(c) Examine the shadow prices on all of the constraints. What do they tell you about the solution?

(d) Construct the **efficient frontier** of the portfolio. In order to do so, you will need to run the model for a variety of different values of the right-hand-side (RHS) of the standard deviation constraint. Plot the standard deviation as the independent variable (on the horizontal axis) and the maximized expected annual return as the dependent variable (on the vertical axis).

Part II

(e) Modify the model to incorporate the effects of transaction costs (at a cost of 0.5% of the transactions for both purchases and sales) and to incorporate the constraints that the maximum change in any asset's portfolio weight from the previous quarter should be ±15%.

(f) What are the optimal portfolio weights for next quarter? What is the expected annual return of the portfolio? How do these numbers differ from your answers in Question (b)?

(g) Examine the shadow prices on all of the constraints. What do they tell you about the solution? Again, how do the shadow prices differ from those in Question (c)?

(h) Create the **efficient frontier** of the portfolio. As before, run the model for a variety of different values of the right-hand-side (RHS) of the standard deviation constraint. Plot the standard deviation as the independent variable (on the horizontal axis) and the maximized expected annual return as the dependent variable (on the vertical axis).

(i) How is the efficient frontier different from your answer to Question (d)?

(j) Based on the model, what portfolio weights would you recommend for the Endurance Private Client Fund?

CAPACITY INVESTMENT, MARKETING, AND PRODUCTION AT ILG, INC.

Mr. Nelson Stein is the Chief Executive Officer of ILG, Inc., an engineering company that he founded almost a decade ago. ILG was an early player in the market for network routers and over the years ILG has acquired a well-deserved reputation for developing innovative networking products and bringing these products to the market very quickly and profitably. However, owing in part to its own success, the market for network routers and related technology is now quite competitive.

ILG has recently developed a new product, tentatively called the "Speed-demon" by the marketing department, that is able to speed up its network routers by a factor of ten or more. Nelson Stein felt that in order to be successful with Speed-demon, ILG would need to take care to coordinate capital planning, manufacturing, and marketing strategy for the new product. He therefore convened a meeting with Jonathan Barr, vice president of manufacturing at ILG; Jenny Thompson, vice president of marketing at ILG; Richard Bradley, chief financial officer at ILG; and Bill Zender, a member of Nelson Stein's staff who is also a recent business school graduate.

In the meeting, Nelson Stein first asked Jonathan Barr about cost estimates for building production capacity for Speed-demon. Jonathan Barr reported that since the technology required to produce Speed-demon is brand new, none of ILG's current production capacity could be used to produce the product. Using cost data from several of ILG's previous new capacity construction projects as the basis for a nonlinear

regression model to forecast cost and capacity, Jonathan Barr's staff has estimated the cost of new capacity as follows: If x_1 is the amount of money (in dollars) invested in new capacity to produce Speed-demon in the first year, then the annual production capacity for the first year is estimated to be

$$c_1 = \frac{x_1}{200} + \sqrt{x_1}.$$

For example, if the company were to invest x_1 = \$1,000,000 in the first year on new capacity for Speed-demon, then the company would have the capacity to produce up to

$$\frac{1{,}000{,}000}{200} + \sqrt{1{,}000{,}000} = 6{,}000 \text{ units per year.}$$

Jonathan Barr expected that the cost of the required production technology will decrease over time, and thus it will be less expensive to expand capacity for Speed-demon in the following year. Jonathan Barr's staff has estimated that in year two, the same amount of investment would lead to 30% more capacity than in year 1. For example, if the company were to spend x_2 = \$1,000,000 at the beginning of the second year, then the production capacity added in the second year would be 7,800 = 1.30 × 6,000 units per year. Nelson Stein asked Jonathan how confident he felt about these cost/capacity estimates. Jonathan responded that he was confident overall, but that there was the most uncertainty about the 30% increase that he quoted for the second year. He explained that this number could vary between 20% and 35%.

Jenny Thompson then reported on the marketing analysis for Speed-demon. She estimated that there would be a demand for 4,000 units in the first year of production, even if ILG were not to expend any money on marketing promotions for the new product. She also added that her staff had estimated that every additional \$400 spent on promotions for Speed-demon at the beginning of the first year would increase the demand by one unit. Regarding the second year of the product's life, she estimated that even if no money is spent on promotions at the beginning of the second year, the demand during the second year would be 75% of the demand during the first year. She also felt that a promotion strategy in the second year would be more cost-effective, as the new product would have already achieved some acceptance in the market. Her staff estimated that every \$300 spent on promotions of the product at the beginning of the second year would lead to an incremental demand of one unit. Once again, Nelson Stein asked Jenny Thompson how confident she was in her staff's analysis. Jenny Thompson responded that she was most uncertain about the 75% number. This was her staff's best estimate, but she felt that the number could be as low as 60% or as high as 90%.

Richard Bradley then presented his estimates of profit margins. The finance group estimated that variable profit (that is, revenue minus variable production costs) for the first year would be \$800 per unit sold. This number did not account for capacity investment costs or the cost of marketing promotions. The variable profit for the second year would be \$850 per unit sold (again not including any additional investment cost in capacity or in marketing promotions). Due to the rapid changes in the market, everyone at the meeting understood that units produced during the first year would not have any sale value in the second year of the product life-cycle.

Nelson Stein decided that given the overall strategy of ILG, he was prepared to commit up to \$2 million in capital to finance capacity construction/expansion and product promotion for Speed-demon. He also added that profits from units sold during the first year, as well as unspent funds from the first year, could be used to finance capacity expansion and product promotion for the second year. As he left the meeting, Nelson Stein instructed Bill Zender to prepare a recommendation for a