfare, we utilize the number of tickets sold in each quarter as a measure of the relative access of the public to air travel. The number of tickets sold is calculated based on passenger miles flown from the TranStats database[1] and the average trip length in each year provided by Airlines for America[6].

Finally, it is necessary to consider other effects on welfare external to technology. We consider 4 major external events; the September 11, 2001 terrorist attack, the financial crises of 2000-2002 and 2007-2009, and the merger between Boeing and McDonnell-Douglas. We also remove from the data an accounting artifact related to the bankruptcy filings of Delta and Northwest in 2005. Additionally, effects of progressing time and changes in fuel prices are considered in the analysis.

In order to quantify the impact of each of these inputs on welfare of each of the stakeholders, we construct surrogate models for each stakeholder welfare in terms of all of these inputs considered, and calculate the effect of each component of the model. By grouping each input into either technology-related or an external effect, we are able to determine the total welfare impact on each stakeholder. Because much of our input data is noisy and highly correlated, we find that traditional polynomial response surface (PRS) models exhibit poor performance, particularly with respect to predicted residual sum of squares (PRESS) error.

We instead utilize the support vector regression (SVR) model, as it provides us with two useful tools: error insensitivity and flatness. Error or epsilon insensitivity means that the surrogate will ignore errors within a specified range, reducing the tendancy to fit noise in the data. Flatness means that SVR applies a penalty to large coefficients, thereby reducing the effect of

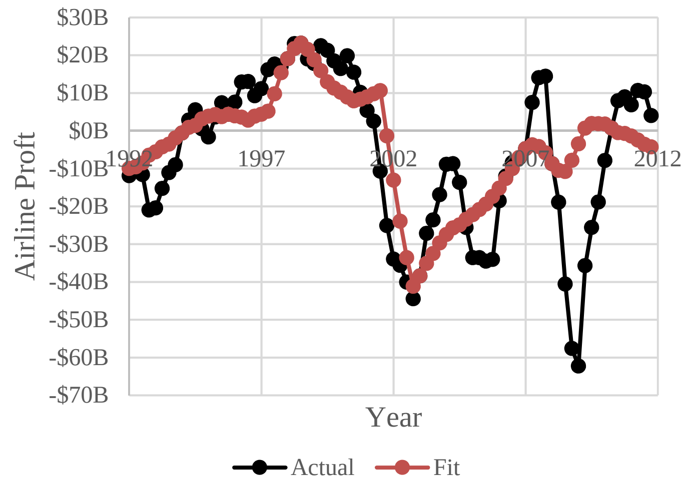

Figure 2. Airline profit and SVR model

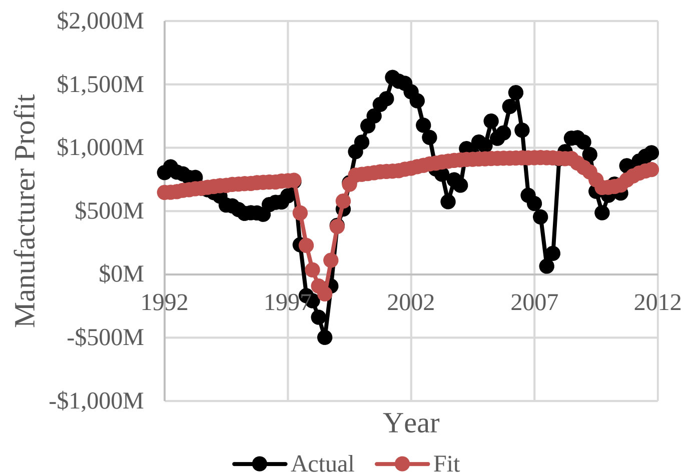

Figure 3. Manufacturer profit and SVR model

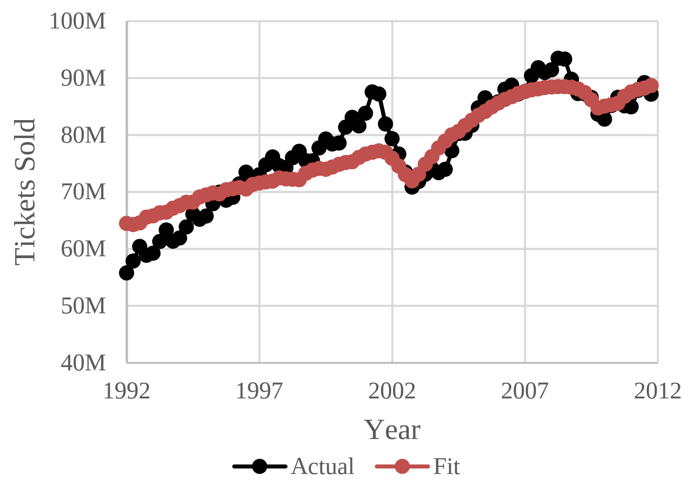

Figure 4. Tickets sold and SVR model

correlated inputs and noise. Our preliminary SVR models for each stakeholder group are presented in figures 2-4.

We now use finite differences to calculate the relative contribution of each of the variables, and combine these variables into technology utilization and external effects to judge the impact on each stakeholder. It should be pointed out that a change in technology utilization does not necessarily indicate a change in available technology. Figures 5-7 provide the cumulative change in welfare for each respective agent attributable to technology and external effects. Table 1 provides a summary of the absolute change in welfare and percent change versus the range for each stakeholder. We see that airlines are shown to have seen enormous welfare gains of $35B through advanced technology, however they have suffered slighlty greater losses due to external factors for a net negative welfare change. Manufacturers also enjoyed significant gains of $725M due to technology, though only an $174M increase overall when offset by external forces. Finally, the public is shown to have roughly zero net external effects while gaining a combined 24M increase in ticket sales.

It may also be of interest to consider the impact of each input individually in order to judge their relative importance. Table 2 provides the relative contribution of each input, ordered by the magnitude of change brought about for each stakeholder, respectively. As might be expected, major world events, fuel prices, and efficiency are near the top of the list for all three stakeholders. It should be noted that SVR does not provide error measures for individual inputs, so additional analysis is necessary to determine the confidence in these values.

In the full paper, we will look further into the data collected in order to discuss the these results in detail. We will also attempt to refine our surrogate modeling process in order to reflect the true market behavior as accurately as possible. Finally, we will provide discussion on the implications of our analysis for guiding future research and identifying potential opportunities for new aircraft designs.

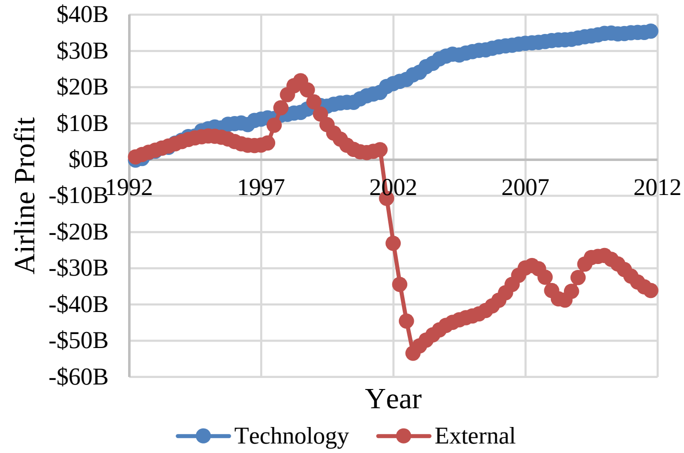

Figure 5. Airline technology and external cumulative effect

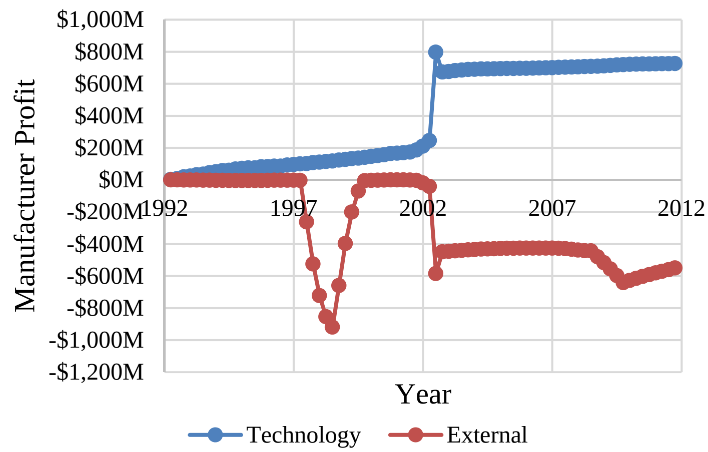

Figure 6. Manufacturer technology and external cumulative effect

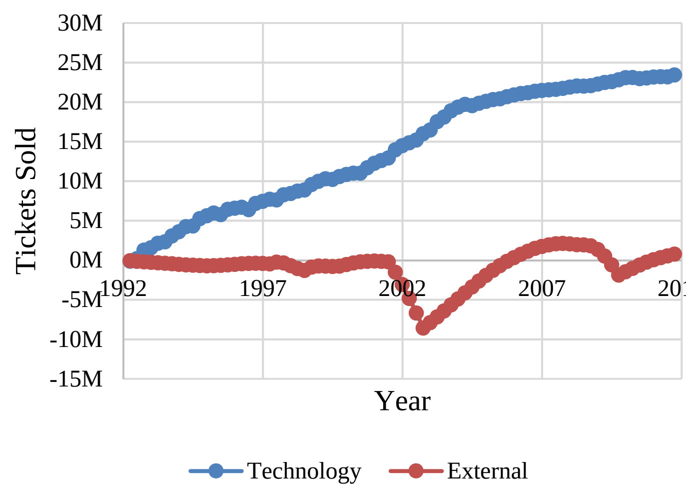

Figure 7. Public technology and external cumulative effect

Table 1. Cumulative technology and external effects

Airline		Manufacturer		Public	
Technology	External	Technology	External	Technologgy	External
$35B (41%)	-$36B (-42%)	$725M (35%)	-$551M (-27%)	23.4M (62%)	0.7M (2.0%)

Table 2. Relative impact of each input on stakeholders

Airline		Manufacturer		Public	
Fuel Price	-802%	9/11	-235%	Fuel Efficiency	21%
Fuel Efficiency	148%	Range	131%	Crew	13%
Crew	131%	Aircraft Price	100%	OEW	11%
ASM/Gal	117%	Fuel Efficiency	90%	Fuel Capacity	10%
ZFW	101%	Crew	84%	ZFW	9.5%
Fuel Capacity	91%	ASM/Gal	68%	Passenger Capacity	7.8%
OEW	89%	Mortgage	-61%	Fuel Price	7.3%
MTOW	58%	OEW	-15%	Range	7.2%
Passenger Capacity	50%	ZFW	-14%	MTOW	6.5%
Payload	46%	Fuel Capacity	-11%	ASM/Gal	5.5%
Mortgage	42%	Fuel Price	-10%	Mortgage	-5.0%
Range	34%	Passenger Capacity	-10%	Payload	4.4%
9/11	-23%	MTOW	-8.8%	Aircraft Price	1.5%
Merger	12%	Payload	-8.7%	9/11	0.71%
Aircraft Price	5.8%	Max Speed	0.85%	Max Speed	0.14%
Max Speed	1.6%	Merger	0.18%	Merger	0.09%
Year	0.23%	Year	0.06%	Year	0.02%

References

[1]Bureau of Transportation Statisictics. "TranStats Database: Air Carrier Summary : T2: U.S. Air Carrier TRAFFIC And Capacity Statistics by Aircraft Type." URL: http://www.transtats.bts.gov/Fields.asp?Table_ID=254 [cited 2 June 2013].

[2]Bureau of Transportation Statisictics. "TranStats Database: Air Carrier Summary : Schedule P-1.1." URL: http://www.transtats.bts.gov/Fields.asp?Table_ID=290 [cited 2 June 2013].

[3]Bureau of Transportation Statisictics. "TranStats Database: Air Carrier Summary : Schedule P-1.2." URL: http://www.transtats.bts.gov/Fields.asp?Table_ID=295 [cited 2 June 2013].

[4]Boeing Archived Quarterly Earnings Releases. URL: http://www.boeing.com/boeing/companyoffices/financial/quarterly.page [cited 2 June 2013].

[5]EADS Archived Financial Results. URL: http://www.eads.com/eads/int/en/investor-relations/key-financial-information/Financial-Statements-and-Presentations/archived-results.html [cited 2 June 2013].

[6]Airlines for America. "Average round-trip fares and fees." URL: http://www.airlines.org/Pages/Annual-Round-Trip-Fares-and-Fees-Domestic.aspx [cited 2 June 2013].