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Analysis of the factors that influence the relationship between business air travel and videoconferencing

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ABSTRACT

This paper seeks to investigate the relationship between business air travel and videoconferencing for intra-firm communication using econometric models developed through survey data from Taiwan's technology industry. The survey respondents include business firms that either use or do not use videoconferencing currently. Based on survey data analyses, negative binomial models are developed for the set of current adopters of videoconferencing, and a Poisson regression model is developed for the non-adopters. They suggest substitution relationships between business air travel and videoconferencing for the two groups. However, the substitution effect is perceptibly stronger when videoconferencing is used as a substitute for business air travel. The analysis highlights that the meeting context significantly influences the choice of the communication mechanism; meeting contexts that do not specifically require face-to-face interaction tend to foster increased videoconferencing usage. Further, the perceptions of the respondents in terms of the relative benefits and weaknesses of each communication option influence the likelihood of substitution.

1. Introduction

Business travelers are big customers of airlines; they travel frequently and usually pay full fare which is less susceptible to seasonal fluctuations. Mason (2005) indicates that nearly 50% of the short-haul business air travelers in UK and over 65% in Continental Europe bought business class and full fare economy class tickets. Hence, business travel is the key target market for airline passenger revenues. However, this market has been shrinking gradually for multiple reasons ranging from security issues to cost considerations under adverse economic conditions. For example, in a 2003 survey in Norway, 73% of the firms indicated that they have had less travel due to terror threats (Denstadli, 2004). Also, many recent studies find that an increasing number of business travelers are buying discounted economy tickets or choosing low cost carriers to reduce travel costs (Mason, 2005; Stephenson and Bender, 1996). Another factor that has surfaced in recent years as a key reason for reduced business air travel is videoconferencing usage. Denstadli (2004) indicates that 150,000–200,000 business trips (2.5–3.5% of domestic business air travel) in Norway were replaced by videoconferencing between 1998 and 2003, mostly substituting intra-company travel. Over the past decade, some studies have used survey data to infer on whether videoconferencing can substitute for business air travel. Most conclude that videoconferencing would be a modest substitute for business air travel to varying degrees. For example, they predict that videoconferencing would replace 7% of the business air travel in

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the USA by 2010 (Denstadli, 2004), 1.8% in Canada in the long-term (Roy and Filiatrault, 1998), and 2.5–3.5% in Norway (Denstadli, 2004). Lian and Denstadli (2004) find that while 25% of the surveyed videoconferencing users perceive videoconferencing to have substituted large parts of business travel activity, up to 70% believe this to be the case in the future. These studies base their conclusions either on raw data from surveys, or trend analyses involving air traffic demand and sales of videoconferencing facilities. Also, the respondents for most survey-based studies are randomly chosen individuals or air passengers rather than decision-makers at business firms who influence travel and/or videoconferencing related policy decisions. Bonsall and Shires (2006) use linear regression models to analyze business-related meetings among European firms from an employer perspective and suggest that business trips would decline by 8.9% if information and communication technology (ICT) capabilities achieve the most bullish forecasts and the associated costs decrease significantly. However, their study does not consider factors related to the communication (meeting) contexts, which may be important in determining the communication mechanism (Bennison, 1988; Khan, 1987).

In an opinion article, Saffo (1993) hypothesizes that videoconferencing may have a negligible substitution impact on business air travel, and instead may stimulate more air traffic. Salomon (1986) suggests that additional forms of telecommunication could induce additional travel due to the enhanced interactions. Based on a survey of travel managers and travelers from large multinational UK firms, Mason (2002) reports that 22% of the respondents will likely use ICTs as a substitute for travel involving internal meetings and meetings with well-established partners. However, the respondents also believe that this substitution would be a small amount. A larger group of respondents (36%) believe that business air travel would increase. In the context of knowledge organizations, Lassen et al. (2006) find that 51% of Hewlett–Packard respondents perceive that videoconferencing can replace some trips, while only 21% of Aalborg University (AAU) respondents feel so. Instead, almost 80% of the AAU respondents perceive that videoconferencing is only a supplement to physical meetings. Irrespective of the level of substitution, the studies discussed heretofore focus only on the substitution of business air travel by videoconferencing, and not the other way around.

The dichotomy in the suggested relationship between videoconferencing and business air travel, the lack of rigorous econometric analyses, the need to better understand the influence of factors such as meeting context, and/or the sample-related limitations associated with most existing surveys, motivates the need for studies to better understand the linkages between business air travel and videoconferencing. Another aspect that needs to be explored is the extent to which the substitution effect is bi-directional, as this may have implications for the airline industry. An important factor that needs to be considered in studies examining the relationship between business air travel and videoconferencing is the perspective of the same business firm on the usage of these two alternatives. This perspective is influenced by several common factors such as the firm's characteristics, the communication needs and contexts, prevailing economic conditions, and business strategies. Hence, the relationship between business air travel and videoconferencing may be based on factors that influence both of them. However, these aspects have not been addressed in previous studies.

This paper focuses on understanding the relationship between business air travel and videoconferencing in terms of the various factors that influence their usage. Econometric models are used to analyze the relationships between business air travel and videoconferencing, and identify variables that influence both alternatives, through a survey of Taiwan's technology industry in the context of intra-firm communication. The survey respondents consist of firms that use videoconferencing and those that do not currently do so. Based on preliminary modeling analyses in Section 3, negative binomial models are developed for current videoconferencing users, and a Poisson regression model is developed for firms that currently do not use videoconferencing.

The remainder of this paper is organized as follows. The next section describes the survey mechanism, design, and implementation for Taiwan's technology industry, and insights from the raw survey data. This is followed by the development of the econometric models to analyze the interactions between business air travel and videoconferencing. Then, the chosen models are estimated using the survey data and the resulting insights on the relationship between business air travel and videoconferencing are discussed. Finally, some concluding comments are provided.

2. Case study: survey of the Taiwanese technology industry

The relationship between business air travel and videoconferencing is investigated in this paper using Taiwan's technology industry as a case study. A stated preference (SP) survey seeks information related to business air travel, videoconferencing usage, and firm policies from a sample of firms.

2.1. Survey setup description

The survey is conducted by sending questionnaires to managers in the financial or human resources departments of some firms in Taiwan's technology industry. It focuses on intra-firm communication activities only so as to ensure that there is consistency in communications capabilities and that the communication-related decision-making is within the jurisdiction of this firm. This circumvents issues of non-availability or incompatibility of ICT options that may arise for inter-firm communication. Most Taiwanese technology firms have branch offices around the world, including in China, providing the option to trade-off business air travel and videoconferencing. Also, until mid-2008, no direct flights existed from Taiwan to China, providing an incentive to adopt videoconferencing to communicate with the China branch offices.

2.2. Survey questionnaire design

The survey questionnaire comprises of four parts. The first part seeks information related to business air travel in terms of trip details, meeting characteristics, and trends associated with expenses. The trip details relate to the number of trips, the average trip period, and cost. The questions on meeting characteristics seek information on the average number of people at the meeting, the employee designation (for example, manager or regular employee) for those who make trips frequently, and the purpose/context of the meeting that required one or more employees to have air travel. The expense-related questions aim to determine the trends in the amount of expenses per year and potential causes for those trends. The objective of this part of the questionnaire is to understand the factors that motivate air travel for intra-firm meetings, the relevant costs, and factors that cause increases or decreases in the air travel expenses of the firm.

The second part explores a firm's experience related to the use of videoconferencing. Akin to the first part, information is sought on videoconferencing details, purpose, and trends in expenses. The videoconferencing details include the amount of time that it has been used, the frequency of usage, cost, and duration. The questions on meeting characteristics and trends in expenses are similar to the first part. A question is also asked on the effect of videoconferencing on business trips. For respondents without past experience in videoconferencing, their likelihood of adopting it is queried. In summary, the second part of the questionnaire analyzes experience with videoconferencing and trends related to the associated expenses.

The third part of the survey questionnaire seeks opinions related to the usage of business air travel and videoconferencing as two alternative mechanisms for communication. Table 1 lists the "opinion variables" which gauge the perceived benefits and weaknesses of the two alternatives. A five-point Likert scale ranging from "Strongly agree" (=5) to "Strongly disagree" (=1) is used for this purpose. This part seeks to understand the motivations for the decisions made by the firms relative to the usage of the two alternatives.

The last part of the survey obtains details on the firm's profile in terms of the nature of the business, personnel size, and number of offices around the world. Further, it seeks the percentages of communication activities conducted by the various mechanisms (air travel, videoconferencing, teleconferencing, web conferencing). It also aims to understand the influence of better ICT capabilities on the amount of business air travel.

2.3. Survey sample characteristics

The survey targets firms in the three main science industry parks in Taiwan. They are technology oriented, and span industries such as semi-conductor, telecommunication, bio-technology, software, networking, and optoelectronics. According to data published by the Administration of Science Industry Park of Taiwan, there were 600 technology firms at the time of the survey. The survey questionnaire was sent to all 600 firms in early 2008. Responses (116) were received, for a response rate of about 20% across the total population of firms.

The sample characteristics are summarized in Table 2. Of the 116 respondents, more than 60% are involved in making travel budget decisions for their firms. The profiles of their firms suggest that around 53% of these firms have no more than 100 employees in the respondent's office, 42.6% have up to 500 employees world-wide, and 68.7% have up to 10 branch offices around the world. Hence, roughly half of the respondents are relatively small-size firms. Also, 53.9% of the respondents work at their firm's head office. Excluding the "other business" group, "software/networking" has the largest share in the sample at 20%. About 30% of the respondents fall in the "other business" category, and most operate in the manufacturing domain.

In terms of business air travel, 72.2% of the firms had at most 40 employees making business air trips in 2007. However, the average number of employees making air trips in 2007 across the entire sample was 140. About 70% of the firms had only 25% of their employees making business air trips, while 6% had more than 75% of their employees doing so. In 58.3% of the sample firms, employees making business air trips averaged no more than four trips per person. Also, employees belonging to the managerial cadre traveled more frequently than regular employees. Nearly 70% of the firms had increased business air travel expenses in 2007. The reasons for this trend include increases in: scale of operation (44%), business activities (70%), travel budget (26%), communication activities (54%), and airfare (30%). By contrast, the primary reason (66%) for firms with decreased expenses in 2007 is the use of communication software such as Skype or Instant Messenger.

Table 3 reports the sample characteristics related to videoconferencing activities. Of the 116 firms represented by the survey respondents, 74 (63.8%) firms have adopted videoconferencing. Of these 74, about 65% adopted it for at most 2 years, indicating that videoconferencing is a relatively recent communication mechanism in Taiwan's technology industry. About 37% of the adopters use videoconferencing no more than once a month, implying that it is still not a common mechanism to communicate in the intra-firm context. However, nearly one-third of the adopters use it extensively, at a rate of more than six times in a month. Around 78% of the videoconferencing adopters had increased expenses in 2007. The causes include increases in: scale of operation (46%), business activities (60%), budget allocated to videoconferencing (39%), frequency of meetings (64%), and duration of meetings (54%), and significantly, decrease in business air travel (32%). For firms with decreased videoconferencing expenses in 2007, the primary reason is the reduced duration (38%) of the videoconference.

Fig. 1 illustrates the distribution of the various meeting purposes for business air travel (face-to-face meeting) and videoconferencing. Among the 74 respondents who use both business air travel and videoconferencing for communication within their firms, videoconferencing represents a valid communication alternative in many meeting contexts, especially for technical information exchange, scheduled/management meeting, training, consulting, report or project presentations,

Table 1
Definition of variables.

Dependent variables (correspond to *y* variables)	
YATP	Number of business air trips between intra-firm offices in 2007
YVCF	Frequency of videoconferencing usage in 2007
Independent variables	
*Firm profile variables (correspond to the **X** vector)*	
LSZ1	Number of employees in respondent's office (=1, if up to 100)
LSZ2	Number of employees in respondent's office (=1, if range is between 101 and 299)
NOFF	Number of offices around the world (=1, if more than 30)
WSZE	Number of total employees in the world (=1, if more than 2000)
HEAD	(=1, if head office)
Business air travel variables (correspond to the $\mathbf{Z}_{i,\ i=1}$ vector)	
TDAY	Number of days of a business air trip
AEXP	Average expense for a business air trip
PFFM	Average number of persons in a face-to-face meeting (=1, if more than 15)
Videoconferencing variables (correspond to the $\mathbf{Z}_{i,\ i=2}$ vector)	
YEAR	Number of years videoconferencing has been adopted (=1, if more than 2 years)
VDUR	Duration of a videoconference meeting (=1, if less than 20 min)
VEXP	Annual expenses for videoconferencing
PVCM	Average number of persons in a videoconference meeting (=1 if less than 6)
Meeting context variables (correspond to the $\mathbf{K}_{i,\ i=1,\ 2}$ vector)	
CTX1	(=1, if "technology/information exchange")
CTX2	(=1, if "scheduled/management meeting")
CTX3	(=1, if "training and consultancy")
CTX4	(=1, if "project report/presentation")
CTX5	(=1, if "marketing and sales/demonstration")
CTX6	(=1, if "event participation")
CTX7	(=1, if "business cooperation and development")
CTX8	(=1, if "negotiation")
CTX9	(=1, if "market research and survey")
*Opinion variables (correspond to the **W** vector)*	
Business air trips among the various offices	
OPN1	Represent the main communication mechanism in our firm
OPN2	Promote opportunity for interactions with other offices
OPN3	Foster the development of personal relationships within our firm
OPNP	Average of the sum of above three opinion variables, representing the benefits for business air travel
OPN4	Increase the travel expenses of our firm
OPN5	Decrease our employee productivity
OPN6	Are allowed only if necessary
OPN7	Require the least expensive air travel option
OPNN	Average of the sum of the above four opinion variables, representing the weaknesses of business air travel
Videoconferencing	
OPN8	Can increase communication efficiency within our firm
OPN9	Can replace some business air trips within our firm to reduce cost
OPN10	Can improve our employee productivity
OPN11	Can improve the quality of training in our firm
OPN12	Can improve our employees' quality of life
OPN13	Fits our firm needs or profile
OPNV	Average of the sum of the above six opinion variables, representing the benefits for videoconferencing

and negotiations, as illustrated in Fig. 1a. However, a face-to-face meeting is preferred for meeting contexts such as business development discussions, marketing sales and demonstrations, event participation, and market research. This suggests that videoconferencing can be a potentially acceptable alternative to business air travel in some contexts that do not specifically require face-to-face interaction, and the preferred alternative in other contexts (for example, for report presentation). While Fig. 1a indicates higher usage of videoconferencing for negotiations, business air travel is also a major alternative for negotiations as it was the primary meeting purpose for respondent firms with substantial business trips. Among the 42 respondent firms who did not adopt videoconferencing, the trend of the distribution of the various meeting purposes for business air travel (Fig. 1b) was similar to that for the adopter sample. Since these firms have not used videoconferencing, meeting contexts with less need for face-to-face interactions such as information exchange, scheduled/management meeting, and training or consulting, also represent major purposes for business air travel for them.

3. Model structure

This section describes the model structure development process to analyze the survey data. A preliminary analysis investigates whether simultaneous direct or indirect interaction relationships exist between business air travel and

Table 2
Sample characteristics (total number of sample firms = 116).

Sample attributes	%
Decision role of respondents	
Involved in travel budget decisions	
Yes	62.1
No	37.9
Profile	
Number of employees in respondent's office	
⩽100	53.0
101–300	19.3
>300	27.7
Number of employees in the world	
⩽500	42.6
501–3000	24.4
>3000	33.0
Worldwide branch offices	
⩽10	68.7
11–30	17.4
>30	13.9
Respondent's office is the head office	
Yes	53.9
No	46.1
Nature of business	
Computer/consumer electronics	11.3
Bio-technology	2.6
Software/networking	20.0
Semi-conductor	13.9
Electronic components	12.2
Photoelectricity/optics	8.7
Precise instruments	7.0
Telecommunications	10.4
Other business	28.7
Business air travel activities	
Number of employees making business air trips in 2007	
⩽10	53.9
11–40	18.3
>40	27.8
% of employees making business air trips in 2007	
⩽25%	67.2
26–50%	16.4
51–75%	10.3
>75%	6.0
Number of trips per employee in 2007	
⩽4	58.3
5–8	27.7
>8	14.0
Employees who travel a lot	
High-level managers	67.8
Mid-level managers	61.7
Regular employees	30.4
Trend in air travel expenses	
Increase	69.6
Decrease	30.4

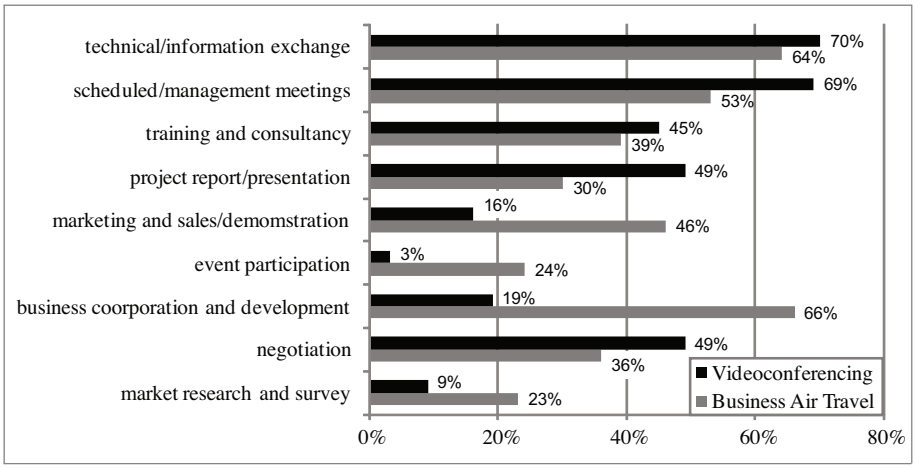
videoconferencing. It indicates the absence of such relationships, and points to the need for Poisson and negative binomial regression models. Then, these two models are briefly described.

3.1. Preliminary analysis

First, the preliminary analysis explores whether a simultaneous direct relationship exists between the two communication mechanisms within a firm. It is assumed that the number of business air trips and the frequency of videoconferencing usage may simultaneously determine each other and have direct interaction relationships. In addition, factors including firm characteristics, variables related to business air travel or videoconferencing, meeting context variables, and opinion variables related to the benefits and weaknesses of the two communication mechanisms within a firm, may impact the use of these two alternatives. Hence, the simultaneous equation model (Pindyck and Rubinfeld, 1998), shown as Eq. (1), is proposed to analyze the survey data:

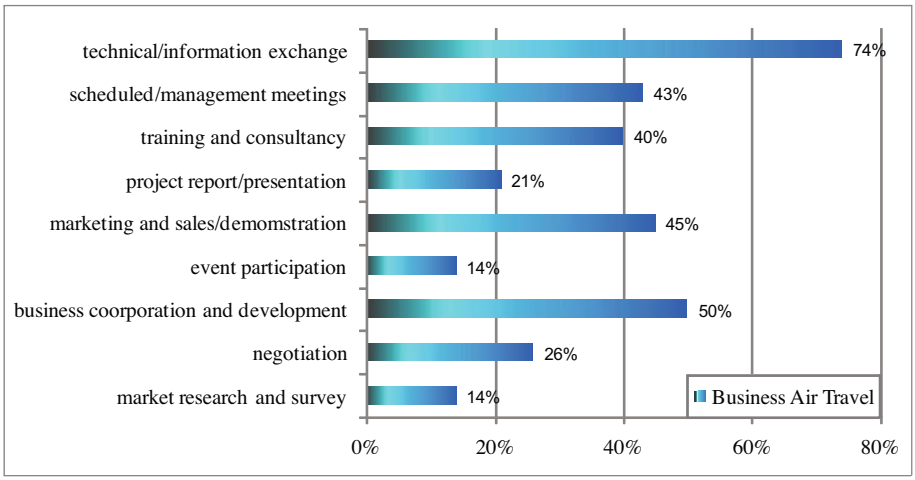
Table 3
Sample characteristics related to videoconferencing adopters (number of firms who have used videoconferencing = 74).

Sample attributes	%
Videoconferencing activities	
Number of years videoconferencing adopted	
⩽2 years	65.2
>2 years	34.8
Frequency of videoconferencing usage in 2007	
⩽1 per month	37.0
2–6 per month	34.2
>6 per month	28.8
Employees who use videoconferencing a lot	
High-level managers	69.9
Mid-level managers	76.7
Regular employees	31.9
Trend in videoconferencing expenses	
Increase	78.1
Decrease	21.9



* The sum of the percentages under communication alternative can be more than 100 as multiple purposes can exist.

(a) Respondent firms that use both using business air travel and videoconferencing (n=74)



* The sum of the percentages under communication alternative can be more than 100 as multiple purposes can exist.

(b) Respondent firms that use business air travel only (n=42)

Fig. 1. Meeting contexts (purpose) for business air travel (face-to-face meeting) and videoconferencing. The sum of the percentages under communication alternative can be more than 100 as multiple purposes can exist.

$$y_1 = \alpha_1 + \omega_{12} y_2 + \beta_1 \mathbf{X} + \gamma_1 \mathbf{Z}_1 + \delta_1 \mathbf{K}_1 + \upsilon_1 \mathbf{W} + \varepsilon_1$$
$$y_2 = \alpha_2 + \omega_{21} y_1 + \beta_2 \mathbf{X} + \gamma_2 \mathbf{Z}_2 + \delta_2 \mathbf{K}_2 + \upsilon_2 \mathbf{W} + \varepsilon_2 \quad (1)$$

For expository convenience, the subscript to denote an observation is ignored here and in the other relevant equations in the paper. Here, y_1 indicates the number of business air trips in 2007 and y_2 represents the frequency of videoconferencing usage in 2007. $\mathbf{X}$ is the vector of variables associated with the firm characteristics of all respondents. $\mathbf{Z}_i$ is the vector of variables associated with business air travel ($i = 1$) or videoconferencing ($i = 2$). $\mathbf{K}_i$ is the vector of meeting context variables for business air travel ($i = 1$) or videoconferencing ($i = 2$). $\mathbf{W}$ is the vector of opinion variables related to business air travel and videoconferencing for all respondents independent of whether they use videoconferencing currently. α, ω, β, γ, δ, and υ are vectors of the coefficients, and represent the parameters to be estimated. ε denotes the disturbance term. Table 1 lists the definitions of the variables used in the analysis to develop the models. Since most variables are dummies, the definitions of their base variables are not shown in the table. For example, LSZ1 and LSZ2 are 0–1 dummies that indicate the number of employees in respondent's office being up to 100 and ranging from 101 to 299, respectively. Their base variable (LSZE) is the number of employees in the respondent's office being more than 300. The value of LSZE is equal to $(1 - \text{LSZ1} - \text{LSZ2})$.

As illustrated in Eq. (1), y_1 and y_2 are both dependent and independent variables. Hence, if the parameters ω are estimated as being statistically significant, it may be concluded that a strong direct relationship exists between business air travel and videoconferencing. Also, the sign of the estimated coefficient values may indicate whether a substitution effect (negative coefficient), a stimulation effect (positive coefficient), or no significant direct relationship (coefficient value close to zero) exists between these two alternatives. However, the t-statistics of the coefficients ω_1 and ω_2 for the survey data using 3SLS estimation technique are insignificant, and the coefficient values are close to zero. This suggests that a strong direct interaction relationship may not exist between these two alternatives.

Based on the above insights, the second part of the preliminary analysis explores whether the number of business air trips and the frequency of videoconferencing usage have an indirect interaction relationship as the decisions on using these two alternatives are made by the same firm, leading to the possibility of some shared unobserved characteristics such as the communication atmosphere and body language among the people requiring the meeting. In other words, these two variables may not directly determine each other, but instead are determined by some common factors. Therefore, a seemingly unrelated regression equations (SURE) model (Washington et al., 2003; Zellner, 1962) is proposed to analyze the possibility of an indirect interaction relationship between business air travel and videoconferencing:

$$y_1 = \alpha_1 + \beta_1 \mathbf{X} + \gamma_1 \mathbf{Z}_1 + \delta_1 \mathbf{K}_1 + \upsilon_1 \mathbf{W} + \varepsilon_1$$
$$y_2 = \alpha_2 + \beta_2 \mathbf{X} + \gamma_2 \mathbf{Z}_2 + \delta_2 \mathbf{K}_2 + \upsilon_2 \mathbf{W} + \varepsilon_2 \quad (2)$$

The difference between this model and Eq. (1) is the elimination of the two dependent variables from the right-hand-side here, implying the absence of a direct relationship. The possible cross-equation correlation of the error terms can be determined by examining their variance–covariance structure. Then, the sign of the correlation coefficient of the error terms can indicate whether the relationship between business air travel and videoconferencing is substitutional or complementary. However, the results estimated for the survey data suggest a poor goodness-of-fit of the equations in terms of R^2 (less than 0.1), and only a few coefficients reaching the significance level of 0.1. They indicate the lack of a significant indirect relationship between the two alternatives.

The preliminary analyses suggest that the effect of frequency of videoconferencing usage on business air trips and vice versa within the same firm may lack strong interaction linkages. Next, we focus on the count data nature of the number of business air trips and the frequency of videoconferencing usage, and consider the Poisson and negative binomial regression models for further analysis of the survey data.

3.2. Poisson regression model

The models in the preliminary analyses are based on linear regression. However, linear regression analysis has statistical issues when the dependent variable is a non-negative integer. Since the number of business air trips and the frequency of videoconferencing are non-negative integers, Poisson regression represents a potential analysis method for modeling them. The Poisson regression model is illustrated as

$$P(y_i) = \frac{EXP(-\lambda_i)\lambda_i^{y_i}}{y_i!}; \quad i = 1, 2 \quad (3)$$

Here $i = 1$ represents business air travel and $i = 2$ indicates videoconferencing. So, y_1 indicates the number of business air trips in 2007 and y_2 represents the frequency of videoconferencing usage in 2007. $P(y_i)$ is the probability of y_i business air trips or the videoconferencing usage frequency in 2007. λ_i denotes the Poisson parameter, which is equal to the expected number of business air trips or the expected frequency of videoconferencing usage, $E[y_i]$.

The Poisson parameter can be further specified as a log-linear function of the explanatory variables contained in Table 1:

$$LN(\lambda_i) = \alpha_i + \theta_{ij} y_j + \beta_i \mathbf{X} + \gamma_i \mathbf{Z}_i + \delta_i \mathbf{K}_i + \upsilon_i \mathbf{W} \quad i, j \in \{1, 2\};\ i \neq j \quad (4)$$

Although y_j ($j = 1, 2$; $j \neq i$) is hypothesized as an endogenous explanatory variable and refers to the number of business air trips or the frequency of videoconferencing usage, it differs from Eq. (1) in that the models are estimated independently. That is, if the parameter θ_{ij} is estimated as being statistically significant, it would indicate that a strong direct relationship, but not a simultaneous interaction, exists between business air travel and videoconferencing in the corresponding direction. Also, the sign of the estimated θ_{ij} value indicates whether a substitution effect (negative coefficient) or a stimulation effect (positive coefficient) exists between these alternatives.

3.3. Negative binomial model

The Poisson regression model is a standard model for count data. However, its assumption of the equality of the mean and variance ($E[y_i] = VAR[y_i]$) is often violated in observed data. A key reason is that the unobserved heterogeneity in the data will often cause the variance to exceed the mean (Jang, 2005). The negative binomial regression model addresses this by adding an error term to Eq. (4) to capture the effect of the unobserved heterogeneity (Washington et al., 2003):

$$LN(\lambda_i) = \alpha_i + \theta_{ij} y_j + \beta_i \mathbf{X} + \gamma_i \mathbf{Z}_i + \delta_i \mathbf{K}_i + \upsilon_i \mathbf{W} + \varepsilon_i \quad i,j \in \{1,2\};\ i \neq j \tag{5}$$

where $EXP(\varepsilon_i)$ is the gamma distributed error term with mean 1 and variance ϕ^2. The addition of this term allows the variance to be different from the mean:

$$VAR[y_i] = E[y_i][1 + \phi E[y_i]] = E[y_i] + \phi E[y_i]^2 \tag{6}$$

ϕ is also referred to as the overdispersion parameter. If it approaches zero, then from Eq. (6) $E[y_i] = VAR[y_i]$, leading to the Poisson regression model. However, if ϕ significantly differs from zero, the negative binomial model is appropriate. Hence, the selection of the specific model is dependent on a test of whether the value of the overdispersion parameter is equal to zero (Jang, 2005; Washington et al., 2003).

4. Model analysis and insights

The LIMDEP software (Greene, 2002) is used to estimate the parameters of the various models. Two sets of models are developed; one for videoconferencing adopters and the other for videoconferencing non-adopters. The models for the videoconferencing adopters use 74 observations corresponding to the respondents who use videoconferencing. The models for videoconferencing non-adopters use 42 observations. In each case, the statistically insignificant variables of the intermediate models estimated using LIMDEP are omitted in the final model.

4.1. Models for videoconferencing adopters

The two dependent variables, the number of business air trips and the frequency of videoconferencing usage in 2007, are estimated separately. They have a very wide range of values due to the heterogeneity in the profile characteristics of the various firms in the survey and the time period considered (1 year). Hence, their distributions are close to the Poisson distribution, as confirmed by the robustness of the estimated Poisson regression models. However, a test of the overdispersion parameter rejects the null hypothesis of a zero value. Hence, negative binomial models are estimated for the videoconferencing adopter sample.

Table 4 reports the results of the negative binomial models individually estimated for business air travel (YATP) and videoconferencing (YVCF). The overdispersion parameters in these models are estimated as being statistically significant, validating the selection of the negative binomial models for the analysis. A few variables such as OPNV in the business air travel model and VEXP in the videoconferencing model are estimated as not being significant at 90% confidence. However, they are retained in the models as their t-statistic values are close to 1.645.

4.1.1. Business air travel model

The column corresponding to YATP in Table 4 illustrates the business air travel model for videoconferencing adopters. The frequency of videoconferencing usage (YVCF) has a negative coefficient, indicating that videoconferencing can be a substitute for business air trips. In terms of firm characteristics, the positive coefficient for LSZE (respondent's office has more than 300 employees) indicates that a larger office is more likely to generate more business air trips. Similarly, WSZE (the number of the firm's employees around the world is over 2000) is a statistically significant variable, implying that when a firm has a larger number of global employees, it may induce more business air travel among intra-firm offices around the world.

The expenses per business air trip (AEXP) variable has a negative effect, implying that increased expenses per trip induce reduced number of business trips. Meeting context variables, which correspond to the purpose of communication, have seldom been analyzed in the existing literature. The model suggests that marketing sales and demonstrations (CTX5), business cooperation (CTX7), and negotiations (CTX8) are more likely to require face-to-face meetings (implied by business air travel), as indicated by the positive coefficients.

The opinion variables reflect the perceptions of the respondents with regard to business air travel and videoconferencing. The opinions on air travel are categorized into two parts: perceived benefits and perceived weaknesses. The perceived

Table 4
Negative binomial models for business air travel and videoconferencing.

Variable	YATP model		YVCF model	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Constant	2.14	1.49	0.94	1.22
Endogenous variables				
YVCF	−0.00164	−2.95		
YATP			−0.00007	−2.27
Firm characteristics				
LSZ1			0.68	2.13
LSZE(=1 − LSZ1 − LSZ2)	1.40	3.18		
WSZE	2.02	5.31	0.71	2.58
HEAD			0.67	2.87
Business air travel variables				
AEXP	−0.14	−1.74		
Videoconferencing variables				
YEAR			0.77	3.20
VEXP			−0.02	−1.59
VDUR			0.65	1.73
Meeting context variables				
CTX2			0.84	3.12
CTX3			0.24	1.77
CTX5	0.39	1.85		
CTX7	0.47	2.10		
CTX8	1.05	3.14	0.78	2.00
Opinion variables				
OPNP	0.75	2.83		
OPNN			0.22	1.65
OPNV	−0.44	−1.55		
Overdispersion parameter	1.30	6.99	0.76	6.45
Observations	74		74	
Restricted log likelihood (constant term only)	−121119.20		−2957.69	
Log likelihood at convergence	−1448.67		−367.33	
ρ_c^2	0.98		0.88	
χ^2 (*p*-value)	53740.33 (<0.0001)		2941.55 (<0.0001)	

benefits of using business air travel variable (OPNP) is the average of the sum of OPN1, OPN2, and OPN3, implying the positive impacts of using air travel. The perceived weaknesses of using business air travel variable (OPNN) is the average of the sum of OPN4, OPN5, OPN6, and OPN7, implying the negative impacts of using air travel. Since the opinions OPN8–OPN13 for videoconferencing are all positive, the average of the sum of these opinions is directly defined as the perceived benefits for videoconferencing, OPNV. The model indicates that the perceived benefits of using air travel (OPNP) and videoconferencing (OPNV) have positive and negative coefficients, respectively. It implies that a positive attitude towards the use of business air travel (higher score for OPNP) is favorable to the air travel option. Similarly, a positive perception of videoconferencing (higher score for OPNV) would negatively affect the number of business air trips, implying that videoconferencing could potentially substitute for business air travel.

4.1.2. Videoconferencing model

The negative binomial model for videoconferencing, corresponding to the column YVCF in Table 4, indicates that number of business air trips (YATP) has a negative effect on the frequency of videoconferencing usage (YVCF). This indicates that business air travel can potentially substitute for videoconferencing, suggesting a bi-directional substitution effect between them when the results in Section 4.1.1 are factored in. However, the magnitude of the YATP coefficient here is much smaller than that of YVCF in Section 4.1.1 due to the difference in the magnitudes of the usage of business air travel (average of 1043) and videoconferencing (average of 42) in 2007.

In terms of the firm characteristics, if the respondent's office size is small (LSZ1; up to 100 employees), the likelihood of videoconferencing for intra-firm communications is higher. Also, the likelihood of videoconferencing increases when firms have larger number of employees world-wide (WSZE). This is because more employees, and possibly more offices, induce greater possibilities for videoconferencing usage. Similarly, head offices (HEAD) are more likely to have greater videoconferencing usage due to their larger communication needs as well as higher possibility of their having adequate videoconferencing capabilities.

The number of years videoconferencing has been adopted (YEAR) is a key variable and has a positive coefficient. This implies that greater familiarity with videoconferencing leads to greater comfort with its usage as well as suggests it as a viable communication option in more instances due to this familiarity. Higher expenses for videoconferencing (VEXP) have a

negative effect on its usage. Also, videoconferencing is favored for smaller meeting durations (VDUR; meeting duration less than 20 min).

From a meeting context (purpose) perspective, meetings associated with scheduled/management meetings (CTX2), training and consulting (CTX3), and negotiations (CTX8), lead to increased frequency of videoconferencing usage. Based on the conclusions in Section 4.1.1, meetings involving negotiations induce higher usage of both business air travel and videoconferencing. Finally, if the perceptions associated with business air travel tend to be negative (higher score for OPNN), the likelihood of videoconferencing usage increases.

4.1.3. Elasticity analysis

Since the interpretation of the estimated coefficient values is not straightforward for Poisson or negative binomial models, elasticities or pseudo-elasticities (Washington et al., 2003) are computed to evaluate the marginal effects of the explanatory variables in the business air travel and videoconferencing models. The elasticity of the expected number of business air trips or the expected frequency of videoconferencing usage, λ_i, with respect to a specific explanatory variable is defined as (Washington et al., 2003):

$$E_{x_{ik}}^{\lambda_i} = \frac{\partial \lambda_i}{\lambda_i} \times \frac{x_{ik}}{\partial x_{ik}} = b_{ik} x_{ik} \tag{7}$$

Here E represents the elasticity of λ_i with respect to x_{ik}. x_{ik} is the value of the kth explanatory variable corresponding to any of the vector of variables in Eqs. (4) and (5), $\mathbf{X}$, $\mathbf{Z}$, $\mathbf{K}$, and $\mathbf{W}$. y_j can also be an explanatory variable. b_{ik} is the coefficient for the kth explanatory variable and corresponds to β, γ, δ, or υ in Eqs. (4) and (5). It corresponds to θ_{ij} when y_j is the explanatory variable. Note that while elasticities are computed for each observation, it is common to report a single average elasticity over all observations for analysis purposes. We use the average elasticity values in our analysis hereafter for the continuous variables.

The elasticity in Eq. (7) is appropriate for continuous variables such as the expenses for business air travel or videoconferencing (AEXP, VEXP). For indicator variables (which take binary values 0 or 1), a pseudo-elasticity is computed that estimates the incremental changes in the number of business air trips or the frequency of videoconferencing usage caused by changes in those variables:

$$E_{x_{ik}}^{\lambda_i} = \left[\frac{EXP(b_{ik}) - 1}{EXP(b_{ik})}\right] \times 100 \tag{8}$$

Pseudo-elasticity indicates the percent change in λ_i when the indicator variable changes from 0 to 1.

The models in Sections 4.1.1 and 4.1.2 use Eqs. (7) and (8) to compute the average elasticities and pseudo-elasticities for the variables in Table 4. They are shown in Table 5. The pseudo-elasticities are computed for all variables other than YVCF, YATP, AEXP, VEXP, OPNP, OPNN, and OPNV.

Among the continuous variables for which average elasticities are calculated, OPNP and OPNV show significant influence. This implies that though the remaining continuous variables in Table 4 are estimated as being statistically significant, they have smaller effects on the dependent variables. However, Table 5 illustrates some important insights even for these variables. First, the elasticities of −0.11 (0.11% decrease in business air trips for a 1% increase in the frequency of videoconferencing) and −0.05 for YVCF and YATP, respectively, indicate that the substitution effect of videoconferencing for business air travel is stronger than that of business air travel for videoconferencing. Second, among the non-endogenous continuous explanatory variables, the opinion (or perception) variables have a relative higher impact on the dependent variables. This suggests that perceptions on business air travel and videoconferencing have an important influence on the choice of the communication alternative. This has important implications for the airline industry in the context of travel-related perceptions. One potential strategy for airlines is to enhance the level of ICT adoption both at the airports and in the airplanes to provide seamless connectivity for ensuring sustained productivity capabilities for business travelers.

A comparison of the pseudo-elasticities for the indicator variables suggests that firm profile plays an important role in determining the communication-related choices. This is especially so for the YATP model, implying that the scale of operation of the firm influences the usage of business air travel. For example, if the number of employees world-wide in a firm is greater than 2000 for the YATP model, there is a 86.69% increase in business air trips compared to if a firm has up to 2000 employees world-wide. Similarly, some specific meeting context variables (CTX8, CTX2) have larger pseudo-elasticities, indicating that they have a higher impact on the communication mechanism chosen.

4.2. Model for non-adopters of videoconferencing

The models in Section 4.1 excluded 42 firms who have not adopted videoconferencing. However, in the survey, these firms provide information on their profile characteristics, business air travel activities, and perceptions on the two communication mechanisms. In this section, we analyze the attitudes of the videoconferencing non-adopters to understand how they differ from those of the videoconferencing adopters. Then, a Poisson regression model for business air travel is developed for the videoconferencing non-adopters.

Table 5
Average elasticities and pseudo-elasticities for the models shown in Table 4.

Variables	YATP model	YVCF model
Endogenous variables		
YVCF	−0.11	
YATP		−0.05
Firm characteristics		
LSZ1		49.39[a]
LSZE(=1-LSZ1-LSZ2)	75.32[a]	
WSZE	86.69[a]	51.03[a]
HEAD		48.82[a]
Business air travel variables		
AEXP	−0.19	
Videoconferencing variable		
YEAR		53.51[a]
VEXP		−0.08
VDUR		47.74[a]
Meeting context variables		
CTX2		56.70[a]
CTX3		21.18[a]
CTX5	32.22[a]	
CTX7	36.69[a]	
CTX8	65.11[a]	54.30[a]
Opinion variables		
OPNP	2.80	
OPNN		0.80
OPNV	−1.69	

[a] Pseudo-elasticities computed using Eq. (8).

4.2.1. Comparative raw data analysis

The raw survey data is used to compare the samples of videoconferencing adopters and non-adopters. A greater percentage of the non-adopter firms (62%) have smaller size for the respondent's office compared to the adopter firms (47%). 35% of the adopter firms in the sample have more than 300 employees. Also, only 30% of the non-adopter sample has more than 2000 employees world-wide, compared to nearly 45% for the adopter sample. Finally, for close to 60% of the non-adopter sample, the respondent's office is not the head office. By contrast, for 61% of the adopter sample, the respondent's office is the head office of their firm. In summary, non-adopters generally tend to have a smaller scale of business operation compared to adopters.

The relative number of business air trips generated by non-adopter firms is greater than that of the adopter firms in the survey sample. Also, the business air travel expenses increased by 17% in 2007 for non-adopters compared to about 3% for the adopters. This suggests that interactions between business air travel and videoconferencing exist for the adopter firms; the analysis in Section 4.1 indicates that there is a significant substitution relationship between these two alternatives.

Table 6 illustrates the results of the ANOVA (analysis of variance) conducted to examine whether perceptions (opinions) on the two communication mechanisms are significantly different between the videoconferencing adopters and non-adopters. They indicate that OPN4 (business air travel increases travel expenses), OPN5 (business air travel decreases employee productivity), OPN7 (business air travel requires the least expensive air travel option), and OPNN (average of OPN4 to OPN7 indicating the negative perception of business air travel) values differ significantly between the two groups. Further, all variables except OPN6 (business air travel allowed only if necessary) and OPN13 (videoconferencing fits our firm's needs or profile) have higher mean scores for the non-adopter group.

The results suggest that non-adopters may have optimistic perceptions of the advantages of videoconferencing as a potential alternative as they have no experience with it. Also, since they only use business air travel, their negative perceptions with this option are higher. By contrast, videoconferencing adopters are satisfied with the value provided by this option (OPN13), and view it as an alternative to business air travel (OPN6).

4.2.2. Business air travel model for non-adopters

A Poisson regression model is used to represent the business air travel model for videoconferencing non-adopters. As shown in Table 7, it is validated since the non-adopter sample data fails to reject the null hypothesis of the overdispersion parameter being zero. Due to the large range of values for the dependent variable (4–30,000), its frequency distribution is close to the Poisson distribution form. Hence, the model has significant explanatory power, as reflected by the large *t*-statistic values and high ρ_c^2 in Table 7.

From Table 7, it is observed that business air travel variables (Table 1) do not appear in the model. This is because business air travel is the primary form of intra-firm communication for the non-adopter firms. The firm characteristics suggest

Table 6
ANOVA: videoconferencing adopters and non-adopters.

	Adopter (=74)	Non-adopter (=42)	Significance
OPN1	3.09	3.40	
OPN2	4.16	4.21	
OPN3	3.96	4.00	
OPN4	4.19	4.69	***
OPN5	2.77	3.17	**
OPN6	4.31	4.17	
OPN7	3.28	3.69	*
OPN8	4.31	4.38	
OPN9	4.16	4.26	
OPN10	3.67	3.93	
OPN11	3.59	3.67	
OPN12	3.31	3.60	
OPN13	4.00	3.76	
OPNP	3.74	3.87	
OPNN	3.64	3.92	**
OPNV	3.84	3.93	

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 7
Business air travel poisson model for non-adopter sample.

Variable	Coefficient	*t*-Statistic	Elasticities or pseudo-elasticities
Constant	4.91	34.98	
Firm characteristics			
LSZE (=1-LSZ1-LSZ2)	4.38	92.78	98.74[a]
WSZE	1.63	42.19	80.41[a]
HEAD	−1.23	−50.83	−242.12[a]
Meeting context variables			
CTX2	0.85	20.07	57.25[a]
CTX5	1.12	56.94	67.37[a]
CTX6	2.18	30.91	88.70[a]
CTX7	2.03	38.56	86.87[a]
Opinion variables			
OPNN	−0.91	−23.25	−3.57
Observations	42		
Restricted log likelihood (constant term only)	−173296.70		
Log likelihood at convergence	−2087.807		
ρ_c^2	0.98		
χ^2 (*p*-value)	342417.80 (<0.0001)		

[a] Pseudo-elasticities computed using Eq. (8).

that large firm sizes generate more business air travel. The negative coefficient for HEAD indicates that if the respondent's office is the head office, it induces less business travel. This is because business meetings are more likely to be held at the head office.

The coefficients for CTX2, CTX5, CTX6, and CTX7 suggest that business air travel is induced when face-to-face communication needs exist. Event participation (CTX6) has the largest coefficient, indicating that business air travel may be required for this purpose. The positive coefficients for CTX2 (scheduled/management meetings), CTX5 (marketing/sales demonstrations), and CTX7 (business development/cooperation) suggest that these meeting purposes also entail face-to-face meetings. Negative perceptions of business air travel (OPNN) tend to have a negative impact on such trips and a positive effect on videoconferencing usage. Hence, if airlines maintain high fare policies without providing better services to improve business traveler productivity, it can have a negative impact on business air trips. Then, if videoconferencing becomes an option, its usage would potentially increase.

The last column in Table 7 indicates that negative perceptions of business air travel (as illustrated by the elasticity −3.57) can have a strong negative impact on the number of business air trips. Among the indicator variables, HEAD has significant influence on YATP. This reinforces the notion discussed earlier that a head office may conduct a large number of business

meetings on-site. Among the meeting context variables, business development/cooperation and marketing sales/demonstrations induce relatively more business air travel.

5. Concluding comments

This study uses econometric models to analyze the relationship between business air travel and videoconferencing. The models suggest that substitution relationships exist between these two alternatives in the context of intra-firm communication. The substitution effect of videoconferencing for business air travel is stronger than the effect of videoconferencing being substituted by business air travel. Also, the analysis indicates that the meeting purpose significantly influences the frequency of business air travel and videoconferencing usage. By contrast, most past studies in this context have based their inferences on raw survey data, focused only on the ability of videoconferencing to substitute for business air travel rather than in both directions, and not considered meeting context as a factor. Obtaining an understanding of the factors that enable business air travel to substitute for videoconferencing has implications for the strategies and policies adopted by the airline industry.

The survey results suggest that the meeting context is a key factor that influences the choice of business air travel and videoconferencing. Business air travel is induced by meetings that require face-to-face communication such as business discussions, negotiations, marketing demonstrations, and event participation, while videoconferencing is adequate for information exchange, management meetings, training, and consulting. In the context of inducing the potential substitution of videoconferencing by business air travel, implications for the airline industry include the need to introduce advanced ICT services both at airports and in airplanes, so that communication capabilities are provided to enable seamless productivity during the air travel.

More broadly, there can be multiple reasons for the decrease in air traffic. Business air travel can be impacted by well-known factors such as economic recession, cost-cutting and travel restriction policies of firms, and reduced airline competition. Increasing concerns on the environmental impacts of air travel can also negatively impact air travel (Aguilera, 2008; Lassen et al., 2006). Hence, the attitudes of organizations or business travelers in this context need to be examined for their impacts on business air travel. Consequently, it would be useful to explore the primary focus of the current study, the relationship between business air travel and videoconferencing usage, through a panel data analysis due to the dynamic nature of the causative factors as well as changing values.

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References

Aguilera, A., 2008. Business travel and mobile workers. Transportation Research Part A 42 (8), 1109–1116.
Bennison, D.J., 1988. Transportation/telecommunication interactions: empirical evidence from a videoconferencing field trial in the United Kingdom. Transportation Research Part A 22 (4), 291–300.
Bonsall, P., Shires, J., 2006. Employer expectations for commuting and business-related travel in an environment rich in information and communication technologies. In: Transportation Research Record: Journal of the Transportation Research Board, No. 1977. Transportation Research Board of the National Academics, Washington, DC, pp. 268–276.
Denstadli, J.M., 2004. Impacts of videoconferencing on business travel: the Norwegian experience. Journal of Air Transport Management 10, 371–376.
Greene, W.H., 2002. LIMDEP Version 8.3 User's Manual. Econometric Software, Inc.
Jang, T.Y., 2005. Count data models for trip generation. Journal of Transportation Engineering 131 (6), 444–450.
Khan, A.M., 1987. Sociotechnical factors in air travel: some new insights into telecommunications interactions. In: Transportation Research Record: Journal of the Transportation Research Board, No. 1147. Transportation Research Board of the National Academics, Washington, DC, pp. 6–14.
Lassen, C., Laugen, B.T., Næss, P., 2006. Virtual mobility and organizational reality – a note on the mobility needs in knowledge organizations. Transportation Research Part D 11 (6), 459–463.
Lian, J.I., Denstadli, J.M., 2004. Norwegian business air travel-segments and trends. Journal of Air Transport Management 10, 109–118.
Mason, K.J., 2002. Future trends in business travel decision making. Journal of Air Transportation 7 (1), 47–68.
Mason, K.J., 2005. Observations of fundamental changes in the demand for aviation services. Journal of Air Transport Management 11, 19–25.
Pindyck, R.S., Rubinfeld, D.L., 1998. Econometric Models and Economic Forecasts. Irwin/McGraw-Hill.
Roy, J., Filiatrault, P., 1998. The impact of new business practices and information technologies on business air travel demand. Journal of Air Transport Management 4, 77–86.
Saffo, P., 1993. The future of travel. Fortune Autumn 128 (7), 112–126.
Salomon, I., 1986. Telecommunications and travel relationships: a review. Transportation Research Part A 20 (3), 223–238.
Stephenson, F.J., Bender, A., 1996. Watershed: the future of U.S. business air travel. Transportation Journal 35 (3), 14–32.
Washington, S.P., Karlaftis, M.G., Mannering, F.L., 2003. Statistical and Econometric Methods for Transportation Data Analysis. Chapman & Hall/CRC.
Zellner, A., 1962. An efficient method of estimating seeming unrelated regressions and test for aggregation bias. Journal of the American Statistical Association 57, 348–368.