Airline Capacity Strategies in an Era of Tight Oligopoly

John Howard Brown, Corresponding Author

Associate Professor

Department of Finance and Economics

P.O. Box 8152

Georgia Southern University

Statesboro, GA 30460

Email: jbrown@georgiasouthern.edu

Rand Ressler,

Professor

Department of Finance and Economics

P.O. Box 8152

Georgia Southern University

Statesboro, GA 30460

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ABSTRACT

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One of the surprises of deregulation in American network industries has been the substantial concentration of activity in a limited number of firms. In the American airline industry the number of firms has shrunk from the approximately dozen incumbents prior to deregulation to three major network airlines and Southwest, which has not adopted the hub-and-spoke networks characterizing the other surviving majors. Recently there have been rising suspicions that the remaining majors have been colluding to restrict output and raise prices.

However, this is not the only possibility. Specifically, we investigate whether a Cournot game in capacity may be playing out in these markets. To implement our model, we employ a sample of the top 100 origin and destination markets for a single week in July 2014. This sample was chosen because these high density routes are most likely to display competitive behavior and July is among the peak months for air travel. The model is implemented empirically using simultaneous equations techniques.

The theoretical model is implemented using the three stage least squares technique in a six equation matrix representing the four major airlines (American, Delta, United, and USAir), Southwest, and the combined observations of the remaining 9 airlines servicing these routes. The results suggest that both collusive conduct and Cournot behaviors may be present in this market.

Introduction

One of the surprises of deregulation in American network industries has been the substantial concentration of activity in a limited number of firms. In the American airline industry the number of firms has shrunk from the approximately dozen incumbents prior to deregulation to three major network airlines and Southwest, which has not adopted the hub-and-spoke networks characterizing the other surviving majors. Since the number of firms competing in any given origin and destination market is likely to be very limited, a range of behaviors associated with oligopolistic markets rather than competitive markets may be observed.

Recently there have been rising suspicions that the remaining majors have been colluding to restrict output and raise prices.(Nicas, et al, 2015) This suspicion is reinforced by the characteristics of airline markets. In particular, rival firm's output choices are really observable on the industry standard computerized reservation systems (CRS). This clearly facilitates collusive coordination. The reported preference of airlines for increasing seating capacity of aircraft rather than flights is also suggestive of an attempt to limit competition.(Carey and Nicas, 2015)

However, these are not the only possibilities. Specifically, we investigate whether a Cournot game in capacity may be playing out in these markets. In such markets, firms earn supracompetive profits without explicit communication. Ciliberto and Tamer (2009) present a sophisticated game theoretic and econometric model of airline decisions based upon an imputed profit function. These alternatives represent the short run competitive strategies in a market where the structures are determined after the manner of Ciliberto and Kamer

Ciliberto and Kamer's model incorporates unobserved firm heterogeneity based upon network structure. The empirical model is based on airport to airport routes with an adjustment for competition from other airports adjacent to the respective endpoints. It is oriented towards the airport level entry decisions and assumes that the existing market structures represent long-run equilibrium. In contrast, our model employs an observable firm behavior, the capacity offered in a market.

The balance of the paper consists of four sections. The next section discusses how the Cournot model can be adapted to reflect the specific characteristics of airline markets. A subsequent section describes the data used in our empirical tests and discusses the relationship of measured variables to the theoretical model of the prior section. The third section reports the empirical results of the estimates. The final section provides a conclusion and suggestions for additional research.

<u>Cournot model adapted to airline markets:</u>

The Cournot model starts with an inverse demand function for a good:

$$P = a - bq_i - nbq_n \qquad (1)$$

Where P is price as is standard, q_i is the quantity of firm i, n is the number of other participants in the market, and q_n is the quantity produced by firm n. Under the standard assumptions of the model the firms are completely symmetric in their behavior. In the airline industry we would expect the firms to differ so that the equation becomes:

$$P = a - b_i q_i - \sum b_n q_n \qquad (2)$$

where the summation is from 2 to n and each firm's quantity and slope variable is unique to that firm. This complicates the computation considerably. Each firm has revenue function:

$R_i = aq_i – b_iq_i^2 - q_i\sum b_nq_n$ (3) and a marginal revenue function:

$MR_i = a – 2b_iq_i - \sum b_nq_n$ (4)

These marginal revenue equations can be set equal to marginal costs (c), then solved for reaction functions. These show how a firm varies its profit maximizing quantity in response to rivals output choices. These take the general form:

$q_i = (a – c)/2b_i - 1/2b_i \sum b_nq_n$ (5)

There is a system on n equations for each market where each individual participating airline is represented by an equation. The exact nature of the empirical model will be discussed further below.

However, theoretical predictions about the behavior of individual firm output can be made independently of the place holder value of c. The predictions of the Cournot model duplicate those of the standard models for extreme values of the number of firms. Thus when a single firm serves a market, Cournot reproduces the monopoly outcome. Where the number of firms grows very large, output converges to perfectly competitive. In the airline industry, intermediate cases are relevant. For the sample drawn for the empirical estimates reported below, the observed number of firms in a market varies from two to six.

Behavior will also differ between a collusive oligopoly and a Cournot oligopoly in a predictable manner. In collusion, the firms strive to maintain the monopoly outcome. Thus increased output for one firm will be matched by an equal and opposite reduction for another firm. In contrast, Cournot behavior will result in increases of output matched by reductions of approximately one half the amount on the part of other firms in the market

A simplifying assumption of the standard Cournot model is that MC = 0. Clearly this is untenable in the airline industry. Thus a model of airline costs and the marginal costs which they imply is necessary to solve the model and implement an empirical test in the airline industry. The standard model of costs in transportation industries incorporates three varieties of costs.

The first is fixed facilities costs. These are the costs of capital used in delivering transportation but providing capital services only at a fixed location. Notable examples of fixed facilities in the airline industry are passenger handling facilities (i.e. ticketing counters, gates, and luggage service facilities,) runways, the air traffic control system, and hangar and maintenance facilities. None of these fixed facilities are specific to any particular city-pair market. (I.e. there are no gates that can only be used for flights to Palm Beach.) Of course, the use of any of these facilities has an opportunity cost associated with a given use. However these costs may largely be taken as fixed in the short run.

However there is one additional issue of fixed facility costs to be addressed. Some airports are and have been operating at their physical capacity. These airports are designated by the FAA as “slot constrained.” Such airports will have higher opportunity costs associated with the use of their facilities.

The second category of transportation related costs are vehicle costs. Airlines have a menu of aircraft types which they may select for use on a city-pair route. The most important considerations in choosing a particular type aircraft are capacity and operating costs. The capacity of aircraft is only available in discrete units. In general, the average costs of employing a particular type of aircraft are ranked so that $AC(I_1)$ for $q=0$ to $I_1 < AC(I_2)$ for $q= I_1$ to $I_2 < \ldots < AC(I_n)$ for $q= I_{n-1}$ to I_n; where I is a measure of the capacity of a particular equipment type and the subscript indicates capacity. Capacity and operating costs interact in a complex manner. Once a variety of aircraft is assigned to a city-pair market, these costs, too, are largely fixed.

The final category of costs related to supplying transportation are operating costs. Given a particular aircraft type and route, these costs will be increasing in q_i, in n, the number of distinct flights offered, and route distance. In addition, the costs of operating a particular aircraft on a given route will also depend on the service classes offered on the flight. Many of operating costs are likewise essentially fixed once aircraft and route are selected, e.g. air crew, distance, and fuel costs. This is transformed into an estimable system below.

Data description:

The 100 top domestic origin and destination markets are sampled for the week of July 21, 2014 from the Official Airline Guide.[1] Only direct flights are considered. Flights offered less than two days of the week are excluded. Only domestic carriers are considered, since foreign carriers cannot operate domestically due to the absence of cabotage rights. Data gathered includes, seating capacity on a flight. In the data there are fourteen airlines offering flights on these routes. Each airline's competitive characteristics (discussed in the prior section) enter as an observation for each of the 100 markets considered.

The data include, the number of flights in each market in total and for each participating airline, and the capacity measured in terms of available seats for each market and airline. These

[1] The markets are listed in Appendix A, available from the authors upon request.

variables are identified as XXpass where XX is the two letter code for the airlines. The major airlines (American, Delta, United, USAir, and Southwest) are all tested this way. All other airlines providing services are merged into a single Other variables. Two related variables were constructed XXpass2 and XXpass3. These are created by multiplying XXpass by dummy variables identifying markets with only two and three airlines respectively.

The number of code sharing flights offered by each firm was included. Other exogenous variables were constructed to further identify relevant route supply characteristics. These included whether one of the end points was a locality where slot constraints had been imposed on airline operations and if one of the endpoints was an operational hub for an airline operating in the market. Both of these were constructed as dummy variables taking a value of 1 where the characteristic was present and zero otherwise.

In addition, the third quarter 2014 survey of air traffic by the Department of Transportation DB1B was employed. This survey takes a ten percent sample of all airline itineraries in each calendar quarter. An essential demand statistic was culled from the database for the markets represented. This was the total passengers in each market. This serves as a demand proxy representing a in the equations supra. This is computed by multiplying the number of observed itineraries in each market by the average number of passengers on each itinerary. This provids the number of passengers.

A second variable drawn from DB1B is the average number of coupons for each itinerary. The data from the OAG includes only direct flights. However, many of the city pairs among the top 100 airline routes are also be serviced by itineraries with one or more intermediate stops. Such indirect itineraries provide an element of competition which may not be present in direct flights. This then represents an additional demand side variable.

Table 1 provides definitions for each of the variables.

<Table 1 about here>

Table 2 shows the mean, standard deviation, maximum, and minimum for each of the variables.

<Tables 2 about here>

Empirical Model

Equation 5 above suggests a simultaneous equations model. As discussed previously the sign of the parameters on other firms quantities is always expected to be negative. If collusion is occurring, the values of the parameters should be statistically indistinct from one.

The estimated equation takes there form:

q_i = άpass + δ market coupons + γ slot constrained -1/2b_i ∑b_nXXpass + η XXcodeshare + μ XXhub + ε (6)

In order to identify the three stage least squares model, additional exogenous variables are required. These additional variables generate an estimable form. First, is the Passengers for the route. This serves as a proxy for both demand conditions incorporated in the theoretical treatment. The parameter value of this variable is expected to be positive.

The number of coupons for itineraries on a route captures the effects of competition supplied by indirect connections between the end points of the route. The parameter of this variable is expected to be positive.

The following variables serve as proxies for costs. A route which is slot constrained ought to have higher opportunity costs associated with operations. The expected parameter o this variable in estimates is expected to be negative. A route with an operational hub at one of the end points should display increased quantities due to the cost savings available in operations through a hub and the coefficient should have a positive sign. Because code sharing duplicates some of the advantages of hub-and-spoke networking, the coefficient of the code share variable should likewise be positive.

Empirical Results

Table 3 begins reporting results of estimating equation 6 using 3 stage least squares(3SLS) by reporting goodness of fit measures. All six equations have chi-squared measures in excess of 100 indicating an insignificant likelihood that the results occurred by chance.

Table 4 reports the parameter estimates for the identifying variables in the equations. The signs for the passenger variable are almost always positive in line with a priori expectations but rarely at statistically significant levels. Operating from slot constrained airports likewise results in parameter values consistent with theory but rarely significant. Only USAir shows a notable positive influence of operating from their own hub, although other firms also have positive but insignificant effects. USAir is also the only airline where code sharing has a statistically significant positive effect. Finally, average coupons in the market has a positive and statistically significant effect as expected for all airlines.

The results in Tables 5 through 7 address the research question of this paper by illustrating the effects of market structures on firm’s strategic interactions. These tables are six by six tables where each row represents the estimated equation for the specific airline. Each column is the parameter reflecting the subject airline’s response to changing output by another airlines. The numbers in the cell below represent estimated standard errors. Parameters with * are statistically significantly different from zero with 95% probability. Those parameters which are also statistically significantly different from -1 with at least 95% confidence are underlined. The equations estimated included terms capturing these interdependencies for markets with only two or three participants. Thus the results reported in Table 5 reflect behavior in markets with more competitive structures.

American Airlines passenger traffic has negative and statistically different from zero interactions with all of the individual airlines in the sample. These may be read across the first line of Table 5. Only the other category, encompassing nine distinct airlines does not result in a statistically significant outcome. Of these interactions, those with their major peers, Delta and United, are significantly greater than one in absolute value. Curiously, the effects of Americans output on these rivals is not symmetric, with the effect on Delta's insignificant and United's significant but signifying a Cournot response. In contrast, USAir and Southwest, have coefficients of approximately -0.5. These results suggest that American may play a unique role in the airline industry, functioning as a swing producer in maintaining collusive output with its chief rivals. At the same time, it responds to lesser rivals as a player in a Cournot game.

Delta, represented by the second row in Table 5, experienced three of five statistically significant negative parameter estimates. American and Southwest quantities do not apparently have any effect on Delta's output choices. United's quantity choices seem to have a one for one displacement effect on Delta's. USAir and other airlines seem to have effects consistent with Cournot responses.

In the third row of Table 5, United also has three significant parameter estimates. As noted earlier, United's response to American's quantity choices is asymmetric, suggesting

United's decision-making follows a Cournot rule. United's response to Delta in contrast is symmetric, since the estimated parameter is not statistically different from one. The United interaction with USAir is symmetric and consistent with Cournot.

USAir's responses to its major peers are negative significant, as illustrated in the fourth row of Table 5. Its reaction to American's quantities is both symmetric and apparently inspired by Cournot. However its reactions to Delta and United are consistent with collusive accommodation. They are also asymmetric.

Southwest's parameter estimates are significantly different from zero in four of five cases. Its response to each of the majors, save USAir, suggests an active avoidance of disrupting markets with disproportionate reductions in the face Delta and United increases. American's responses are greeted with one for one changes. Finally, the other airlines appear to elicit a Bertrand response with one for one increases in output.

Other airlines show only two significant responses. These are both accommodative of collusion. These responses are also asymmetric with the major's responses to other airlines. Although, the reaction of the other airlines to Delta's quantity cannot be statistically distinguished from the response of Delta to those airlines.

In summary, the message of Table 5 is that estimated parameter values are consistent with both collusive and Cournot behaviors for the major airlines and Southwest (WN) where the most competitive markets, those with four or more serving airlines, are considered. In table 6, the parameter for an airline's quantity is interacted with a dummy identifying markets with only two suppliers.[2]

[2] Markets with only three suppliers are also treated in this manner. The results are reported in Table 7.

The estimated values for this variable are adjustments to be applied to the slope estimates for an airline's quantity. The potential range of these estimates is larger than before, since values greater than zero are conceivable. This would indicate movement towards greater competition. Negative values of these estimates suggest decreased competition.

A striking feature of these estimates is that the response of both USAir and Southwest is reflected by coefficients which become significantly more negative by approximately 0.5. This suggests a switch from Cournot to collusive behavior in markets where American and either of these airlines form a duopoly.

Another noteworthy change is the role that the "other" airlines play in duopoly markets. For instance, in more competitive markets, Southwest was indicated to behave as a Bertrand competitor, increasing output one for one with "other" airlines. In duopoly markets, behavior appears to be transformed into something much more collusive. In general the responses of others is statistically significant and tending towards collusive outcomes.

In fact, major airline's reactions to Southwest's behavior become much more significant both statistically and in terms of practical impact. American and Delta's responses to Southwest become implicitly collusive. At the same time, United is more likely to react to Southwest along Cournot lines. In short air route duopoly generally seems to result in less competition.

What will be the response where a triopoly rather than a duopoly exists? Table 7 reports that parameters relevant to that question. For American airlines, its major peers, Delta and United once again have positive coefficients and Delta's is significantly different from zero.

On the other hand, both USAir and Southwest have negative coefficients significant at the 95% and 90% levels of confidence respectively. These parameters added to the original parameters suggest that in a three firm market that American will participate in collusive output restrictions with these firms.

In three firm markets, Southwest (the fifth row in the table) appears to become substantially more aggressive with respect to the majors, except USair with whom collusion becomes the norm. The Other category of airlines seem to also move towards more accommodation of their larger rivals in these markets.

Conclusion

This paper has examined the possibilities of cooperative and non-cooperative departures from competitive behavior in the airline industry. A model of airline behavior related to the Cournot model of non-cooperative output determination was developed. The empirical implications of this model were developed.

The empirical model was implemented using data from the top 100 domestic airline markets from the Official Airline Guide. These data were supplemented by the Department of Transportation's Origin and Destination Survey (DB1B). The resulting statistical estimates were highly significant statistically, and robust across specifications.

The empirical results of suggest that in the largest airline markets a mix of collusive and Cournot behaviors may be present. This appears to be particularly true where the number of actual suppliers in a market is limited to two or three.

The empirical results of this study should be interpreted cautiously. There are several reasons for this. First, the data for this paper is drawn from a single week in the third quarter of 2014. There is no reason to believe that a randomly chosen will be unrepresentative. However seasonal effects are well known to be important in the airline industry. Ideally, then this study should be extended by drawing samples from each calendar quarter.

An additional complication is the dynamic nature of oligopoly. Either demand or supply shocks can drastically alter the equilibrium.

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Table 1 Variable Definitions

Variable	Definition
pass	Passengers on itinerary connecting route endpoints from Bureau of Transportation Statistics 10% sample for the selected markets (DB1B).
market coupons	The average number of coupons per itinerary (DB1B).
Slot constrained	1 if either endpoint of a route is FAA slot constrained, zero otherwise
XXpass	The available seat-miles on a route divided by route distance from Official Airline Guide (OAG); XX is airline code (OAG).
XXpass2	XXpass interacted with a dummy taking value 1 where only two firms serve a market, zero otherwise; XX is airline code (OAG).
XXpass3	XXpass interacted with a dummy taking value 1 where only three firms serve a market, zero otherwise; XX is airline code (OAG).
XXcodeshare	The number of flights in the market which offer code share service, from OAG; XX is airline code (OAG)
XXhub	1 if either endpoint of a route is an operational hub for XX, zero otherwise, only applies to AA, DL, UA, US.

Table 2 - Descriptive Statistics for Sample Routes

Variable |	Obs	Mean	Std. Dev	Min	Max
pass |	100	28346.11	34816.42	1878	318473.5
aapass |	100	359.0596	402.9159	0	1274.759
aapass2 |	100	71.54975	249.2643	0	1249.954
aapass3 |	100	73.64515	232.0344	0	1064.072
AAhub |	100	0.32	0.468826	0	1
aacodeshare |	100	10.26	13.72649	0	64
dlpass |	100	318.6704	348.3258	0	1024.642
dlpass2 |	100	17.61477	104.2614	0	742.6148
dlpass3 |	100	118.8225	279.9049	0	992.9244
DLhub |	100	0.51	0.502418	0	1
DLCodeshare|	100	9.34	14.03619	0	84
uapass |	100	234.9665	199.3885	0	1359.95
uapass2 |	100	10.47537	60.3629	0	401.0036
uapass3 |	100	52.1523	120.8189	0	418.5155
UAhub |	100	0.59	0.494311	0	1
UACodeshare|	100	14.69	15.02166	0	57
uspass |	100	142.4563	317.2204	0	192.663
uspass2 |	100	33.32059	169.6397	0	1046.752
uspass3 |	100	30.73332	156.1243	0	1092.663
UShub |	100	0.18	0.386123	0	1
USCodeshare|	100	4.07	10.97955	0	73
wnpass |	100	557.8092	490.7344	0	3725.307
wnpass2 |	100	54.27234	190.3977	0	819.9188
wnpass3 |	100	183.5916	338.7604	0	891.0848
WNCodeshare|	100	3.15	4.026114	0	19
otherpass |	100	974.1333	862.0244	0	4802.267
otherpass2 |	100	14.9988	108.4836	0	927.1022
otherpass3 |	100	239.591	452.4727	0	1993.219
othercodes~e |	100	5.8	9.351714	0	53
Slotconstr~d |	99	0.434343	0.498193	0	1
market_cou~s |	100	1.172823	.1281099	1.03671	1.535019

Table 3 – Statistical Measures of Goodness of Fit

Three-stage least-squares regression

Equation	Obs	Parms	RMSE	"R-sq"	chi^2	Probability
aapass	99	20	491.7537	0.1734	215.96	0.0000
dlpass	99	20	368.2507	0.3662	230.21	0.0000
uapass	99	20	235.4082	0.4199	256.37	0.0000
uspass	99	20	276.2082	0.3702	196.94	0.0000
wnpass	99	19	815.6252	-0.1984	115.44	0.0000
otherpass	99	18	707.2466	0.7001	355.10	0.0000

Table 4 – Demand and Cost Variables

EXO Var / Dep Var	Passengers ά	Slot constrained	Average Market coupons	Own Codeshare	Own Hub
aapass	.0015961 .0012318	-144.1334 96.9968	1624.64* 183.908	2.835753 1.967478	5.200051 39.55744
dlpass	.0022745* .0010441	-197.0458* 82.10493	1216.526* 152.6841	-.0153786 1.737043	1.229165 45.98474
uapass	.0011287 .0008343	-109.0508 78.50304	797.2986* 171.5388	-.6328893 1.245354	17.72313 34.23222
uspass	.0005611 .0009312	-33.69708 76.42362	768.9063* 216.2007	7.623559* 2.051059	320.3324* 94.22732
wnpass	-.0008442 .0020669	-33.52492 174.9222	1610.304* 290.7044	13.61788 11.59173	---
otherpass	.0048002* .0020805	-418.495* 169.6958	1872.351* 325.3294	---	---

Standard error appears below parameter estimate. Starred variable (*) indicate parameter estimate is statistically significantly different from zero at 95% confidence level. Caret (^) indicates 90% significance.

Table 5 – Capacity Interactions Among Airlines

Endo Var / Dep Var	aapass	dlpass	uapass	uspass	wnpass	otherpass
aapass	--	-1.7448* .2538	-2.5171* .5968	-.4765* .2086	-.4168* .17818	.1589 .1713
dlpass	-.2505 .1976572	--	-1.047287* .461626	-.5766779* .1745305	-.1789676 .1633272	-.3088564* .1386715
uapass	-.2756* .1346	-.7226* .1748	--	-.3144* .1378	-.1760 .1181	-.0595 .1101
uspass	-.5174* .19084	-.9669* .2623	-1.3014* .5326	--	-.1581 .1196	.1503 .1810
wnpass	-1.64684* .4909	-2.1781* .5610	-4.0715* 1.3213	-.0150 .3683	--	1.0536* .3777
othrpass	.1124 .4454	-1.2099* .5180	-.5828 .8517	-1.1370* .3563	-.0601 .3211	--

Starred variable (*) indicate parameter estimate is statistically significantly different from zero at 95% confidence level. Caret (^) indicates 90% significance. Underlined indicates parameter estimate is statistically significantly different from -1 at 95% confidence level, only applied to parameter estimates significantly different from zero.

Table 6 – Capacity Interactions Among Duopoly Airlines

ENDO VAR / Dep Var	Aapass2	Dlpass2	Uapass2	Uspass2	Wnpass2	Otherpass 2
aapass	--	.3387 .3096	.2986 .6835	-.55506* .23066	-.8755* .2835	-1.7393* .4015
dlpass	-.4205* .2097	--	-.5645 .5007	-.1946 .2405	-.9413* .2748	-.6396* .2549
uapass	-.1680 .1573	.0661 .1488	--	-.1975 .1599	-.5012* .2258	-.5968* .2457
uspass	.0031 .1947	.2730 .2624	.06169 .6147	--	-.3353 .2400	-1.1295* .3658
wnpass	-.6292 .4753	.7107 .7712	2.097 1.629	-.9812* .4251	--	-3.0977* .7832
othpass	-1.0839* .4787	-.2830 .4797	-2.0434 1.2568	-.0612 .5199	-1.8811* .5539	--

Starred variable (*) indicate parameter estimate is statistically significantly different from zero at 95% confidence level. Caret (^) indicates 90% significance.

Table 7 – Capacity Interactions Among Triopoly Airlines

End Var / Dep Var	Aapass3	Dlpass3	Uapass3	Uspass3	Wnpass3	Otherpass3
aapass	--	.4517* .21784	.3474 .5681	-.6367* .2376	-.3438^ .1868	-.7520* .1981
dlpass	-.3613^ .1990	--	-.4148 .4142	-.2522 .2452	-.3284^ .1975	-.2296 .1443
uapass	-.1658 .1349	.0525 .1150	--	-.2449 .1675	-.1533 .1518	-.2709* .0923
uspass	.0985 .1847	.3562^ .1955	.1344 .5219	--	-.2386^ .13616	-.3960* .1889
wnpass	.9955* .5005	.9955* .5005	1.8354 1.3590	-1.0604* .4316	--	-1.4569* .4111
otherpass	-.9608 .4707	-.2967 .3476	-1.3870 .9620	-.1023 .5374	-.6413 .3985	--

Starred variable (*) indicate parameter estimate is statistically significantly different from zero at 95% confidence level. Caret (^) indicates 90% significance. Underlined indicates parameter estimate is tatistically significantly different from -1 at 95% confidence level, only significant parameter estimate