

Modeling the Cyclical Nature of Aggregate Airline Industry Profits

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Abstract

The aggregate profits of the airline industry have been dominated by a cyclical mode since before deregulation in the 1970's. In this paper we discuss several dynamics that combine to cause profit cycles: The misperception of the delay around capacity acquisition, the pro-cyclical ticket price setting policy and the countercyclical effect of industry congestion on passenger demand. By adding numerous endogenous feedbacks, extensions of previously used standard structures and wholly new structures we quantify the strength of these feedbacks, replicate the past behavior of the industry, and prescribe policies that can help to remove the cycle from airline industry earnings.

1 - Introduction

The Airline industry is an extremely important part of the modern economy, contributing nearly 0.5% of total U.S. GDP on its own in 2006 and providing the transportation that allows professionals in many other industries to increase their output. As the valid, albeit event-oriented, notion that there was a "September 11th Recession" shows, even small disruptions in our nation's transportation network can magnify into huge disruptions in the larger economy.

Yet despite the importance of air transportation robust strategies for creating consistent profitability within the industry have been elusive. As Helen Jiang's 2000 thesis with John Hansman shows, air transportation has consistently gone through profitability cycles with a period of approximately ten years (Hansman and Jiang 2000). Industry analysts and experts are not blind to this behavior but consistently argue either that specific events were the sole cause for the pattern of profits, a common argument professionals in our field confront, or that new strategies will dampen the cycle in the future even though the long history of the adoption of

strategies for flexible capacity such as leasing and mothballing has shown that the market has failed to stabilize aggregate profits.

In this paper we build a model of the airline industry that seeks to answer the question of why airline industry profits cycle. While this question has been tackled before by the literature, most notably by (Liehr et al 2001) and (Lyneis 2000), we extend the existing work by including many endogenous feedbacks left out of earlier models, most notably endogenous wage setting, though the specific structure of some earlier models is unknown due to their proprietary nature. We also include a new structure for simulating the data reporting process that can be used in many other settings. Additionally, by creating this model outside of a corporate setting and thereby allowing it to be published in full for the academic community to critique and extend there is an additional, less novel extension of the literature.

The rest of this paper proceeds in ten sections beginning with section 2 which introduces the data used in the model, section 3 reviews the core dynamic hypothesis for the industry, section 4 discusses our decisions on where to place the model boundary, section 5 gives details on the model structure, section 6 shows the partial model tests we used to help validate the model, section 7 discusses the parameter estimation process, section 8 shows the final model fit to historical data, section 9 evaluates policy recommendations and section 10 concludes.

2 - Airline Industry Data

Data is publicly available for the airline industry over a long time horizon, making it an ideal industry in which to construct a system dynamics model. Our data comes primarily from the Air Transport Association (ATA) (www.airlines.org) the nation's oldest and largest airline trade association. They gather and store data from the Bureau of Transportation Statistics (BTS)

and perform several transformations of it that are very useful for system dynamics modeling. For instance, they publish airline ticket prices as an industry wide average in dollars per seat mile rather than the index that is published by the BTS and calculate the average wage of a worker in the industry from the numerous filings of each individual carrier.

We download time series data on airline available seat miles (capacity), revenue passenger miles (demand), average ticket prices per seat mile (price), average wage and operating profit from the period beginning in 1970. While operating costs are available as a separate data item, several details of the accounting reporting process and the airline industry cause the reported operating costs from the ATA to not equal operating revenue minus operating profit when revenue is naively defined as price multiplied by demand. Because of this we make the simplifying assumption that operating costs equal that they would have had to have been given the profit for the year and the revenue implied by recorded demand and ticket prices. When we match our simulated costs to the data, we then match to this time series rather than the time series of operating costs available publicly.

Exogenous Inputs

There are several exogenous inputs to the model: Population, Domestic GDP, World GDP, the Consumer Price Index, the Producer Price Index, jet fuel prices, national average wage, and unemployment. Population comes from the Census Bureau, while yearly GDP data for both the U.S. and the world is taken from World Bank website and measured in real 2000 US dollars per capita. The CPI, the PPI, the national average wage and the unemployment time series come from the U.S. Department of Labor's Bureau of Labor Statistics. Jet Fuel Prices per gallon are

obtained from the ATA. We will discuss where these exogenous variables enter the model in more detail in section 4 of the paper.

3 - Dynamic Hypothesis

The core dynamic hypothesis of the model is that while demand for airline seat miles is growing exponentially, profits follow an oscillatory path with an exponentially growing envelope. As was discussed by (Meadows 1970), one cause of these oscillations in many markets is a misperception of the delayed negative feedback controlling the capacity acquisition decisions of the industry. However there are several other interesting feedbacks that exacerbate this dynamic in our setting.

(Insert figure 1 about here)

Suppose that demand was initially high relative to the available capacity and the industry was experiencing high load factors and profitability. The industry would add capacity in this situation but face a delay of two years before their decisions manifest as new planes. In the interim the high margins and load factors bring downward pressure on prices eroding the profitability of air travel to an extent. Additionally airline passengers perceive air transportation to be less attractive due to congestion and overbooking, but only with a delay. Once the new planes that were ordered arrive they immediately add to the costs of the industry, but their seats will not be filled sufficiently to make operating them profitable with prices depressed and consumers perceiving high congestion even though congestion has fallen. There is a reinforcing feedback between additional capacity and more demand but the strength of this feedback is overwhelmed by the strength of the balancing feedbacks around capacity, attractiveness and

price control. In short, price setting and congestion form two additional balancing feedbacks with delays that contribute to the cyclical pattern of industry profits.

The following simplified causal loop diagram illustrates this dynamic.

(Insert figure 2 about here)

4 - Model Boundary

We model many of the important variables in the airline industry endogenously and will use this section to discuss where we have chosen to draw the model boundary. Demand is partially exogenous, with the growth path being driven by population and both U.S. and world gross domestic product. While there certainly are several feedbacks from air transportation to the growth of GDP, these feedbacks are likely complex and poorly understood and thus we feel that leaving them out is a justifiable simplifying assumption to make.

Wages are partially exogenously driven as well with the national average wage, the unemployment rate and the Consumer Price Index all treated as exogenous. The effect of airline employment on unemployment and the national average wage is likely relatively small, and developing a macroeconomic model of employment and wages would be prohibitively complex given our model's purpose.

Similarly we drive the cost sector of the model with several exogenous inputs, including the producer price index and jet fuel. Of all of our decisions about what to model as exogenous, the choice to sever the feedback between airlines and jet fuel prices is potentially the least defensible. However, we argue that while airline usage of fuel is undoubtedly the main driver of demand for jet fuel the physics of the production of jet fuel cause the supply of jet fuel to be

largely determined by macroeconomic factors unrelated to the capacity of the airline industry. When crude oil is refined into useable products each barrel is 'cracked' into a fixed fraction of different grades of petrochemical materials. Jet fuel is made from a very small fraction of this refined crude, and so any fluctuations in refining activity due to increased demand for gasoline or home heating oil will have large effects on the supply of jet fuel. For this reason, we feel that modeling jet fuel prices as exogenous is a reasonable decision.

5 - Model Structure

In the following section we will broadly describe the structure of the model. Readers who are interested can find a complete equation listing in the appendix. The model is comprised of four key sectors: Capacity, Demand, Prices and Costs. These sectors allow us to parsimoniously arrive at the aggregate profits of the airline industry. Demand is measured in revenue passenger miles, and when multiplied by price per seat mile gives the revenue for the industry. Revenue minus costs then computes profit.

The capacity sector of the model has at its foundation a stock control formulation that is adapted from the standard one in system dynamics (Sterman 2000). The stock of airline industry capacity is compared to the desired capacity of the industry and this indicated change in capacity is then adjusted for the supply line of capacity and the forecasted growth of the industry. The forecasted growth rate is determined using a standard third order forecasting structure (Sterman 2000). Desired capacity is determined by projecting forward the growth rate indicated by the forecasting structure over a variable horizon that is empirically estimated along with the other model parameters. We assume that each seat flies a constant number of miles per year in order to arrive at the available seat miles of the industry. The stock and flow chain of productive capacity

and capacity being constructed use explicitly modeled third order delays with total delay times of 2 years for the construction of planes and 30 years for the average service life of planes. We include both mothballing of capacity and cancellation of orders for planes as endogenous decisions in the model.

Demand per person is conceptualized as a linear function of Gross Domestic Product, both domestic and international, with separate, empirically estimated slopes. This is then multiplicatively influenced by several pressures: prices normalized by the initial ticket price, changes to capacity, and congestion in the industry. The feedback from capacity changes represents the fact that new routes and more accommodating schedules will tend to create their own demand. Congestion is measured as the ratio of the current load factor and the normal industry load factor, where the normal load factor is the best fit line of the historical load factor data. The load factor where congestion begins to be felt is affected by numerous things including technological advances in yield management and prediction of no-shows. Since we have little ground on which to build a dynamic hypothesis of how these variables interact we leave this task to future researchers. The linear approximation fits well over the period from 1970 until 2007, the entire data set we have available, with an R^2 of 87%. We then smooth this actual congestion in order to represent the delay in consumers perceiving congestion and choosing not to fly. Once demand per person is determined it is multiplied by the population of the United States in order to determine the total system wide demand of domestic air carriers in seat miles.

Prices employ an integral control formulation that is also standard in system dynamics modeling practice (Sterman 2000). Current ticket prices adjust over a period of time to the indicated ticket price, which is a function of margin, costs and the load factor of the industry.

Margin is normalized by an empirically estimated “target margin,” cost pressures come from a comparison of the current ticket price per seat mile with the current costs per seat mile, increased by a constant fractional “target percentage above costs,” and load factor is compared to the normal load factor in the industry calculated as discussed above.

Costs are calculated from several inputs, some exogenous and some endogenous. Fuel prices are exogenous in the model for the reasons discussed in the model boundary section of the paper. The average fuel efficiency of jets from 1995 until 2005 is assumed to be the constant fuel efficiency over the course of the model. Available seat miles are multiplied by the fuel efficiency in gallons per seat mile in order to arrive at the total gallons of jet fuel used by the industry. This in turn is multiplied by the price of fuel in dollars per gallon in order to arrive at variable costs from fuel. Other variable costs are assumed to be a constant dollar amount per seat mile that is empirically estimated and inflated by the Producer Price Index.

The final component of costs in the model comes from wages, which are endogenously set based on several pressures. We employ an integral control formulation similar to the one we use from price, but with five effects all multiplicatively combined to form the indicated wage: inflation, industry margin, unemployment, new hires and outside opportunities. We assume that all else equal the indicated average wage for the industry would increase at the inflation rate each year, and so the strength of the inflation effect on worker compensation is set equal to one. Margin is smoothed over an empirically determined length of time to represent the delay in unions perceiving long term trends in the profits of the airlines and then is compared to a normal margin. When the perceived long term margin is higher than the normal margin there is upward pressure on wages, and when it is lower there is downward pressure. Economy wide unemployment is normalized by the “normal unemployment rate” set equal to 3% in order to

compute the unemployment effect on wages. We measure the one year percentage change in capacity as the difference between the current capacity and a one year smooth of capacity in order to represent the recent change in the number of workers in the industry. This variable is then used in the wage formulation as a downward pressure on wages from new hires since rookies have lower wages. Finally, outside opportunities are measured as a proxy equal to dividing the average industry wage by the national average wage. On average airline wages will be higher than the national mean and so they are adjusted up by a constant percentage, which represents the skill premium offered for jobs in this industry and is empirically estimated.

This structure is not the one we would have liked to include if we had more finely delineated data on the structure of labor in the airline industry. If future academics can obtain information on the average tenure of industry workers they ought to create a labor aging chain with a co-flow for average wage instead of our simple integral control structure. This model would need input from air carriers about how hiring and firing decisions are made and could then use an integral controller to simulate the yearly fractional raises and initial wage of the workers.

The model also employs the summary statistics found in Sterman 1984 with a few minor modifications. We decompose the mean square error into its three Theil statistics, and additionally measure the square of the error at each data point normalized by the mean of the historical data for that variable, outputting the final value of the sum of these normalized square errors in order to fit the model to the data.

One of the major challenges in fitting models to reported data is the fact that the process of measuring and reporting the data makes it potentially erroneous to directly compare the reported data with the model's continuously computed variables. For instance, the instantaneous

demand simulated during any particular time step of 1970 is not the same as the total annual demand for 1970, since the demand for 1970 that is reported is the sum of all of the seat miles used over the year while the instantaneous rate of demand could be higher or lower than this level at any particular point during the year. One of the contributions of this paper to the system dynamics literature is to propose a simple formulation that replicates the reporting process so that we can be sure that our model is accurately replicating the historical behavior of the system.

Figure 3 shows this structure.

(Insert figure 3 about here)

The actual reporting process records the variable of interest continuously, filling a stock that is waiting to be reported over time. The stock measures what the reported variable would be at any point in time if it were to be published during that time step. Once the reporting period has passed (one year in this model, but the structure will work for any reporting period that is a non-negative multiple of the time step) the stock is drained at a rate that will empty it in one time step. The reported variable is this rate adjusted for the size of the time step and annualized by dividing by the length of the reporting period. Equations for this structure can be found in the appendix.

6 - Partial Model Tests

Tests of Fit when Driven by Historical Variables

Each stock in the model was able to replicate its historically observed behavior when it was removed from the endogenous model and driven by the other historical variables. In almost all cases, this partial model calibration produced parameter estimates that were close to what we obtained from the full, endogenous model calibration reported in the Parameter Estimation

section. Capacity and demand are the lone exceptions, since they are tightly coupled sectors in the model and small errors in one feedback and are magnified by the other. Even in this case however, the partial model parameter estimates were qualitatively similar to the full model parameter estimates.

We also conducted several tests of the model's behavior under idealized inputs so that we could verify that the sectors produced realistic behaviors under a range of conditions more varied than the idiosyncratic, historical path of the industry. We report the nature and results of these tests below.

Growth Adjusted Capacity Control

The structure we use to represent the capital stock control decisions of the airline industry in aggregate is based on the standard stock management structure, but has been modified in several ways. First we include an adjustment for growth that insures that the industry's policies will not result in steady state error under a consistent growth path. Second we include weights on each of the adjustment terms so that we can allow these to vary during our model fitting procedures in order to make an estimate of how close the industry gets to using the fully rational adjustments in practice.

In this section we will outline a short proof that our adjustment for growth produces no steady state error under an exponential growth path. This quality is essential given the fact that demand in the airline industry is growing exponentially and the aggregate behavior of the industry is not likely to under-estimate demand over long time horizons in the way that the standard stock management structure will. We hope that this structure (equation listing found in appendix A) will serve as a standard modification to the stock management structure that other

academics can use in their models when the reference mode for the stock in question is exponential growth.

Having no steady state error is defined as having a stock of capacity that is equal to the desired capacity in the steady state. To simplify this proof we assume that the stocks are all first order and that the delay in ordering is negligible.

The stock of capacity will equal the desired capacity in the steady state if the inflow of airplane completion equals the retirement of capacity plus the current stock multiplied by the exogenous growth rate of demand. Since the inflow of airplane completion is equal to the stock of capacity on order divided by the time necessary to manufacture an airplane as long as the stock of capacity on order is equal to capacity times the growth rate of demand plus retirements zero steady state error will be achieved.

Since zero steady state error must have capacity equal to desired capacity the adjustment for capacity will equal zero. This makes the desired capacity acquisition rate equal to:

$$R + C * g$$

Where R is retirements, C is capacity and g is the growth rate of demand. This means that the desired supply line will be equal to:

$$(R + C * g) * \tau$$

Where tau is the time required to manufacture an airplane. Since the supply line will equal the desired supply line we have an adjustment for the supply line equal to zero and orders for capacity of:

$$(R + C * g) * \tau + SL * g$$

The extra term for the supply line of capacity (SL) comes from the addition of the ‘adjustment for growth in the supply line’ variable in the equation for indicated orders. This order rate ensures that the net inflow of aircraft to the supply line of capacity will be the current supply line times the growth rate of capacity, guaranteeing zero steady state error under a constant exponential growth path because the supply line will grow at the same rate as demand. Following from the argument above this supply line will guarantee that the stock of capacity is always equal to the desired capacity in the steady state, eliminating steady state error.

Price Setting

The aggregate ticket price setting structure has been coded to disallow an indicated ticket price below the aggregate cost per seat mile of the industry, limiting the industry to not price below marginal cost. While the historical replication simulations we carry out never force this constraint to be binding it is reasonable to speculate that while competition might cause certain airlines to offer certain routes at certain times below their marginal cost, the industry would never allow aggregate prices to drop below marginal cost.

The integral control structure performs well for simple experiments. Adjusting ticket price in an effort to improve profitability when faced with a sudden spike in costs or a sudden drop in load factor or margin is both the simulated behavior of the model and what we would expect aggregate ticket price to do in reality. When testing this structure care should be taken to completely isolate price setting from endogenous feedbacks because it is highly important for determining the model’s overall behavior. If any feedbacks to or from price are allowed to

remain endogenous then price will be governed by those influences rather than the exogenous data series or functions we are testing it with.

7 - Parameter Estimation

Numerical Issues and Fixes

For our parameter estimation we chose to limit the final sum of the square error between the historical data and our model's simulated reported output scaled by the square of the mean of the historical data. This structure enables us to closely match the methodology of least squares estimation while avoiding two potential pitfalls. First, by scaling by a constant that is expected to be proportional to the variance of estimation error we can avoid over-weighting errors in larger variables when optimizing in several dimensions. For instance, since price is on average 0.1061 dollars per seat mile in the historical data while profit is on average $1.783 \cdot 10^9$ dollars per year if we did not scale the errors by their respective means then a one percent error in price would be weighted much less severely than a one percent error in profit and our estimation procedure would tend to neglect the fitting of price in favor of fitting the variables with a larger mean. Also, since both the historical data and the variables we are simulating are not continuous we need to utilize the "pick" function in the summary statistics model from Sterman 2000 to ensure that we are only fitting our model to the data when it is appropriate. If we used the calibration function from a typical system dynamics software package we would be fitting the data at each time step and would introduce errors into our estimation procedure because only a small percentage of the time steps correspond to actual data points in the historical series.

We have taken steps to ensure proper fitting of the data with respect to the endpoint problem. The endpoint problem arises when reported data for a particular year does not match

correctly with the time step it is compared against when continuously simulated variables are calculated in models. For our data, all of the historical time series we fit against are reported sums or averages over particular years, for instance airline demand for 1970 is the sum of demand for each day during 1970, which is mathematically equivalent to the average daily demand multiplied by the number of days in a year. Since our model simulates this summation process but does not output it until the end of the year we have modified each of the variables representing the historical time series so that their data for a given year will be output in the model at the end of year in question (first time step of the next year). For example, say that the model has computed the average ticket price over the year of 1995 and outputs that value when the time step is exactly equal to 1996, we match this data to the historical time series' value in 1995 by calling a table function that contains the historical data with the input (Time-1) rather than simply (Time). This ensures that our modeled output exactly aligns with the historical data it intends to match, but means that the graphs showing our model's fit display data from a given year one year after it ought to be displayed.

Approach to Fitting

In order to fit the entire model to the available data we proceeded sequentially, starting with capacity and demand and adding model sections to our estimation process until the entire model is endogenously feeding back on itself. We adopt this methodology because initial attempts to search through a high dimensional parameter space for the globally closest fit were computationally intensive and highly sensitive to the initial position we specified in the parameter space. By identifying which sections of the model are highly interrelated and driving these sections with historical inputs we were able to do a much more thorough search through the

parameter combinations of these portions of the model to ensure the correct fit before including new sections.

We began this sequential estimation with capacity and demand since these two sections of the model feed back onto one another a great deal, while only being influenced by other sections of the model in insignificant ways. We cut the feedback from margin to mothballing and hence to capacity by driving the mothballing decisions with historical operating margin and similarly cut the feedback from price to demand by using historical average ticket prices during our first estimation pass. Later we replaced these endogenous feedbacks. After we estimated the parameters for these two sections we next estimated wages, using endogenous capacity but exogenous operating margin. After wages we determined operating costs since they are modeled as a function only of capacity, average wages and several exogenous inputs. Finally we matched the data for airline prices using only endogenous variables, including margin. The estimated parameters are reported below.

(Insert figure 4 about here)

8 - Evaluation of Fit

In this section we will discuss the output from our model following our parameter estimation procedure. In each of the following figures the historical data is the solid line and the simulated data is the series of delta functions.

Summary Table

(Insert figure 5 about here)

The overall fit of the model is impressive, with very high R^2 , low error as a percentage of the mean and Thiel U statistics that indicate that most of the error comes from random variations in the data rather than bias or inconsistent trends (standard deviations) between the simulated and historical variables. We will discuss the fit of the model for each individual section below.

Capacity

(Insert figure 6 about here)

The simulation for capacity is very close to the historical variable, with the only major deviation occurring around 1992 when the industry contracted due to the first gulf war. This exogenous influence is not modeled and naturally has an effect on the fit for demand. Since modeled demand does not dip in 1992 capacity does not either.

The parameters estimated for capacity are reasonable, with roughly similar adjustment times for capacity and the supply line. The fact that the supply line adjustment time is slightly smaller than the capacity adjustment time confirms the finding from Forrester and Senge 1980 that supply line adjustment tends to be more reactive than stock adjustment. The short delay time for ordering and the parameters surrounding the forecast of demand are all within acceptable bounds. The estimated parameters indicate that the industry fully incorporates the supply line of aircraft but does not place much weight on demand forecasts.

Demand

(Insert figure 7 about here)

The overall fit of demand shows a similar pattern to that of capacity with one significant divergence from the historical path in 1992. In addition, the model overestimates demand at the beginning of the run and underestimates it slightly towards the end of the run. This indicates that our model of linear dependence of airline demand on GDP per capita oversimplifies the actual relationship. Over time the gross domestic product has become more dependent on travel as services such as consulting have increased their share of the GDP relative to manufacturing. Future modeling work might look to this relationship as a place to improve upon our model by specifying the dependence of airline demand on each component of GDP rather than the simple structure offered here or determining an entirely new functional form of the relationship.

The parameters estimated for demand make sense. The number of miles per capita demanded for each dollar of world GDP is much higher than the miles demanded per dollar of domestic GDP since international flights are longer. Demand is price elastic, but only weakly so, additional capacity increases overall demand by a substantial amount and demand is very sensitive to congestion, though it takes a long time for this effect to be felt.

Wages

(Insert figure 8 about here)

The fit for simulated wages, shown in the figure as CPI deflated real wages, is very close to the historical average real wage in the industry with one significant deviation from the historical path in the early nineteen eighties. During this period inflation was very high, and the model's assumption that wages in the industry will always increase by the rate of inflation given equilibrium in the rest of the model likely did not hold. This causes simulated wages to rise

more quickly in the model than actual wages did in the industry and indicates another area where future academics could refine the model.

The parameters estimated for wages indicate that margin is a particularly large determinant of airline industry wages but that there is a long term smooth of these profits that drives changes in wages. They also show that unemployment in the overall economy and outside opportunities have very little impact on average wages in the industry compared to the other factors. The change in the number of workers has the largest impact on average wages because new workers being added to the industry will necessarily be getting paid salaries closer to the entry level, which is by definition lower than average.

Costs

(Insert figure 9 about here)

The fit for costs is reasonable given the very simple structure we have modeled for this sector of the industry. The main period of time where there is a significant deviation from the historical data is during the early nineteen nineties when the model under estimates operating costs for a few years. This result indicates that a feedback from margin onto efforts to cut costs would improve the fit of the model since the early nineties saw large losses for the industry. Future modelers should consider incorporating this effect, however we did not have sufficient data, or industry experience to postulate how this effect manifested in the industry or how symmetric the effect was with respect to positive margins.

Only one parameter needs to be estimated for costs in order to set the variable costs coming from sources other than wages or fuel. The value of 1970 variable costs that was estimated is within reasonable bounds.

Prices

(Insert figure 10 about here)

Price is the one component of profit with the poorest fit to historical data in the model. While the R^2 is still a respectable 91.8% for a variable with very low standard deviation there is a significant deviation between the simulated and historical series for the beginning of the model run. We hypothesize that this deviation is primarily caused by the failure of our model to incorporate the effect that deregulation had towards depressing prices in the late 1970's and early 1980's. Quantifying and including this effect would be an excellent project for future modelers.

The parameters that our estimation procedure found for the price setting structure are all acceptable, but have very large confidence intervals. All of our attempts to fit simulated prices to the data indicated that margin had a relatively smaller effect on prices than either costs or load factors, and that as long as the sensitivity of price to costs was roughly twice the sensitivity of price to load factors the model arrived at more or less the same solution for price. The estimation procedure also tended to want to lower the time to adjust ticket prices and increase the sensitivities indicating that airlines are highly reactive in their price setting.

Profit

(Insert figure 11 about here)

While profit is the simulated variable we found most difficult to fit to historical data, since profit is the difference of two very large numbers it was also the most ambitious. The figure clearly shows a tendency to cycle between high profit periods and low profit periods, though the fit for the late 1980's caused by an underestimation of demand during the period

obscures this periodic, oscillatory dynamic. The poor fit during the early 90's is a direct result of our underestimation of operating costs during the same period.

Overall the 80% R^2 for the fit to historical profits along with the tendency of our simulated profits to oscillate in a similar fashion to the data leads us to assert that our model has captured the endogenous dynamics that are causing airline industry profits to cycle at an aggregate level.

9 - Policy Recommendations

Only a very small fraction of the constants in our model are potential policy levers that the airline industry could use to maximize their profits. Demand cannot be directly controlled, and constants such as the elasticity of demand with respect to price or the miles per person per dollar of GDP are obviously out of the control of managers in the industry. Additionally we have assumed that the parameters surrounding the wage setting and cost calculation parts of the model are also not available for industry managers to manipulate in order to stabilize profits. It is likely already the case that managers spend a great deal of time minimizing costs through whatever methods possible, and our simulation model will not be of any aid to them if our policy recommendations hinged on further reductions to costs.

Similarly one particularly effective way for the simulated industry to improve profitability is to build in a higher margin above costs when setting prices. Short of a re-regulation of the industry however this policy lever is unlikely to be available since first movers towards higher prices would see their market share erode from competition.

In order to mitigate the oscillations arising from the balancing feedbacks around capacity decisions the industry could proceed on two fronts. Increasing the time to adjust capacity and

lengthening the time horizon used for reference demand in the forecasting procedure combine to make capacity decisions much less responsive to momentary changes in demand, allowing them to more closely fit the roughly exponential growth of demand. If the industry were able to collectively agree to reduce the responsiveness of capacity growth and demand forecasts this would be an excellent avenue for reducing the cyclical nature of profits.

One final approach to lessening the cyclical nature of profits would be to weaken the remaining two balancing feedbacks in the model. By updating consumer perceptions of congestion more quickly and stabilizing price setting the airline industry would weaken the gain of those two negative feedback loops and lessen their contribution to profit cycles.

Overall, the policy that keeps airline industry profits high for the life of the run involves increasing the time to adjust capacity, the time horizon for reference demand, the time to adjust ticket prices and lowering the consumer's time to perceive congestion. When this policy is implemented simulated profits are positive for the entire model run.

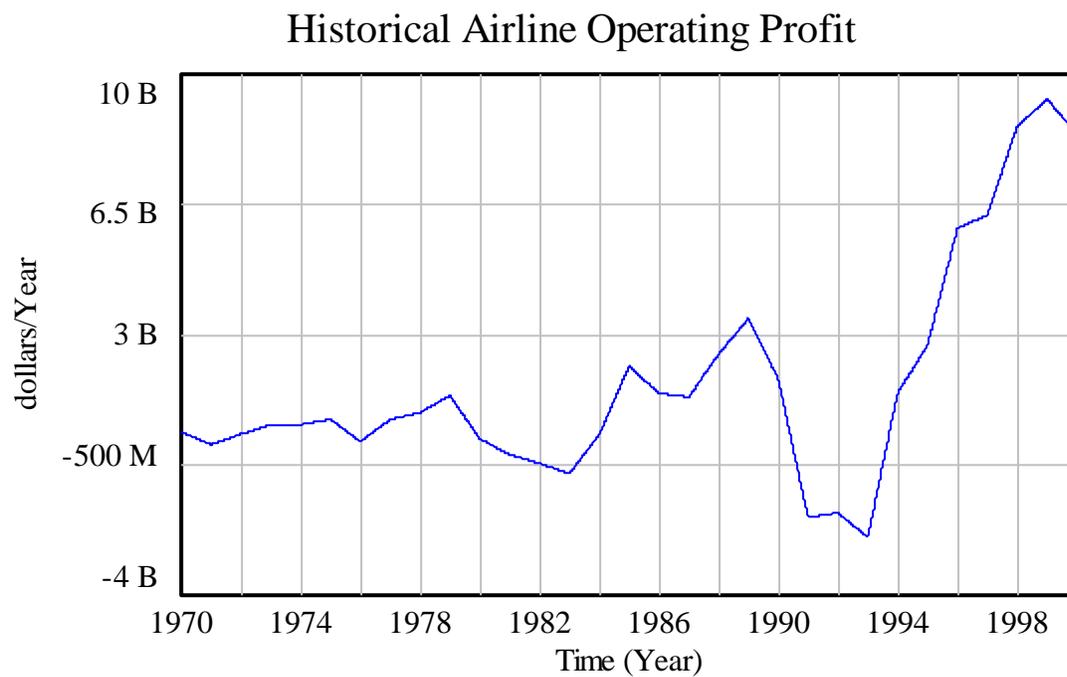
10 – Conclusion

Several balancing loops with significant delays combine to produce an endogenous explanation for the cyclical path of aggregate airline industry profits. Aggressive capacity expansion policies, ticket pricing and a flying public that responds with a delay to congestion in the industry are the three main culprits found in this paper. While the solutions to the problem require an unprecedented degree of cooperation between the major players in the industry the importance of finding a strategy that will ensure airline's long term survival is high.

There are many places in which this model is still deficient, and so there are numerous opportunities for academics and practitioners to revise and extend our work. The problem of

cyclicality on aggregate profits extends far beyond our research setting as well, and it is our hope that this paper will serve as a stepping stone for research into how we can eliminate cyclical modes from the profits on many other industries.

List of Figures



Historical Airline Operating Profit : Final

Figure 1 – Airline Operating Profit

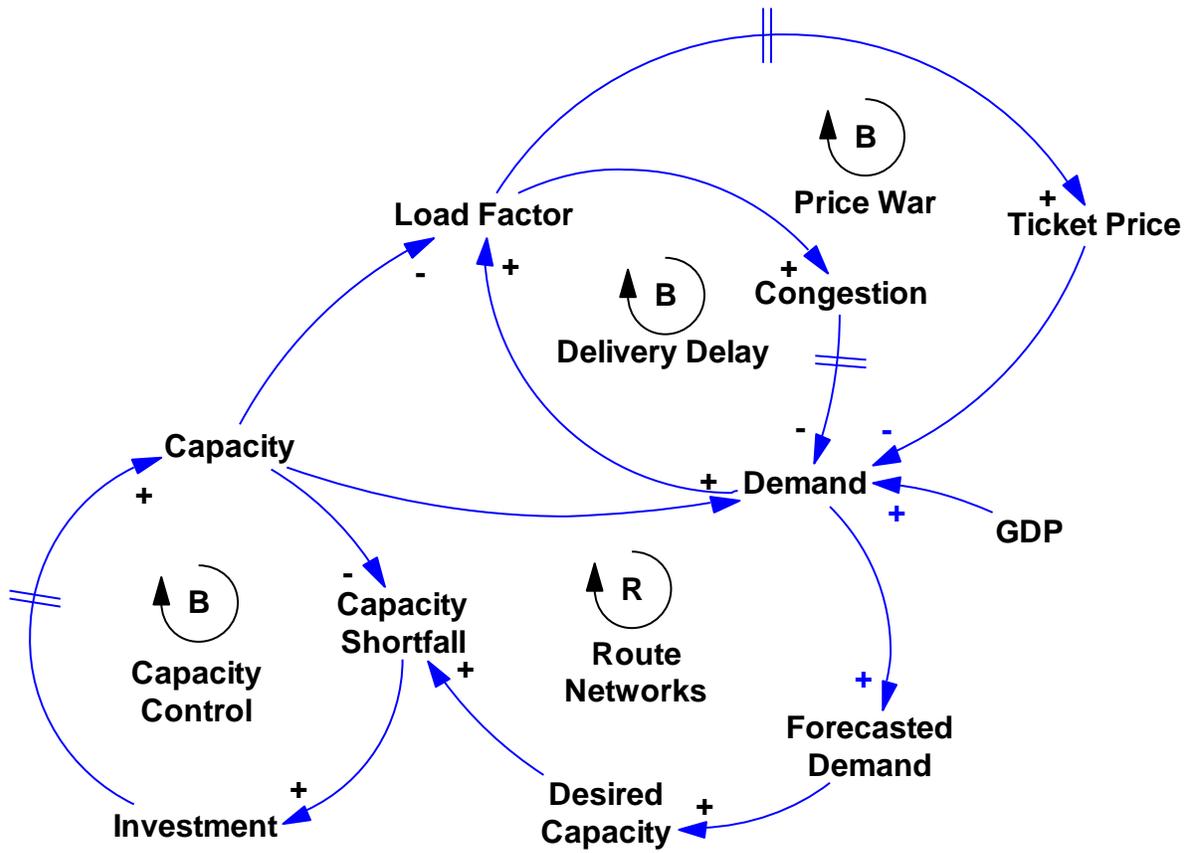


Figure 2 – Causal Loop Diagram

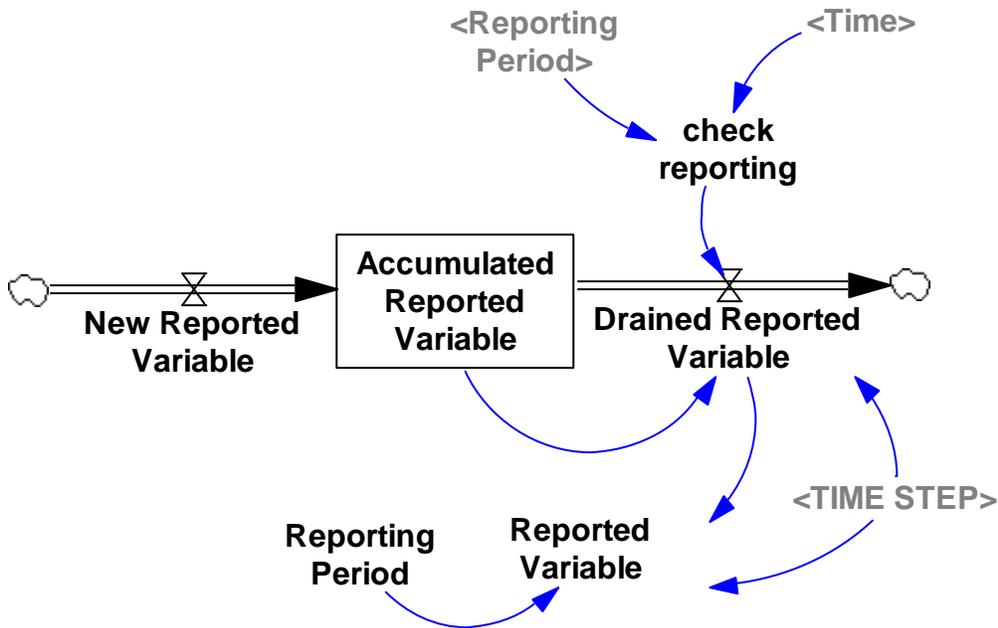


Figure 3 – Data Reporting Structure

Parameter

Estimated Value

	<i>Capacity</i>	
Demand Forecast Horizon		0.356805
Initial Expected Growth Rate in Demand		-0.158158
Margin Threshold to Initiate Mothballing		-0.1
Order Approval Delay Time		0.25908
Supply Line Adjustment Time		0.129641
Time Horizon for Reference Demand		3.85269
Time to Adjust Capacity		0.160743
Time to Mothball		0.5
Time to Perceive Changes in Demand		0.218727
Time to Perceive Trend in Demand		2.84796
Weight on Demand Forecast Orders		0.0671269
Weight on Supply Line Adjustment		1
	<i>Demand</i>	
Congestion Perception Time		1.9918
Constant Demand Adjustment		-1044.47
Elasticity of Demand with Respect to Price		0.111921
Miles per Person per Dollar of GDP		0.0645965
Sensitivity of Demand to Congestion		-3
Strength of New Capacity Effect on Demand		0.869749
World Miles per Person per Dollar of GDP		0.246414

<i>Wages</i>	
Initial Margin	-0.1
Margin Perception Delay	4.67515
Normal Margin	0.0732597
Strength of Margin on Worker Compensation	0.266628
Strength of New Hire Effect on Worker Compensation	-0.400418
Strength of Outside Opportunities on Worker Compensation	0.0188198
Strength of Unemployment Effect on Wages	0
Time to Change Worker Compensation	0.703619
<i>Costs</i>	
1970 Other Variable Costs	0.0149139
<i>Prices</i>	
Sensitivity of Price to Costs	5.636
Sensitivity of Price to Demand Supply Balance	10
Sensitivity of Price to Margin	0
Target Margin	0.0327476
Target Percentage Above Cost	0.671692
Time to Adjust Ticket Prices	0.25

Figure 4 – Estimated Parameter Values

<u>Variable</u>	<u>R²</u>	<u>MAE</u>	<u>RMSE</u>	<u>Um</u>	<u>Us</u>	<u>Uc</u>
<i>Capacity</i>	95.60%	3.79%	9.46%	4.65%	14.54%	80.81%
<i>Demand</i>	97.10%	4.39%	8.25%	6.32%	0.18%	93.50%
<i>Wages</i>	54.31%	2.80%	3.64%	23.43%	0.30%	76.26%
<i>Cost</i>	99.33%	3.77%	5.50%	4.88%	11.22%	83.90%
<i>Prices</i>	91.80%	7.24%	12.13%	4.61%	46.95%	48.44%
<i>Profit</i>	80.08%	57.78%	80.42%	0.00%	2.04%	97.96%

Figure 5 – Summary Statistics

Historical and Simulated Airline Capacity

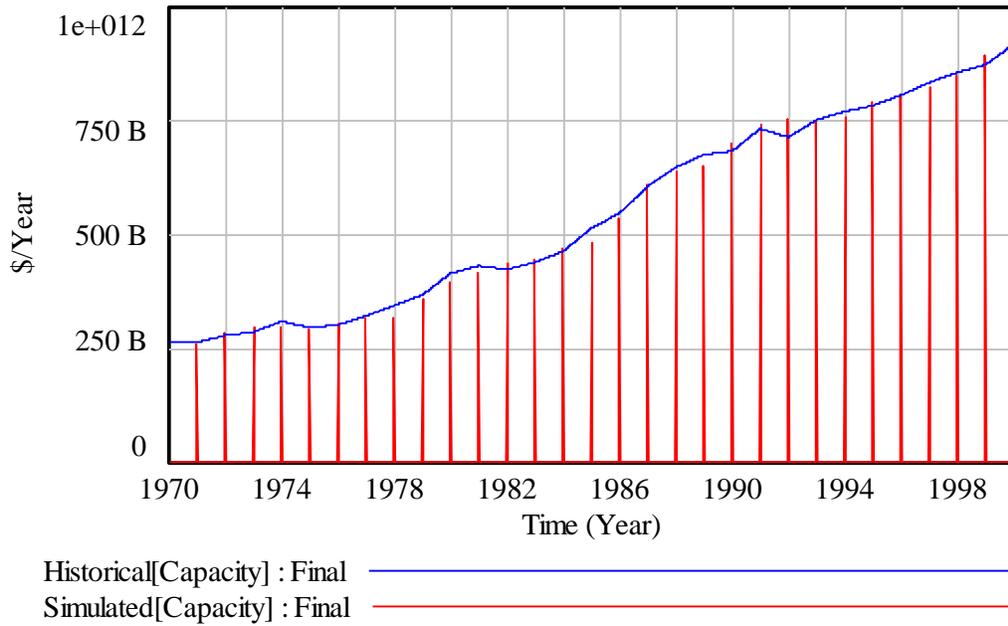


Figure 6 – Capacity

Historical and Simulated Revenue Passenger Miles

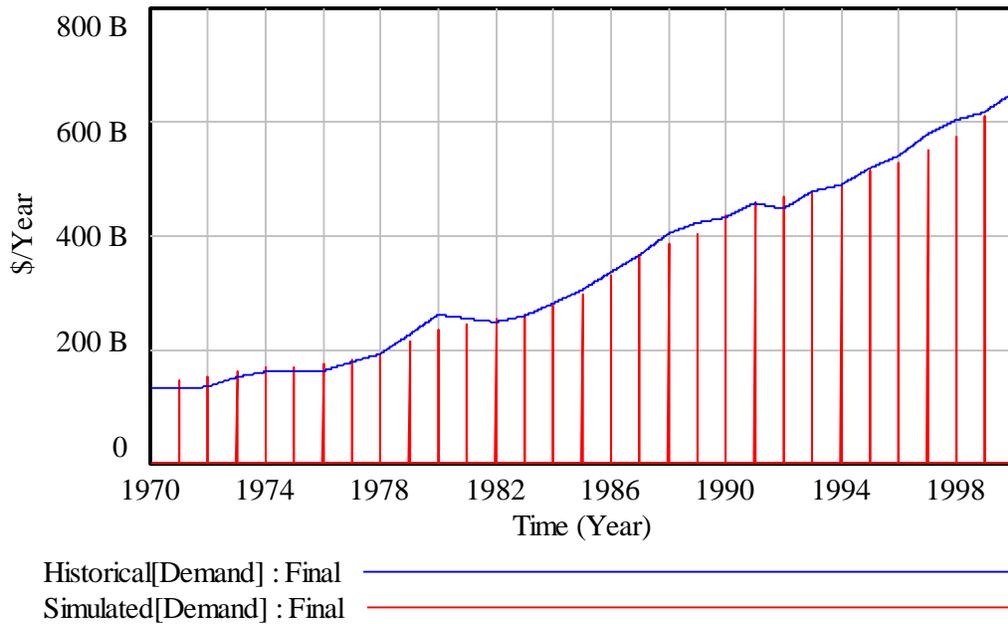


Figure 7 – Demand

Historical and Simulated Average Real Wages

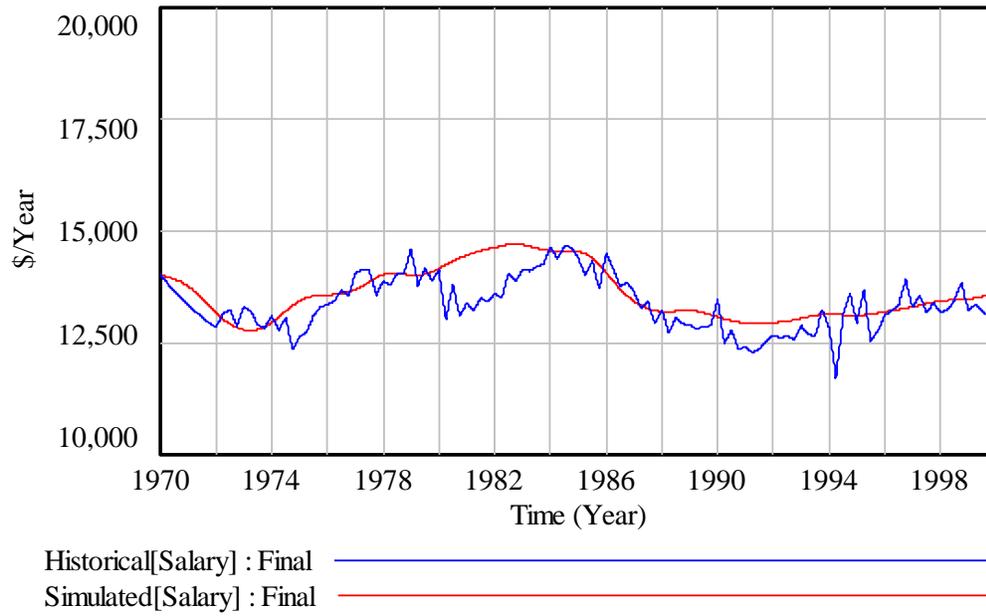


Figure 8 – Wages

Historical and Simulated Operating Costs

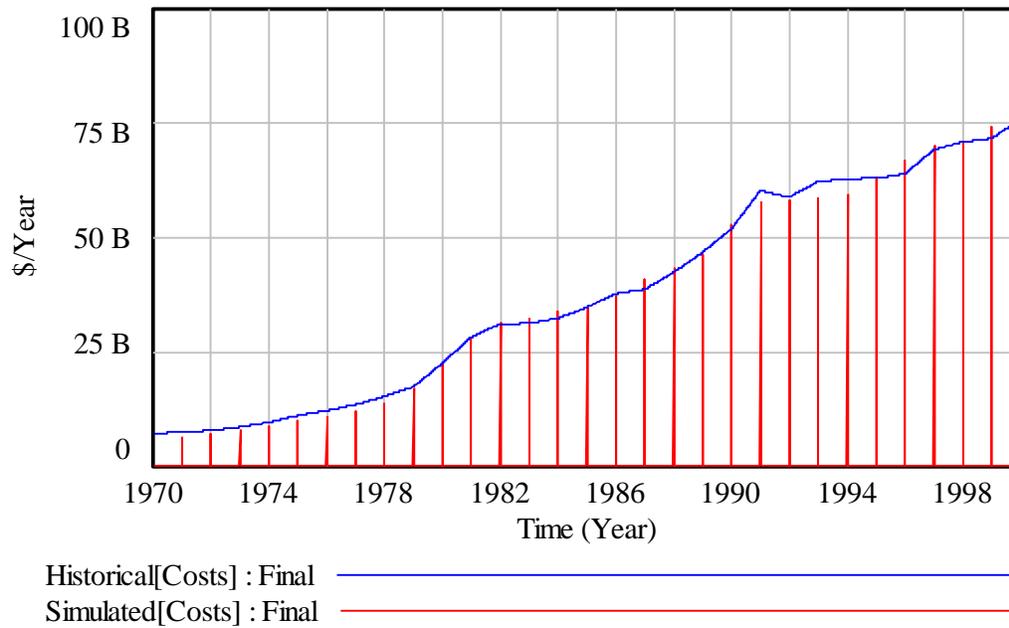


Figure 9 – Costs

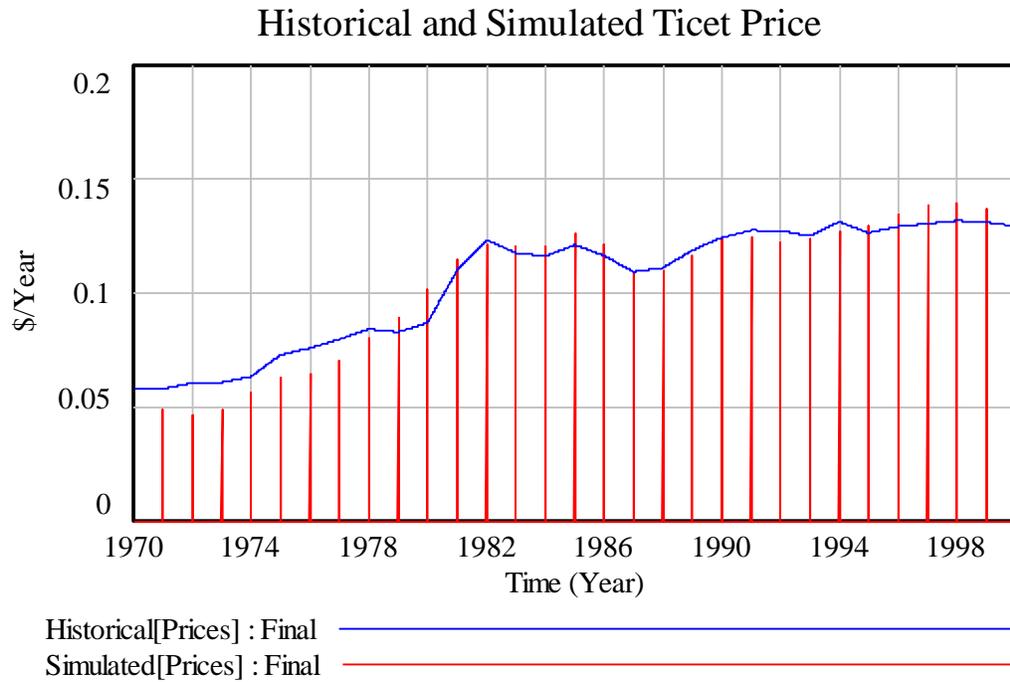


Figure 10 – Prices

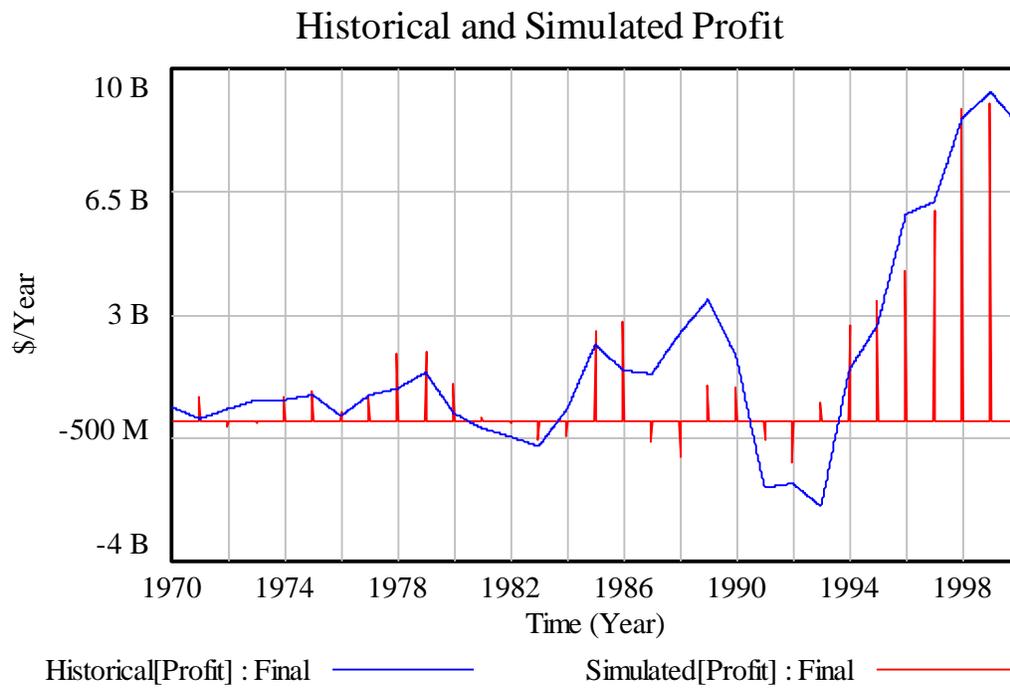


Figure 11 – Profit

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Appendix 1: Documented Equation Listing

"1 to 2"=

Capacity on Order 1/(Time Required to Manufacture an Airplane/3)
Units: Seat/Year
This is the flow of material from the first third of the delay
to the second

"1970 Other Variable Costs"=

0.014912
Units: dollars/(Seat*mile) [0,0.02]

"2 to 3"=

Capacity on Order 2/(Time Required to Manufacture an Airplane/3)
Units: Seat/Year
This is the flow of airplanes from the second stock to the third

Accumulated Reported Variable[Data]= INTEG (
New Reported Variable[Data]-Drained Reported Variable[Data],
0)

Units: dollars

The reporting process creates a delay between when the money was
actually made by the industry and when the profits are reported
to investors

Actual Demand For Seat Miles=
Population*Demand for Seat Miles per Capita

Units: Seat*miles/Year

This is the real demand for seat miles seen by the airlines

Adjustment For Capacity=
(Desired Capacity-Airline Capacity)/Time to Adjust Capacity

Units: Seat/Year

This is the additional capacity desired based on the current demand, current capacity and the desired load factor

Adjustment for the Supply Line=
Weight on Supply Line Adjustment*(Desired Aircraft Supply Line - Airline Capacity
Supply Line

)/Supply Line Adjustment Time

Units: Seat/Year

Aircraft ordering is adjusted for the gap between seats on order and the desired supply line

Airline Capacity= INTEG (
Airplane Manufacturing Completion+Off Mothballing-Airplane Retirements-
Mothballing

,
Initial Airline Capacity)

Units: Seat

This is the number of seat miles per quarter that can be flown by the airline

Airline Capacity Supply Line= INTEG (
Orders of Airplanes-Airplane Manufacturing Completion-Cancellation,
Initial Capacity on Order)

Units: Seat

This is the capacity on order at the airlines

Airplane Manufacturing Completion=
Airline Capacity Supply Line/Time Required to Manufacture an Airplane*Switch for
Partial Model Tests

+Completion*(1-Switch for Partial Model Tests)

Units: Seat/Year

This is the completion rate for aircraft that are coming off of the assembly line

Airplane Retirements=

Retired*(1-Switch for Partial Model Tests)+Airline Capacity/Average Service Life

*Switch for Partial Model Tests

Units: Seat/Year

This is the rate at which airplanes are retired from the fleet

Available Seat Miles=

Airline Capacity*Number of Miles Flown per Seat

Units: Seat*miles/Year

The number of seat miles the airlines fly in a given year is the number of seats of capacity they operate multiplied by the number of miles flown by each seat

Average Service Life=

30

Units: years [0,40]

The average life of an airplane is approximately 30 years

Average Worker Compensation= INTEG (

Change in Worker Compensation,

Initial Worker Compensation)

Units: dollars/Year/worker

This is the level of pilot compensation including salary, bonus and benefits

Cancellation=

Cancelled Orders

Units: seats/Year

This is the rate of airline order cancellations

Cancelled Orders=

IF THEN ELSE(Indicated Orders for Capacity<0 , Min(-Indicated Orders for Capacity ,Capacity on Order 1/Time to Cancel) ,0)

Units: seats/Year

This is the rate of airline order cancellations

Cap 1 to 2=

Capacity 1/(Average Service Life/3)

Units: seats/Year

Cap 2 to 3=

Capacity 2/(Average Service Life/3)

Units: seats/Year

Capacity 1= INTEG (

New Capacity-Cap 1 to 2,

Initial Airline Capacity/3)

Units: seats

Capacity 2= INTEG (
Cap 1 to 2-Cap 2 to 3,
Initial Airline Capacity/3)

Units: seats

Capacity 3= INTEG (
Cap 2 to 3+Return to Service-Into Storage-Retired,
Initial Airline Capacity/3)

Units: seats

Capacity Adjustment for Growth in Demand=
Airline Capacity*Expected Growth Rate for Demand*Weight on Demand Forecast
Orders

Units: Seat/Year

Capacity on Mothball= INTEG (
Into Storage-Return to Service,
0)

Units: seats

This is the stock of planes waiting on mothball

Capacity on Order 1= INTEG (
Ordering-"1 to 2"-Cancelled Orders,
Initial Capacity on Order/3)

Units: Seat

this is the first stock of airline capacity on order

Capacity on Order 2= INTEG (
"1 to 2"- "2 to 3",
Initial Capacity on Order/3)

Units: Seat

This is the stock of Capacity on Order in the second stage of
production

Capacity on Order 3= INTEG (
"2 to 3"-Completion,
Initial Capacity on Order/3)

Units: Seat

This is the stock of airplanes ordered that is nearing delivery

Change in Demand Perception=
Gap in Demand Perception/Time to Percieve Changes in Demand

Units: Seat*miles/Year/Year

Change in Expected Growth Rate=

$$\frac{(\text{Indicated Growth Rate}-\text{Expected Growth Rate for Demand})/\text{Time to Percieve Trend in Demand}}{*(1-\text{Switch for Partial Model Tests})}$$

Units: dmn/Year/Year

Change in Reference Demand=
$$\frac{(\text{Perceived Demand}-\text{Reference Demand})/\text{Time Horizion for Reference Demand}}$$

Units: Seat*miles/Year/Year

Change in Ticket Price=
$$\frac{(\text{Indicated Price}-\text{Ticket Price})/\text{Time to Adjust Ticket Prices}}$$

Units: dollars/(Seat*mile)/Year
This is the process of adjustment in the airlines expected ticket price

Change in Worker Compensation=
$$\frac{\text{Gap For Worker Compensation}/\text{Time to Change Worker Compensation}}$$

Units: dollars/Year/worker/Year

check reporting[Data]=
$$\text{MODULO}(\text{Time, Reporting Period[Data]})$$

Units: Year

Comfortable Industry Load Factor=
$$\frac{\text{Initial Industry Desired Load Factor}+\text{Effect of Time on Load Factor}}$$

Units: dmn/

Completion=
$$\frac{\text{Capacity on Order } 3/(\text{Time Required to Manufacture an Airplane}/3)}$$

Units: Seat/Year
This is the flow of completed aircraft

Congestion Perception Time=
1.9918
Units: Year
The perception of the airline industry's congestion takes a while to change

Constant Demand Adjustment=
-1044.47
Units: Seat*miles/person/Year [-2000,1000]

Cost per Available Seat Mile=
$$\frac{\text{Operating Costs from Passengers}/(\text{Historical Available Seat Miles}*\text{Switch for Historical Variables}}{+(1-\text{Switch for Historical Variables})*\text{Available Seat Miles}}$$

Units: dollars/(Seat*mile)

this is the current cost the airlines see per seat mile they fly. It will serve as the at cost ticket price for teh airlines

Costs from Wages=

Total Worker Salary by Type

Units: dollars/Year

This is the quaterly cost of wages fro the airline

Count[Data]= INTEG (
pick[Data]/dt,
0)

Units: Dimensionless

Counter for # of points

CPI= INTEG (
CPI*CPI Percentage Change,
1)

Units: dmnl

With 1970 as a value of 1

CPI Data(
[(1950,-2)-(2008,15)],(1952,1.9),(1953,0.8),(1954,0.7),(1955,-0.4),(1956,1.5
,(1957,3.3),(1958,2.8),(1959,0.7),(1960,1.7),(1961,1),(1962,1),(1963,1.3),
(1964,1.3),(1965,1.6),(1966,2.9),(1967,3.1),(1968,4.2),(1969,5.5),(1970,5.7
,(1971,4.4),(1972,3.2),(1973,6.2),(1974,11),(1975,9.1),(1976,5.8),(1977,6.5
,(1978,7.6),(1979,11.3),(1980,13.5),(1981,10.3),(1982,6.2),(1983,3.2),(1984
,4.3),(1985,3.6),(1986,1.9),(1987,3.6),(1988,4.1),(1989,4.8),(1990,5.4),(1991
,4.2),(1992,3),(1993,3),(1994,2.6),(1995,2.8),(1996,3),(1997,2.3),(1998,1.6
,(1999,2.2),(2000,3.4),(2001,2.8),(2002,1.6),(2003,2.3),(2004,2.7),(2005,3.4
,(2006,3.2),(2007,2.8))

Units: dmnl/Year

CPI Percentage Change=

CPI Data(Time)/100

Units: dmnl/Year

Data from the BLS on the Consumer Price Index, reported as the percentage change year on year of hte average CPI during hte year

Data:

Profit, Costs, Prices, Demand, Capacity, Salary

Days per Year=

365

Units: days/Year

The number of days in a year

Demand for Seat Miles per Capita=
Effect of Congestion on Demand*Effect of Price on Demand*Effect of New Capacity on Demand

*Total Seat Miles Desired from GDP per Capita

Units: Seat*mile/Year/people

This is the yearly demand for seat miles per person

Demand Forecast Horizon=

0.356805

Units: years

Desired Aircraft Supply Line=

Desired Capacity Acquisition Rate*Time Required to Manufacture an Airplane

Units: Seat

In order to achieve the capacity acquisition rate given the

delay in aircraft manufacture the industry needs this many seats on order

Desired Capacity=

Desired Seat Miles/Number of Miles Flown per Seat*(1-Switch for Partial Model Tests)+Initial Capacity for Partial Model Test*Exp(Expected Growth Rate for Demand *(Time-INITIAL TIME))*Switch for Partial Model Tests

Units: Seat

Desired Capacity Acquisition Rate=

Planned Replacement Orders+Capacity Adjustment for Growth in Demand+Adjustment For Capacity

Units: Seat/Year

The desired rate of addition of new seats to the industry is

their planned retirements plus an addition to correct for the gap between capacity and its desired level

Desired Load Factor=

Comfortable Industry Load Factor

Units: fraction [0.5,0.8]

this is the desired load factor of the industry as a whole

Desired Seat Miles=

Expected Demand/Desired Load Factor

Units: Seat*miles/Year

This is the desired number of seat miles given the desired load factor

dif cov[Data]=

2*Sx[Data]*Sy[Data]*(1-r[Data])

Units: (dollars/Year)*(dollars/Year)
Difference of covariances

dif mean[Data]=
(M X[Data]-M Y[Data])*(M X[Data]-M Y[Data])
Units: dollars*dollars/(Year*Year)
difference of the means

dif var[Data]=
(Sx[Data]-Sy[Data])*(Sx[Data]-Sy[Data])
Units: dollars*dollars/(Year*Year)
Differnece of the Variances

Drained Reported Variable[Data]=
IF THEN ELSE(check reporting[Data]=0, Accumulated Reported Variable[Data]/
TIME STEP , 0)
Units: dollars/Year
Operating profit is reported once per year, and so the profit
was actually gained inthe prior year.

dt=
TIME STEP
Units: Year

Effect of Congestion on Demand=
smoothi(Indicated Effect of Congestion on Demand,Congestion Perception Time
,1)
Units: dmn1
It will take a certain amount of time for passengers to change
their attitudes about how congested flights will be.

Effect of Costs on Price=
(((Switch for Historical Variables)*Historical Operating Cost per Available Seat Mile
+(1-Switch for Historical Variables)*Cost per Available Seat Mile)*(1+Target Percentage
Above Cost
) /Ticket Price)^Sensitivity of Price to Costs
Units: dmn1

Effect of Demand Supply Balance on Price=
((Historical Airline Load Factor*Switch for Historical Variables+(1-Switch for Historical
Variables
) *Load Factor) /Desired Load Factor)^Sensitivity of Price to Demand Supply Balance
Units: dmn1
When load factors are high the industry can raise prices because
demand is robust compared to the supply of seats. When load
factors are below the target prices feel a downward pressure

because there is little demand relative to the number of seats being offered in the industry

Effect of Inflation in Worker Compensation=

$$1 + \text{CPI Percentage Change} * \text{Strength of Inflation on Worker Compensation}$$

Units: dmnl

The normal change in compensation per year all else equal This can be thought of as arising from inflation and other constant effects that would change compensation

Effect of Margin on Price=

$$\left(\frac{\text{Historical Airline Operating Margin} * \text{Switch for Historical Variables} + (1 - \text{Switch for Historical Variables}) * \text{Operating Margin}}{\text{Target Margin}} \right)^{\text{Sensitivity of Price to Margin}}$$

Units: dmnl

Effect of New Capacity on Demand=

$$1 + \text{One Year Percent Change in Capacity} * \text{Strength of New Capacity Effect on Demand}$$

Units: dmnl

New Capacity will effect how many seat miles the average person demands because new capacity represents new routes and schedules that will spur demand

Effect of New Hires on Worker Compensation=

$$1 + \text{Strength of New Hire Effect on Worker Compensation} * \text{One Year Change in New Hires}$$

Units: dmnl

Hiring more workers in a given year will have dual effects.

First workers with less tenure than average will enter the industry at a salary below the average, putting downward pressure on the average. Second there will be more demand for a particular skill set driving wages for that skill up. The regression estimates how strong the net effect of these two pressures will be.

Effect of Operating Margin on Worker Compensation=

$$1 + (\text{Recent Margin} - \text{Normal Margin}) * \text{Strength of Margin on Worker Compensation}$$

Units: dmnl

Effect of Outside Opportunities on Worker Compensation=

$$1 + \text{Wage Relative to Average} * \text{Strength of Outside Opportunities on Worker Compensation}$$

Units: dmnl

Outside opportunities and rising wages in other fields will force the airline industry to change its wages as well in order to attract the level of worker it needs

Effect of Price on Demand=
 (Reference Ticket Price/((Switch for Historical Variables)*Historical Airline Ticket
 Prices
 +(1-Switch for Historical Variables)*Ticket Price))^Elasticity of Demand with Respect to Price
 Units: dmnl
 This measures the change in demand due to changes in ticket
 price charged by the airlines

Effect of Time on Load Factor=
 (Time-INITIAL TIME)*Yearly increase in Desired Load Factor
 Units: dmnl

Effect of Unemployment on Worker Compensation=
 1+(Historical Unemployment-Normal Unemployment)*Strength of Unemployment
 Effect on Wages
 Units: dmnl
 Higher Unemployment will enable airlines to offer lower wages to
 their employees on average

Elasticity of Demand with Respect to Price=
 0.111921
 Units: dmnl [0,1]

End Time=
 2005
 Units: Year
 Date of last data point

Error over Mean Squared[Data]=
 ZIDZ(Residuals[Data],Historical Mean[Data])^2
 Units: dmnl

Expected Demand=
 Perceived Demand*(1+Expected Growth Rate for Demand*Time to Percieve Changes in
 Demand
)*Exp(Demand Forecast Horizon*Expected Growth Rate for Demand)
 Units: Seat*miles/Year

Expected Growth Rate for Demand= INTEG (
 Change in Expected Growth Rate,
 Initial Expected Growth Rate in Demand)
 Units: dmnl/Year

FINAL TIME = 2000
 Units: Year

The final time for the simulation.

Fuel Cost per Gallon=

IF THEN ELSE(Time<2006, Historical Jet Fuel Cost per Gallon(Time), Projected Fuel Cost

)

Units: \$/gallon

This is the Fuel Cost per Gallon

Gallons per Seat Mile=

0.018

Units: gallons/(Seat*mile) [0,0.06]

This is the number of gallons of jet fuel used per seat mile

Gap For Worker Compensation=

Indicated Compensation-Average Worker Compensation

Units: dollars/worker/Year

Worker compensation will move toward the indicated level with some delay

Gap in Demand Perception=

(Historical Airline Demand*Switch for Historical Variables+(1-Switch for Historical Variables

)*Actual Demand For Seat Miles)-Perceived Demand

Units: Seat*miles/Year

GDP per Capita=

Historical GDP Data(Time-1)

Units: dollars/person

this is the GDP per capita in america

Historical[Profit]=

Historical Airline Operating Profit

Historical[Costs]=

(Historical Airline Passenger Operating Costs)

Historical[Prices]=

Historical Airline Ticket Prices*Unit Equiv 2

Historical[Demand]=

(Historical Airline Demand*Unit Equiv 1)

Historical[Capacity]=

(Historical Available Seat Miles*Unit Equiv 1)

Historical[Salary]=

Historical Real Wage*Units Equiv 3

Units: \$/Year

Set equal to the historical data series.

Historical Airline Capacity=

Historical Available Seat Miles/Number of Miles Flown per Seat

Units: seats

The historical capacity of the airlines in seats

Historical Airline Demand=

"Table for Historical Airline Demad (Revenue Passanger Miles)"(Time-1)*1e+006

Units: Seat*miles/Year

Historical Airline Load Factor=

Historical Airline Demand/Historical Available Seat Miles

Units: fraction

The load factors experienced by the industry

Historical Airline Operating Costs=

Table for Historical Airline Operating Costs(Time-1)*1000

Units: dollars/Year

Historical Airline Operating Margin=

Historical Airline Operating Profit/(Historical Airline Demand*Historical Airline Ticket Prices

)

Units: fraction

The operating margin experienced by the industry historically

Historical Airline Operating Profit=

Table for Historical Airline Operating Profit(Time-1)*1000

Units: dollars/Year

The actual airline industry operating profit

Historical Airline Passenger Operating Costs=

Historical Airline Ticket Prices*Historical Airline Demand-Historical Airline Operating Profit

Units: \$/Year

Historical Airline Salaries=

Historical Salary Data(Time-1)

Units: dollars/worker/Year

Historical data on worker salaries

Historical Airline Ticket Prices=

Table for Historical Airline Ticket Prices(Time-1)

Units: dollars/(Seat*mile)

The actual ticket prices charged by the industry in nominal dollars (cents)

Historical Available Seat Miles=

Table for Historical Airline Available Seat Miles(Time-1)*1e+006

Units: Seat*miles/Year

Historical Average Real Wage=

National Average Wage/CPI

Units: dollars/Year/worker

Historical GDP Data(

[(1968,0)-(2008,80000)],(1969,18578),(1970,18395),(1971,18774),(1972,19557),
(1973,20488),(1974,20199),(1975,19962),(1976,20826),(1977,21570),(1978,22531),
(1979,22987),(1980,22666),(1981,23011),(1982,22350),(1983,23148),(1984,24598),
(1985,25386),(1986,26028),(1987,26668),(1988,27519),(1989,28226),(1990,28435),
(1991,28011),(1992,28559),(1993,28943),(1994,29744),(1995,30131),(1996,30886),
(1997,31891),(1998,32837),(1999,33908),(2000,34770),(2001,34701),(2002,34931),
(2003,35479),(2004,36433),(2005,37206),(2006,37928),(2007,38340))

Units: dollars/person

This is the historical GDP per capita expressed in real 2000

dollars

Historical Jet Fuel Cost per Gallon(

[(1970,0)-(2010,1.5)],(1940,0.2),(1976,0.25),(1977,0.35),(1978,0.39),(1979,
,0.56),(1980,0.86),(1981,1.02),(1982,0.97),(1983,0.88),(1984,0.84),(1985,0.8
,0.55),(1987,0.55),(1988,0.52),(1989,0.6),(1990,0.76),(1991,0.67),(1992
,0.62),(1993,0.59),(1994,0.54),(1995,0.55),(1996,0.65),(1997,0.63),(1998,0.5
,0.52),(2000,0.69),(2001,0.85),(2002,0.59),(2003,0.83),(2004,0.95),(
2005,1.27))

Units: dollars/gallon

The historical data series for jet fuel costs in 2000 dollars

Historical Mean[Data]=

1.783e+009,24.14,0.1061,26.46,26.96,13352

Units: \$/Year

The mean over the simulation of the historical variables

Historical Operating Cost per Available Seat Mile=

Historical Airline Passenger Operating Costs/Historical Available Seat Miles

Units: \$/(Seat*mile)

Historical Population Data and Projections(

[(1930,0)-(2060,3)],(1940,0.65),(1950,0.74434),(1960,0.88205),(1970,1),(1980
,1.1143),(1990,1.223),(2000,1.3842),(2010,1.5157),(2020,1.6476),(2030,1.7843
,2040,1.9235),(2050,2.06))

Units: dmnl

This is the historical data on US population normalized to the

population at the beginning of the model run. Includes government

projections of future population for the life of the model
run\!!

Historical Real Wage=
Historical Airline Salaries/CPI
Units: dollars/Year/worker

Historical Salary Data(

[(1970,0)-(2008,300000)],(1971,14035.8),(1971.25,14497.5),(1971.5,14759.5)
,(1971.75,14531.9),(1972,15234.1),(1972.25,15382),(1972.5,15314.2),(1972.75
,15595.4),(1973,16338.6),(1973.25,16393.6),(1973.5,17165.3),(1973.75,16646.4
,1974,17429.5),(1974.25,17961.2),(1974.5,18861.4),(1974.75,19471.3),(1975
,19863.6),(1975.25,20272),(1975.5,20934.6),(1975.75,21087.6),(1976,22229.3)
,(1976.25,22725),(1976.5,23087.1),(1976.75,22591.7),(1977,23537.4),(1977.25
,23850.9),(1977.5,24862.4),(1977.75,25505.2),(1978,27197.7),(1978.25,26421.6
,1978.5,28033.9),(1978.75,28317.6),(1979,29784),(1979.25,28404.2),(1979.5
,31010.8),(1979.75,30293.2),(1980,31828.2),(1980.25,32197.5),(1980.5,33612.8
,1980.75,34040.1),(1981,35120.9),(1981.25,35353.2),(1981.5,37282),(1981.75
,37236.4),(1982,38204.6),(1982.25,38492.1),(1982.5,39088.7),(1982.75,39652.1
,1983,41088.6),(1983.25,40862.9),(1983.5,42030.4),(1983.75,42384.5),(1984
,42060.7),(1984.25,41251.3),(1984.5,42536.8),(1984.75,40956.6),(1985,43519.4
,1985.25,42761.5),(1985.5,41786.8),(1985.75,42398.2),(1986,42114.5),(1986.25
,41368.4),(1986.5,42213),(1986.75,41029.6),(1987,42456.3),(1987.25,41239.9)
,(1987.5,42781.2),(1987.75,42843.3),(1988,43251.9),(1988.25,43476.1),(1988.5
,44221.6),(1988.75,44853.2),(1989,47502.5),(1989.25,44682.9),(1989.5,46277.3
,1989.75,45215.1),(1990,45975.9),(1990.25,45924.6),(1990.5,46653.6),(1990.75
,47783.4),(1991,48640.1),(1991.25,48746.4),(1991.5,49317.6),(1991.75,49308.1
,1992,50944.7),(1992.25,50628.9),(1992.5,50749.3),(1992.75,53535.4),(1993
,52284.6),(1993.25,47967.2),(1993.5,54023.5),(1993.75,56433.3),(1994,54124.1
,1994.25,57557.9),(1994.5,53170.7),(1994.75,54459.1),(1995,56453.4),(1995.25
,57268.8),(1995.5,58292.8),(1995.75,61069.3),(1996,58715.9),(1996.25,60227.9
,1996.5,58842.6),(1996.75,60088.1),(1997,59377.2),(1997.25,59836.3),(1997.5
,61115.3),(1997.75,63211.4),(1998,60705.4),(1998.25,61670.4),(1998.5,61353.6
,1998.75,61328.1),(1999,61728.1),(1999.25,55908.6),(1999.5,56820.5),(1999.75
,66850.3),(2000,61249.3),(2000.25,63455.8),(2000.5,65984.4),(2000.75,65501.2
,2001,69405.2),(2001.25,68537.5),(2001.5,74493.8),(2001.75,69333.9),(2002
,73742.1),(2002.25,77246),(2002.5,75607.3),(2002.75,76288.7),(2003,79445),(
2003.25,79014.1),(2003.5,76661.6),(2003.75,77986.3),(2004,78414.3),(2004.25
,78295.1),(2004.5,79378.8),(2004.75,76781.5),(2005,76041),(2005.25,74853.9)
,(2005.5,73001.8),(2005.75,73816.9),(2006,75858.7),(2006.25,76219),(2006.5,
75714.5),(2006.75,74058.2),(2007,73695.8),(2007.25,75181.3),(2007.5,75993.6
,2007.75,74259.1),(2008,71428))

Units: dollars/worker/Year

\!! 1971.00 14035.82 1971.25 14497.47 1971.50 14759.47 1971.75
14531.88 1972.00 15234.13 1972.25 15381.97 1972.50 15314.18
1972.75 15595.37 1973.00 16338.56 1973.25 16393.57 1973.50

17165.34 1973.75 16646.38 1974.00 17429.52 1974.25 17961.18
 1974.50 18861.36 1974.75 19471.25 1975.00 19863.57 1975.25
 20271.97 1975.50 20934.58 1975.75 21087.60 1976.00 22229.35
 1976.25 22725.03 1976.50 23087.13 1976.75 22591.70 1977.00
 23537.43 1977.25 23850.93 1977.50 24862.42 1977.75 25505.20
 1978.00 27197.67 1978.25 26421.62 1978.50 28033.93 1978.75
 28317.63 1979.00 29783.97 1979.25 28404.21 1979.50 31010.75
 1979.75 30293.23 1980.00 31828.15 1980.25 32197.49 1980.50
 33612.78 1980.75 34040.07 1981.00 35120.89 1981.25 35353.19
 1981.50 37281.96 1981.75 37236.43 1982.00 38204.65 1982.25
 38492.05 1982.50 39088.66 1982.75 39652.08 1983.00 41088.56
 1983.25 40862.86 1983.50 42030.37 1983.75 42384.52 1984.00
 42060.70 1984.25 41251.26 1984.50 42536.83 1984.75 40956.55
 1985.00 43519.45 1985.25 42761.50 1985.50 41786.75 1985.75
 42398.19 1986.00 42114.54 1986.25 41368.37 1986.50 42212.96
 1986.75 41029.63 1987.00 42456.27 1987.25 41239.91 1987.50
 42781.16 1987.75 42843.27 1988.00 43251.93 1988.25 43476.09
 1988.50 44221.56 1988.75 44853.18 1989.00 47502.51 1989.25
 44682.89 1989.50 46277.31 1989.75 45215.15 1990.00 45975.92
 1990.25 45924.56 1990.50 46653.56 1990.75 47783.45 1991.00
 48640.14 1991.25 48746.42 1991.50 49317.64 1991.75 49308.07
 1992.00 50944.66 1992.25 50628.86 1992.50 50749.30 1992.75
 53535.42 1993.00 52284.56 1993.25 47967.21 1993.50 54023.52
 1993.75 56433.27 1994.00 54124.11 1994.25 57557.94 1994.50
 53170.73 1994.75 54459.12 1995.00 56453.43 1995.25 57268.75
 1995.50 58292.83 1995.75 61069.32 1996.00 58715.95 1996.25
 60227.93 1996.50 58842.59 1996.75 60088.14 1997.00 59377.21
 1997.25 59836.26 1997.50 61115.26 1997.75 63211.36 1998.00
 60705.36 1998.25 61670.40 1998.50 61353.64 1998.75 61328.05
 1999.00 61728.10 1999.25 55908.60 1999.50 56820.48 1999.75
 66850.31 2000.00 61249.34 2000.25 63455.83 2000.50 65984.36
 2000.75 65501.18 2001.00 69405.21 2001.25 68537.51 2001.50
 74493.80 2001.75 69333.94 2002.00 73742.08 2002.25 77246.00
 2002.50 75607.27 2002.75 76288.73 2003.00 79444.95 2003.25
 79014.08 2003.50 76661.58 2003.75 77986.28 2004.00 78414.31
 2004.25 78295.10 2004.50 79378.79 2004.75 76781.54 2005.00
 76040.95 2005.25 74853.92 2005.50 73001.84 2005.75 73816.94
 2006.00 75858.66 2006.25 76218.97 2006.50 75714.46 2006.75
 74058.24 2007.00 73695.78 2007.25 75181.25 2007.50 75993.58
 2007.75 74259.06 2008.00 71428.02\!

Historical Unemployment=

Historical Unemployment Data(Time)/100

Units: dmn1

This is historical data on the unemployment rate in percentage of the labor force looking for work.

Historical Unemployment Data(

[(1945,0)-(2008,12)],(1950,6.5),(1950.08,6.4),(1950.17,6.3),(1950.25,5.8),
(1950.33,5.5),(1950.42,5.4),(1950.5,5),(1950.58,4.5),(1950.67,4.4),(1950.75
,4.2),(1950.83,4.2),(1950.92,4.3),(1951,3.7),(1951.08,3.4),(1951.17,3.4),(1951.25
,3.1),(1951.33,3),(1951.42,3.2),(1951.5,3.1),(1951.58,3.1),(1951.67,3.3),(1951.75
,3.5),(1951.83,3.5),(1951.92,3.1),(1952,3.2),(1952.08,3.1),(1952.17,2.9),(1952.25
,2.9),(1952.33,3),(1952.42,3),(1952.5,3.2),(1952.58,3.4),(1952.67,3.1),(1952.75
,3),(1952.83,2.8),(1952.92,2.7),(1953,2.9),(1953.08,2.6),(1953.17,2.6),(1953.25
,2.7),(1953.33,2.5),(1953.42,2.5),(1953.5,2.6),(1953.58,2.7),(1953.67,2.9),
(1953.75,3.1),(1953.83,3.5),(1953.92,4.5),(1954,4.9),(1954.08,5.2),(1954.17
,5.7),(1954.25,5.9),(1954.33,5.9),(1954.42,5.6),(1954.5,5.8),(1954.58,6),(1954.67
,6.1),(1954.75,5.7),(1954.83,5.3),(1954.92,5),(1955,4.9),(1955.08,4.7),(1955.17
,4.6),(1955.25,4.7),(1955.33,4.3),(1955.42,4.2),(1955.5,4),(1955.58,4.2),(1955.67
,4.1),(1955.75,4.3),(1955.83,4.2),(1955.92,4.2),(1956,4),(1956.08,3.9),(1956.17
,4.2),(1956.25,4),(1956.33,4.3),(1956.42,4.3),(1956.5,4.4),(1956.58,4.1),(1956.67
,3.9),(1956.75,3.9),(1956.83,4.3),(1956.92,4.2),(1957,4.2),(1957.08,3.9),(1957.17
,3.7),(1957.25,3.9),(1957.33,4.1),(1957.42,4.3),(1957.5,4.2),(1957.58,4.1),
(1957.67,4.4),(1957.75,4.5),(1957.83,5.1),(1957.92,5.2),(1958,5.8),(1958.08
,6.4),(1958.17,6.7),(1958.25,7.4),(1958.33,7.4),(1958.42,7.3),(1958.5,7.5),
(1958.58,7.4),(1958.67,7.1),(1958.75,6.7),(1958.83,6.2),(1958.92,6.2),(1959
,6),(1959.08,5.9),(1959.17,5.6),(1959.25,5.2),(1959.33,5.1),(1959.42,5),(1959.5
,5.1),(1959.58,5.2),(1959.67,5.5),(1959.75,5.7),(1959.83,5.8),(1959.92,5.3)
,(1960,5.2),(1960.08,4.8),(1960.17,5.4),(1960.25,5.2),(1960.33,5.1),(1960.42
,5.4),(1960.5,5.5),(1960.58,5.6),(1960.67,5.5),(1960.75,6.1),(1960.83,6.1),
(1960.92,6.6),(1961,6.6),(1961.08,6.9),(1961.17,6.9),(1961.25,7),(1961.33,7.1
,(1961.42,6.9),(1961.5,7),(1961.58,6.6),(1961.67,6.7),(1961.75,6.5),(1961.83
,6.1),(1961.92,6),(1962,5.8),(1962.08,5.5),(1962.17,5.6),(1962.25,5.6),(1962.33
,5.5),(1962.42,5.5),(1962.5,5.4),(1962.58,5.7),(1962.67,5.6),(1962.75,5.4),
(1962.83,5.7),(1962.92,5.5),(1963,5.7),(1963.08,5.9),(1963.17,5.7),(1963.25
,5.7),(1963.33,5.9),(1963.42,5.6),(1963.5,5.6),(1963.58,5.4),(1963.67,5.5),
(1963.75,5.5),(1963.83,5.7),(1963.92,5.5),(1964,5.6),(1964.08,5.4),(1964.17
,5.4),(1964.25,5.3),(1964.33,5.1),(1964.42,5.2),(1964.5,4.9),(1964.58,5),(1964.67
,5.1),(1964.75,5.1),(1964.83,4.8),(1964.92,5),(1965,4.9),(1965.08,5.1),(1965.17
,4.7),(1965.25,4.8),(1965.33,4.6),(1965.42,4.6),(1965.5,4.4),(1965.58,4.4),
(1965.67,4.3),(1965.75,4.2),(1965.83,4.1),(1965.92,4),(1966,4),(1966.08,3.8
,(1966.17,3.8),(1966.25,3.8),(1966.33,3.9),(1966.42,3.8),(1966.5,3.8),(1966.58
,3.8),(1966.67,3.7),(1966.75,3.7),(1966.83,3.6),(1966.92,3.8),(1967,3.9),(1967.08
,3.8),(1967.17,3.8),(1967.25,3.8),(1967.33,3.8),(1967.42,3.9),(1967.5,3.8),
(1967.58,3.8),(1967.67,3.8),(1967.75,4),(1967.83,3.9),(1967.92,3.8),(1968,3.7
,(1968.08,3.8),(1968.17,3.7),(1968.25,3.5),(1968.33,3.5),(1968.42,3.7),(1968.5
,3.7),(1968.58,3.5),(1968.67,3.4),(1968.75,3.4),(1968.83,3.4),(1968.92,3.4)
,(1969,3.4),(1969.08,3.4),(1969.17,3.4),(1969.25,3.4),(1969.33,3.4),(1969.42
,3.5),(1969.5,3.5),(1969.58,3.5),(1969.67,3.7),(1969.75,3.7),(1969.83,3.5),
(1969.92,3.5),(1970,3.9),(1970.08,4.2),(1970.17,4.4),(1970.25,4.6),(1970.33
,4.8),(1970.42,4.9),(1970.5,5),(1970.58,5.1),(1970.67,5.4),(1970.75,5.5),(1970.83

,5.9),(1970.92,6.1),(1971,5.9),(1971.08,5.9),(1971.17,6),(1971.25,5.9),(1971.33,5.9),(1971.42,5.9),(1971.5,6),(1971.58,6.1),(1971.67,6),(1971.75,5.8),(1971.83,6),(1971.92,6),(1972,5.8),(1972.08,5.7),(1972.17,5.8),(1972.25,5.7),(1972.33,5.7),(1972.42,5.7),(1972.5,5.6),(1972.58,5.6),(1972.67,5.5),(1972.75,5.6),(1972.83,5.3),(1972.92,5.2),(1973,4.9),(1973.08,5),(1973.17,4.9),(1973.25,5),(1973.33,4.9),(1973.42,4.9),(1973.5,4.8),(1973.58,4.8),(1973.67,4.8),(1973.75,4.6),(1973.83,4.8),(1973.92,4.9),(1974,5.1),(1974.08,5.2),(1974.17,5.1),(1974.25,5.1),(1974.33,5.1),(1974.42,5.4),(1974.5,5.5),(1974.58,5.5),(1974.67,5.9),(1974.75,6),(1974.83,6.6),(1974.92,7.2),(1975,8.1),(1975.08,8.1),(1975.17,8.6),(1975.25,8.8),(1975.33,9),(1975.42,8.8),(1975.5,8.6),(1975.58,8.4),(1975.67,8.4),(1975.75,8.4),(1975.83,8.3),(1975.92,8.2),(1976,7.9),(1976.08,7.7),(1976.17,7.6),(1976.25,7.7),(1976.33,7.4),(1976.42,7.6),(1976.5,7.8),(1976.58,7.8),(1976.67,7.6),(1976.75,7.7),(1976.83,7.8),(1976.92,7.8),(1977,7.5),(1977.08,7.6),(1977.17,7.4),(1977.25,7.2),(1977.33,7),(1977.42,7.2),(1977.5,6.9),(1977.58,7),(1977.67,6.8),(1977.75,6.8),(1977.83,6.8),(1977.92,6.4),(1978,6.4),(1978.08,6.3),(1978.17,6.3),(1978.25,6.1),(1978.33,6),(1978.42,5.9),(1978.5,6.2),(1978.58,5.9),(1978.67,6),(1978.75,5.8),(1978.83,5.9),(1978.92,6),(1979,5.9),(1979.08,5.9),(1979.17,5.8),(1979.25,5.8),(1979.33,5.6),(1979.42,5.7),(1979.5,5.7),(1979.58,6),(1979.67,5.9),(1979.75,6),(1979.83,5.9),(1979.92,6),(1980,6.3),(1980.08,6.3),(1980.17,6.3),(1980.25,6.9),(1980.33,7.5),(1980.42,7.6),(1980.5,7.8),(1980.58,7.7),(1980.67,7.5),(1980.75,7.5),(1980.83,7.5),(1980.92,7.2),(1981,7.5),(1981.08,7.4),(1981.17,7.4),(1981.25,7.2),(1981.33,7.5),(1981.42,7.5),(1981.5,7.2),(1981.58,7.4),(1981.67,7.6),(1981.75,7.9),(1981.83,8.3),(1981.92,8.5),(1982,8.6),(1982.08,8.9),(1982.17,9),(1982.25,9.3),(1982.33,9.4),(1982.42,9.6),(1982.5,9.8),(1982.58,9.8),(1982.67,10.1),(1982.75,10.4),(1982.83,10.8),(1982.92,10.8),(1983,10.4),(1983.08,10.4),(1983.17,10.3),(1983.25,10.2),(1983.33,10.1),(1983.42,10.1),(1983.5,9.4),(1983.58,9.5),(1983.67,9.2),(1983.75,8.8),(1983.83,8.5),(1983.92,8.3),(1984,8),(1984.08,7.8),(1984.17,7.8),(1984.25,7.7),(1984.33,7.4),(1984.42,7.2),(1984.5,7.5),(1984.58,7.5),(1984.67,7.3),(1984.75,7.4),(1984.83,7.2),(1984.92,7.3),(1985,7.3),(1985.08,7.2),(1985.17,7.2),(1985.25,7.3),(1985.33,7.2),(1985.42,7.4),(1985.5,7.4),(1985.58,7.1),(1985.67,7.1),(1985.75,7.1),(1985.83,7),(1985.92,7),(1986,6.7),(1986.08,7.2),(1986.17,7.2),(1986.25,7.1),(1986.33,7.2),(1986.42,7.2),(1986.5,7),(1986.58,6.9),(1986.67,7),(1986.75,7),(1986.83,6.9),(1986.92,6.6),(1987,6.6),(1987.08,6.6),(1987.17,6.6),(1987.25,6.3),(1987.33,6.3),(1987.42,6.2),(1987.5,6.1),(1987.58,6),(1987.67,5.9),(1987.75,6),(1987.83,5.8),(1987.92,5.7),(1988,5.7),(1988.08,5.7),(1988.17,5.7),(1988.25,5.4),(1988.33,5.6),(1988.42,5.4),(1988.5,5.4),(1988.58,5.6),(1988.67,5.4),(1988.75,5.4),(1988.83,5.3),(1988.92,5.3),(1989,5.4),(1989.08,5.2),(1989.17,5),(1989.25,5.2),(1989.33,5.2),(1989.42,5.3),(1989.5,5.2),(1989.58,5.2),(1989.67,5.3),(1989.75,5.3),(1989.83,5.4),(1989.92,5.4),(1990,5.4),(1990.08,5.3),(1990.17,5.2),(1990.25,5.4),(1990.33,5.4),(1990.42,5.2),(1990.5,5.5),(1990.58,5.7),(1990.67,5.9),(1990.75,5.9),(1990.83,6.2),(1990.92,6.3),(1991,6.4),(1991.08,6.6),(1991.17,6.8),(1991.25,6.7),(1991.33,6.9),(1991.42,6.9),(1991.5,6.8),(1991.58,6.9),(1991.67,6.9),(1991.75,7),(1991.83,7),(1991.92,7.3),(1992,7.3),(1992.08,7.4),(1992.17,7.4),(1992.25,7.4),(1992.33,7.6),(1992.42,7.8),(1992.5,7.7),(1992.58,7.6),(1992.67

,7.6),(1992.75,7.3),(1992.83,7.4),(1992.92,7.4),(1993,7.3),(1993.08,7.1),(1993.17,7),(1993.25,7.1),(1993.33,7.1),(1993.42,7),(1993.5,6.9),(1993.58,6.8),(1993.67,6.7),(1993.75,6.8),(1993.83,6.6),(1993.92,6.5),(1994,6.6),(1994.08,6.6),(1994.17,6.5),(1994.25,6.4),(1994.33,6.1),(1994.42,6.1),(1994.5,6.1),(1994.58,6),(1994.67,5.9),(1994.75,5.8),(1994.83,5.6),(1994.92,5.5),(1995,5.6),(1995.08,5.4),(1995.17,5.4),(1995.25,5.8),(1995.33,5.6),(1995.42,5.6),(1995.5,5.7),(1995.58,5.7),(1995.67,5.6),(1995.75,5.5),(1995.83,5.6),(1995.92,5.6),(1996,5.6),(1996.08,5.5),(1996.17,5.5),(1996.25,5.6),(1996.33,5.6),(1996.42,5.3),(1996.5,5.5),(1996.58,5.1),(1996.67,5.2),(1996.75,5.2),(1996.83,5.4),(1996.92,5.4),(1997,5.3),(1997.08,5.2),(1997.17,5.2),(1997.25,5.1),(1997.33,4.9),(1997.42,5),(1997.5,4.9),(1997.58,4.8),(1997.67,4.9),(1997.75,4.7),(1997.83,4.6),(1997.92,4.7),(1998,4.6),(1998.08,4.6),(1998.17,4.7),(1998.25,4.3),(1998.33,4.4),(1998.42,4.5),(1998.5,4.5),(1998.58,4.5),(1998.67,4.6),(1998.75,4.5),(1998.83,4.4),(1998.92,4.4),(1999,4.3),(1999.08,4.4),(1999.17,4.2),(1999.25,4.3),(1999.33,4.2),(1999.42,4.3),(1999.5,4.3),(1999.58,4.2),(1999.67,4.2),(1999.75,4.1),(1999.83,4.1),(1999.92,4),(2000,4),(2000.08,4.1),(2000.17,4),(2000.25,3.8),(2000.33,4),(2000.42,4),(2000.5,4),(2000.58,4.1),(2000.67,3.9),(2000.75,3.9),(2000.83,3.9),(2000.92,3.9),(2001,4.2),(2001.08,4.2),(2001.17,4.3),(2001.25,4.4),(2001.33,4.3),(2001.42,4.5),(2001.5,4.6),(2001.58,4.9),(2001.67,5),(2001.75,5.3),(2001.83,5.5),(2001.92,5.7),(2002,5.7),(2002.08,5.7),(2002.17,5.7),(2002.25,5.9),(2002.33,5.8),(2002.42,5.8),(2002.5,5.8),(2002.58,5.7),(2002.67,5.7),(2002.75,5.7),(2002.83,5.9),(2002.92,6),(2003,5.8),(2003.08,5.9),(2003.17,5.9),(2003.25,6),(2003.33,6.1),(2003.42,6.3),(2003.5,6.2),(2003.58,6.1),(2003.67,6.1),(2003.75,6),(2003.83,5.8),(2003.92,5.7),(2004,5.7),(2004.08,5.6),(2004.17,5.8),(2004.25,5.6),(2004.33,5.6),(2004.42,5.6),(2004.5,5.5),(2004.58,5.4),(2004.67,5.4),(2004.75,5.5),(2004.83,5.4),(2004.92,5.4),(2005,5.2),(2005.08,5.4),(2005.17,5.2),(2005.25,5.1),(2005.33,5.1),(2005.42,5),(2005.5,5),(2005.58,4.9),(2005.67,5.1),(2005.75,5),(2005.83,5),(2005.92,4.8),(2006,4.7),(2006.08,4.7),(2006.17,4.7),(2006.25,4.7),(2006.33,4.7),(2006.42,4.6),(2006.5,4.7),(2006.58,4.7),(2006.67,4.5),(2006.75,4.4),(2006.83,4.5),(2006.92,4.4),(2007,4.6),(2007.08,4.5),(2007.17,4.4),(2007.25,4.5),(2007.33,4.5),(2007.42,4.6),(2007.5,4.7),(2007.58,4.7),(2007.67,4.7),(2007.75,4.8),(2007.83,4.7),(2007.92,5),(2008,4.9),(2008.08,4.8),(2008.17,5.1),(2008.25,5),(2008.33,5.5),(2008.42,5.5),(2008.5,5.7),(2008.58,6.1))

Units: dmnl

Indicated Capacity Adjustment=

Desired Capacity Acquisition Rate+Adjustment for the Supply Line+Supply Line Adjustment for Growth in Demand

Units: seats/Year

The indicated order for seats for the industry is equal to the

desired capacity acquisition rate plus an adjustment for the supply on order and a further adjustment for the expected growth rate of the industry

Indicated Compensation=

Average Worker Compensation*Effect of New Hires on Worker Compensation*Effect of Inflation in Worker Compensation
*Effect of Operating Margin on Worker Compensation*Effect of Outside Opportunities on Worker Compensation

*Effect of Unemployment on Worker Compensation

Units: dollars/Year/worker

Average worker compensation is pressured to change by a certain percentage. Each of the five effects modeled will indicate a certain percentage change, and their sum total effect will be the indicated change in compensation

Indicated Effect of Congestion on Demand=

((Historical Airline Load Factor*Switch for Historical Variables+(1-Switch for Historical Variables)
) * Indicated Load Factor) / Comfortable Industry Load Factor)^Sensitivity of Demand to Congestion

Units: dmnl

When load factor is very high people will be dissatisfied with their flying experience and choose alternative modes of transportation if possible.

Indicated Growth Rate=

(Perceived Demand-Reference Demand)/(Reference Demand*Time Horizon for Reference Demand
)

Units: dmnl/Year

Indicated Load Factor=

Actual Demand For Seat Miles/Available Seat Miles
Units: dmnl

The indicated load factor is the load factor that the industry would experience if there were only one route and one time slot that everyone wanted to fly. Multiple routes cause some to be oversubscribed relative to others and the overall load factor to be different.

Indicated Orders for Capacity=

SMOOTH(Indicated Capacity Adjustment, Order Approval Delay Time)*(1-Switch for Partial Model Tests
) + Indicated Capacity Adjustment * Switch for Partial Model Tests

Units: seats/Year

There is a delay between the capacity adjustment being indicated by the fundamental of the industry and the airlines actually approving that change in capacity and ordering new seats

Indicated Price=

Max(Minimum Ticket Price, Indicated Ticket Price per Seat Mile)
Units: dollars/(Seat*mile)
This is the price limited to be larger than the minimum

Indicated Ticket Price per Seat Mile=
Ticket Price*Effect of Demand Supply Balance on Price*Effect of Margin on Price
*Effect of Costs on Price
Units: dollars/(Seat*mile)
This is the ticket price per seat mile

Initial Airline Capacity=
Historical Airline Demand/Number of Miles Flown per Seat/Desired Load Factor
*(1-Switch for Partial Model Tests)+Initial Capacity for Partial Model Test
*
Switch for Partial Model Tests
Units: Seat
This is the initial capacity of seat miles per quarter

Initial Capacity for Partial Model Test=
100
Units: seats
The number of seats of capacity needs to be initialized for the
partial model test so that we can see that the stock of capacity
track the desired capacity without steady state error

Initial Capacity on Order=
(Initial Airline Capacity/Average Service Life+Initial Airline Capacity*Initial Expected
Growth Rate in Demand
*Weight on Demand Forecast Orders)*Time Required to Manufacture an Airplane
Units: Seat
The initial value of capacity on order to get the capacity to
balance expected retirements

Initial Expected Growth Rate in Demand=
-0.158158*(1-Switch for Partial Model Tests)+Partial Model Growth Rate*Switch for
Partial Model Tests
Units: dmnl/Year [-0.2,0.2]

Initial Industry Desired Load Factor=
0.5114
Units: dmnl

Initial Percieved Margin=
-0.1
Units: dmnl

Initial Population=
2.03302e+008

Units: people

This is the population of the US at the beginning of the model run

Initial Ticket Price=
0.0579

Units: dollars/(Seat*mile)

The initial ticket price

INITIAL TIME = 1970

Units: Year

The initial time for the simulation.

Initial Worker Compensation=
14035

Units: dollars/(worker*Year)

The initial worker salary in 1970

Interval[Data]=
1,1,1,1,1,0.25

Units: Year

Interval between data points

Into Storage=

IF THEN ELSE(Time>1980,IF THEN ELSE(((1-Switch for Historical
Variables)*Operating Margin
+(Switch for Historical Variables)*Historical Airline Operating Margin)<=Margin Threshold to
Initiate Mothballing
, IF THEN ELSE(Indicated Orders for Capacity<0,Min
(-Indicated Orders for Capacity,Capacity 3/Time to Mothball),0), 0), 0)

Units: seats/Year

This is the flow of planes into mothballing

Inverse of Standard Deviation[Data]=
1/Whole Sample Standard Deviation[Data]

Units: dmn1

Inverse of the Variance[Data]=
ZIDZ(1,Var X[Data])

Units: 1/((dollars/Year)*(dollars/Year))

Lag for Measuring Changes=
1

Units: Year

Load Factor=

Table for the Load Factor Experienced(Indicated Load Factor)

Units: fraction

Load factor is defined as the revenue passenger miles divided by the available seat miles, however since the model aggregates over all of the routes in the industry, we calculate load factor as the output of that ratio in a table function

Load Factor Gap=

Load Factor-Desired Load Factor

Units: fraction

The difference between the current load factor and the desired load factor

M X[Data]=

ZIDZ(Sum Xi[Data],Count[Data])

Units: dollars/Year

Mean of x (sum x)/n

M Y[Data]=

ZIDZ(Sum Yi[Data],Count[Data])

Units: dollars/Year

Mean of y (sum y)/n

MAE over Mean[Data]=

ZIDZ(ZIDZ(Sum AE[Data],Count[Data]),M X[Data])

Units: dmnl

Mean Absolute Error as a fraction of the mean

MAPE[Data]=

ZIDZ(Sum APE[Data],Count[Data])

Units: dmnl

Mean Absolute Percent Error

Margin Perception Delay=

4.67515

Units: years

It takes this long for margin to be perceived by unions and used in wage negotiations

Margin Threshold to Initiate Mothballing=

-0.1

Units: fraction [-0.4,0]

this is the operating margin threshold that will cause airlines to mothball capacity

Miles per Person per Dollar of GDP=
0.0645965

Units: (Seat*miles)/(Year*\$) [0,0.15]

The number of miles per person demanded per dollar of GDP per capita

Miles traveled per hour flown=
160

Units: miles/hour

This is the average number of miles flown per hour

Minimum Ticket Price=
Cost per Available Seat Mile

Units: dollars/(Seat*mile)

The current price can not fall below variable costs

Mothballed Capacity= INTEG (
Mothballing-Off Mothballing,
0)

Units: seats

The stock of planes currently mothballed

Mothballing=
Into Storage

Units: seats/Year

the flow of planes into mothballing

MSE[Data]=
dif cov[Data]+dif mean[Data]+dif var[Data]

Units: dollars*dollars/(Year*Year)

Mean Square Error

MX2[Data]=
ZIDZ(SumX2[Data],Count[Data])

Units: (dollars/Year)*(dollars/Year)

Mean of x^2 (sum x^2)/n

Mxy[Data]=
ZIDZ(SumXY[Data],Count[Data])

Units: (dollars/Year)*(dollars/Year)

Mean of $x*y$ (sum $x*y$)/n

MY2[Data]=
ZIDZ(SumY2[Data],Count[Data])

Units: (dollars/Year)*(dollars/Year)

Mean of y^2 (sum y^2)/n

National Average Wage=
National Average Wage Data(Time)
Units: dollars/worker/Year
data from the social security administration on the national
average wage

National Average Wage Data(
[(1950,0)-(2006,40000)],(1951,2799.16),(1952,2973.32),(1953,3139.44),(1954,
3155.64),(1955,3301.44),(1956,3532.36),(1957,3641.72),(1958,3673.8),(1959,
3855.8),(1960,4007.12),(1961,4086.76),(1962,4291.4),(1963,4396.64),(1964,4576.32
),(1965,4658.72),(1966,4938.36),(1967,5213.44),(1968,5571.76),(1969,5893.76
),(1970,6186.24),(1971,6497.08),(1972,7133.8),(1973,7580.16),(1974,8030.76)
),(1975,8630.92),(1976,9226.48),(1977,9779.44),(1978,10556),(1979,11479.5),(
1980,12513.5),(1981,13773.1),(1982,14531.3),(1983,15239.2),(1984,16135.1),(
1985,16822.5),(1986,17321.8),(1987,18426.5),(1988,19334),(1989,20099.6),(1990
,21028),(1991,21811.6),(1992,22935.4),(1993,23132.7),(1994,23753.5),(1995,24705.7
),(1996,25913.9),(1997,27426),(1998,28861.4),(1999,30469.8),(2000,32154.8),
(2001,32921.9),(2002,33252.1),(2003,34064.9),(2004,35648.6),(2005,36952.9),
(2006,38651.4))

Units: dollars/worker/Year

\!1951 2799.16 1952 2973.32 1953 3139.44 1954 3155.64 1955
3301.44 1956 3532.36 1957 3641.72 1958 3673.8 1959 3855.8 1960
4007.12 1961 4086.76 1962 4291.4 1963 4396.64 1964 4576.32 1965
4658.72 1966 4938.36 1967 5213.44 1968 5571.76 1969 5893.76 1970
6186.24 1971 6497.08 1972 7133.8 1973 7580.16 1974 8030.76 1975
8630.92 1976 9226.48 1977 9779.44 1978 10556.03 1979 11479.46
1980 12513.46 1981 13773.1 1982 14531.34 1983 15239.24 1984
16135.07 1985 16822.51 1986 17321.82 1987 18426.51 1988 19334.04
1989 20099.55 1990 21027.98 1991 21811.6 1992 22935.42 1993
23132.67 1994 23753.53 1995 24705.66 1996 25913.9 1997 27426
1998 28861.44 1999 30469.84 2000 32154.82 2001 32921.92 2002
33252.09 2003 34064.95 2004 35648.55 2005 36952.94 2006 38651.41

New Capacity=
Airplane Manufacturing Completion
Units: seats/Year

New Operating Costs=
Total Operating Costs
Units: dollars/Year
Profit is made at a certain annual rate, and fills the stock of
accumulated profit

New Operating Costs 0=
Total Operating Costs

Units: dollars/Year

Profit is made at a certain annual rate, and fills the stock of accumulated profit

New Reported Variable[Profit]=
Operating Profit

New Reported Variable[Costs]=
Total Operating Costs

New Reported Variable[Prices]=
Ticket Price*Unit Equiv 2

New Reported Variable[Demand]=
Actual Demand For Seat Miles*Unit Equiv 1

New Reported Variable[Capacity]=
Available Seat Miles*Unit Equiv 1

New Reported Variable[Salary]=
Average Worker Compensation*Units Equiv 3

Units: dollars/Year

Reported Variables fill a stock that averages their values over the reporting period

Normal Margin=
0.0732597

Units: dmnl

Normal Number of Hours Flown per Day=
9

Units: hours/day

This is the normal number of flying hours each plane gets per day, found from the constant part of the regression of plane utilization on load factor

Normal Unemployment=
0.03

Units: dmnl

There is some normal level of unemployment at which there will be no effect of unemployment on wages

Number of Miles Flown per Seat=
Days per Year*Miles traveled per hour flown*Normal Number of Hours Flown per Day

Units: miles/Year

This is the number of miles the airlines would like to use each seat every year

Off Mothballing=
Return to Service

Units: seats/Year

The flow of planes off mothballing

One Year Change in New Hires=

$$\frac{((\text{Switch for Historical Variables} * \text{Historical Airline Capacity} + (1 - \text{Switch for Historical Variables}) * \text{Recent Airline Capacity}) - \text{Recent Airline Capacity})}{\text{Recent Airline Capacity}}$$

Units: dmnl

Since the number of workers needed by the industry are assumed to be proportional to the number of seats the industry operates the change in demand for workers recently is simply the change in seats recently

One Year Percent Change in Capacity=

$$\frac{(\text{Historical Available Seat Miles} * \text{Switch for Historical Variables} + (1 - \text{Switch for Historical Variables}) * \text{SMOOTH}((\text{Historical Available Seat Miles} * \text{Switch for Historical Variables} + (1 - \text{Switch for Historical Variables}) * \text{Available Seat Miles})), \text{Lag for Measuring Changes}) - 1}{\text{SMOOTH}((\text{Historical Available Seat Miles} * \text{Switch for Historical Variables} + (1 - \text{Switch for Historical Variables}) * \text{Available Seat Miles}))}$$

-1

Units: dmnl

The recent change in seat miles made available by the airlines

Operating Costs from Passengers=

$$\text{Variable Cost from Operations} + \text{Costs from Wages}$$

Units: dollars/Year

This is the sum of all costs of the airline

Operating Margin=

$$\text{ZIDZ}(\text{Operating Profit}, \text{Passenger Revenue})$$

Units: fraction

The percentage profit of the airline industry

Operating Profit=

$$\text{Operating Revenue} - \text{Total Operating Costs}$$

Units: dollars/Year

Operating Revenue=

$$\text{Passenger Revenue}$$

Units: dollars/Year

Order Approval Delay Time=

0.25908

Units: Year [0,4]

It takes this long for airlines to move forward with their plans to order aircraft

Ordering=

Orders of Airplanes

Units: Seat/Year

this lower structure represents the fact that airplane ordering is a higher order delay process than would be indicated by the one stock representation above

Orders of Airplanes=

Max(Indicated Orders for Capacity-Return to Service,0)

Units: Seat/Year

Airlines first reduce orders for new capacity by the amount of capacity returned to service from any mothballed fleet, then order what they need to replace retirements and adjust capacity to target levels. Orders are constrained to be nonnegative.

Other Payoff[Data]=

IF THEN ELSE(Time > FINAL TIME-TIME STEP/2, RMSE over Mean[Data],0)

Units: dmnl

Other Variable Costs=

Producer Price Index*"1970 Other Variable Costs"

Units: dollars/(Seat*mile)

These are all the variable costs other than jet fuel that the airline experiences. Does not include costs from labor expenses or transport related costs. These costs scale with PPI in order to keep them current

Partial Model Growth Rate=

0.05

Units: dmnl

Passenger Revenue=

Revenue Seat Miles*Ticket Price

Units: dollars/Year

Payoff Element[Data]=

IF THEN ELSE(Time > FINAL TIME-TIME STEP/2, Sum of Error Squared over Mean[Data],0)

Units: dmnl

Perceived Demand= INTEG (

Change in Demand Perception,
Actual Demand For Seat Miles)

Units: Seat*miles/Year

This is the industry's perception of the total demand for seat miles

Percent Error[Data]=
(Simulated[Data]-Historical[Data])/Historical[Data]

Units: dmnl

pick[Data]=
STEP(1,Start Time[Data])*(1-STEP(1,End Time + TIME STEP/2))*IF THEN
ELSE(Time
/Interval[Data] = Integer(Time/Interval[Data]),1 , 0)

Units: Dimensionless

Takes a value of one for every data point available, assuming
the data are available at intervals of Interval between the
Start Time and End Time.

Planned Replacement Orders=
Airplane Retirements

Units: seats/Year

Population=
Initial Population*Historical Population Data and Projections(Time-1)

Units: people

This is the population of the United States

Producer Price Index=
Table for Producer Price Index(Time)*1000/369

Units: dmnl

An Index that measures the average cost of goods for producers
inthe economy. With 1970 set equal to 1

Projected Fuel Cost=
1

Units: \$/gallon

This is the future fuel cost per gallon for the model to use

r[Data]=
ZIDZ(Mxy[Data]-(M X[Data]*M Y[Data]),Sx[Data]*Sy[Data])

Units: Dimensionless

Correlation coefficient. Calculated through the 'hand
computation' formula. Sterman (1984) pg. 63

"R^2"[Data]=
r[Data]*r[Data]

Units: Dimensionless

Correlation coefficient squared

Recent Airline Capacity=

SMOOTH(Switch for Historical Variables*Historical Airline Capacity+(1-Switch for Historical Variables)*Airline Capacity,Lag for Measuring Changes)
 Units: seats

Recent Margin=
 smoothi(((Switch for Historical Variables)*Historical Airline Operating Margin +(1-Switch for Historical Variables)*Operating Margin),Margin Perception Delay , Initial Percieved Margin)
 Units: dmnl

The margin currently affecting airline salaries is not the current margin, but rather recent margin, since it takes some time for the margin the airlines are experiencing to be percieved.

Reference Demand= INTEG (Change in Reference Demand, Perceived Demand/(1+Initial Expected Growth Rate in Demand*Time Horizion for Reference Demand))
 Units: Seat*miles/Year

Reference Ticket Price=
 Initial Ticket Price*CPI
 Units: dollars/(Seat*mile)
 This is the GDP per capita adjusted ticket price relative to the initial price

Reported Variable[Data]=
 Drained Reported Variable[Data]*TIME STEP/Reporting Period[Data]
 Units: dollars/Year

Reporting Period[Data]=
 1
 Units: Year

Reporting Period 0=
 1
 Units: Year

Residuals[Data]=
 Yi[Data]-Xi[Data]
 Units: dollars/Year
 The error

Retired=

Capacity $3 / (\text{Average Service Life} / 3)$

Units: seats/Year

Return to Service=

IF THEN ELSE(Operating Margin > 0, Min(Max(Indicated Orders for Capacity, 0), Capacity on Mothball/Time to Mothball), 0)

Units: seats/Year

this is the flow of planes off of mothballing and back into the stock of capacity

Revenue Seat Miles=

Available Seat Miles * Load Factor

Units: Seat*miles/Year

These are the revenue generating seat miles that the airlines fly

RMSE[Data]=

SQRT(MSE[Data])

Units: dollars/Year

Root Mean Square Error

RMSE over Mean[Data]=

ZIDZ(RMSE[Data], M X[Data])

Units: dmnl

Root Mean Squared Error as a fraction of the mean

SAVEPER =

TIME STEP

Units: Year [0,?]

The frequency with which output is stored.

Seat Miles Desired from GDP per Capita=

GDP per Capita * Miles per Person per Dollar of GDP + Constant Demand Adjustment

Units: Seat*miles/person/Year

This variable adjusts demand based on the affect of changes in consumer income compared to a reference level

Sensitivity of Demand to Congestion=

-3

Units: dmnl

Demand is lower when people feel that flights are too congested, this will manifest as a negative sensitivity of demand to congestion.

Sensitivity of Price to Costs=

5.636

Units: dmnl

Sensitivity of Price to Demand Supply Balance=
10

Units: dmnl [0,100]

Sensitivity of Price to Margin=
0

Units: dmnl [0,1]

Simulated[Profit]=
Reported Variable[Profit]

Simulated[Costs]=
IF THEN ELSE(Reported Variable[Costs]=0, 1 , (Reported Variable[Costs]))

Simulated[Prices]=
Reported Variable[Prices]

Simulated[Demand]=
IF THEN ELSE(Reported Variable[Demand]=0, 1 , (Reported
Variable[Demand])
)

Simulated[Capacity]=
IF THEN ELSE(Reported Variable[Capacity]=0, 1 , (Reported Variable[Capacity
]))

Simulated[Salary]=
Simulated Real Wage*Units Equiv 3

Units: \$/Year

Set equal to the simulated data series.

Simulated Real Wage=
Average Worker Compensation/CPI

Units: dollars/Year/worker

Start Time[Profit]=
1970

Start Time[Costs]=
1970

Start Time[Prices]=
1970

Start Time[Demand]=
1970

Start Time[Capacity]=
1970

Start Time[Salary]=
1971

Units: Year

Date of first data point

Strength of Inflation on Worker Compensation=
1

Units: Year

Strength of Margin on Worker Compensation=
0.266628

Units: dmn1

Strength of New Capacity Effect on Demand=
0.869749

Units: dmn1 [0,2]

The number of seat miles demanded per capita for every increase
of one seat mile offered by the airlines

Strength of New Hire Effect on Worker Compensation=
-0.400418

Units: dmn1

Strength of Outside Opportunities on Worker Compensation=
0.0188198

Units: dmn1

Strength of Unemployment Effect on Wages=
0

Units: dmn1

While the Strength of the unemployment effect is an empirical
matter these coefficients only make sense if they are negative.

Sum AE[Data]= INTEG (
ABS(Xi[Data] - Yi[Data])/dt,
0)

Units: dollars/Year

Sum Absolute Error

Sum APE[Data]= INTEG (
ABS(ZIDZ(Xi[Data]-Yi[Data],Yi[Data]))/dt,
0)

Units: dmn1

Sum of Absolute Percent Errors

Sum of Error Squared over Mean[Data]= INTEG (
Error over Mean Squared[Data]/dt,
0)

Units: dmn1

Sum of Squared Error[Data]= INTEG (
Error over Mean Squared[Data]/dt,
0)

Residuals[Data]^2/dt,
0)
Units: dollars*dollars/(Year*Year)

Sum Xi[Data]= INTEG (
Xi[Data]/dt,
0)
Units: dollars/Year
Sum of x's (simulated)

Sum Yi[Data]= INTEG (
Yi[Data]/dt,
0)
Units: dollars/Year
Sum of y'

SumX2[Data]= INTEG (
Xi[Data]*Xi[Data]/dt,
0)
Units: (dollars/Year)*(dollars/Year)
Sum of x^

SumXY[Data]= INTEG (
Xi[Data]*Yi[Data]/dt,
0)
Units: (dollars/Year)*(dollars/Year)
Sum of x*y

SumY2[Data]= INTEG (
Yi[Data]*Yi[Data]/dt,
0)
Units: (dollars/Year)*(dollars/Year)
Sum of y^

Supply Line Adjustment for Growth in Demand=
Weight on Demand Forecast Orders*Expected Growth Rate for Demand*(Airline
Capacity Supply Line
)
Units: Seat/Year

Supply Line Adjustment Time=
0.129641
Units: Year [0,2]
Decisions to adjust the supply line are smoothed over this time
period

Switch for Historical Variables=

0

Units: dmnl

Set this variable to zero in order to use historical inputs for
all of the model sectors

Switch for Partial Model Tests=

0

Units: dmnl

Sx[Data]=

$\text{SQRT}(\text{MX2}[\text{Data}] - (\text{M X}[\text{Data}] * \text{M X}[\text{Data}]))$

Units: dollars/Year

Standard Deviation of x. Calculated using the 'hand computation'
formula to calculate the standard deviation without prior
knowledge of the mean. Sterman (1984), pg. 64

Sy[Data]=

$\text{SQRT}(\text{MY2}[\text{Data}] - (\text{M Y}[\text{Data}] * \text{M Y}[\text{Data}]))$

Units: dollars/Year

Standard Deviation of y. Calculated using the 'hand computation'
formula to calculate the standard deviation without prior
knowledge of the mean. Sterman (1984), pg. 64

Table for Historical Airline Available Seat Miles(

[(1970,0)-(2005,2e+006)],(1970,265120),(1971,279823),(1972,287411),(1973,310597),
(1974,297006),(1975,303006),(1976,322822),(1977,345566),(1978,368751),(1979,
,416126),(1980,432535),(1981,424897),(1982,440119),(1983,464538),(1984,515323),
(1985,547788),(1986,607436),(1987,648721),(1988,676802),(1989,684376),(1990,
,733375),(1991,715199),(1992,752772),(1993,771641),(1994,784331),(1995,807078),
(1996,835071),(1997,857232),(1998,874089),(1999,918419),(2000,956950),(2001,
,930511),(2002,892554),(2003,893824),(2004,971466),(2005,1.00331e+006))

Units: Seat*miles/Year

"Table for Historical Airline Demad (Revenue Passanger Miles)"(

[(1970,0)-(2005,800000)],(1970,131710),(1971,135658),(1972,152406),(1973,161957),
(1974,162919),(1975,162810),(1976,178988),(1977,193219),(1978,226781),(1979,
,262023),(1980,255192),(1981,248888),(1982,259644),(1983,281829),(1984,305116),
(1985,336403),(1986,366546),(1987,404471),(1988,423302),(1989,432714),(1990,
,457926),(1991,447955),(1992,478554),(1993,489684),(1994,519382),(1995,540656),
(1996,578663),(1997,603419),(1998,618087),(1999,652047),(2000,692757),(2001,
,651700),(2002,641102),(2003,656909),(2004,733680),(2005,779004))

Units: Seat*miles/Year

Table for Historical Airline Operating Costs(

[(1970,0)-(2005,2e+008)],(1970,9.49016e+006),(1971,1.00176e+007),(1972,1.09484e+007),
 (1973,1.21921e+007),(1974,1.43775e+007),(1975,1.54401e+007),(1976,1.69379e+007),
 (1977,1.91723e+007),(1978,2.16874e+007),(1979,2.68798e+007),(1980,3.37104e+007),
 (1981,3.69634e+007),(1982,3.73234e+007),(1983,3.91417e+007),(1984,4.30004e+007),
 (1985,4.58017e+007),(1986,5.07598e+007),(1987,5.63923e+007),(1988,6.20633e+007),
 (1989,6.9188e+007),(1990,8.00627e+007),(1991,7.71744e+007),(1992,8.31483e+007),
 (1993,8.7434e+007),(1994,8.93807e+007),(1995,9.28039e+007),(1996,9.96398e+007),
 (1997,1.0475e+008),(1998,1.08907e+008),(1999,1.14095e+008),(2000,1.28352e+008),
 (2001,1.23802e+008),(2002,1.17994e+008),(2003,1.20291e+008),(2004,1.42105e+008),
 (2005,1.56437e+008))

Units: dollars/Year

Table for Historical Airline Operating Profit(

[(1940,-2e+007)-(2010,1e+007)],(1950,75990),(1951,127624),(1952,195167),(1953,106336),
 (1954,124375),(1955,142624),(1956,134890),(1957,65005),(1958,107512),
 (1959,122349),(1960,77591),(1961,20059),(1962,189999),(1963,279787),(1964,470097),
 (1965,671928),(1966,775497),(1967,708194),(1968,504888),(1969,391931),
 (1970,43031),(1971,328475),(1972,584470),(1973,585266),(1974,725740),(1975,127879),
 (1976,721933),(1977,908040),(1978,1.36486e+006),(1979,199055),(1980,-221615),
 (1981,-454800),(1982,-733435),(1983,310410),(1984,2.15151e+006),(1985,1.42626e+006),
 (1986,1.3231e+006),(1987,2.46889e+006),(1988,3.4365e+006),
 (1989,1.81127e+006),(1990,-1.91234e+006),(1991,-1.78474e+006),(1992,-2.44446e+006),
 (1993,1.43817e+006),(1994,2.71346e+006),(1995,5.85952e+006),(1996,6.20907e+006),
 (1997,8.58679e+006),(1998,9.32781e+006),(1999,8.40331e+006),(2000,6.99893e+006),
 (2001,-1.03259e+007),(2002,-8.56641e+006),(2003,-2.10825e+006),(2004,-1.49109e+006),
 (2005,299281))

Units: dollars/Year

This is the data for actual airline operating profits by year since 1950 in reported dollars\!\\!

Table for Historical Airline Ticket Prices(

[(1970,0)-(2005,0.15)],(1970,0.0579),(1971,0.0606),(1972,0.0608),(1973,0.0634),
 (1974,0.0729),(1975,0.0759),(1976,0.0797),(1977,0.0842),(1978,0.0829),(1979,0.087),
 (1980,0.1099),(1981,0.1234),(1982,0.1177),(1983,0.1162),(1984,0.1211),
 (1985,0.1166),(1986,0.1093),(1987,0.1111),(1988,0.1188),(1989,0.1243),(1990,0.1276),
 (1991,0.1274),(1992,0.1251),(1993,0.1313),(1994,0.1265),(1995,0.1292),
 (1996,0.1305),(1997,0.1318),(1998,0.1311),(1999,0.1294),(2000,0.1351),(2001,0.1242),
 (2002,0.1145),(2003,0.1178),(2004,0.1167),(2005,0.12))

Units: dollars/(Seat*mile)

Table for Producer Price Index(

[(1970,0)-(2005,2)],(1970,0.369),(1971,0.381083),(1972,0.397917),(1973,0.45025),
 (1974,0.534833),(1975,0.584167),(1976,0.611333),(1977,0.64875),(1978,0.699417),
 (1979,0.78725),(1980,0.898083),(1981,0.980333),(1982,1.00017),(1983,1.0125),
 (1984,1.03675),(1985,1.0315),(1986,1.00167),(1987,1.02808),(1988,1.06942)

,(1989,1.12242),(1990,1.16292),(1991,1.16533),(1992,1.17192),(1993,1.18908)
,(1994,1.2045),(1995,1.24758),(1996,1.27683),(1997,1.276),(1998,1.24433),(1999
,1.25475),(2000,1.32742),(2001,1.34192),(2002,1.31117),(2003,1.38125),(2004
,1.46675),(2005,1.574))
Units: dmn1

Table for the Load Factor Experienced(
[(0,0)-(1.3,1)],(0,0),(0.9,0.9),(0.925,0.9175),(0.95,0.93),(1,0.95),(1.05,
0.9675),(1.1,0.98),(1.15,0.99),(1.2,0.9975),(1.25,1),(1.3,1))
Units: dmn1

Target Margin=
0.0327476
Units: dmn1

Target Percentage Above Cost=
0.671692
Units: dmn1 [0,1]
this is the level of profitability where airlines will no longer
raise fares

Ticket Price= INTEG (
Change in Ticket Price,
Initial Ticket Price)
Units: dollars/(Seat*mile)
This is the expected ticket price or the airlines

Time Horizon for Reference Demand=
3.85269
Units: Year

Time Required to Manufacture an Airplane=
2
Units: years [0,3]
This is the average lag before aircraft orders are delivered

TIME STEP = 0.015625
Units: Year [0,?]
The time step for the simulation.

Time to Adjust Capacity=
0.160743
Units: Year
This is the horizon over which the capacity adjustment is
evaluated

Time to Adjust Ticket Prices=
0.25

Units: Year [0,2]

This is how long it takes airlines to adjust prices to the level
suggested by the indicated price

Time to Cancel=
0.1

Units: years

This time constant controls how quickly orders of airplanes can
be canceled

Time to Change Worker Compensation=
0.703619

Units: years

Workers only negotiate their wages every few years, and so it
take time to wages to adjust to new conditions in the industry

Time to Mothball=
0.5

Units: years

this is how long it takes airlines to mothball capacity

Time to Percieve Changes in Demand=
0.218727

Units: Year [0,2]

This is how long it takes the industry to percieve changes in
demand and for their calculation of desired capacity

Time to Percieve Trend in Demand=
2.84796

Units: Year

Total Operating Costs=
Operating Costs from Passengers
Units: dollars/Year

Total Seat Miles Desired from GDP per Capita=
World Seat Miles Desired from GDP per Capita+Seat Miles Desired from GDP per
Capita

Units: Seat*mile/Year/people

Total Worker Salary by Type=
Average Worker Compensation*Total Workers by Type

Units: \$/Year

Total Workers by Type=
(Historical Airline Capacity*Switch for Historical Variables+(1-Switch for Historical Variables

)*Airline Capacity)*Workers Per Seat of Capacity

Units: worker

The airline industry employs this many workers, the variable is subscripted to represent the different types of workers. This formulation assumes that there is a constant number of workers of each type for every seat of capacity

Uc[Data]=

ZIDZ(dif cov[Data],MSE[Data])

Units: dmnl

Covariance inequality proportion

Um[Data]=

ZIDZ(dif mean[Data],MSE[Data])

Units: dmnl

Bias inequality proportion

Unit Equiv 1=

1

Units: \$(Seat*mile)

converts seat miles per year into dollars per year

Unit Equiv 2=

1

Units: (Seat*miles)/Year

converts \$/seat mile inot \$/year

Units Equiv 3=

1

Units: worker

Us[Data]=

ZIDZ(dif var[Data],MSE[Data])

Units: dmnl

Variance inequality proportion

Var X[Data]=

Sx[Data]*Sx[Data]

Units: (dollars/Year)*(dollars/Year)

the variance of the data

Variable Cost from Operations=

$(\text{Historical Available Seat Miles} * \text{Switch for Historical Variables} + (1 - \text{Switch for Historical Variables}) * \text{Available Seat Miles}) * \text{Variable Costs per Seat Mile}$
Units: dollars/Year
This is the variable cost of operations the airlines see

Variable Costs from Jet Fuel=
 $\text{Fuel Cost per Gallon} * \text{Gallons per Seat Mile}$
Units: \$/(Seat*mile)
This is the variable cost seen per dollar of jet fuel costs

Variable Costs per Seat Mile=
 $\text{Variable Costs from Jet Fuel} + \text{Other Variable Costs}$
Units: dollars/(Seat*mile)
This is the variable cost of running a seat for an hour

Wage Premium for Skill=
0.46
Units: dmnl
Each class of worker has particular skills or training that enable it to command higher wages than the average. Wages will still react to changes relative to the national average, but without this renormalization of the average wage our model would not have an equilibrium where pilots (for instance) made more than the average wage nationally.

Wage Relative to Average=
 $(\text{National Average Wage} / \text{Wage Premium for Skill}) / \text{Average Worker Compensation}$
Units: dmnl
The ratio of the average wage in the economy compared to the average wage of people in the airline industry

Wages per Available Seat Mile=
 $\text{Costs from Wages} / \text{Available Seat Miles}$
Units: dollars/(Seat*mile)

Weight on Demand Forecast Orders=
0.0671269
Units: fraction [0,1]
this is the weight that the industry places on forward looking demand forecasts

Weight on Supply Line Adjustment=
1
Units: fraction [0,1]
Allows for the industry to weight future supply adjustments

Whole Sample Standard Deviation[Data]=
2.978e+009,0.7461,0.0252,0.4961,0.404,826.06

Units: dmn1

Workers Per Seat of Capacity=
0.2

Units: worker/Seat [0.15,0.3]

The number of workers of each type is assumed to be a constant
fraction of the seats of capacity of the industry

World GDP per Capita=
World Historical GDP Data(Time-1)

Units: dollars/person

this is the GDP per capita in america

World Historical GDP Data(
[(1968,0)-(2008,6000)],(1969,2351),(1970,2444),(1971,2492),(1972,2574),(1973,
.2683),(1974,2682),(1975,2674),(1976,2749),(1977,2801),(1978,2861),(1979,2939
,(1980,2964),(1981,2959),(1982,2948),(1983,2962),(1984,3015),(1985,3061),(
1986,3108),(1987,3170),(1988,3262),(1989,3327),(1990,3375),(1991,3393),(1992
,3394),(1993,3391),(1994,3441),(1995,3496),(1996,3558),(1997,3628),(1998,3634
,(1999,3679),(2000,3789),(2001,3811),(2002,3838),(2003,3891),(2004,4002),(
2005,4094),(2006,4215),(2007,4334))

Units: dollars/person

This is the historical world GDP per capita expressed in real
2000 dollars

World Miles per Person per Dollar of GDP=
0.246414

Units: (Seat*miles)/(Year*\$) [0,0.5]

The number of miles per person demanded per dollar of GDP per
capita

World Seat Miles Desired from GDP per Capita=
World GDP per Capita*World Miles per Person per Dollar of GDP

Units: Seat*miles/person/Year

This variable adjusts demand based on the affect of changes in
consumer income compared to a reference level

X[Data]=
Historical[Data]

Units: dollars/Year

The historical data input

Xi[Data]=

$\text{pick}[\text{Data}] * X[\text{Data}]$
Units: dollars/Year
The historic data series

$Y[\text{Data}] =$
 $\text{Simulated}[\text{Data}]$
Units: dollars/Year
The simulated data series

Yearly increase in Desired Load Factor=
0.0061
Units: dmnl/Year

$Y_i[\text{Data}] =$
 $\text{pick}[\text{Data}] * Y[\text{Data}]$
Units: dollars/Year
Sampled simulated variable