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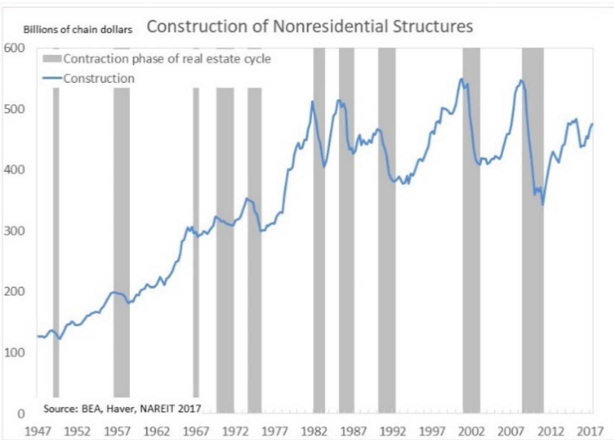
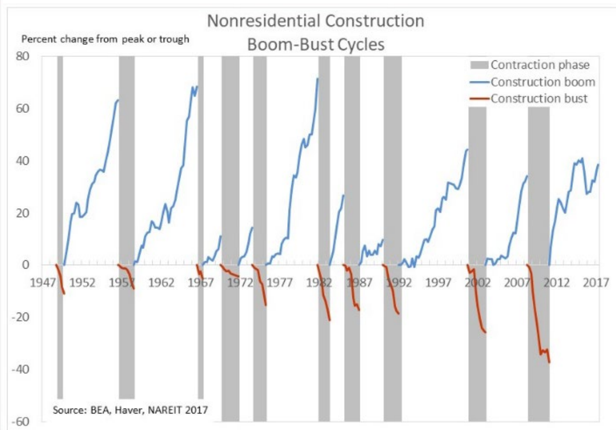
EAS 550/STRATEGY 566: Systems Thinking for Sustainable Development and Enterprise

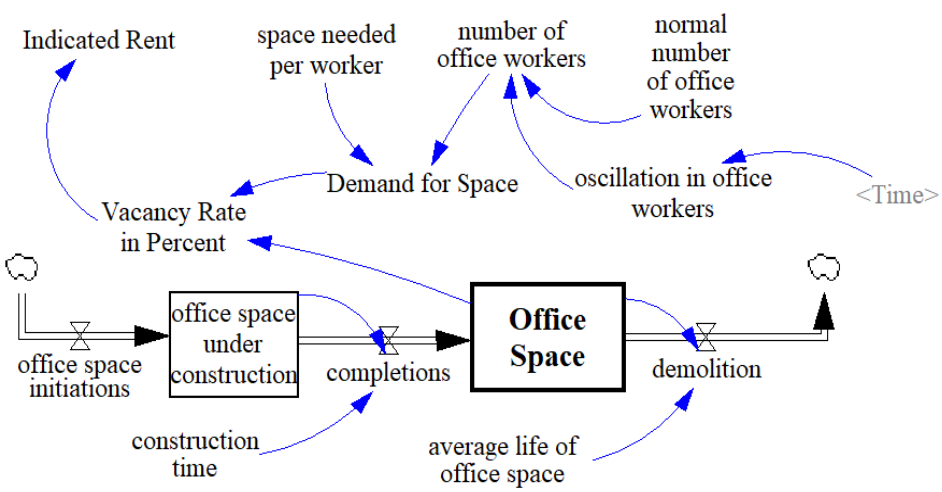
Lab 7 Modeling Real Estate Construction
Questions are in purple.

Commercial real estate has gone through many boom-bust cycles in the past (see figures below). What caused it? We will build a system dynamics model to understand the ups and downs of the real estate market.





1. **Cycles in rent from external factors**
   The create a model in Vensim using the details provided below:



   a. Vacancy rate determines the rent
      Indicated rent ($\$/ft^2$) = lookup (vacancy rate)
      (0%,80),(5%,40),(10%,30),(15%,25),(20%,22),(25%,20),(30%,18),(35%,16),(40%,15),(100%,15)
   b. Vacancy rate = 100*((office space - demand for space)/office space)
      i. Demand for space = number of office workers × space needed per worker
      ii. Space needed per worker = 100 ft^2/worker

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iii. Number of office workers = normal number of office works + oscillation in office workers

iv. Normal number of office workers = 900,000

v. We can use function SIN to give an oscillation to the number of workers: Oscillation in workers = 40000*SIN(Time/2)

c. Office space initiation = 2,000,000 ft^2/yr

i. Initial office space under construction = 4,000,000 ft^2

ii. Completions = office space under construction/construction time

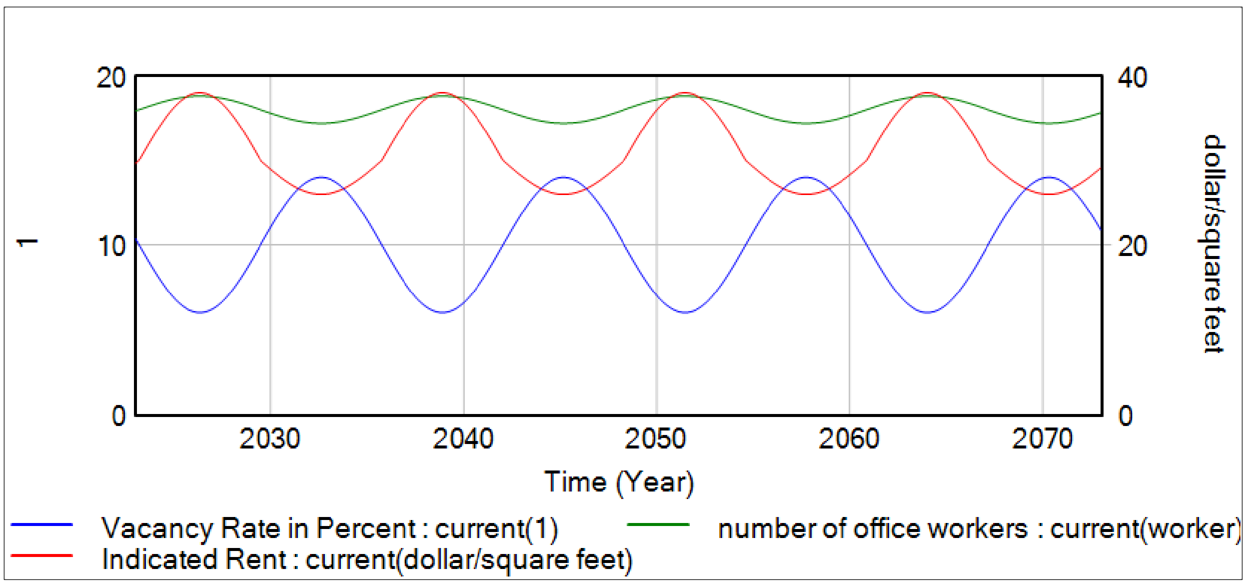
iii. Initial office space = 100,000,000 ft^2

iv. Construction time = 2 yrs

v. Average life of office space = 50 yrs

vi. Demolition = Office space / average life of office space

Question: Run the model for a 50-year time period, using a time step of 0.125. Paste a graph showing how "Vacancy Rate in Percent", "Indicated Rent", and "number of office workers" change over the simulation. In 2-4 sentences, explain how the behavior of these variables compare to one another over time.



Vacancy rate in percent has an opposite vibrant against indicated rent and number of office workers, while the latter two shares similar changes of going up and down over time. As number of office workers increases, demand for space also increases because it is composed of the product of a fixed number of space needed per worker and changeable number of office workers. The increase of demand for space results in the decrease in vacancy rate in percent, which has a negative relationship with indicated rent, and thus indicated rent has a positive relationship with demand for space and number of office workers. There seems to be no delay among the vacancy rate in percent, indicated rent, and number of office workers as the peaks and the troughs are presented at similar time steps.

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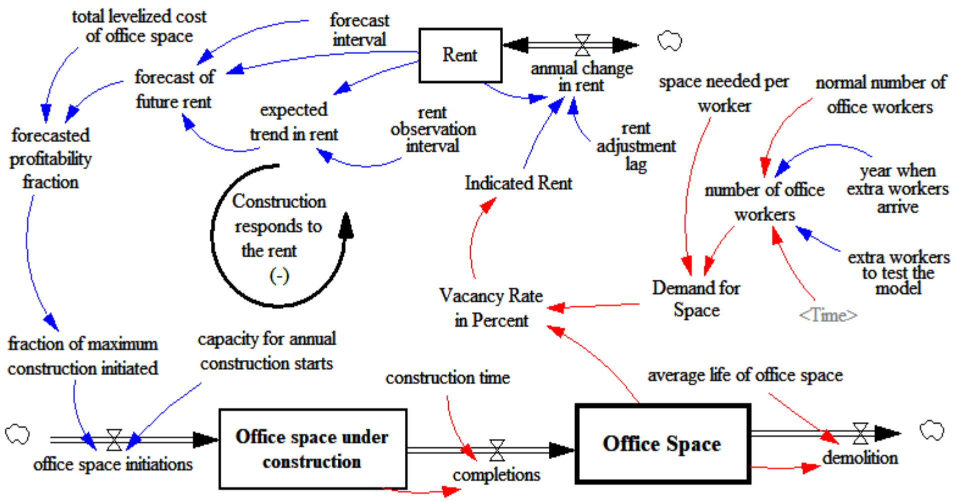
2. **Construction responds to the rent**

   Add to your model from part one using the details provided below. Arrows in red indicate they are part of the previous model. For reference, instructions for creating a two-way flow (as seen in "annual change in rent") can be found here: https://www.vensim.com/documentation/20325.html

   Note: When using a two way flow the equation for rent should be "annual change in rent," *do not subtract!*



   a. Actual rent takes some time to fully respond to changes in vacancies
      i. We assume it takes 2 years for the rent to follow the indicated value
         a) rent adjustment lag = 2 yrs
      ii. The annual change in rent is a dynamic adjustment
         a) annual change in rent = (Indicated Rent-Rent)/rent adjustment lag
      iii. initial value of Rent = \$30 per ft^2
   b. Forecast of future rent
      i. Developers follow the past rents over a 2-year observation interval to ascertain the trend.
         a) Rent observation interval = 2 yrs
         b) Expected trend in rent = TREND(Rent, rent observation interval , 0)
            a. TREND (input, average time, initial trend) returns the fractional change rate of I over horizon H starting with N
      ii. The trend is then used to look ahead 2 years to prepare a forecast of the rent about the time that new projects would become available for occupancy.
         a) Forecast interval = 2 yrs
         b) Forecast of future rent = Rent*(1+expected trend in rent*forecast interval)
   c. Profitability drives the construction
      i. Total levelized cost of office space = \$28 per ft^2
      ii. Forecasted profitability fraction = (forecast of future rent-total levelized cost of office space)/total levelized cost of office space
      iii. Fraction of maximum construction initiated = lookup (Forecasted profitability fraction)(-

1,0),(0,0),(0.05,0.05),(0.07,0.1),(0.1,0.2),(0.2,0.5),(0.3,0.7),(0.4,0.85),(0.5,0.9),(0.8, 0.95),(1,1)

iv. Office space initiations = fraction of maximum construction initiated*capacity for annual construction starts

v. Capacity for annual construction starts = 20,000,000 ft^2

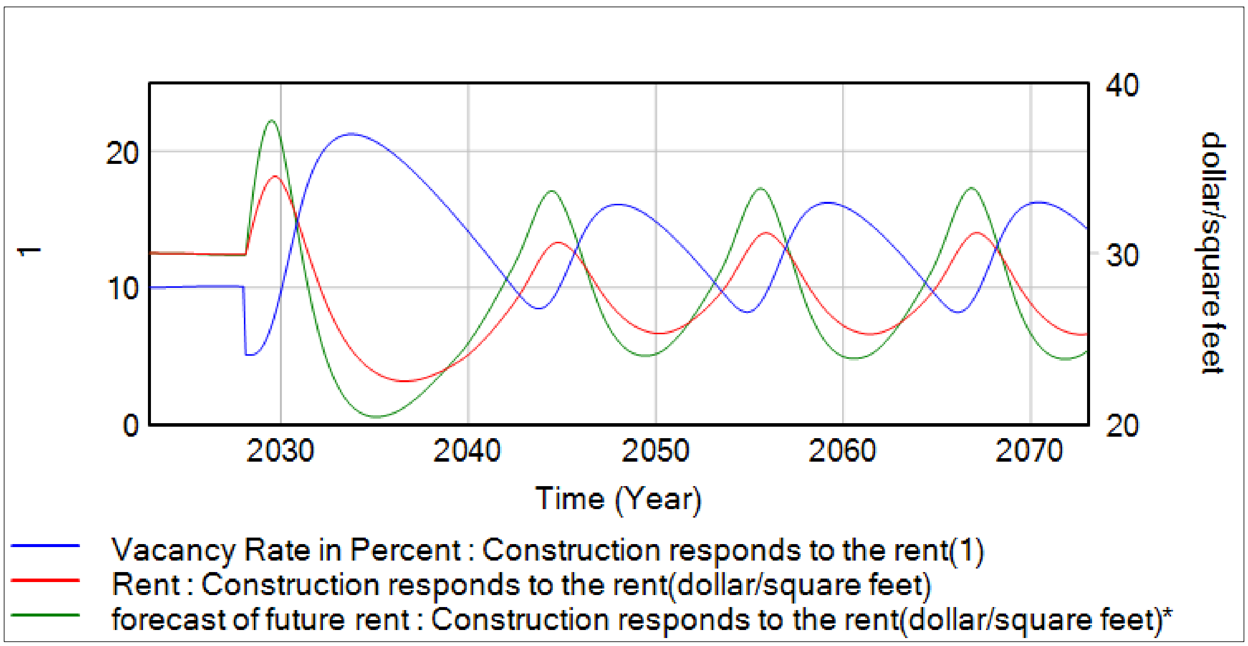
d. Modify number of workers

i. Create an increase of 50,000 workers starting in the 5th year using the two new variables “year when extra workers arrive” and “extra workers to test the model” shown in the stock and flow diagram above.

a) Use the IF THEN ELSE function to define "number of office workers" as follows: normal number of office workers + IF THEN ELSE(Time>year when extra workers arrive, extra workers to test the model, 0)

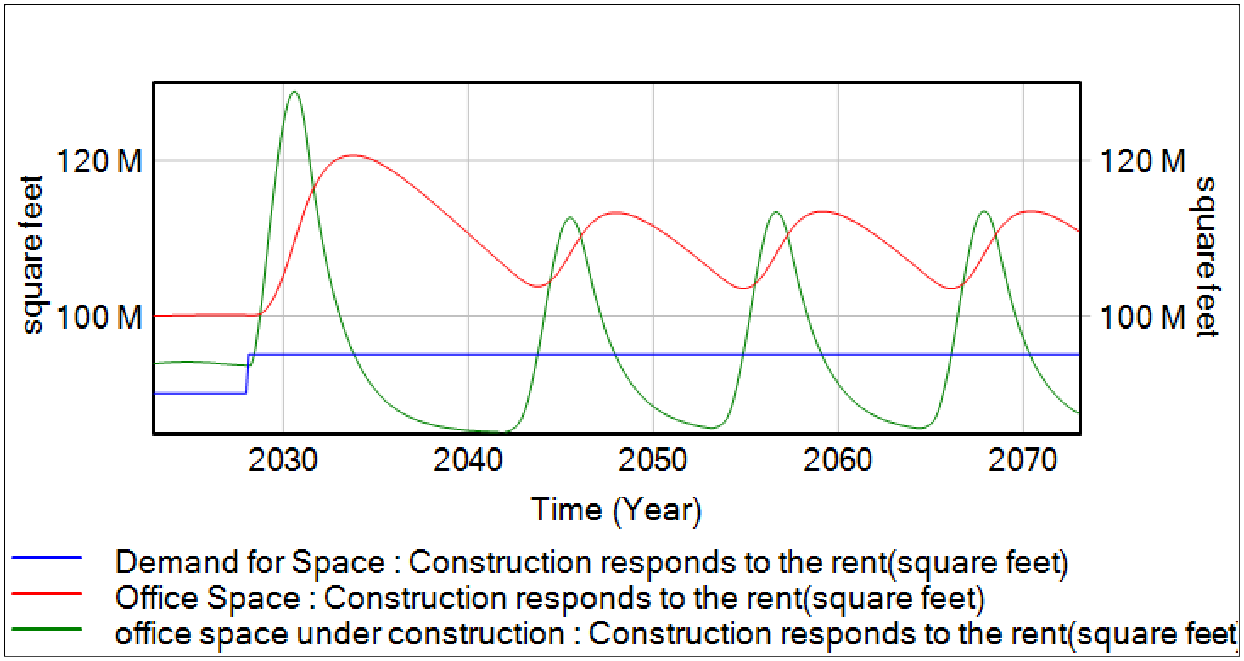
b) Confirm with a peer that you understand how this syntax illustrates the addition of 50,000 workers starting in the 5th year.

Question: Paste a graph below showing the changes of “Vacancy Rate in Percent”, “Rent”, and “forecast of future rent” over 50 years. Paste **another** graph showing the changes of “Demand for Space”, “Office Space”, and “Office space under construction” over 50 years. In 2-4 sentences, explain how the behavior of these variables compare to one another over time.



There seems to be a sequence among these three variables: vacancy rate changes first, forecast of future rent then reacts to the changes, and they are both followed by changes in rent. Vacancy rate has negative relationships with both rent and forecast of future rent. Before the 5th year, which is 2028 in my simulation, forecast of future rent as well as rent decrease gradually, while vacancy rate in percent increases slowly over time. When it comes to the 5th year when extra workers are introduced to the office, the changes are obviously seen: vacancy rate decreases greatly while forecast of future rent and rent increase steeply. After the great changes, when office space changes due to completion and

demolition, the vacancy rate changes accordingly and is followed by forecast of future rent and the actual rent in opposite directions. The volatilities are smaller but stable each time after a great increase/decrease and a greater decrease/increase between years of 2028 and 2038.



Demand for space remains stable except for a sharp increase in the 5th year when 50,000 more workers are introduced to the office. Office space under construction increases tremendously after more workers exist in the office since vacancy rate decreases and forecast of future rent increases while total levelized cost of office space remains stable. Followed by the changes of office space under construction is the positive reactions of office space, which performs about 2-year later after office space under construction has changed.

To conclude the changes presented in the two graphs, the change cycles among these six variables start from the increase of demand for space and vacancy rate. Forecast of future rent and rent then follow the changes in the aforementioned order but with opposite outcomes. Office space under construction and office space are the last to follow the trends. They show similar directions of outputs with forecast of future rent and rent.

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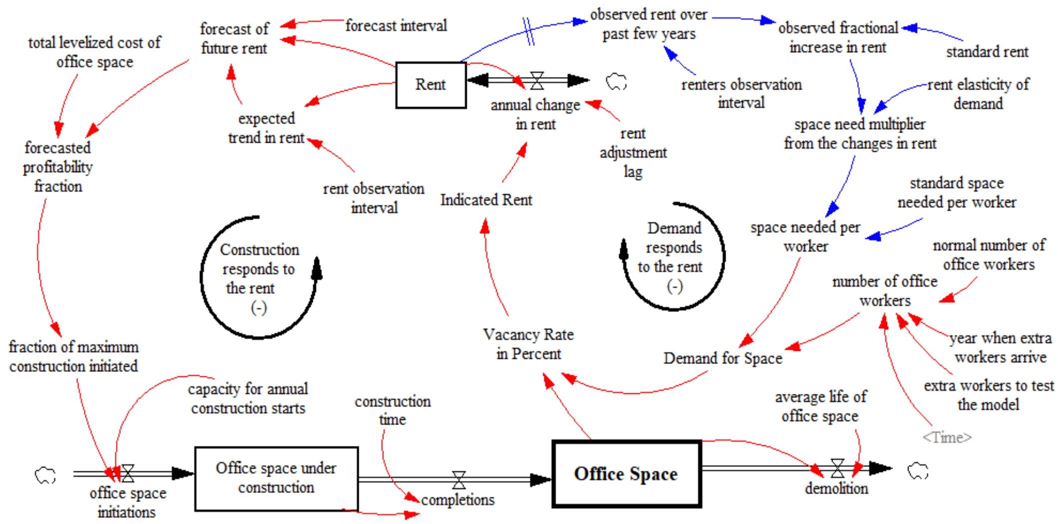
3. Supply and demand responses to rent

Higher rents can induce the companies to make some changes in the space per worker, but the companies do not necessarily want to change their way of doing business unless higher rents appear to be a permanent problem. Add to your model from part two using the details provided below. Arrows in red indicate they are part of the previous model.



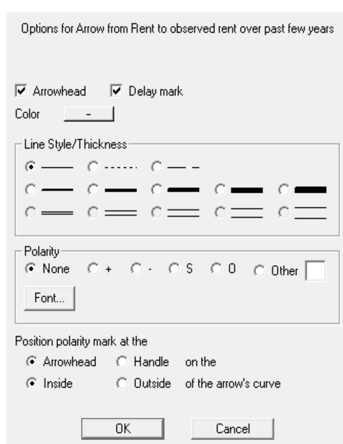
a. If we observe the rent over a **5-yr interval**:

i. Define "Observed rent over past few years" using the SMOOTH function. Write the equation you chose below:

$$\boldsymbol{observed\ rent\ over\ past\ few\ years = SMOOTH(Rent, renters\ observation\ interval)}$$

(unit : dollar/square feet)

ii. The 2 lines going across this arrow in the stock and flow diagram above indicate a delay mark. Insert a delay mark to visually indicate where delays occur by right-clicking on the arrow and checking the "Delay mark" box when this dialogue pops up:



b. Observed rent is compared with a standard rent (\$30 per ft^2) to determine space needed for workers.

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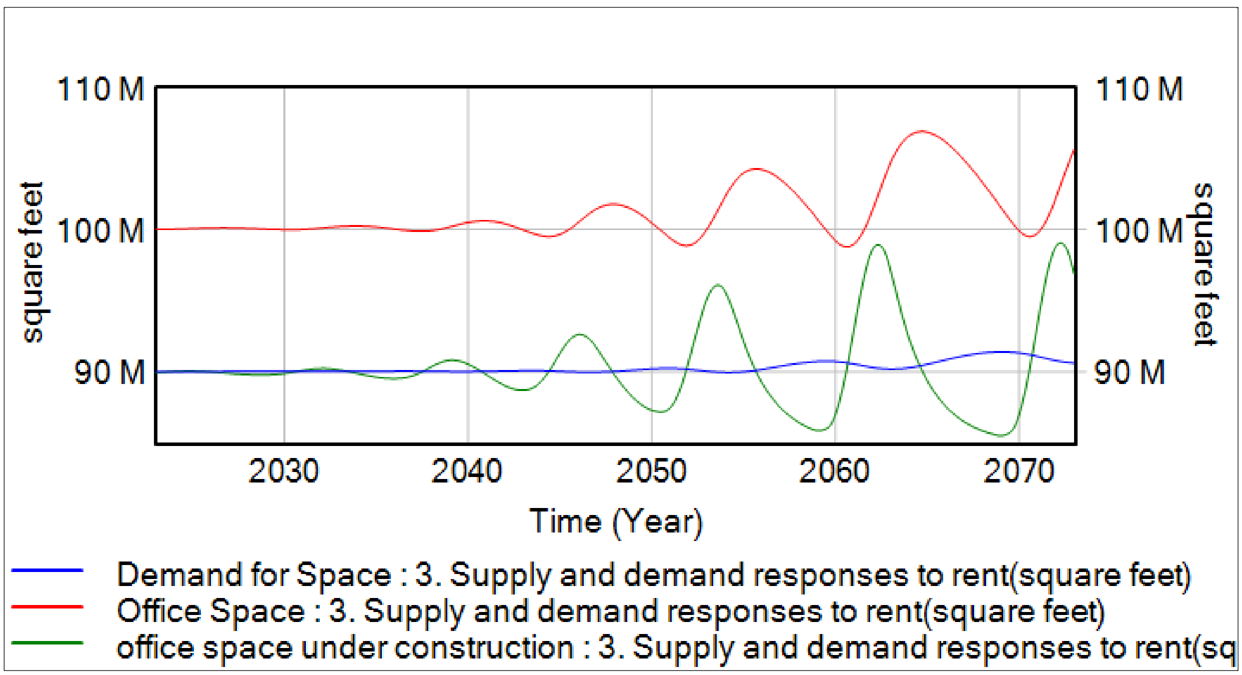
i. Observed fractional increase in rent = (observed rent over past few years-standard rent)/standard rent

c. The demand response tends to be slow (owing to the 5-yr observation interval) and weak elasticity of demand
   i. Rent elasticity of demand = -0.2.
      a) This means 100% increase in rent will lead to a 20% reduction in the office space needed per worker
   ii. Space need multiplier from the changes in rent = 1+observed fractional increase in rent*rent elasticity of demand
d. Changes to space needs
   i. Standard space needed per worker = 100 ft^2/worker
   ii. Space needed per worker = standard space needed per worker * space need multiplier from the changes in rent (units: ft^2/worker)
e. Change the values of "year when extra workers arrive" and "extra workers to test the model" to 0.

Question: Paste a graph showing changes of “Demand for Space”, “Office Space”, and “Office space under construction” over 50 years.



Question: Reintroduce the 50,000 extra workers in year 5. What are your results for “office space”, “demand for space”, and “office space under construction”? Provide a graph of your model results below. In 3-4 sentences, explain how the cycle of office space under construction in this model (considering the addition of demand response) compares to your results from the second model in terms of volatility and overall behavior pattern.

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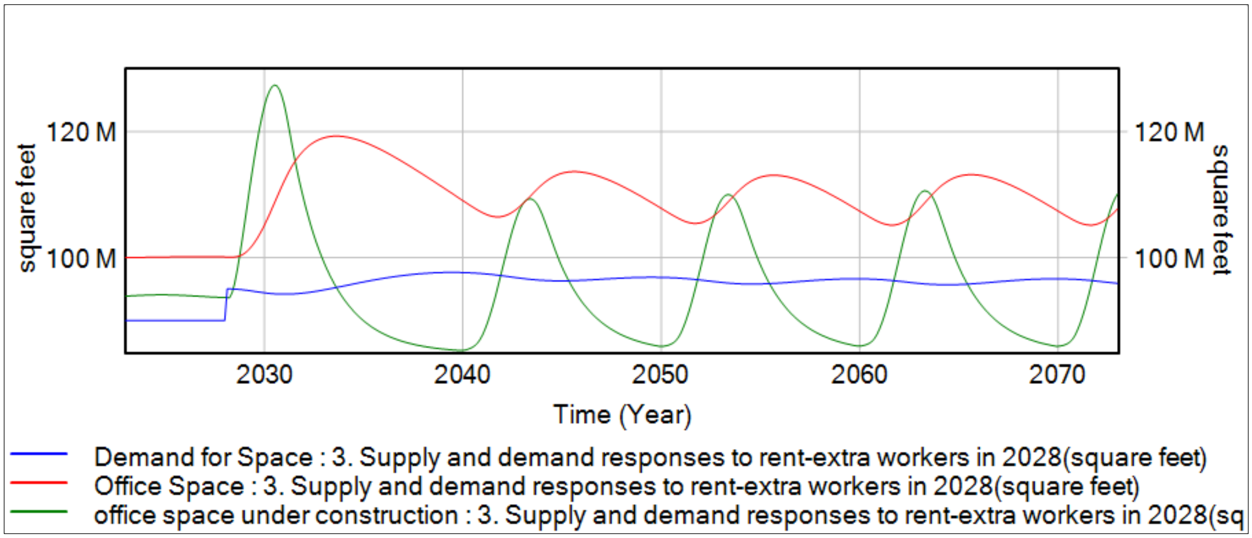
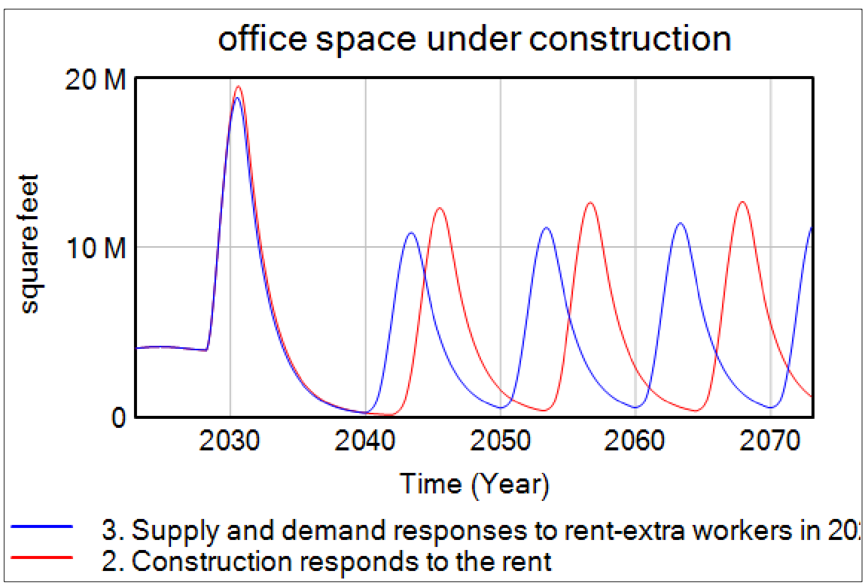


Demand for space has a small vibrant after the sharp increase in the 5th year when 50000 more workers are introduced to the office, contrary to staying stable in the second model. Office space under construction increases tremendously after more workers exist in the office since vacancy rate decreases and forecast of future rent increases while total levelized cost of office space remains stable. Followed by the changes of office space under construction is the positive reactions of office space, which performs about 2-year later after office space under construction has changed. Comparing to the second model, office space in this model is slightly higher than in the second model; office space under construction is slightly lower in this model over the second model.



Office space under construction remains similar between the second and the third models in terms of trends of changes. Before the extra workers are introduced, the two lines are completely aligned. But with rent elasticity of demand that effects office space needed per worker by changes in rent (i.e. model 3), changes in office space under construction take place earlier, and the vibrant is smaller with lower peaks and higher troughs.

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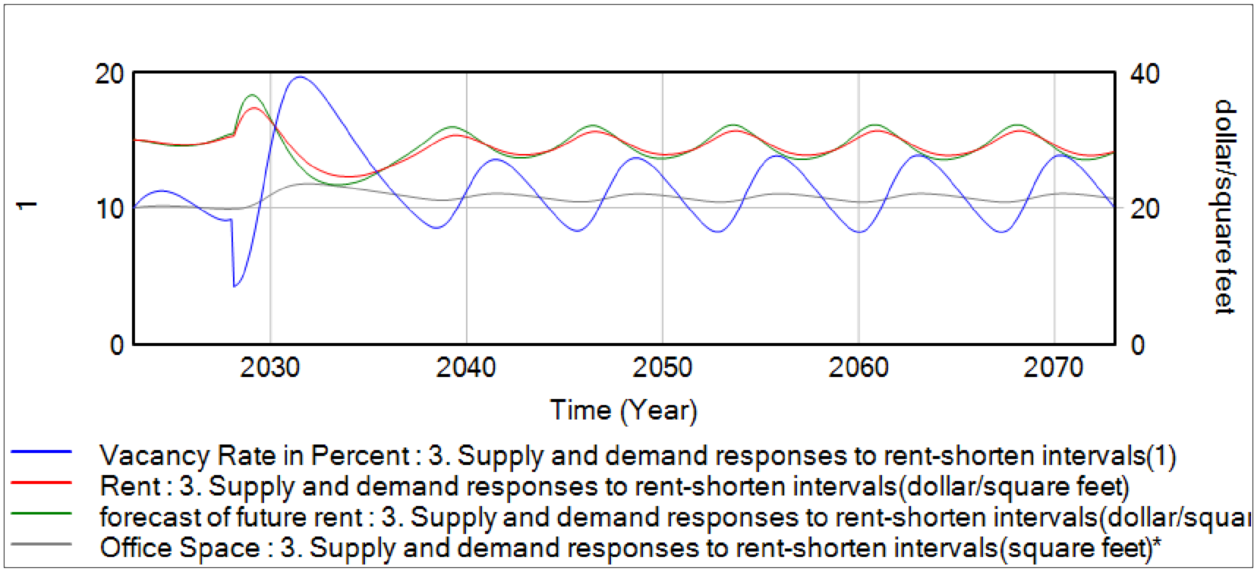
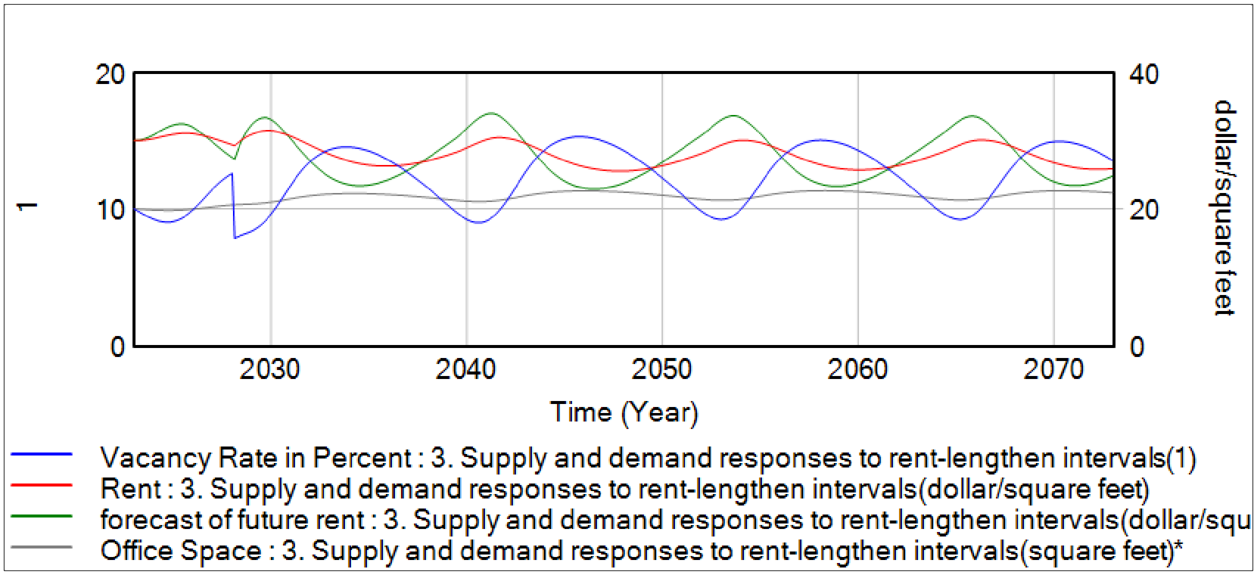
Bonus Point Question [Optional]: How will vacancy rate, rent, forecast of future rent, and office space change when you change the forecast interval, construction time, and renters' observation interval? Provide your results and reasoning below.

Changes of vacancy rate, rent, forecast of future rent, and office space when I shorten the forecast interval, construction time, and renters' observation interval:



Changes of vacancy rate, rent, forecast of future rent, and office space when I lengthen the forecast interval, construction time, and renters' observation interval:



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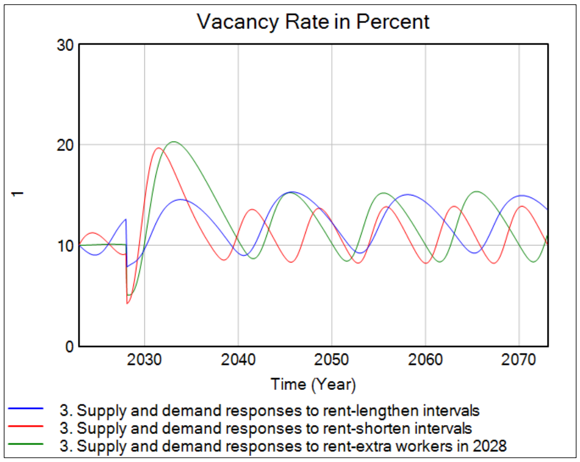

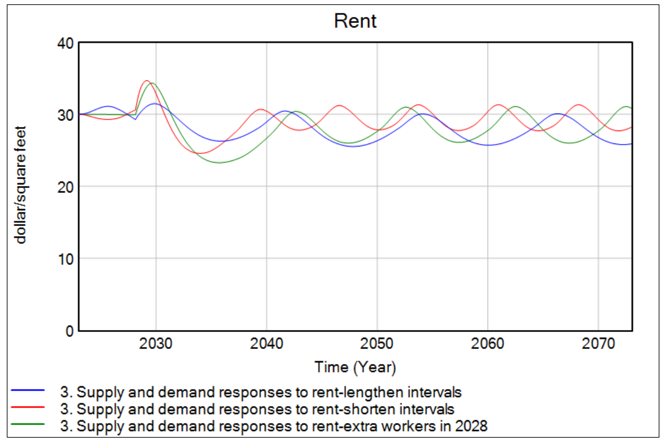

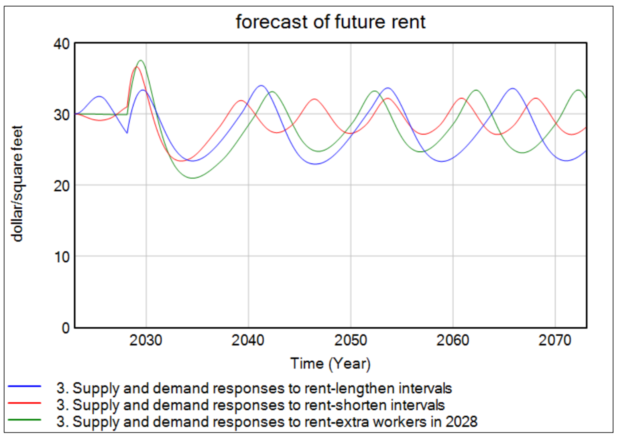

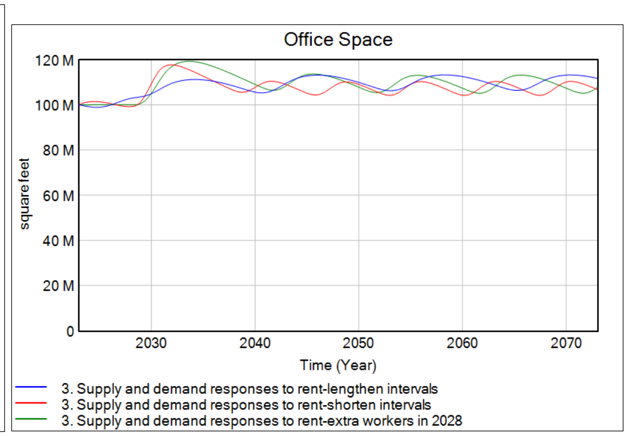

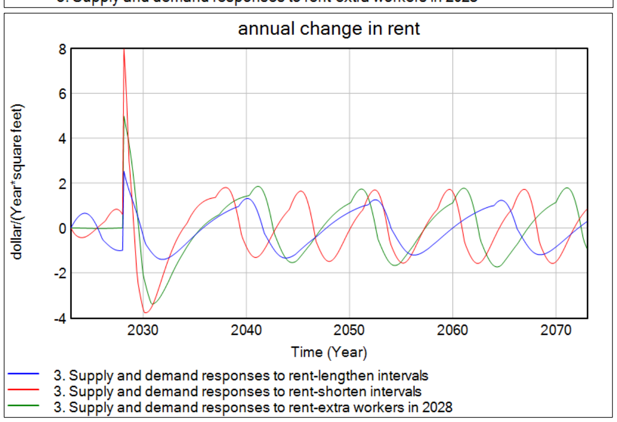

If I shorten the time of forecast interval and construction time by half to 1 year instead of 2, and renters' observation interval to 2 years instead of 5, each of the variable will be resulted in earlier changes; annual change in rent and vacancy rate also come with greater changes before more workers are introduced to the office. The changes happening earlier after shortening the intervals are foreseeable since it takes shorter to construct office space, and the observation of rent is reported more often. However, the greater floating in annual change in rent and vacancy rate before extra workers are presented is out of my expectation. Since renters' observation interval was 5 years before shortening, which meant that the second time when rent was observed by renters, more workers were also introduced to the office. Thus, the changes of rent, annual change in rent, and the other

three variables affected by rent were not significant before the personnel change. This theory can be side prove by the first significant change that takes place in the 3rd year in annual change in rent.
Lengthening the forecast interval, construction time, and renters' observation interval not only postpones the changes in each variable, but the time of delay is also lengthened in the latter cycles. The equilibriums before extra workers are introduced are also broken. The changes come with opposite directions against those of shortening the intervals.