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Bachelor Thesis [Program: International Bachelor Economics and Business Economics]

Is Superjumbo Jet An Engineering Miracle or An Economic Failure? A Study on the Market for Airbus A380

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Table of Contents

I. Summary

Airbus A380 is the largest passenger aircraft in the world. However, the profitability and market of A380 are not so optimistic as what Airbus expected. It is even said that the production line of A380 will be terminated soon. As Airbus A380 is confronted with a fierce competition with Boeing and the stringent environmental considerations of airlines, the central research question of this thesis is "To what extent do the substitution effects of B787 and/or A350 influence the market for A380?"

In total, three hypotheses regarding the substitution effects and the sustainability considerations are formulated. To examine the hypotheses and answer the central research question, the secondary time-series data are retrieved from various sources and several statistical research methods (e.g. t-test, difference-in-difference, etc.) are used.

The conclusion is that the substitution effects of B787 and A350 are significant on A380 particularly with regards to specific airlines and destinations. The orders and deliveries of B787 and A350 significantly decrease the orders of A380. The sustainability considerations of airlines significantly increase the orders of B787 and A350 but decrease the orders of A380. These findings can provide some practical implications to the Airbus, the airlines, and the aviation industry.

II. Introduction

Airbus A380 is the largest passenger aircraft in the world. This superjumbo has been put in service for over ten years. However, the profitability and market of A380 are not so optimistic as what Airbus predicted. Except for Emirates, most of the airlines are not interested in it. It takes nearly ten years to realize breakeven for the first time, and it is said that the production line of A380 will come to an end in the near future.

The situation of A380 could be explained by the competition with Boeing, especially after the release of the Dreamliner B787. B787 is more sustainable, flexible, and fuel-efficient for the current aviation industry. At the same time, A350, another innovative jet aircraft produced by Airbus, may also influence the market for A380. B787 and A350 share a common feature that their airframes are constructed primarily of composite materials, which can largely reduce their weight and noise while increasing their fuel efficiency. In other words, B787 and A350 are more sustainable and environmentally friendly compared to A380. Therefore, this thesis will evaluate the market for A380 and forecast the market trend of superjumbo jet. The central research question is:

> **To what extent do the substitution effects of B787 and/or A350 influence the market for A380?**

There are a lot of existing articles stressing the influence of the competition between Airbus and Boeing on the aircraft manufacturers, the aircraft market, and the air transport economics (Esty and Ghemawat, 2002; Irwin and Pavcnik, 2004; King, 2007). The academic relevance is that this thesis can further analyze the influence of the competition between Airbus and Boeing on the A380 market, the airlines, and the aviation industry by looking into the specific substitution effects on A380 for different destinations (e.g. Tokyo) and different airlines (e.g. Singapore Airlines).

Since the aircraft program of A380 involved huge development costs and consumed investment in the region of over 10 billion U.S. dollars (Clark, 2017), the termination of A380 production might be disastrous for A380 production line due to the failure of cost recovery. Meanwhile, profitability is the most obvious measurement for an airline though, sustainability and environment restrictions also have an important impact on the current air transport economics (Clark, 2017; Holloway, 2017). The societal relevance is that this thesis can provide practical implications for Airbus to adjust marketing strategies of A380 accordingly, and for airlines to embark on fleet planning and decision making economically and sustainably. In a broader sense, this thesis can also encourage the aviation industry to elevate the corporate social responsibility of sustainable development and appeal to the passengers by choosing a more environmentally friendly mode of air transportation.

The thesis will first discuss some existing literature about air transport, superjumbo jet, and environmental considerations as the theoretical framework and formulate three hypotheses. Then, the research approaches including the data to be used and the statistical research methods to be performed will be introduced, followed by the results. Finally, the thesis will draw the conclusion and provide some practical suggestions for the Airbus, the airlines, and the aviation industry.

III. Theoretical framework

After the initial boom of A380 orders in the first decade of the millennium, it is not surprising that the book orders have calmed down since 2007 and remained stalled for a long period. This stagnation could be interpreted by both internal and external factors. Internally, the large size of the superjumbo jet requires investments by airports to re-innovate them to handle and operate it. These excessive airport infrastructure investments are in the nature of sunk costs, such as widening runways, indeed requiring financial incentives for airports (Forsyth, 2005). Besides, the large-sized double-deck A380s are restricted by airports' slot availability as well. For instance, London Heathrow and Gatwick face an artificial limit on A380s' slots due to the environmental considerations of the Quota Count (QC2) noise standard system. Concerning the stringent environmental restrictions, a careful consideration is necessary when airlines are deciding to use large-sized aircraft at slot-constrained airports. Thus, airlines would have no choice but to elevate the environmental considerations to a key decision criterion and a dominant theme in fleet planning (Clark, 2017).

Externally, the competition between Airbus and Boeing can have a huge impact on the whole aviation industry and even on the public sector or international organization. As the weaker market players (e.g. McDonnell Douglas) had flown away by the mid-1990s, the focus of the large commercial aircraft industry had shifted to Airbus and Boeing. The primary examples must be the Airbus - Boeing subsidy war in the 1990s and the following 1992 agreement mediated by the United States and European Union (Leonard, 2001). The 1992 U.S - E.U. agreement on trade in civil aircraft that limits subsidies also directly increased the aircraft prices by about three percent afterward (Irwin and Pavcnik, 2004). Later in 2004, the 1992 agreement was disputed again so that WTO had to agree to form two exclusive panels composed on non-EU and non-US members for Airbus and Boeing each (Leonard, 2001).

More straightforward, the duopoly of the aircraft manufacturing industry plays a dominant role in shaping the air transport market for superjumbo jets. The A380 entry succeeded in reducing the market share of the *Queen of the Skies* - B747 - by up to 14 percent in the long-range wide-body market segment, but at the same time induced the all-new Boeing competitor B787 (Campos, 2001). The interesting fact is that Airbus and Boeing both agreed the overall aviation industry would keep growing over the next 20 years in their *Airbus Industrie's Global Market Forecast 1998 - 2017* and *Current Market Outlook 1998* respectively. However, they diverged in how they interpret such a global market trend (Clark, 2017).

On the one hand, Boeing believed that the growth would gravitate to more flexible mid-sized aircraft (e.g. B787-size) and more point-to-point transits. Boeing predicted that airlines would have little incentive to employ larger aircraft (e.g. B747-size) in tightly regulated markets and congestive airports. Given that larger aircraft size could only contribute 2% of the available seat-kilometer (AKS) growth, the B747-size or larger aircraft would only occupy 7% of the world fleet in 2007 (*Airbus Industrie's Global Market Forecas*t, 1999). On the other hand, Airbus predicted that the growth would rely on the very large-sized aircraft (e.g. A380-size). Airbus forecasted that the traffic growth within an increasingly congested airport and air traffic system needed to be accommodated by the increasing average aircraft size and the increasing number of seats. The strong demand for fleets and seats would increase the widebody aircraft share to 43% (Meskill, 1998).

Seemingly, the global market trend more closely conforms to what Boeing predicts and B787 tends to outcompete A380 in the recent ten years. Therefore, the first hypothesis is formulated as the following:

Hypothesis 1: The orders and/or deliveries of B787 significantly decrease the orders of A380.

To fight back against the challenge from Boeing, Airbus rethinks and comes up with the newly designed and innovated aircraft - A350 - as the market response after the B787's service entry for several years (Marsh, 2007). The updated aircraft mode - A350XWB - can be undoubtedly considered as the real alternative to B787 actively entering the territory of mid-sized aircraft being occupied by Boeing (Marsh, 2010; Holloway, 2017). Given the fact that B787 has been threatening A380's market shares for many years and the positioning of A350 is extremely similar to that of B787, it might be of interest that A350 could be the alternative to A380 too. Therefore, the second hypothesis is put forward as the following:

Hypothesis 2: The orders and/or deliveries of A350 significantly decrease the orders of A380.

According to Christian Jardine, aviation emissions have a greater climate influence than the same emissions made at ground level. The reason is that emissions at altitude can instigate a host of chemical and physical processes that have a more serious negative impact on climate change. What is worse, greenhouse gas emissions from aircraft cannot be simply calculated and henceforth require a special approach (Jardine, 2005). To account for aviation emissions, the implementation of composite materials such as carbon-fiber-reinforced polymers (CFRP) has been unfolded by the aviation industry to reduce aircraft fuel burn and emissions of greenhouse gases. The aircraft architecture based on composite materials has significant environmental benefits compared to the traditional aluminum-based materials, especially with regards to the reduced CO_2 and NO_x emissions (Timmis, Hodzic, Koh, Bonner, Soutis, Schäfer, and Dray, 2015).

This climate care's approach adopted by aircraft manufacturers exactly provides an environmentally sustainable advantage to B787 and A350 compared to the conventional aluminum-based A380. Fundamentally, the substantial use of much lighter composite materials such as Carbon Wings can greatly reduce their weight and ultimately the noise that they make during taking-off and landing (Marsh, 2010). As noise has been put on the global environmental agenda, many different parties have tightened the regulatory standards of noise reduction leading to the more advantageous B787 and A350 are (Holloway, 2017).

By taking advantage of economies of scale, A380 does have lower fuel costs per passenger-kilometer than any existing aircraft modes of the same broad size such as B777 and B747 (King, 2007). Nevertheless, this advantage is also partially offset by the bureaucratic redundancy, decision-making, and overall inertia caused by the broader size (Clark, 2017). More importantly, B787 and A350 also effectively decrease their fuel-burn and increase their fuel-efficiency through technological modernization and interior/exterior modification. The fuel-burn per passenger-kilometer of B787 and A350 is equal to that of a small car. Generally, the smaller aircraft would have lower trip (i.e. aircraft-kilometer) costs but higher unit (i.e. seat-kilometer) costs. Whereas B787 and A350 have broken this relationship (see Table 1 below) by adjusting their seat configuration to make their seat-kilometer costs even lower than larger aircraft modes such as A380 and B777 (Holloway, 2017).

Table 1. The comparison of fuel consumption (per seat) between Airbus and Boeing[1]

Aircraft	Fuel Consumption (per seat)
A380	2.39 L/100 km
A350XWB	2.39 L/100 km
B787	2.37 L/100 km
B777	2.89 L/100 km

[1] Information retrieved from the website of Infinite Flight (2017), https://community.infinite-flight.com/t/airbus-vs-boeing-comprehensive-comparison/113633, on July 2, 2018

B747	3.16 L/100 km

Therefore, the third hypothesis is come up with as the following:

Hypothesis 3: The sustainability considerations of airlines significantly decrease the orders of A380 but increase the orders of B787 and A350.

IV. Data

In order to answer the central research question and testify the three hypotheses, the secondary time-series data are retrieved from various sources, including annual reports, sustainability reports, and the website of *International Air Transport Association* (IATA). Both the annual reports and the sustainability reports are annually audited and publicly disclosed as well as the IATA is the international trade association of the world's airlines, which can ensure the validity and the reliability of the data.

With respect to the first two hypotheses, the orders of A380 from 2000[2] to 2017, the orders of A350 from 2004[3] to 2017, the deliveries of A350 from 2014[4] to 2017, the development costs of A380 from 2008 to 2017, and the development costs of A350 from 2012 to 2017 are retrieved from the annual reports of Airbus[5]. The orders of B787 from 2003[6] to 2017 and the deliveries of B787 from 2011[7] to 2017 are retrieved from the annual reports of Boeing[8] as well. In addition, the number of historical and current A380 routes operated by 12 airlines[9] as well as departing for 28 destinations[10] are retrieved from the website of IATA[11]. These 12 airlines are the operators of A380 among the world's airlines.

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[2] A380 is available for order from 2000.

[3] A350 is available for order from 2004.

[4] The first delivery of A350 was realized in 2014.

[5] Annual reports from 2000 to 2017 retrieved from the website of Airbus (2018), https://www.airbus.com/investors/financial-results-and-annual-reports.html, on May 14, 2018

[6] B787 is available for order from 2003.

[7] The first delivery of B787 was made in 2011.

[8] Annual reports from 2003 to 2017 retrieved from the website of Boeing (2018), http://investors.boeing.com/investors/financial-reports/default.aspx, on May 14, 2018

[9] They are namely Air France, British Airways, Etihad Airways, Korean Air, Lufthansa, Qantas, Qatar Airways, Singapore Airlines, Asiana Airlines, China Southern Airlines, Malaysia Airlines, Thai Airways. Emirates is excluded as it is a large outlier.

[10] They are namely Auckland, Bangkok, Beijing, Delhi, Doha, Dubai, Frankfurt, Guangzhou, Hong Kong, Johannesburg, Kuala Lumpur, London, Los Angeles, Melbourne, Miami, Mumbai, Munich, New York, Paris, San Francisco, Seoul, Shanghai, Singapore, Sydney, Taipei, Tokyo, Washington D.C., Zurich. The Dubai routes operated by Emirates are excluded as they are large outliers.

[11] Data retrieved from the website of IATA, http://www.iata.org/Pages/default.aspx. On May 14, 2018

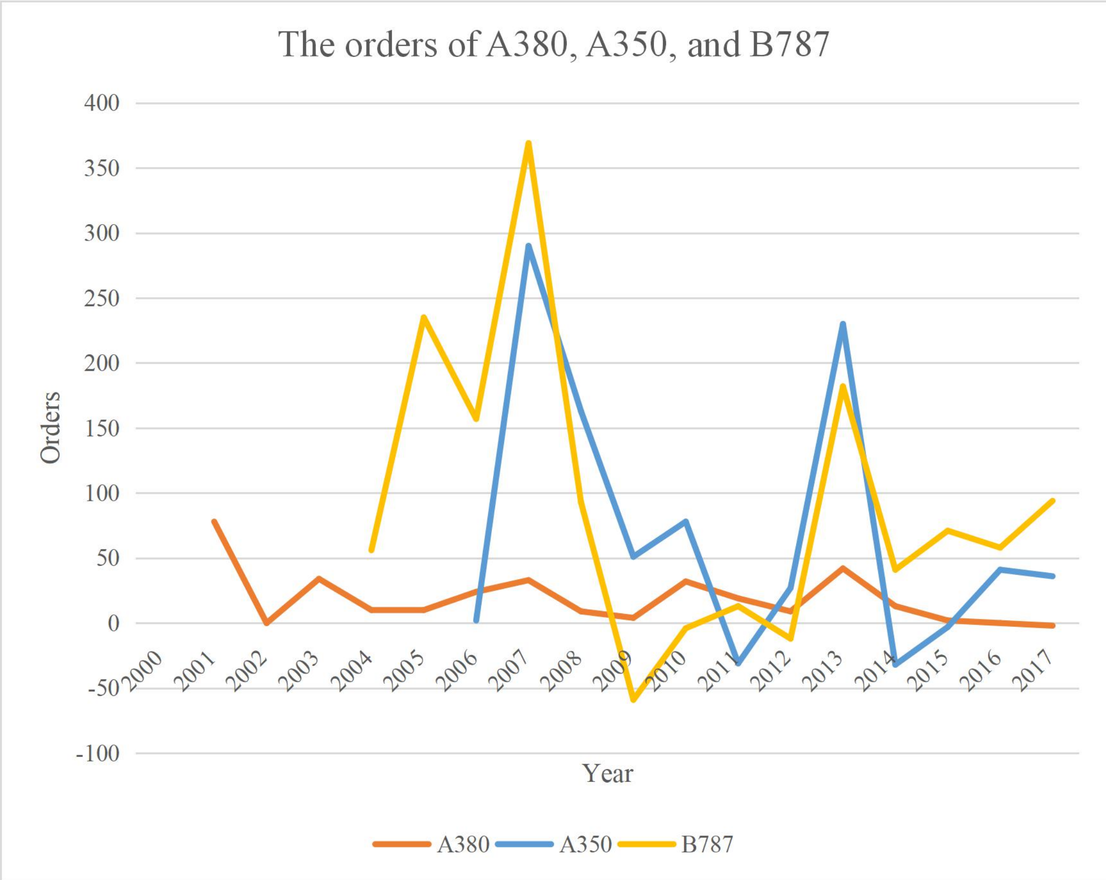

Figure 1. The orders of A380, A350, and B787

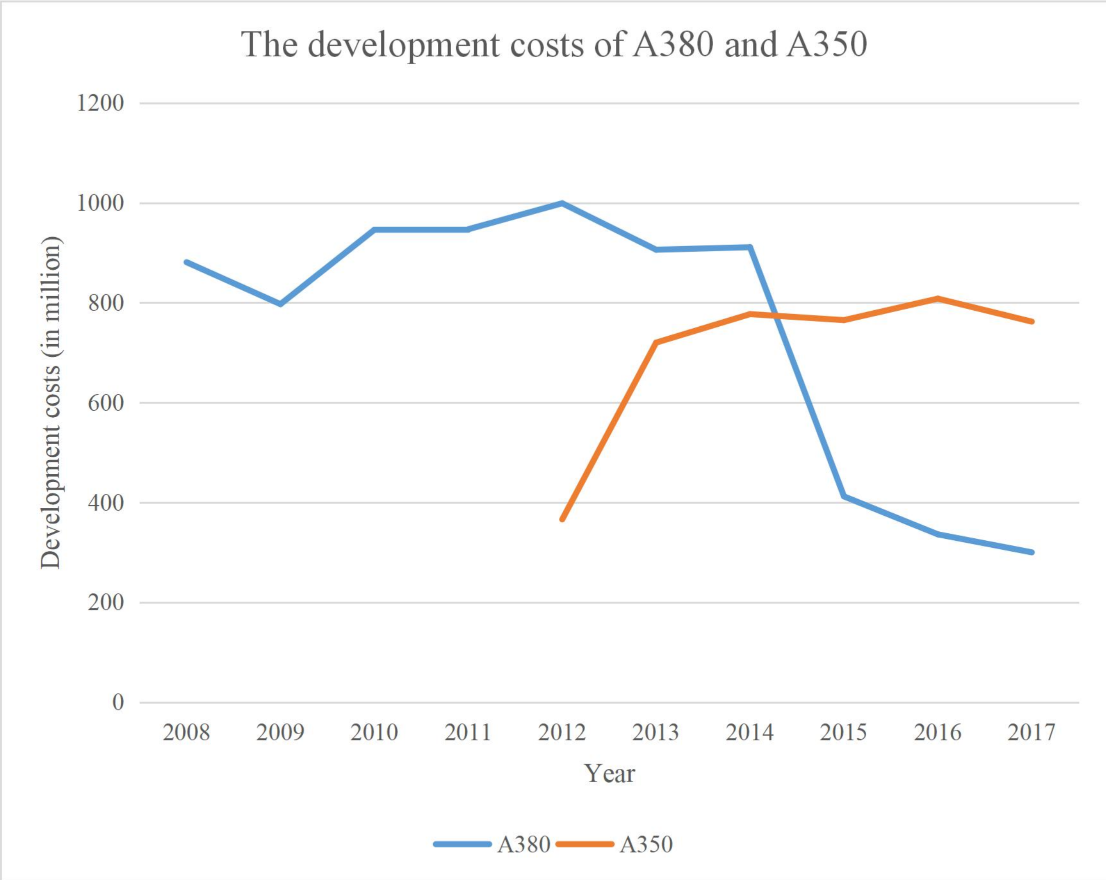

Figure 2. The development costs of A380 and A350 (in million)

With respect to the third and last hypothesis, the orders of A380 from 2001 to 2017, and/or the orders of A350 from 2006 to 2017, and/or the orders of B787 from 2004 to 2017 are retrieved from the annual reports[12] of nine airlines[13]. These nine airlines are the major A380 operators of which the total orders are at least ten. Besides, a dummy variable named "Sustainability" is generated for seven airlines[14] based on the publication of sustainability reports[15]. "Sustainability" equals one if the airlines do publish the sustainable reports; otherwise, it equals zero.

[12] Annual reports from 2001 to 2017 retrieved from the websites of these nine airlines, on May 14, 2018

[13] They are namely Air France, British Airways, Emirates, Etihad Airways, Korean Air, Lufthansa, Qantas, Qatar Airways, Singapore Airlines.

[14] They are namely Air France, Emirates, Etihad Airways, Korean Air, Lufthansa, Qatar Airways, Singapore Airlines. The sustainability reports of British Airways and Qantas are not available on their website.

[15] Sustainability reports retrieved from the websites of these seven airlines, on May 14, 2018

V. Methodology

In order to examine the three hypotheses, the following research methods are used: the linear regression analysis, the paired-sample t-test, the independent sample t-test, and the difference-in-difference analysis. First, the linear regression analysis is used to describe how the response (dependent) variable changes when the explanatory/independent variables change. Second, the paired-sample t-test is used to determine whether the mean difference between the two sets of observations is zero. Third, the independent sample t-test is used to examine whether the means of variables are significantly different between two independent samples. Fourth, the difference-in-difference analysis is used to study the differential effect of a treatment (i.e. the explanatory/independent variable) on an outcome (i.e. the response/dependent variable) between the treatment group and the control group. Throughout the analyses, the Confidence Interval of 95% and the Significance Level of 5% are used.

For the first hypothesis, the linear regression analysis examines the relationship (i.e. the general substitution effect) among the orders of A380, the orders of B787, and the deliveries of B787. It describes how the orders of A380 change when the orders of B787 and the deliveries of B787 change. The reason for including both orders and deliveries as independent variables into one linear regression model is to lower the Omitted Variable Bias since B787_orders, as well as B787_deliveries, can have a direct effect on A380_orders and they are correlated (0.2825) with each other. Thus, the linear regression model is as the following:

$$A380\_orders = \beta_0 + \beta_1 * B787\_orders + \beta_2 * B787\_deliveries + \varepsilon$$

For the second hypothesis, the linear regression analyses examine the relationship (i.e. the general substitution effect) between the orders of A380 and the orders of A350, as well as the relationship between the orders A380 and the deliveries of A350. It describes how the orders of A380 change when the orders of A350 and the deliveries of A350 change. Due to the strong correlation (0.9021) between A350_orders and A350_deliveries, two linear regression models with single independent variable will be performed. Similarly, the linear regression analysis also examines the relationship between the development costs of A380 and the development costs of A350 by showing how the development costs of A380 change when the development costs of A350 change. Thus, the linear regression models are as the followings:

$$A380\_orders = \beta_0 + \beta_1 * A350\_orders + \varepsilon$$

$$A380\_orders = \beta_0 + \beta_1 * A350\_deliveries + \varepsilon$$

$$A380\_development\ costs = \beta_0 + \beta_1 * A350\_development\ costs + \varepsilon$$

In addition to the linear regression analysis from the general perspective of the aviation industry, the paired-sample t-test used for the first two hypotheses determines whether the mean differences between the number of historical A380 routes and the number of current A380 routes are zero specifically for 12 different operators and for 28 different destinations. In other words, it tests whether the A380 routes significantly change after the introduction of B787 and A350 routes (i.e. the specific substitution effect) regarding those operators and destinations.

For the third hypothesis, the dependent sample t-test examines whether the means of the orders of A380, the orders of A350, and the orders of B787 are significantly different before and after the publication of sustainability reports in terms of seven different airliners. Moreover, the difference-in-difference analysis analyzes the differential effect of the publication of sustainability reports on the orders of A380, the orders of B787, and the orders of A350 by comparing the average change over time of those airliners.

VI. Results

The results of the linear regression models regarding the first two hypotheses are as the followings:

Table 2. Regression of "A380_orders" on "B787_orders" and "B787_deliveries"

A380_orders	Coefficient	P-value
B787_orders	0.1790983	0.005
B787_deliveries	-0.2275384	0.009
Constant term	21.09392	0.004

According to Table 2, the deliveries of B787 do have a significantly negative effect on the orders of A380 at the Significance Level of 5%. Surprisingly, the orders of 787, however, have a significantly positive effect on the orders of A380 at the Significance Level of 5%. It is also noticeable that both effects are rather small. Therefore, I can answer the first hypothesis that only the deliveries of B787 significantly decrease the orders of A380 in general.

Table 3. Regression of "A380_orders" on "A350_orders"

A380_orders	Coefficient	P-value
A350_orders	-0.0806191	0.021
Constant term	9.692713	0.049

Table 4. Regression of "A380_orders" on "A350_deliveries"

A380_orders	Coefficient	P-value
A350_deliveries	-0.1583356	0.165
Constant term	8.870915	0.199

Table 5. Regression of "A380_development costs" on "A350_development costs"

A380_development costs	Coefficient	P-value
A350_development costs	-1.180396	0.033
Constant term	1469.884	0.001

According to Table 3, the orders of A350 have a significantly negative effect on the orders of A380 at the Significance Level of 5%, whereas the effect is rather small. Likewise, Table 4 displays that the deliveries of A350 also have a negative effect on the orders of A 380, but the effect is small and insignificant at the Significance Level of 5%. However, the development costs invested in A350 do have a significantly negative effect on those invested in A380 at the Significance Level of 5% according to Table 5. Therefore, I can partially answer the second hypothesis that the orders of A350 significantly decrease the orders of A380 in general. Nevertheless, it is important that Airbus's increasing development costs of A350 is significantly decreasing the development costs of A380.

The results of the paired-sample t-tests regarding the first two hypotheses are as the followings:

Table 6. Paired Samples Test of the number of historical and current A380 routes operated by 12 airlines

Paired Samples Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Before - After	1.500	1.567	0.452	0.505	2.495	3.317	11	0.007

Table 7. The number of historical and current A380 routes operated by 12 airlines before and after the introduction of B787 and/or A350 routes

Airline	Historical A380 routes (Before)	Current A380 routes (After)	B787 and/or A350 routes
Air France	14	11	1
British Airways	10	10	2
Etihad Airways	7	7	1
Korean Air	11	6	0
Lufthansa	16	14	7
Qantas	8	7	2
Qatar Airways	6	6	4
Singapore Airlines	16	13	6
Asiana Airlines	4	4	0
China Southern Airlines	6	5	2
Malaysia Airlines	5	3	1
Thai Airways	6	5	1

According to Table 6, the A380 routes operated by 12 airlines are significantly different after their introduction of B787 and/or A350 routes at the Significance Level of 5%. More specifically, Table 7 shows that 11 airlines have either reduced the operation of A380 routes or have started operating B787 and/or A350 routes, except Asiana Airlines that have the smallest scale of A380 routes. Among them, Lufthansa and Singapore Airlines are the two major A380 operators which are active in developing the new B787 and/or A350 routes. In addition, Air France and Korean Air are also substantively divesting from operating A380 routes. Therefore, I can answer both the first and second hypotheses that B787 and/or A350 significantly decreases A380 specific to different airlines.

Table 8. Paired Samples Test of the number of historical and current A380 routes departing for 28 destinations

Paired Samples Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Before - After	0.607	1.066	0.201	0.194	1.020	3.014	27	0.006

Table 9. The number of historical and current A380 routes departing for 28 destinations before and after the commencement of B787 and/or A350 routes

Destination	Historical A380 routes (Before)	Current A380 routes (After)	B787 and/or A350 routes
Auckland	2	2	0
Bangkok	5	4	1
Beijing	4	4	2
Delhi	2	2	1
Doha	2	2	0
Dubai	3	2	0
Frankfurt	6	5	0
Guangzhou	3	3	0
Hong Kong	9	7	2
Johannesburg	4	3	0
Kuala Lumpur	2	2	0
London	9	9	4

Los Angeles	9	8	3
Melbourne	5	5	2
Miami	3	3	0
Mumbai	3	3	0
Munich	2	2	0
New York	7	5	1
Paris	10	9	1
San Francisco	4	4	0
Seoul	4	4	1
Shanghai	5	4	1
Singapore	5	5	1
Sydney	7	6	0
Taipei	2	2	0
Tokyo	6	1	4
Washington D.C.	3	3	0
Zurich	2	2	0

According to Table 8, the A380 routes departing for 28 destinations are significantly different after the commencement of B787 and/or A350 routes connected to the same destination at the Significance Level of 5%. More specifically, Table 9 indicates that more than half of the destinations (17) have either terminated the A380 routes or have commenced the new B787 and/or A350 routes. Among them, there are no other prime examples than Tokyo's significant route changes, of which five A380 routes have terminated whereas four B787 and/or A350 routes have commenced. Moreover, Hong Kong, New York, and Los Angeles, these three international metropolises display a similar tendency as well. Therefore, I can answer both the first and second hypotheses that B787 and/or A350 significantly decreases A380 specific to different destinations.

The results of independent sample t-tests regarding the third hypothesis are as the followings:

Table 10. Independent Samples Test of "A380_orders", "A350_orders", and "B787_orders" for Air France

Independent Samples Test

	Levene's Test for Equality of Variances	T-test for Equality of Means

		F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
A380_orders	Equal variances assumed	98.824	0.000	0.025	3.333	1.341	0.475	6.192
	Equal variances not assumed			0.423	3.333	3.333	-11.009	17.676
A350_orders	Equal variances assumed	.	.	0.800	-1.500	5.809	-14.051	11.051
	Equal variances not assumed			.	-1.500	.	.	.
B787_orders	Equal variances assumed	.	.	0.800	-1.786	6.916	-16.727	13.155
	Equal variances not assumed			.	-1.786	.	.	.

Table 11. Independent Samples Test of “A380_orders” for Emirates

Independent Samples Test

		Levene’s Test for Equality of Variances		T-test for Equality of Means				
		F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
A380_orders	Equal variances assumed	0.090	0.769	0.837	1.571	7.508	-14.432	17.574
	Equal variances not assumed			0.850	1.571	8.098	-16.582	19.725

Table 12. Independent Samples Test of "A380_orders", "A350_orders", and "B787_orders" for Etihad Airways

Independent Samples Test

		Levene's Test for Equality of Variances		T-test for Equality of Means				
		F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
A380_orders	Equal variances assumed	15.361	0.001	0.049	1.111	0.754	-0.486	2.709
	Equal variances not assumed			0.189	1.111	0.754	-0.627	2.849
A350_orders	Equal variances assumed	0.106	0.751	0.296	0.889	8.844	-18.380	20.158
	Equal variances not assumed			.	0.889	7.743	-16.041	17.819.
B787_orders	Equal variances assumed	0.102	0.755	0.046	0.444	5.818	-12.125	13.014
	Equal variances not assumed			.	0.444	.6.049	-13.142.	14.031

Table 13. Independent Samples Test of "A380_orders" and "B787_orders" for Korean Air

Independent Samples Test

		Levene's Test for Equality of Variances		T-test for Equality of Means			
		F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference

							Lower	Upper
A380_orders	Equal variances assumed	16.593	0.001	0.039	0.627	0.627	-0.330	2.330
	Equal variances not assumed			0.105	0.558	0.558	-0.262	2.262
B787_orders	Equal variances assumed	5.459	0.036	0.251	1.336	1.336	-1.582	4.189
	Equal variances not assumed			0.402	1.434	1.434	-2.193	4.800

Table 14. Independent Samples Test of “A380_orders” and “B787_orders” for Lufthansa

Independent Samples Test

		Levene’s Test for Equality of Variances		T-test for Equality of Means				
		F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
A380_orders	Equal variances assumed	24.490	0.000	0.039	1.667	0.720	0.098	3.236
	Equal variances not assumed			0.105	1.667	0.843	-0.501	3.834
B787_orders	Equal variances assumed	10.279	0.008	0.251	1.875	1.546	-1.527	5.277
	Equal variances not assumed			0.402	1.875	2.004	-3.672	7.422

Table 15. Independent Samples Test of “A380_orders”, “A350_orders”, and “B787_orders” for Qatar Airways

Independent Samples Test

		Levene's Test for Equality of Variances		T-test for Equality of Means				
		F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
A380_orders	Equal variances assumed	4.466	0.054	0.408	0.833	0.975	-1.273	2.940
	Equal variances not assumed			0.107	0.833	0.474	-0.210	1.877
A350_orders	Equal variances assumed	1.279	0.282	0.621	7.273	14.342	-23.976	38.521
	Equal variances not assumed	1.766	0.217	0.341	7.273	7.273	-8.932	23.477
B787_orders	Equal variances assumed			0.476	-6.250	8.406	-25.266	12.766
	Equal variances not assumed			0.605	-6.250	10.680	-43.520	31.020

Table 16. Independent Samples Test of "A380_orders", "A350_orders", and "B787_orders" for Singapore Airlines

Independent Samples Test

	Levene's Test for Equality of Variances		T-test for Equality of Means				
	F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper

A380_orders	Equal variances assumed	8.203	0.011	0.044	4.000	1.759	0.128	7.872
	Equal variances not assumed			0.091	4.000	1.915	-0.922	8.922
A350_orders	Equal variances assumed	12.298	0.003	0.047	-10.833	4.980	-21.515	-0.152
	Equal variances not assumed			0.245	-10.833	7.683	-34.068	12.402

According to Table 10-16, the orders of A380 from five airlines (namely Air France, Etihad Airways, Korean Air, Lufthansa, and Singapore Airlines) are significantly different after the publication of sustainability reports at the Significance Level of 5%. However, only the orders of B787 from Etihad Airways are significantly different after the publication of sustainability reports at the Significance Level of 5%. None of the other results with respect to B787 or A350 are significant at the Significance Level of 5%. Therefore, I can only answer the third hypotheses that the sustainability considerations of airlines significantly influence the orders of A380.

The results of the difference-in-difference analyses regarding the third hypothesis are as the followings:

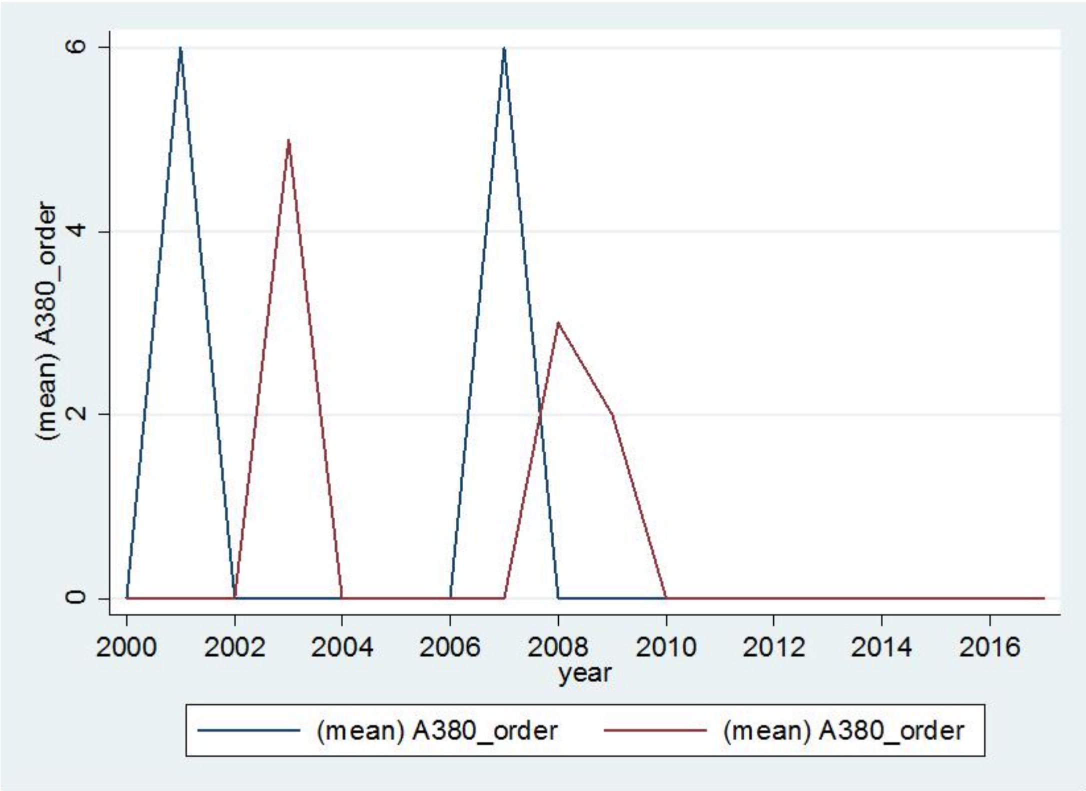

Figure 3. Difference-in-Difference of "A380_orders" for seven airlines with the five-year publication of sustainability reports

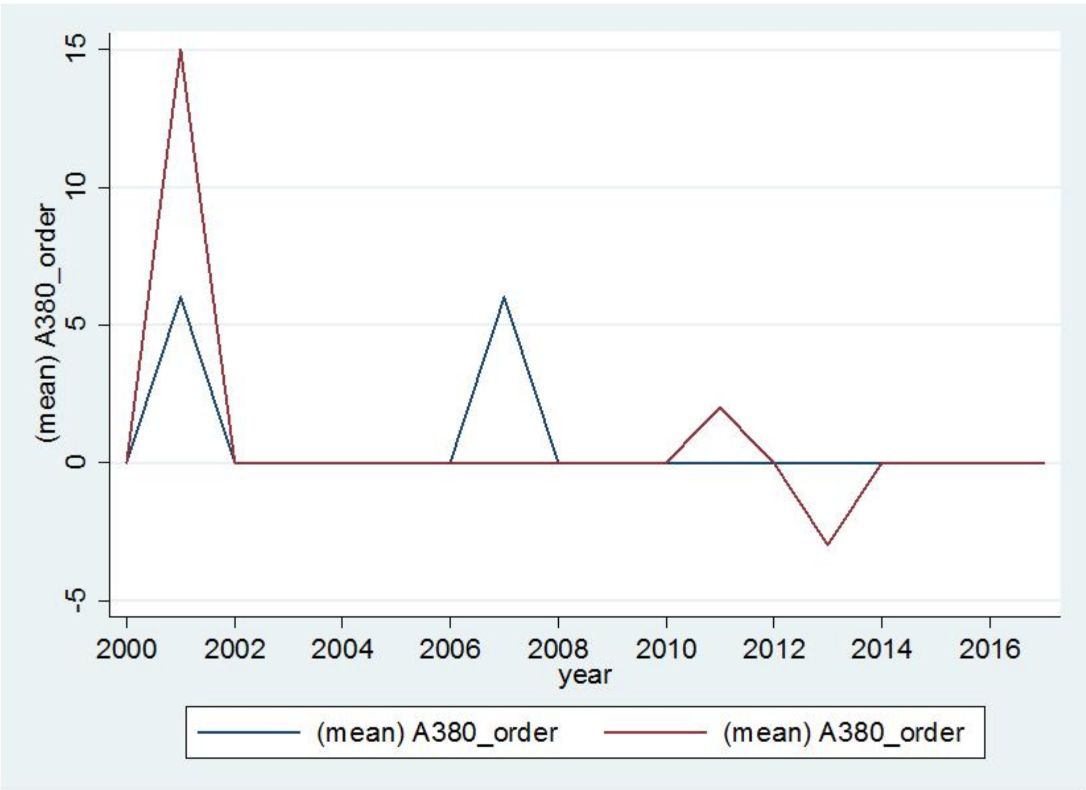

Figure 4. Difference-in-Difference of "A380_orders" for seven airlines with the nine-year

publication of sustainability reports

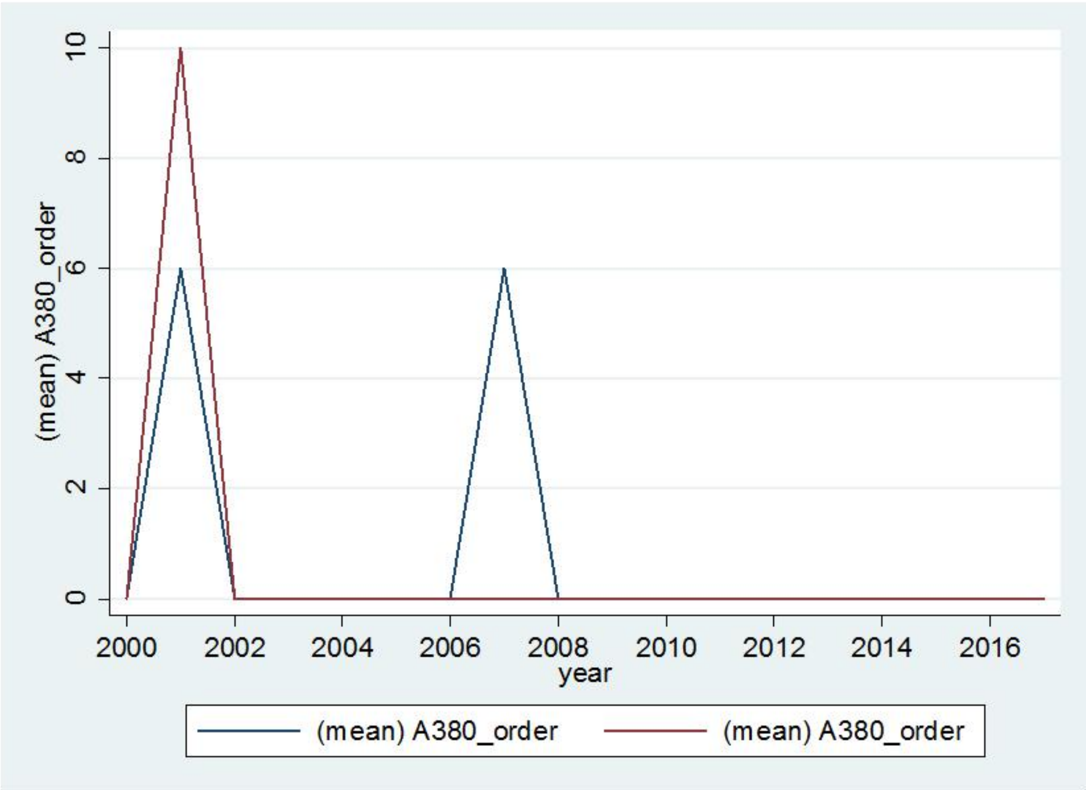

Figure 5. Difference-in-Difference of “A380_orders” for seven airlines with the 14-year publication of sustainability reports

Figure 3-5 show how the orders of A380 are different between the airlines without and with publishing the sustainability reports (i.e. *without - with*). Such order differences can be explained by the sustainability considerations of airlines. In terms of five-year publication (see Figure 3), the differences of A380 orders change from 1 (6-5) between 2001-2003 to 3 (6-3) between 2006-2009. In terms of nine-year publication (see Figure 4), the differences of A380 orders change from -9 (6-15) in 2001 to 6 (6-0) in 2007. In terms of 14-year publication (see Figure 5), the differences of A380 orders change from -4 (6-10) in 2001 to 6 (6-0) in 2007.

No matter how long the publication years are, the results are striking that the A380 orders from the airlines without publishing any sustainability reports do not have any changes in the past 18 years while the A380 orders from their more sustainable counterpart keep declining over the years. Seemingly, the longer the publication years are, the more dramatic the decline is. This is because airlines are more likely to adjust their long-term strategies and reallocate their aircraft and routes in a longer period. Therefore, I can answer the third hypothesis that the sustainability considerations from the airlines do have a significantly negative effect on the orders of A380, in particular from 2007.

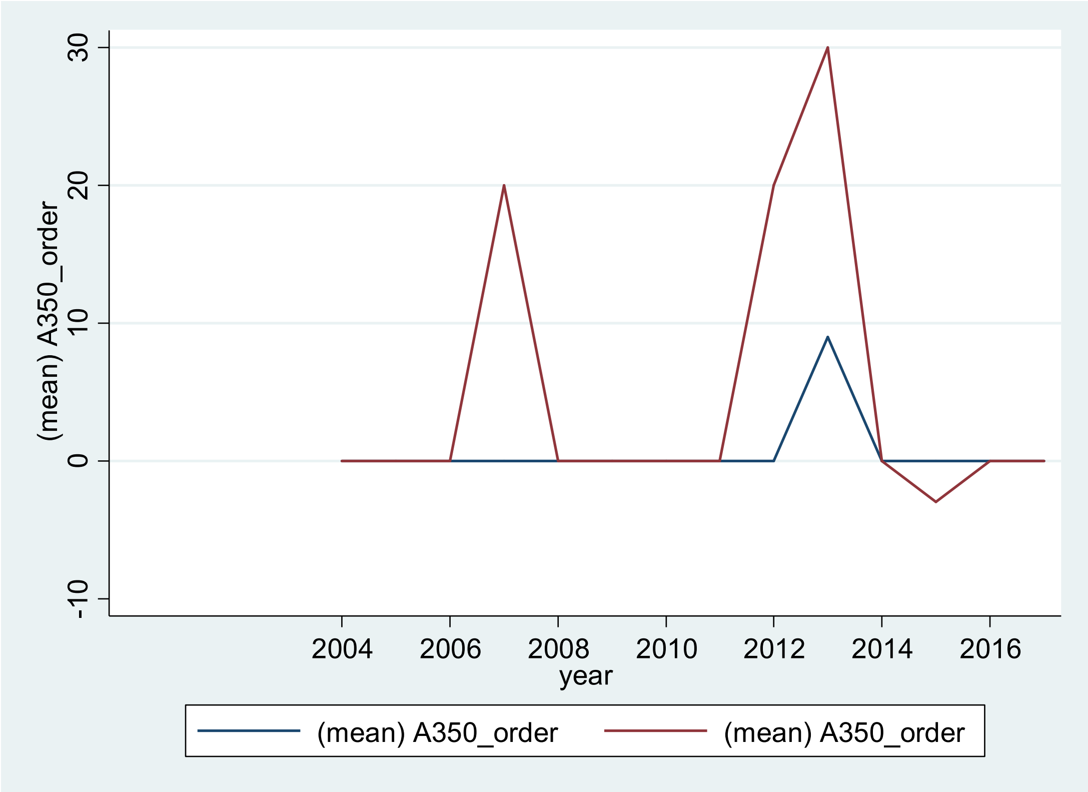

Figure 6. Difference-in-Difference of “A350_orders” for seven airlines with the five-year publication of sustainability reports

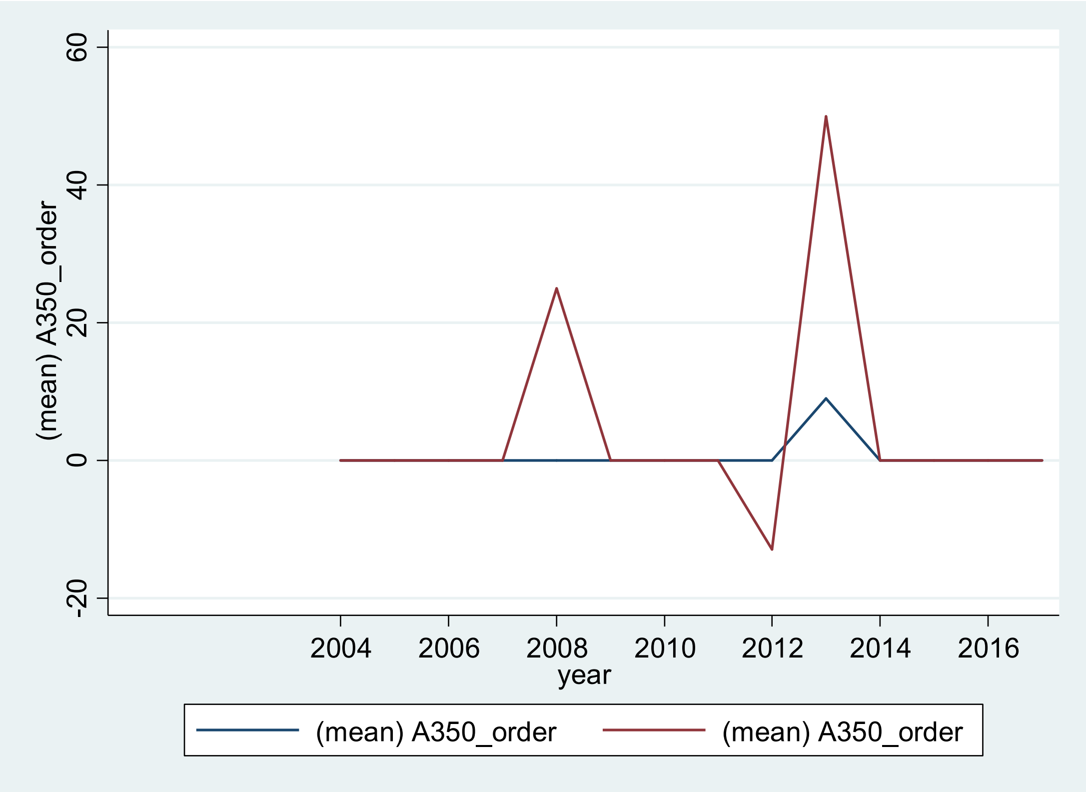

Figure 7. Difference-in-Difference of “A350_orders” for seven airlines with the nine-year publication of sustainability reports

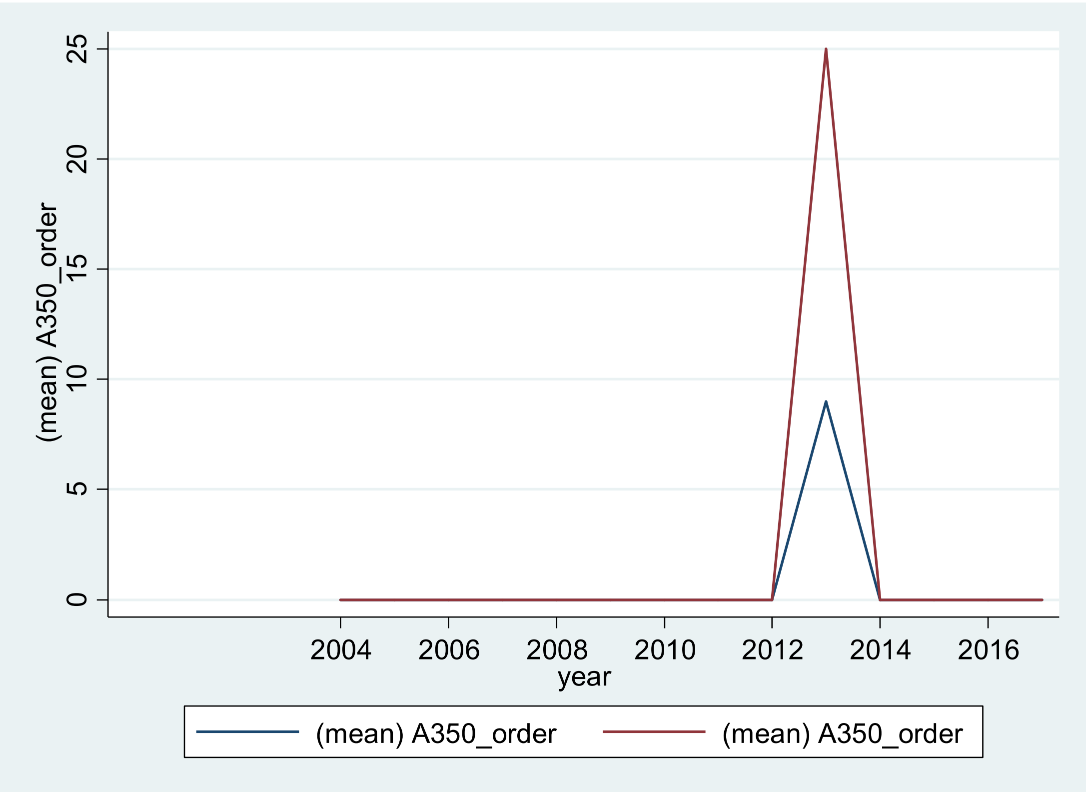

Figure 8. Difference-in-Difference of “A350_orders” for seven airlines with the 14-year

publication of sustainability reports

Figure 6-8 show how the orders of A350 are different between the airlines without and with publishing the sustainability reports (i.e. *without - with*). Such order differences can be explained by the sustainability considerations of airlines. In terms of five-year publication (see Figure 6), the differences of A350 orders change from -20 (0-20) in 2007 to -21 (9-30) between 2012-2013. In terms of nine-year publication (see Figure 7), the differences of A350 orders change from -23 (0-23) in 2008 to -42 (8-50) in 2013. In terms of 14-year publication (see Figure 8), the differences of A350 orders are -16 (9-25) in 2013.

The results show that the negative A350 order differences are noticeable and are even growing larger over the last 14 years. In other words, the growth of A350 orders from the airlines which publish the sustainability reports dramatically outcompetes the growth of A350 orders from those airlines without sustainability reports. Therefore, I can answer the third hypothesis that the sustainability considerations from the airlines do have a significantly positive effect on the orders of A350, in particular from 2013.

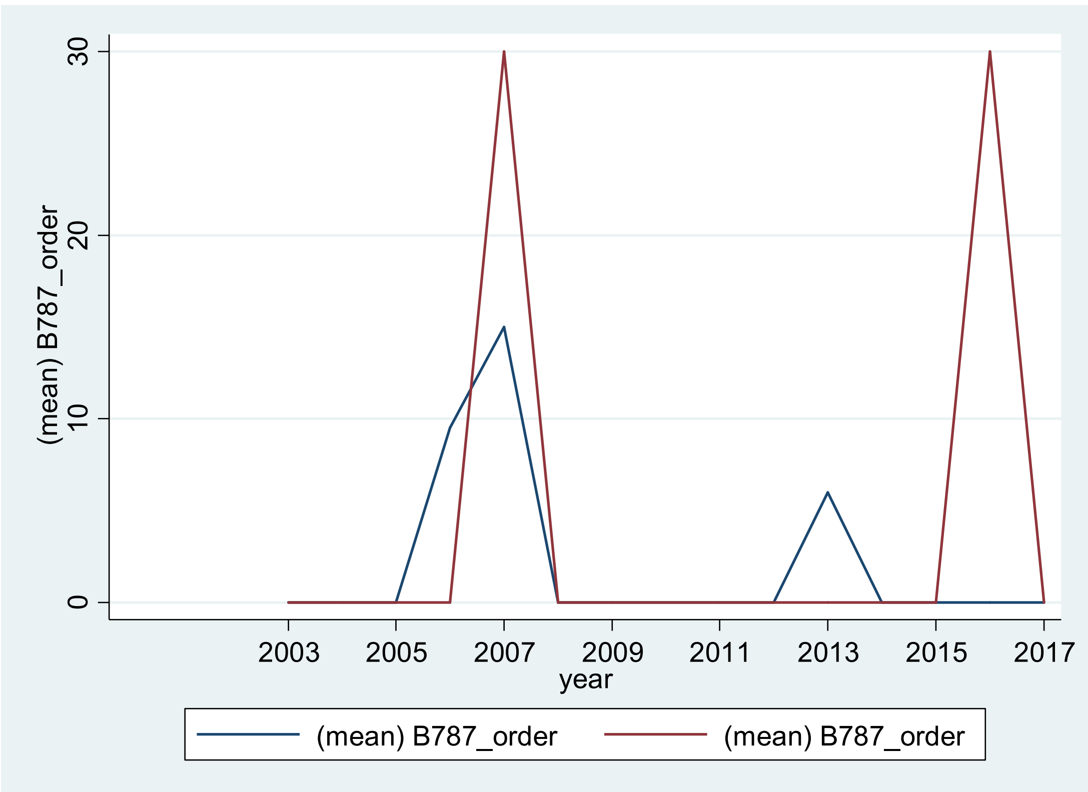

Figure 9. Difference-in-Difference of "B787_orders" for seven airlines with the five-year publication of sustainability reports

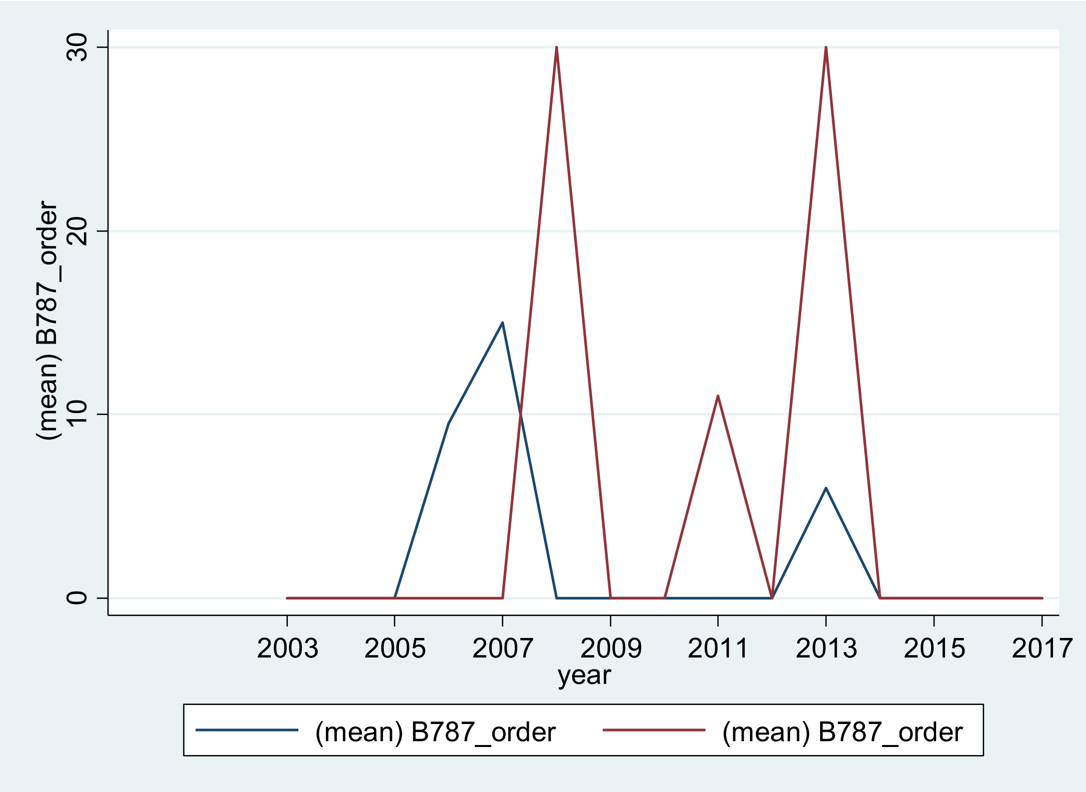

Figure 10. Difference-in-Difference of "B787_orders" for seven airlines with the nine-year publication of sustainability reports

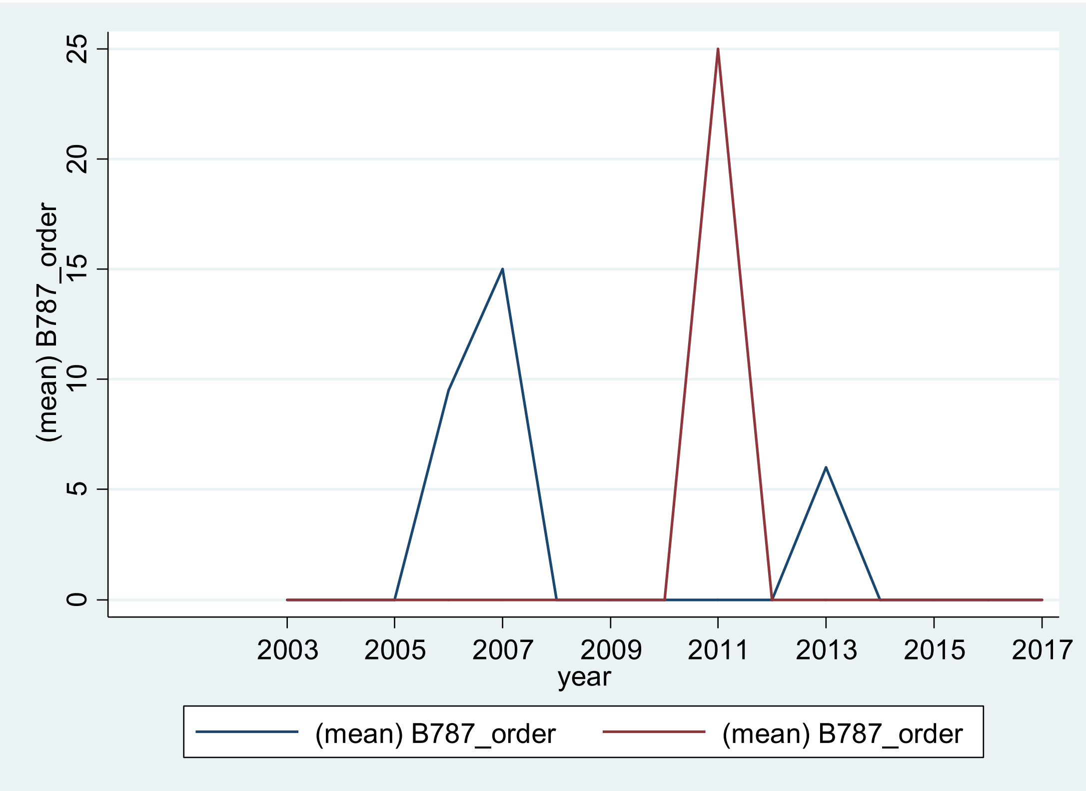

Figure 11. Difference-in-Difference of "B787_orders" for seven airlines with the 14-year

publication of sustainability reports

Figure 9-11 show how the orders of B787 are different between the airlines without and with publishing the sustainability reports (i.e. *without - with*). Such order differences can be explained by the sustainability considerations of airlines. In terms of five-year publication (see Figure 9), the differences of B787 orders change from -15 (15-30) in between 2006-2007 to -30 (0-30) in 2016. In terms of nine-year publication (see Figure 10), the differences of A350 orders change from -15 (15-30) between 2007-2008 to -25 (5-30) in 2013. In terms of 14-year publication (see Figure 11), the differences of A350 orders change from 15 (15-0) in 2007 to -19 (6-25) between 2011-2013.

The results show that there are apparent negative B787 order differences regardless of how long the publication years are. These negative differences are even larger and larger over the last 15 years. In other words, the increase of B787 orders from the airlines publishing the sustainability reports is more than that from the airlines without sustainability reports. Therefore, I can answer the third hypothesis that the sustainability considerations from the airlines do have a significantly positive effect on the orders of B787.

VII. Conclusions & Implications

To summarize the main findings, there is not enough convincing evidence for the general substitution effect of B787 and/or A350 on A380 with respect to the first and second hypothesis. In other words, B787 and/or A350 do not significantly decrease the orders of A380 within the general scope of the aviation industry. This finding may be counter-intuitive and contradictory to the hypotheses, whereas the sorting of data and the effect of large outlier can account for it.

As shown in Figure 1, the line chart has two abrupt "spikes" located in 2007 and 2013. Due to the *Paris Air Show* held in 2007 and 2013, the yearly orders placed by Airbus and Boeing are systematically higher. The monstrous transactions completed during the air shows leading to the spiky-shaped line chart. Thus, the sorting of data can partially explain why the magnitude of the general substation effect is not that obviously strong. More importantly, the A380 orders from Emirates and the A380 deliveries to Emirates can be seen as the large outliers in the database. Till March 31st, 2018, Emirates' accumulative A380 orders and deliveries amount to 162 and 102 respectively, which are almost half of the total A380 orders placed and the total A380 deliveries made by Airbus. Such an effect of large outlier can also disturb the unbiasedness of the linear regression analysis.

On the contrary, the specific substitution effect of B787 and/or A350 can be relatively strong for certain airlines and destinations related to the first and second hypothesis. Airlines such as Singapore Airlines have tried shifting their focus from the superjumbo A380 to mid-sized B787 and/or A350 for the long-haul flights. Such a shift coincides with their most recent business strategies as well. After operating the first two A380s in service for ten years, they have decided not to extend the leasing contracts and these two unwanted superjumbo jets will be broken up for components and sold by Dr. Peters Group[16]. In addition, the decision on future fleet planning made by Singapore Airlines is to strategically select both the A350XWB and the B787, which is able to integrate these two different types to avoid the exposure to the operational or economic penalty. It might be considered appropriate that Singapore Airlines will be less likely to get involved in a hold-up problem by pursuing a dual-supplier strategy. Neither Airbus nor Boeing can become dictatorial in terms of pricing and bargaining (Clark, 2017).

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[16] News retrieved from the website of Dr. Peters Group (2018), https://www.dr-peters.de/en/press/press-releases/2018/2018-06-05.html, on July 2, 2018

As for destinations, the international metropolitans are undoubtedly popular when planning and opening A380 routes. The dominant roles of London, Paris, and Los Angeles can still not be challenged whereas Tokyo has only one A380 route left after the commencement of four new B787 and/or A350 routes. This variation may be due to the number and the scale of the international airport(s) in each city (see Table 17 below). These cities can be categorized into three different types.

Table 17. The total passengers and the total aircraft movements of 18 international airports in eight international metropolises[17]

International Airports	Total Passengers (2017)	Total Aircraft Movements (2017)
London (6)		
Heathrow Airport	78,014,598	476,186
Gatwick Airport	45,554,038	285,969
London Stansted Airport	25,902,618	172,622
Luton Airport	15,799,219	135,538
London City Airport	4,530,439	80,490
London Southend Airport	1,095,914	25,722
New York (3)		
John F. Kennedy International Airport	59,392,500	447,848
Newark Liberty International Airport	43,234,161	438,578
LaGuardia Airport	29,568,304	369,135
Paris (3)		
Paris Charles de Gaulle Airport	69,471,442	481,914
Paris Orly Airport	32,040,890	234,837
Paris Beauvais Airport	3,646,523	31,159
Tokyo (2)		
Haneda International Airport	85,408,975	445,822
Narita International Airport	40,631,193	251,640
Hong Kong (1)		
Hong Kong International Airport	72,665,078	420,630
Los Angeles (1)		
Los Angeles International Airport	84,557,968	702,432
Sydney (1)		

[17] Data retrieved from the website of Airports Council International (2018), http://www.aci.aero/, on July 2, 2018

Sydney Kingsford Smith Airport	43,410,355	302,907
Frankfurt (1)		
Frankfurt Airport	64,500,386	475.537

The first type includes Hong Kong, Los Angeles, Sydney, and Frankfurt. These four cities have only one international airport inside the city area, and all these international airports are ranked top 20 among the busiest airports in the world. What is more, Hong Kong, Sydney, and Los Angeles are also the important air transport hubs in Asia, Oceania, and the west coast of America respectively. A large number of total passengers as well as the frequent aircraft movements can accommodate more than five A380 routes operated by different airlines in one single city.

The second type includes London and Paris. The number of international airports is six for London and three for Paris, whereas the largest ones can dominate any other city airports. For instance, Heathrow is almost twice as large as Gatwick and Charles de Gaulle is more than twice as large as Orly. Thus, the busy air transport systems of Heathrow and Charles de Gaulle are still attractive to ten A380 routes for each.

The third and last type includes New York and Tokyo. Alike the second-type cities, they both have more than two international airports. However, the difference between John F. Kennedy and Newark is not that big and thus, airlines are more willing to serve two airports by operating the more flexible B787s or A350s more evenly and frequently instead of the superjumbo A380s. This suggestion is supported by the empirical evidence that a very strong use of the double-deck superjumbo A380 leads airlines to reduce their flight frequency (Ussinova, Laplace, and Roucolle, 2018). Regarding Tokyo, the small-scaled Narita is a primary airport for international flights while the large-scaled Haneda is a major airport for domestic flights. Such a reverted market segmentation naturally leads to the losses of its five A380 routes.

Finally, Figure 1 also depicts that the market trend of A380 is gradually downward as most of the A380 orders were placed before 2007. By contrast, the orders of B787 and A350 have been rising since 2007, peaking in 2007 as well as 2013. Accordingly, Airbus has adjusted its development focus point from A380 to A350 since 2014. The sustainability considerations of airlines can reasonably explain these market trends because I have testified the third hypothesis that the sustainability considerations do significantly increase the orders of B787 and A350 but decrease the orders of A380. This finding is also in line with Clark's conclusion that the more and more stringent environmental restrictions and regulations, especially in EU and North America, have a significant impact on aircraft manufacturers, airlines, and airports (Clark, 2017).

As the results are supportive of all three hypotheses, I can answer the central research question that the substitution effects of B787 and A350 are significant on the market for A380 particularly with regards to specific airlines and destinations. Henceforth, some practical implications with respect to A380 might deserve the considerations from both Airbus and airlines. For Airbus, it is essential to maintain its biggest business partner, Emirates, and its market of Middle East (i.e. Emirates - Dubai, Etihad Airways - Abu Dhabi, and Qatar Airways - Doha). Early this year, Emirates' 16 new A380 orders worth a potential 16 billion U.S. dollars successfully saved the life days of superjumbo and extended A380 production until 2029[18]. This purchase undeniably reveals the importance of Emirates towards Airbus. Furthermore, Airbus can target the markets of developing countries where environmental standards are less restrictive (Holloway, 2017). Examples could be the populated capital cities of Southeastern and Southern Asian countries, such as Bangkok, Kuala Lumpur, and Delhi.

From the perspectives of airlines, it might be still profitable to operate the A380 routes between the international metropolises with one single large-scale airport, such as London (Heathrow) - Hong Kong, Paris (Charles de Gaulle) - Los Angeles, or Sydney - London (Heathrow). The business activities and total passengers can secure the profitability of the A380 operators, especially for British Airways, Air France, and Qantas whose main airport hubs are located in London, Paris, and Sydney respectively. The other suggestion for fleet planning is to extend the existing A380 routes by connecting more than two destinations as one long-haul fight, such as Hong Kong - Bangkok - Dubai or Sydney - Singapore - London. In this way, operators can capture more passengers from different destinations and further develop the airline networking. Qantas can be used as an example as its initial A380 focus is on increasing frequencies on the Sydney - London route and its Sydney - Singapore - London route is the other business trial (Schofield, 2010).

Insofar, the aviation industry has performed what Boeing forecasted in 1998 and Airbus has handed over the life of superjumbo jet A380 to Emirates. However, this thesis does not include and consider the two most significant developing economies, namely China (Great China Region) and India. The Beijing's new mega-airport - Beijing Daxing International

[18] News retrieved from the website of Bloomberg (2018), https://www.bloomberg.com/news/articles/2018-01-18/emirates-orders-20-a380s-worth-9-billion-in-vital-program-boost, on July 2, 2018

Airport - will open in 2019[19]. Meanwhile, the problem of slot availability in Indian airports might be solved soon (Clark, 2019). The future research can investigate how these two most populated countries with less stringent environmental restrictions will influence the market for A380 and analyze how the airline market trend will change.

[19] News retrieved from the website of Reuters (2017), https://www.reuters.com/article/us-china-airport/beijing-proudly-unveils-mega-airport-due-to-open-in-2019-idUSKBN1CL14A, on July 2, 2018

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