# Documentation Notes:

* Variable names are italicized (Example: *Medical Technology Solutions*)
* View/Sector names are all caps (Example: PO VISIT RATE)
* Parameter tables have “last updated” date
* In Recommendations, number in parenthesis is estimated difficulty of modification on a scale of 1-10. Recommendations which involve significant research are not rated.

# Module: Visit Rate

## Purpose:

The Visit Rate module tracks medical visit rates in units of visits per person per year for the physician office (PO), emergency department (ER), outpatient (OP), and inpatient (IP) venues. A nearly identical structure is used to track inpatient length of stay (LOS) in units of days per visit. Visits rates are somewhat of an abstraction in that they combine the notions of visits per year and services provided per visit. This must be kept in mind when comparing or calibrating against reported visit rates.

## Uses:

* PO VISIT RATE
* ER VISIT RATE
* OP VISIT RATE
* IP VISIT RATE
* LENGTH OF STAY

## Diagram:



Figure 1: Diagram of Visit Rate / LOS sectors
\*\* denotes variables that do not appear in all sectors

## Summary:

The sector calculates an instantaneous indicated visit rate by adjusting the initial rate with factors accounting for changes in the aggregate level of medical technology, the effect of managed care (MCO) initiatives to limit visit rates, and changes in medical malpractice premiums. Improvements in technology encourage visits by those who may be afflicted by newly-treatable ailments, while also decreasing the required inpatient length of stay and shifting some previously inpatient procedures to outpatient venues. MCO visit initiatives attempt to limit visit rates, but may face consumer and provider pushback. Note that the current model structure does not include an endogenous linkage between initiatives and pushback. When malpractice premiums are rising, doctors increase the standard of care both to defend against lawsuits and to offset costs. By increasing the standard of care, they perform more tests and procedures, which increase visit rate.

The indicated rate is harmonized with the measured *XX Visit Rate* over time. In the physician office venue only, the actual visit rate cannot exceed the physician supply-limited rate.

The indicated visit rate is determined in the following manner:

*indicated XX visit rate*[[1]](#footnote-1)= ( 1 + *MMO premium trend effect on utilization* \* *weight on MMO premium trend effect on XX visit rate* ) \* MAX ( ( *technology adjusted XX visit rate* – ( *XX visit initiative effect* – *XX Consumer Response*†† – *XX Initiative PreAuth Implemented*†† ) \* *XX visit initiative effectiveness* ) , *minimum XX visit rate* )

* For policy-testing purposes, minimums will generally be set so as not to interfere with system behavior.
* †† denotes variables that are not present in all sectors and/or whose sign differs by sector. See below for details.

The dynamic influences on the *indicated XX rate* are the following:

* ***Cumulative Medical Technology Trend*** [MEDICAL TECHNOLOGY] – There are many health conditions for which there is no treatment or the remedy is judged to be less desirable than the condition itself. As medical technology (pharmaceutical or otherwise) improves, more conditions can be effectively treated. This spurs some affected individuals to visit the doctor for treatment. In this way, technological progress encourages higher visit rates across most of the health care industry. On the other hand, medical advances decrease the invasiveness and required healing time of many procedures, decreasing average length of stay and allowing some inpatient procedures to shift to outpatient care.
	+ In three of four venues modeled (PO/ER/OP), a change in *Cumulative Medical Technology Growth* produces a change in the *technology adjusted XX visit rate* and the *indicated XX visit rate* in the same direction.
	+ A change in *Cumulative Medical Technology Trend* produces a change in technology adjusted IP visit rate / LOS and indicated IP Visit Rate / indicated LOS in the opposite direction.
* **(PO/ER/OP/IP visit/LOS) initiative effect** – In order to limit reimbursement costs, insurers implement policies and restrictions to reduce patient visits and billed procedures. Tactics include copay/co-insurance increases and restrictions on specialist visits without PCP approval. Many initiatives that limit coverage of high-priced drugs, procedures, or physicians may also curb visit rates, as users will not bother going to the doctor if they do not expect to have their desired treatment covered by insurance.
	+ A change in *XX initiative effect* should produce movement of the visit/LOS rate in the opposite direction.
	+ Influenced by instantaneous level of *XX Initiatives* [from XX VISIT INITIATIVES] and delayed *Perceived XX Initiatives*, weighted according to *weight on XX initiative delay*.
* ***MMO premium trend effect on utilization*** [MMO PREMIUM] – Higher medical malpractice insurance premiums strengthen the incentive to avoid malpractice claims, increasing pressure on physicians to improve the standard of care when premiums increase (defensive medicine). This may manifest in physicians ordering more tests and procedures, which is abstracted as an increase in visit rate. Physicians also make an effort to increase patient load in order to offset the financial cost of higher premiums. All these factors are assumed to work in the opposite direction if premiums decrease. Note that providers are assumed to decide on the standard of care based on the trend rather than level of MMO premiums. This means that it is possible to indefinitely maintain equilibrium in the *XX Rate* despite a constant non-zero premium trend. An alternate assumption replace this formulation with a relationship based on cumulative MMO premium change.
	+ A change in *MMO premium trend effect* should cause a movement of the visit/LOS rate in the same direction.
	+ All sectors share a single *MMO premium trend effect* variable.
	+ *MMO premium trend effect on utilization* utilizes a SMOOTH of the output of the graphical lookup function *MMO premium revenue trend effect on utilization f*, shown in Figure 2.
	+ The lookup takes *MMO premium revenue trend* as input. The range is [-0.1, 0.66]. The graph shape suggests that providers react more strongly to premium increases than decreases. This follows on the assumption that if MMO premiums are stable, physicians generally follow best practices (i.e. low incidence of defensive practice), meaning that there is little excess to eliminate if premiums decline.



Figure 2: Lookup function *MMO premium trend effect on utilization f*.

* ***(PO/ER/OP) Initiative PreAuth Implemented*** [XX VISIT INITIATIVES] – This variable mainly exists to account for historical movements in visit rates due to changes in insurance policies requiring pre-authorization as a prerequisite for the indicated visit types.
	+ There is no preauthorization initiative in the inpatient sector because inpatient referral is considered a sacred physician privilege.
	+ A change in *XX Initiative PreAuth Implemented* should produce movement of the visit rate in the opposite direction in the ER VISIT RATE sector but in the same direction in the PO VISIT RATE and OP VISIT RATE sectors.
		- When pre-authorization initiatives were implemented, patients still desired the same treatment options. Rather than be deterred by a pre-authorization rejection for further treatment, they would often return to their physician to get another referral/prescription that would be approved by their insurer. This had the aggregate effect of increasing physician visits in both office and outpatient settings.
		- On the other hand, ER preauthorization requirements had the intended effect of reducing the visit rate – it was effective enough, in fact, to prompt legislative action restricting the practice.
	+ Note that the model does not explicitly demonstrate any particular chain of events – the *PO Initiative PreAuth Implemented* stock is somewhat of a ”black box.” Furthermore, the strength and timing of such pre-authorization initiatives is fully exogenous.
	+ Variable chain is largely unused in policy testing mode due to exogenous nature.
* ***(PO/IP) Consumer Response*** [XX VISIT INITIATIVES] – As MCOs impose restrictions on coverage of physicians, pharmaceuticals, and procedures, consumers and providers try to find work-arounds which preserve their original level of care and provider income as much as possible. This should tend to increase visit rates above what they would be otherwise. Note that the model structure does not require *XX Consumer Response* to operate in conjunction with *XX Visit Initiatives* – the strength and timing of the former is determined separately and exogenously.
	+ The *XX Consumer Response* variable only appears in the PO VISIT RATEand IP VISIT RATE sectors.
	+ A change in *XX Consumer Response* should produce movement of the visit rate in the same direction.
	+ As with the preauthorization initiative, this variable is primarily used to improve data calibration and account for historical events in forecasting mode – because of its exogenous nature, it will generally not be used in policy-testing mode.
	+ Could be made endogenous – see sector recommendations.

In the PO VISIT RATE sector only, there is a switch to limit visit rate to available physician capacity. Because personnel can be drawn away from private practice to address hospital shortages, the hospital venues are less likely to be impacted by physician scarcity and thus lack this switch.

* ***physician limited office visit rate*** – *PO Visit Rate* is determined by either *indicated PO visit rate* or *physician limited office visit rate* – whichever is larger. The latter variable calculates the maximum visit rate so that the dynamic ratio of total annual visits to practicing physicians cannot exceed the initial value of this ratio. A side effect of this formulation is that the system cannot be initialized with a physician shortage. Due in part to the lack of modeled population health status, a physician supply shortage has no effect on any other variables, though the ratio of *indicated PO visit rate* and *physician limited office visit rate* can be considered a system performance metric.
	+ switch on physician supply constraint: 1 = ON; 0 = OFF
	+ Takes crude physician supply constraint [PHYSICIANS] as input.

## Sector Inputs:

### From other sectors:

See variables listed under Summary heading.

### Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Values / Restrictions** | **Source** | **Notes** |
| **PO** | **Other** |
| *initial actual XX visit rate* | positive | Data | Vensim Data-type variable. |
| *minimum XX visit rate* | positive | Calibration | Minimum rate before MMO trend effect.  |
| *switch on physician supply constraint* | 1 OR 0 | N/A | N/A | 1 = ON. 0 = OFF |
| *time to measure XX visit rate* | positive | Calibration |  |
| *time to perceive XX visit initiative* |  |
| *tune effect of technology on XX visits* |  |
| *XX visit initiative effectiveness* | Within a sector, all initiatives (e.g. PreAuth, Consumer Response, Visit Initiatives) use the same effectiveness parameter. |
| *weight on MMO premium trend effect on XX visit rate* |  |
| *weight on XX visit initiative effect delay* | [0, 1] | Controls relative influence of *XX Visit Initiatives* and (delayed) *Perceived XX Visit Initiatives*. |

## In Isolation (Example sector: PO VISIT RATE):

* Physician supply constraint switched off (switch set to zero)
* *minimum PO visit rate* set to 0

### Equilibrium Requirements:

* PO Visit Rate = indicated PO visit rate = ( 1 + MMO premium trend effect on utilization \* weight on MMO premium trend effect on PO visit rate ) \* MAX ( ( technology adjusted PO visit rate - ( PO Visit Initiatives - PO Consumer Response - PO Initiative PreAuth Implemented ) \* PO visit initiative effectiveness ), minimum PO visit rate )
* Perceived PO Visit Initiatives = PO Visit Initiatives

### Test 1: Effect of medical technology

#### Expectations:

New technology spurs visits by potential beneficiaries. *PO Visit Rate* should move in the same direction as *Cumulative Medical Technology Growth*.

#### Testing:

*Cumulative Medical Technology Growth* = 1 + STEP(±0.1, 2)



Figure 3: effect of step changes in *Cumulative Medical Technology Growth* on *PO Visit Rate*

#### Results:

**Increase in *Cumulative Medical Technology Growth***🡪 increase in *technology adjusted PO rate* 🡪 increase in *indicated PO visit rate* 🡪 **increase in *PO Visit Rate***. *PO Visit Rate* exhibits asymptotically behavior.

### Test 2: *MMO premium trend effect on utilization*

#### Expectations:

Doctors adjust level of care to protect themselves from malpractice claims. *MMO premium trend effect on utilization* and *PO Visit Rate* should move in the same direction.

#### Testing:

*MMO premium trend effect on utilization* = STEP(±0.05, 2)



Figure 4: Effect of step changes in *MMO Premium Trend Effect* on *PO Visit Rate*

#### Result:

**Increase in *MMO premium trend effect on utilization*** 🡪 increase in *indicated PO visit rate* 🡪 **increase in *PO Visit Rate***. The response is immediate and behavior is asymptotic.

Note: *PO Consumer Response* and *PO Initiative PreAuth Implemented* are not shown due both to their lack of usage in policy testing mode and the similarity of their effect on system behavior to that of *MMO premium trend effect on utilization*.

### Test 3: *PO Visit Initiatives*

#### Expectations:

Initiatives are implemented for the purpose of decreasing visit rate. *PO Visit Rate and PO Visit Initiatives* should move in opposite directions.

#### Testing:

*PO Visit Initiatives* = 1 + STEP(±0.1, 2)[[2]](#footnote-2)



Figure 5: Effect of step changes in *PO Visit Rate Initiatives* on *PO Visit Rate*

#### Results:

**Increase in *PO Visit Initiatives*** 🡪 increase in *Perceived PO Visit Initiatives* 🡪 decrease in *indicated PO visit rate* 🡪 **decrease in *PO Visit Rate***. Because a change in *PO Visit Initiatives* is transmitted through a separate stock of *Perceived PO Visit Initiatives,* the effect on *POVR* does not peak until a short period after the shock (see *chg PO visit rate* plotted in red). After that point, *POVR* follows an asymptotic/exponential decay path.

### Conclusion:

All expectations were confirmed – this sector operates according to its intended design.

## Verification of Other Sectors:

* ER VISIT RATE: 🗹
* OP VISIT RATE: 🗹
* IP VISIT RATE: 🗹
* LENGTH OF STAY: 🗹

## Recommendations and suggestions for further work:

* The *initial actual XX visit rate* translates to the initial *technology adjusted XX visit rate*, not the measured *XX visit rate*. Because the initial rate is presumably the data-derived measured rate, adjustments accounting for MMO and initiative impact should be made to produce the initial technology adjusted rate so that the initial *XX visit rate* = *initial actual XX visit rate*. (2)
* Re-examine assumption that providers set level of care dependent on MMO price trend rather than level.
* Consider linking the *physician limited office visit rate* to a separately specified ideal value rather than the initial visit : physicians ratio. This would allow initiating the model with a physician shortage. While the structural change would be easy, verifying that the model behaves when starting with a shortage would be more time-intensive. (2-4)

# Module: Visit & LOS Initiatives

## **Purpose:**

As cost-conscious organizations, managed care organizations (MCOs) would like to control the number of medical visits made by their policyholders – they certainly want to avoid paying for unnecessary care. They have a number of methods to limit visit rates, including the standard HMO requirement for a primary care physician to serve as a “gatekeeper” to specialist access. Other strategies include increasing copays and case management for high-use patients. Policies denying coverage of certain expensive treatments or physicians may also reduce visits, as patients will often only visit their physician if they anticipate receiving their desired care. In this way, a single initiative can influence both visit rates and prices. This module is used to track these visit initiatives and duplicated for the major healthcare venues: the physician office (PO), emergency (ER), outpatient (OP), and inpatient (IP) settings. A nearly identical structure monitors initiatives targeting the average IP length of stay (LOS).

## Uses:

* PO VISIT INITIATIVES
* ER VISIT INITIATIVES
* OP VISIT INITIATIVES
* IP VISIT INITIATIVES
* LOS INITIATIVES

## Diagram:



Figure 6: Diagram of *XX Visit Initiatives* structure

## **Summary:**

All five sectors include a variant of the initiatives/development capacity structure shown in Figure 6. MCOs determines a target visit rate or length of stay, and then adjust their initiative development capacity to meet that target. The model portrays initiative development as reactionary rather than proactive; insurers allocate resources to develop initiatives when increasing visit rates engender higher-than-anticipated payouts. However, no development capacity is allotted to replace initiatives which are “losing effectiveness”, resulting in a chronic shortfall of initiatives. Development capacity takes time to adjust, and initiatives take time to be implemented, though there is no ongoing administrative requirement modeled. Initiatives also lose their effectiveness after a period of time, reflecting, among other possibilities, patients and providers learning how to effectively circumvent restrictions.

A variety of specific MCO initiatives, along with a consumer response stock, are also modeled in some venues, but these are completely separate from both each other and the above structure. These factors take one of two structures: a single stock with an exogenous inflow and a proportional outflow, or a two-stock aging chain, again with an exogenous inflow. Due to their exogenous nature, these structures are primarily used for calibration purposes in the data fitting and forecasting tasks. In the updated model, a number of additional examples representing specific policies (e.g. capitation initiative) have been removed. (See Appendix Y for full list of changes).

## Primary structure:

### Decision Points:

* ***target (XX visit rate / LOS) –*** Medical care organizations are assumed to target visit rates and inpatient length of stay by anchoring on the *technology adjusted XX rate[[3]](#footnote-3)*. In other words, MCOs do not try to push back against tech-driven increases in care usage.
	+ *target XX rate* cannot fall below *minimum XX rate* (MAX function).
	+ Because *technology adjusted XX Rate* is unaffected by initiatives, there is no reinforcing feedback loop where success in limiting *XX Rate* leads to a further fall in *target XX Visit Rate*.
	+ An alternative formulation for visit rate initiatives could assume MCOs do not make adjustments to their “target” based off technological advances but are always trying to limit visit rates to historical levels , similar to how the price initiative sectors are structured.
* ***target XX initiative capacity* –** Developing and implementing initiatives requires organizational resources, represented by the *XX Initiative Development Capacity*. Target capacity is determined by the gap between the target and actual system states (visit rates/length of stay). Target capacity is translated into actual capacity over time, as MCOs adjust the amount of resources directed towards initiatives. It is important to note that target capacity does not take into account existing initiatives and the capacity that will be needed to replace expiring programs. This is intended to model the reactive nature of these initiatives: if an initiative is successful and reimbursement costs decline, the loss of financial urgency will tend to cause the insurer to lose focus on sustaining the initiative, even if it is responsible for the improvement.
	+ *target XX initiative capacity* cannot be negative (MAX function). A negative initiative capacity would represent insurers making efforts to increase the overall cost of care, whether through more frequent visits or longer inpatient stays. Because insurers pay the majority of these costs, such a scenario is unlikely.
* **XX initiative processing & XX initiative losing effectiveness**
	+ *XX initiative processing* = *XX Initiative Development Capacity* / *time to develop XX visit initiative*
	+ The simplifying assumption is made that initiatives do not take resources to implement once they have been developed; if development capacity instantly dropped to zero, initiatives would still remain in effect for their normal lifespan.

### Inputs:

* ***XX Visit Rate /******Length of Stay*** [XX VISIT RATE / LOS]
* ***technology adjusted (XX visit rate******/ Length of Stay)*** [XX VISIT RATE / LOS]

### Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value / Restrictions** | **Source** | **Notes** |
| *desired fract XX visit reduction* | [0,1] | Calibration | Positive values target reductions |
| *XX initiative life* | positive |  |
| *time to change XX visit initiative development capacity* | positive |  |
| *time to develop XX visit initiative* | positive |  |
| last updated 12/9/20  |

## Secondary structures:

#### Single stock:

* *(PO/ER/OP/IP/LOS) Consumer Response*
	+ patient and provider push-back against MCO efforts to limit visits or length of stay
* *ER Initiative PreAuth*
	+ MCO initiative requiring pre-approval before some ER visits

#### Two-stock aging chain:

* PO Initiative PreAuth
	+ requirement for pre-approval for many pharmaceuticals and/or specialist visits
* OP Initiative PreAuth
	+ requirement for pre-approval for outpatient visits and/or procedures.

#### Notes:

* *ER Initiative PreAuth* is a single-stock structure, compared to a two-stock aging chain for the PO & OP preauthorization initiatives. The effectiveness of these initiatives depends on consumer awareness of the policy, and knowledge of the ER initiative spread more quickly thanks to the negative publicity. This is reflected in as a decreased implementation delay, modeled as one stock vs. two.

### Example Stocks:

* Two-stock aging chain: *PO Initiative PreAuth* and *PO Initiative PreAuth Implemented*



Figure 7: Visualization of pulse moving through aging chain including PO Initiative PreAuth and PO Initiative PreAuth Implemented stocks

* Single Stock: PO Consumer Response



Figure 8: Example PO Consumer Response stock with pulse years 1995 & 2006

## In Isolation:

* All the secondary structures have flows that stop and start based on IF THEN ELSE statements. Setting them in equilibrium can be done in a number of ways with trivial difficulty.

### For equilibrium:

* *PO Visit Initiatives* [Initial] = *PO visit initiative effectiveness \* PO visit initiative life \**

MAX ( *PO Visit Rate -* MAX ( *technology adjusted PO visit rate* \* ( 1 - *desired fract PO visit reduction* ), *minimum PO visit rate* ), 0 ) */ time to develop PO visit initiative*

* *PO Visit Initiative Development Capacity* [Initial] = *target PO visit initiative capacity*

### Test 1: *PO Visit Rate*

#### Expectations:

The model assumes that insurers target a fixed percentage decrease in visit rates, meaning they desire larger absolute decreases when the visit rate is higher. Because initiatives have an additive effect on the visit rate, the required quantity of initiatives is proportional to the desired absolute decrease. Alternately stated, *PO Visit Initiatives* will respond to a change in the *PO Visit Rate* with movement in the same direction.

#### Testing[[4]](#footnote-4):

*PO Visit Rate* = 3 + STEP( ±0.3, 2)

Note: *PO Visit Rate* must remain at or above the *target PO visit rate* for the following behavior to be observed.



Figure 9: Effect of STEP in *PO Visit Rate* on *PO Visit Initiatives*

#### Result:

Increase in *PO visit rate* 🡪 increase in *PO Visit Initiative Development Capacity* 🡪 increase in *PO Visit Initiatives*. Asymptotic growth.

### Test 2: *technology adjusted PO visit rate*

#### Expectations:

Because MCOs are assumed to adjust their visit rate expectations based on technological developments, an increase in *technology adjusted PO visit rate* should result in a concurrent rise in *target PO visit rate*. With *PO Visit Rate* remaining constant, fewer initiatives will be required to reach the target rate. Therefore, a change in *technology adjusted PO visit rate* should result in movement of *PO Visit Initiatives* in the opposite direction.

#### Testing:

*technology adjusted PO visit rate* = 3 + STEP(±0.3, 2)

Note: *PO Visit Rate* must remain at or above the *target PO visit rate* for the following behavior to be observed.



Figure 10: Effect of STEP in *technology adjusted PO visit rate* on *PO Visit Initiatives*

#### Result:

With the qualification that the *PO Visit Rate* is sufficiently high relative to *technology adjusted PO visit rate*, an increase in the latter narrows the gap between targeted and actual rates. As a result, *PO Visit Initiative Development Capacity* is relatively too large and therefore decreases to compensate. A decrease in *PO Visit Initiatives* must follow.

### Conclusion:

All expectations were confirmed – this sector operates according to its intended design.

## Verification of other sectors:

ER Visit Initiatives: 🗹

OP Visit Initiatives: 🗹

IP Visit Initiatives: 🗹

LOS Initiatives: 🗹

## Recommendations and suggestions for further work:

* Scrutinize the assumption that MCOs account for tech changes directly when targeting visit rate (rather than simply picking up the influence on historical rates).
* Integrate Consumer Response structure into Visit Initiatives (2)

# Module: Capacity

## Purpose:

The capacity module calculates the national hospital capacity in the emergency department (ER), outpatient (OP), and inpatient (IP) venues. These sectors primarily measure infrastructure and capacity – physician count is tracked separately, and all other resources are assumed to be available in non-constraining quantities.

## Uses:

* ER CAPACITY
* OP CAPACITY
* IP CAPACITY

## Diagram:



Figure 11: Diagram of the basic structure of the *XX Capacity* module.
\*\* denotes a variable excluded from the IP CAPACITY formulation.

## Summary:

Due to the delays involved with planning, funding, and constructing capacity, healthcare facilities must forecast demand – formally or not – when projecting capacity requirements. In addition to adjusting for expected changes in future demand, facilities must account for infrastructure and equipment aging or becoming obsolete. Therefore, this model has one way to add capacity (appropriately named *adding XX capacity*) but two ways for it to be removed: d*ecreasing XX capacity* accounts for infrastructure that has reached the end of its lifespan and/or become obsolete, while *retiring XX capacity* denotes capacity retired “early” due to oversupply. As reflected in historical data, ER and OP capacityadjustment times decrease when the relative capacity gap is larger, but IP adjustment times are fixed. In the model, the *Planned XX Capacity* is determined by a combination of forecasted and historical demand, augmented by a capacity reserve for handling surges and seasonal demand fluctuations.

### Decision points:

* ***Forecast XX Demand* –** Long delays in capacity adjustment require forecasting visit rates. This variable takes two inputs: *forecast annual XX visits[[5]](#footnote-5)*, which uses a FORECAST function, and *average annual XX visits*, which is a first-degree SMOOTH of *annual XX visits*. The relative weights are determined by the parameter *weight on forecast XX demand* and (1 – *weight on forecast XX demand*), respectively.
* ***Planned XX Capacity* –** Because immediate medical demand is variable, with peaks and valleys, facilities need to maintain a “cushion” of excess capacity above normal utilization rates. *Planned XX Capacity* accounts for this reserve.
	+ Reserve capacityis a fixed percentage of forecasted demand.
* ***required change in available XX capacity*** – This variable calculates the difference between available and planned capacity. It accounts for capacity depreciation; thus, even if *XX Capacity* equals *Planned XX Capacity*, the *required change in available XX capacity* is still positive to account for capacity that must be replaced, although there is no model differentiation between replacement and new additional capacity.
	+ Specifically, in an equilibrium scenario where *Planned XX Capacity* always equals *XX Capacity*, *required change in available XX capacity* = *decreasing XX capacity* \* *time to increase XX capacity*.
* ***adding XX capacity / XX capacity retirement* –** These flows represent the variable-rate input and output, respectively, of the *XX Capacity* stock (*decreasing XX capacity* is the fixed-rate end-of-life depreciation stock). They are controlled by IF THEN ELSE statements:
	+ IF (*required change in available XX capacity* > 0),

THEN (*adding XX capacity* = *required change in available XX capacity*).

* + IF (*required change in available XX capacity* < 0),

THEN (*retiring XX capacity* = -1 \* *required change in available XX capacity*).

* + In both cases: ELSE (0)
	+ Depending on parameterization, most or all capacity reductions are handled by a decrease in *adding XX capacity* below *decreasing XX capacity*, with *XX capacity retirement* remaining at zero.
* ***average fractional XX capacity gap*** – A significant gap between desired and actual capacities is undesirable. In the case of a shortage, facilities are overcrowded and cannot treat all prospective patients, presumably resulting in negative health consequences. If there is excess capacity above that needed for handling expected surges, facilities are needlessly spending money. In either case, greater deviations from the ideal encourage quick action. This is reflected in the model by a decrease in *time to increase XX capacity* if the gap is less than zero (shortage) or a fall in *time to retire XX capacity* in the case of a positive gap (excess). These effects create a pair of potential (i.e. not always active) balancing loops.
	+ This variable is absent in the IP CAPACITY sector, as data did not indicate a significant change in IP capacity adjustment times dependent on differences in utilization
	+ In the ER CAPACITY sector, *ER Capacity* is compared to *Desired ER Capacity*, which is based on immediate utilization levels plus reserve capacity.
	+ In the OP CAPACITY sector, *IP Capacity* is compared to *Planned OP Capacity*, which is based on forecasted and averaged utilization plus reserve capacity, and also has its own delay.
	+ The reason for this difference in ER and OP formulations is unclear (JPT, Oct. 2020).
	+ In the ER and OP sectors, there are minimum adjustment times (MAX function).

## Sector Inputs:

### From other sectors:

* ***annual (ER/OP visits / IP bed days)*** [ XX Visit Rate ]: *forecast (XX visit rate / bed days)* & *average (XX visit rate / bed days)*
	+ *annual ER visits* and *annual OP visits* (as well as *ER/OP Capacity*)are measured in visits per year (visit rate \* population)
	+ *annual IP bed days* / *IP Capacity* are measured in [bed] days per year (visit rate \* population \* length of stay).

### Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value and/or Restrictions** | **Source** | **Notes** |
| **ER** | **OP** | **IP** |
| *XX capacity depreciation rate* | 0.125 | 0.1 | 0.0625 |  | Percent of capacity reaching end-of-life annually |
| *XX capacity planning delay* | 5 | 5 | 5 |  |  |
| *XX capacity reserve* | 1.1 | 1.1 | 0.7 |  | Desired reserve capacity to handle surges |
| *(XX visit / IP bed days)* *forecast horizon* | 3 | 3 | 3 |  | How far out demand is planned for. |
| *max fract IP retirement* | N/A | N/A | 0.1 |  | Maximum fraction that can be removed **in addition to** normal depreciation. IP only. |
| *min time to increase XX capacity* | 1 | 1 | N/A |  | *time to increase IP capacity* is fixed. |
| *min time to retire XX capacity* | 0.5 | 0.5 | N/A |  | *time to retire excess IP capacity* is fixed. |
| *(nm) time to increase XX capacity* | 2 | 2 | 5 |  |  |
| *(nm) time to retire excess XX capacity* | 1 | 1 | 5 | Calibration?? |  |
| *time to average XX capacity gap* | 1 | 1 | N/A |  | Not used in IP venue |
| *time to average XX visit rate / time to average IP bed days* | 1 | Calibration?? | Shared by *forecast XX* and *average XX* variables |
| *weight on forecast XX demand* | [0,1] | Calibration | The closer to 1, the more weight on forecast and less on historical average visit rate |
| last updated: 12/7/2020 |

## In Isolation (Example Sector: ER CAPACITY):

### For equilibrium:

* *ER Capacity* [Initial]= *Planned ER Capacity*
* *Planned ER Capacity* [Initial] = *Forecast ER Demand* \* ( 1 + *ER capacity reserve* )

### Test 1: *annual ER visits*

#### Expectations:

Because capacity exists to accommodate utilization, a change in visits will cause a change in *ER Capacity* in the same direction, though the adjustment will take time.

#### Testing:

*annual emergency visits* = 3x109 + STEP(-6x108, 2) + RAMP(3x108, 4, 10)

Figure 12: Effect of changes in *annual ER visits* on *ER Capacity*, comparison of several runs

#### Results:

Figure 12 demonstrates the differences in sector formulation regarding *fractional XX capacity gap*. Although all tests were run in the ER sector, the runs titled “test no effect” mirror the IP CAPACITY sector, “test planned” mirror OP CAPACITY, and “test desired” represent ER CAPACITY. There are “delay = 2” and “delay = 7” versions of each, denoting the value for the *ER capacity planning delay*. In all cases, *ER Capacity* moves in the same direction as *annual ER visits*, as expected. The differences are generally quite minor, but the “no effect” (IP) runs, where fractional gap has no effect on adjustment times, react most slowly. When *ER capacity planning delay* is longer, the “desired” (ER) version adjusts most rapidly, but there is a threshold value for the delay under which “planned” (OP) version adjusts most quickly (this essentially happens because *Planned ER Capacity* may “overreact” to sharp changes if *ER capacity planning delay* is short).

As shown in all the “delay = 2” runs, it is possible for capacity changes to “overshoot.” This becomes more likely as *weight on forecast XX demand* moves closer to one.

### Conclusion:

All expectations were confirmed – the sector operates according to its intended design.

## Verification of other sectors:

* OP CAPACITY: 🗹
* IP CAPACITY: 🗹

## Recommendations and suggestions for further work:

* Is there a valid reason for ER and OP venues to have different fractional capacity gap formulations?
* Should *XX Capacity planning delay* be influenced by fractional capacity gap?
* Is there a difference in planning horizon for an increase vs. a decrease in capacity?

# Module: Asset Value

## Purpose:

The Asset Value module tracks the aggregate value of infrastructure and equipment used in the emergency department (ER), outpatient (OP), and inpatient (IP) venues. All assets are treated as proportional inputs– in other words, if there is zero capacity, there are zero assets. Moreover, there is no overlap between venue assets: each unit of assets can only belong to one venue.

## Uses:

* ER ASSET VALUE
* OP ASSET VALUE
* IP ASSET VALUE

## Diagram:



Figure 13: Diagram of the basic structure of the *XX Asset* module.

## Summary:

The basic operation of the sector is quite simple: asset value is added to by newly built capacity, and it is subtracted from by the removal of capacity. The book value of new capacity is the initial value modified by a construction cost index (*CCI*) and by cumulative growth in medical technology, as measured by *Technology Effect on Hospital Construction Cost*. More technology leads to a higher book value for each new unit of capacity. The book value of each removed unit of capacity is the average value of all capacity (Capacity ÷ Asset Value). As a result, if the stock of technology is increasing, even a constant capacity will exhibit increasing aggregate asset value.

Although the modeling is technically only counting depreciation of removed units, the usage of the average value results in a value for *XX depreciation charge* that well approximates the annual depreciation cost reported on an income statement. This becomes less true the larger *XX capacity retirement* is relative to *decreasing XX capacity,* assuming the oldest units are favored for premature removal. It also means that *XX Asset Value* will take longer to adjust to changes in new asset unit values than it “should.” See Test 1: *cumulative medical technology growth* (& *CCI*) for an example.

### From other sectors:

* ***cumulative medical technology growth*** [Medical Technology]
* ***adding XX capacity*** [XX Capacity]
* ***decreasing XX capacity*** & ***XX capacity retirement*** [XX Capacity]
	+ *decreasing XX capacity* tracks end-of-life / obsolete capacity removal
	+ *XX capacity retirement* tracks premature capacity removal in response to oversupply (see Capacity module documentation for more detail)

### Decision points:

* ***adding XX asset value* –** unit value is initial value \* ( *CCI* + *Technology Effect on HCC* )
	+ *Technology Effect on Hospital Construction Cost* is shared among all venues.

## Parameters & Exogenous inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value** | **Source** | **Notes** |
| **ER** | **OP** | **IP** |
| *CCI* | Data type variable |  | *Engineering News-Record* Construction Cost Index. Tracks cumulative price change over base year. Must be formulated such that initial index value equals one (1).  |
| *bed day per year* | 365 | N/A | Used to convert between IP beds and IP bed-days.  |
| *initial XX asset unit cost / initial cost per IP bed* | 100 | 200 | 30,000 |  |  |
| *time for tech to affect hcc* | 1 |  | hcc = hospital construction cost. Time for new technology to be adopted. Shared. |
| Last updated: 10/20/2020 |

## In Isolation (Example Sector: OP Asset Value):

### For equilibrium:

* *adding OP capacity* = *decreasing OP capacity* + *OP capacity retirement*
* *OP Asset Value* = *OP Capacity* \* *initial* *OP asset unit cost* \* (*CCI* + *cumulative medical technology growth*)
* *Technology Effect on Hospital Construction Cost* [Initial] = *cumulative medical technology growth*

To make the sector behave as if the entire model is in equilibrium, set *OP capacity retirement* = 0, *CCI =* 1, *cumulative medical technology growth* = 0, and ensure the above conditions are also met.

### Test 1: *cumulative medical technology growth* (& *CCI*)

#### Expectations:

When more medical technology is in use, a larger quantity of and/or more expensive equipment must be purchased. A change in *cumulative medical technology growth* should produce movement of *OP Asset Value* in the same direction, with a delay.

A change in *CCI* will propagate in a similar manner.

#### Testing:

*cumulative medical technology growth* = 0.2 + STEP(±0.1, 2)



Figure 14: Effect of STEP in *cumulative medical technology growth* on *OP Asset Value* and *OP Capacity*

#### Results:

 **Increase in *cumulative medical technology growth***🡪 increase in *Technology Effect on Hospital Construction Cost* 🡪 increase in *adding OP asset value* 🡪 **increase in *OP Asset Value***. *OP Capacity* remains constant. Note that eighteen years is not enough for the system to stabilize after the shock, despite a 10% depreciation rate meaning that capacity should have a 10-year lifespan and thus be fully replaced with “upgraded” tech by approximately year 15, accounting for the technology diffusion time. This is due to the “mixing effect” in the stock.

### Test 2: *adding OP capacity* / *OP capacity retirement*

#### Expectations:

This effect is simple: adding more capacity at a constant value will increase total asset value. A change in *adding OP capacity* will result in movement of *OP Asset Value* in the same direction. It will settle in a new equilibrium when *OP Capacity* = (*adding OP capacity – OP capacity retirement*) */ OP capacity depreciation rate*.

Because *OP capacity retirement* has the opposite effect of *adding OP capacity*, a change in the former will result in opposite direction movement in *OP Asset Value*.

#### Testing:

1. *adding OP capacity* = 100 + STEP(10, 2)



Figure 15: Effect of positive STEP in *adding OP capacity* on *OP Capacity* and *OP Asset Value*

1. *OP capacity retirement*  = 20 + STEP(2, 2)



Figure 16: Effect of positive STEP in *OP capacity retirement* on *OP Capacity* and *OP Asset Value*

#### Results:

**increase in *adding OP capacity***🡪 increase in *adding OP asset value* 🡪 **increase in *OP Asset Value***

**increase in *OP capacity retirement***🡪 increase in *OP depreciation charge* 🡪 **decrease in *OP Asset Value***

### Conclusion:

All expectations were confirmed – the sector operates according to its intended design.

## Verification of other sectors:

* ER ASSET VALUE: 🗹
* IP ASSET VALUE: 🗹

## Recommendations and suggestions for further work:

None

# Module: Hospital Cost

## Purpose:

The hospital cost module estimates average per visit operating costs for the outpatient and emergency venues and the average per day cost for inpatient visits.

## Uses:

* HOSPITAL COSTS

## Diagram:



Figure 17: Diagram of venue cost structure

## Summary:

This sector is mostly computational, with similar calculations for ER, OP, IP, and non-treatment operating costs. Cost changes due to general inflation and labor cost fluctuations are tracked through the *Cumulative XX Inflation Index* stock, while the specified initial venue operating cost provides an anchor. In the manner of balance-sheet accounting, long-term asset costs are accounted for through depreciation charges. Among other factors (see module guide for more detail), asset cost depends on medical technology level, with a higher relative value increasing average asset costs. All units of venue capacity incur the same costs, whether they are utilized or not. Non-treatment operating costs (e.g. administrative overhead, facilities maintenance) are distributed among the emergency, outpatient, and inpatient venues proportional to each venue’s share of total hospital costs. This division was perhaps more realistic in the era when nearly all outpatient procedures were done in hospitals, but we still judge it to be an reasonable abstraction at this level of aggregation.

### Notable variables:

* ***annual XX operating cost* =***initial annual XX operating cost* \* *Cumulative XX Inflation Index* \* *XX Capacity*
+ *XX depreciation charge*
* ***chg cumulative XX inflation index*** =
*Cumulative XX Operating Cost Inflation* \* (*annual CPI U* + *est hosp wage inflation impact*)
* ***est hosp wage inflation impact***
	+ Estimated rate of real price change of hospital wages and salaries
	+ Does not affect non-treatment operating cost

## Inputs:

### From other sectors:

* ***annual ER visits*** [ER VISIT RATE]: *chg average ER operating cost*
* ***annual IP bed days*** [IP VISIT RATE]: *chg average IP operating cost*
* ***annual OP visits*** [OP VISIT RATE]: *chg average OP operating cost*
* ***IP Capacity*** [IP CAPACITY]: *IP bed capacity*
* ***IP depreciation charge*** [IP ASSET VALUE]: *annual IP operating cost*
* ***ER Capacity*** [ER CAPACITY]: *annual ER operating cost*
* ***ER depreciation charge*** [ER ASSET VALUE]: *annual ER operating cost*
* ***OP Capacity*** [OP CAPACITY]: *annual OP operating cost*
* ***OP depreciation charge*** [OP ASSET VALUE]: *annual OP operating cost*

### Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value** | **Source** | **Notes** |
| **ER** | **OP** | **IP** |
| *annual CPI hospital and related services* | Data Input (opt.) |  | Vensim data-type variable. Used to calculate wage inflation. |
| *annual CPI U* | Data Input (opt.) |  | Vensim data-type variable. General inflation. |
| *bed day per year* |  |  | 365 | N/A | Used to convert between IP beds and IP bed-days.  |
| *initial annual XX (unit/per bed) operating cost* | 150 | 350 | 210000 |  | This variable multiplied by the corresponding *initial XX inflation index* should equal the actual value in the simulation start year. |
| *initial annual non treatment operating cost* | 2,000,000,000= 2 x 109 |  | see above |
| *initial XX inflation index* | 1 | 1 | 1 |  | see note for *initial annual XX unit operating cost* |
| *initial non treatment inflation index* | 1 |  | see above |
| *time hosp cost delay* | 0.5 |  | Delay in wage inflation being reflected in costs[[6]](#footnote-6) |
| *time to measure hosp cost* | 1 |  |  |
| *wage fract hosp operating cost* | 0.3 |  | Fraction of non-depreciation costs used for medical staff wages and salaries. |
| last updated 12/9/20 |

## In Isolation (Example venue: IP Cost)

### For equilibrium:

* *Average (ER/OP/IP) Operating Cost* [Initial] = *annual XX operating cost + annual XX operating cost / total hospital treatment cost* \* *non treatment operating cost* / *annual XX visits*
	+ IP venue uses *annual IP bed days* rather than visits
* *Average Non Treatment Operating Cost* [Initial] = *non treatment operating cost*
* *annual CPI U* = 0

### Test 1: *annual CPI U*, *est hosp wage inflation impact*, and *IP depreciation charge*

To verify that *annual IP operating cost* behaves correctly with regards to inflation and depreciation influences, the following staggered input changes were tested in a single run. All values are fictional.

* *annual CPI U* = STEP (0.1, 2) – STEP (0.1, 10)
* *est hosp wage inflation impact* = STEP (0.2, 11) – STEP (0.2, 15)
* *IP depreciation charge* = 500,000 + RAMP (100,000, 18, 20) – RAMP (200,000, 20, 22)

For this run, the normal impact of *annual CPI U* on *est hosp wage inflation impact* was removed to allow separate testing.



Figure 18: Effect of changes in *annual CPI U*, *est. hosp wage inflation impact*, and *IP depreciation charge* on *annual IP operating cost*

As the results in Figure 18 demonstrate, non-zero values of either *annual CPI U* or *est. hosp wage inflation impact* cause exponential growth, as they should. When both are zero, changes in *annual IP operating cost* mirror the changes (or lack thereof) in *IP depreciation charge*.

### Test 2: *IP Capacity*

#### Expectations:

When capacity increases, the overall operating cost will increase. Additionally, because the venue will now account for a larger share of *total hospital treatment cost,* it will take on a larger share of *non treatment operating cost*. Because the number of bed days and visits remains constant, the per day cost will also be higher. If capacity decreases, both annual and per day costs will decrease.

#### Testing:

*IP bed capacity[[7]](#footnote-7)*  = 100 + STEP (±20, 2)



Figure 19: Effect of step changes in *IP bed capacity* on *annual IP operating cost* and *Average IP Operating Cost*

#### Results:

As expected, a change in *IP bed capacity* causes movement of both *annual IP operating cost* and *Average IP Operating Cost* in the same direction. The adjustment in the former is immediate, while the latter variable follows an asymptotic adjustment path consistent with measurement delay.

### Test 3: *annual IP bed days*

#### Expectations:

The variable *annual IP bed days* is the product of annual IP visits and average length of stay. As long as capacity remains constant, annual operating costs will remain constant regardless of changes in utilized bed days. However, if *annual IP bed days* increases (or decreases), the ability to spread the total cost over more (fewer) patients will decrease (increase) *Average IP Operating Cost*.

#### Testing:

*annual IP bed days* = 20,000 + STEP (±2,000, 2)



Figure 20: Effect of step changes in *annual IP bed days* on *Average IP Operating Cost* and *annual IP operating cost*

#### Results:

As anticipated, *Average IP Operating Cost* is inversely related to *annual IP bed days*, although there is a measurement delay. *Annual IP operating cost* is constant.

### Conclusion:

All expectations were confirmed – this sector operates according to its intended design.

## Verification of other venues:

* ER Cost: 🗹
* OP Cost: 🗹

## Recommendations and suggestions for further work:

None

# Module: PO Price

## Purpose:

As the name implies, the PO Price module tracks physician office visit price. Because of the diversity in payment setups (insurance reimbursement, full or partial out-of-pocket), not to mention the variation among regions and even individual physicians, the price stock here denotes the national average in the most basic sense: total spent on physician visits divided by the number of annual visits. Thus, it incorporates payments made by both insurers and individuals.

## Uses:

* PO PRICE

## Diagram:



Figure 21: Diagram of PO Price structure

## Summary:

This structure can be divided into two sub-structures: the physicians’ desired price and the actual average price paid, accounting for the downward price pressure exerted by insurers. This setup allows representation of disparate incentives for MCOs and providers.

Particularly given the level of aggregation, *Desired Price* necessarily represents a theoretical or unstated value that accounts for the markup physicians would like to receive for their services. The billed price is perhaps similar in concept, though there should be no expectation that the magnitude of the sticker markup is a reflection of the desired value as tracked by the model. Physicians are assumed to desire reimbursement that increases slightly faster than general inflation. If, for instance, the percentage increase in *PO Price* over a period (*indicated PO inflation*) is less than the sum of *average cpi u* and *target PO price spread above inflation*, *Pressure to Change PO Price* will grow. The trend in MMO premiums also influences desired price – if premiums are rising, *Desired PO Price* will rise as well, and the reverse.

*Desired PO Price* is the integral of the following flow:

*chg desired PO* p*rice* = ( *PO Price* \* ( 1 + *Pressure to Change PO Price* + *MMO premium trend effect on PO price* ) - *Desired PO Price* ) / *time to change desired PO price*

* ***Pressure to Change PO Price* –** Physicians would like their incomes to grow in real terms; most also consider themselves above-average practitioners and thus deserving of higher-than-average compensation. *Pressure to Change PO Price* models this desire. If PO price is increasing at a rate equal to general inflation plus *target PO price spread above inflation*, *Pressure to Change PO Price* tends towards zero. If PO price inflation falls below this desired rate, price pressureincreases, in time producing a proportional increase in *Desired PO Price* and *PO Price*. *Pressure to Change PO Price* can take negative values, under the assumption that physicians do not want to increase prices so quickly as to scare away patients and insurers.
* ***MMO premium trend effect on PO price* –** Higher medical malpractice insurance premiums cut into the net revenue received by providers. They are assumed to respond to premium hikes by increasing their desired price. Similarly, declining premiums engender a lower desired price. The relationship between the inflation-adjusted premium trend and the desired price is specified by the graphical (aka lookup) function shown in Figure 22, modified by a constant *tune MMO premium trend effect on PO price*. This relationship specifies that providers are assumed to pass on a greater share of cost increases than they do savings.
	+ Uses first-degree SMOOTH of lookup function
	+ Because the immediate rather than cumulative trend is used, it is possible for the model to run in equilibrium despite a sustained non-zero trend. See Test 1: *MMO premium trend effect on price* and **Error! Reference source not found.**.

Figure 22: MMO premium effect on price f lookup function

Insurance initiatives may reduce the actual amount the hospital receives. *XX Price* is altered through the following bi-flow:

*chg XX Price* = ( ( *Desired PO Price* - *weight on XX price initiative* \* *XX Price Initiatives* \* *XX Price initiative effectiveness* ) - *XX Price* ) / *time to change XX price*

* ***PO Price Initiatives –*** MCO efforts to reduce required reimbursement cost. Because co-pays/co-insurance are included in the modeled price, the PO *Price Initiatives* variable does not include schemes which simply shift payment responsibility without changing total cost.
* ***PO Price initiative effectiveness*** – This parameter is currently static, unlike in the hospital cost sectors where increasing utilization improves effectiveness as a reflection of stronger initiative enforcement. This should be updated to match the hospital sectors (See Recommendations).

## Inputs:

### From Other Sectors:

* ***PO Price Initiatives*** [PO PRICE INITIATIVES]
* ***MMO premium trend effect on price*** [MMO PREMIUMS]

### Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Value / Restrictions** | **Source** | **Notes** |
| *annual CPI U* | Data Input (opt.) |  | *average cpi u* is a 1st degree SMOOTH of *annual CPI U* |
| *nm PO Price initiative effectiveness* | non-negative | Calibration |  |
| *nm target PO price spread above inflation* |  | Generally assumed to be positive in practice, but there is no mathematical reason it cannot be zero or negative. |
| *time to average cpi u* | positive | See note for *annual CPI U*. |
| *time to build PO price pressure* | positive |  |
| *time to change desired PO price* | positive |  |
| *time to change PO price* | positive |  |
| *tune MMO premium trend effect on PO price* | non-negative |  |
| *weight on PO price initiative* | non-negative |  |
| last updated 12/9/20 |

## In Isolation:

### Initial values for equilibrium:

* *Desired PO Price* [Initial] = *PO Price* \* ( 1 + *Pressure to Change PO Price* + *MMO premium trend effect on PO price* )
* *PO Price* [Initial] = *PO Price Initiatives* \* *weight on PO price initiative* \* *PO price initiative effectiveness* / ( *average cpi u* + *target PO price spread above inflation* + *MMO premium trend effect on PO price* )

### Test 1: *MMO premium trend effect on price*

#### *Expectations*:

MMO premiums are an expense and thus accounted for in the desired price. When premiums increase, physicians will increase their desired price to compensate. With fixed MCO initiatives, this will also produce a delayed change in *PO Price* of the same direction and magnitude. Thus, a change in *MMO premium trend effect on price* should produce movement in the same direction in both *Desired PO Price* and *PO Price.* Because the input is the trend in premiums, not the value, a one-time positive pulse reflects a permanently higher premium price, which should be reflected in a permanently higher *PO Price*. A step decrease in premium trend, on the other hand, should be reflected in a steadily declining *PO Price*.

#### Testing:

*MMO premium effect on price* = 0.05 + STEP (± 0.2, 2)



Figure 23: Effect of step change in *MMO premium trend effect on price* on *Desired PO Price*. *PO Price* is not shown but follows a similar trajectory.

#### Results:

Both *Desired PO Price* and *PO Price* react to a change in *MMO premium effect on price* with movement in the same direction of the latter and each other, as expected. However, this test exposes a number of worrying behaviors. First, before time 2, the sector is in equilibrium despite a non-zero MMO premium trend. In other words, MMO premiums were continually increasing, yet *PO Price* can remain constant perpetually. This happens because *Pressure to Change PO Price* is not cumulative. Additionally, *PO Price* and *Desired Price* can become negative as long as *PO Price Initiatives* are positive. Granted, in the full model price initiatives would decline as *PO Price* trended towards zero, so it would likely never take negative values but could still reach zero. This is certainly not representative of real-world physician behavior.

### Test 2: *PO Price Initiatives*

#### Expectations:

*PO Price Initiatives* aim to decrease physician visit price. Thus, *PO Price Initiatives* and *PO Price* should move in opposite directions. The likely effect on *Desired PO Price* is quite a bit less certain – perhaps physicians will increase their billed price in an attempt to maintain their previous income, or maybe they will become accustomed to lower prices over time and decrease their desired price. Or perhaps a combination of the two. In the current model structure, only the latter is represented. A step change in price initiatives should lead to asymptotic changes in *PO Price*, but the actual result is different.

#### Testing[[8]](#footnote-8):

*OP Price Initiatives* = 10 + STEP(+/-10, 2)



Figure 24: Effect of step changes in *PO Price Initiatives* on *Desired PO Price* and *PO Price*

#### Results:

A decrease in *PO Price Initiatives* causes a sustained exponential decrease in both *PO Price* and *Desired PO Price*. Given that *target PO price spread above inflation* is zero, this is slightly concerning, but at least it seems plausible that physician prices might spiral if insurers reduce cost control efforts. More concerning is what happens in the other direction: a one-time increase in *PO Price Initiative* produces a sustained exponential decrease in *PO Price* and *Desired PO Price*. This behavior is extremely implausible on an aggregate scale.

### Conclusion:

There are a number of scenarios where input changes produce outcomes that are at odds with common sense and realistic behavior. More work is needed on this sector.

## Recommendations and suggestions for further work:

* There are a few thorny dimensional inconsistencies in this sector. Due to the other changes that need to be made, it may be worthwhile to wait on fixing units. (3)
* Unlike in the hospital price structures, demand has no effect on either initiative effectiveness or desired price. The link between demand and initiative effectiveness should be added. (1)
* The link between demand and desired price deserves further investigation. In particular, some previous research has found that physicians *increase* prices when demand falls in order to maintain a desired income level (Ratanawijistrasin, 1993). Such a finding suggests that increasing demand should reduce the desired price spread above inflation. The direction and magnitude of such an effect may depend on type of insurance (traditional fee-for-service vs PPO, for instance).
* Testing should be conducted to better examine alternate formulations for *MMO premium effect on price*. As it currently stands, the effect is based off the total aggregate (nationwide) premiums payed, adjusted for inflation. Perhaps it would be advisable to include adjustments for changes to total visits, for instance, to reflect the wider base over which premium costs can be spread. Other possibilities can surely be devised as well.
* To correct the problems noted in the above testing, I suggest severing the negative feedback loop between *Pressure to Change PO Price* and its flow. This would make the stock cumulative and solve a number of problems – notably the runaway response to a one-time step increase in inputs. To ensure that the path of *PO Price* didn’t always return exactly to its original trajectory, there could be a separate “fading pressure” outflow.
* One possibility: (3)
	+ *chg desired PO price* = ( *PO Price* \* ( 1 + *Pressure to Change PO Price* ) - *Desired PO Price* ) / *time to change desired PO price*
	+ *Pressure to Change PO Price* = INTEG ( *building PO price pressure* ); Initial = 0
	+ *building PO price pressure* = - ( *indicated PO inflation* - *average cpi u* - *target PO price spread above inflation* - *MMO premium trend effect on PO price* ) / *time to build PO price pressure*

# Module: Hospital Price

## Purpose:

The Hospital Price module tracks price for the three hospital venues: emergency department (ER), outpatient (OP), and inpatient (IP). Because of the extremely wide range of possible services delivered, diversity in payment setups and price variations among hospitals, the price stock here denotes the national average in the most basic sense: total spent in the given venue divided by the number of annual venue visits (or annual bed days, in the case of the IP venue). Thus, it includes payments made by both insurers and individuals.

## Uses:

HOSPITAL PRICE: Although organized in a single sector, the three venues have separate but identical structures with a few shared inputs.

## Diagram:



Figure 25: Diagram of XX Price structure

## Summary:

As with the PO PRICE sector which it resembles, this module’s structure can be divided into two sub-structures: the providers’ desired price and the actual average price paid, accounting for the downward price pressure exerted by insurers. This setup allows the model to represent the price tug of war between providers and payers. Elements of both are affected by the level of demand.

Particularly given the level of aggregation, *Desired Price* necessarily represents a theoretical or unstated value that accounts for the markup providers would like to receive for their services. The billed price is perhaps similar in concept, though there should be no expectation that the magnitude of the sticker markup is a reflection of the desired value as tracked by the model. Unlike for the physician price, the desired price in the hospital venues is anchored on the calculated costs for the respective sectors. Cost is multiplied by the total desired margin – composed of constant and demand-sensitive elements – plus the malpractice premium impact. Because the *Desired XX Price* has a semi-exogenous anchor, *chg desired XX price* must be modified by the cumulative (not instantaneous) MMO premium trend.

*Desired XX Price* is the integral of the following flow:

*chg desired XX* p*rice* = ( *Average XX Operating Cost* \* ( 1 + *minimum hospital operating margin* + *stretch margin on XX cost* + *MMO premium effect on hospital price* ) – *Desired XX Price* ) / *time to change desired XX price*

* ***Average (ER/OP/IP) Operating Cost*** – Operating cost serves as the primary anchor for *Desired XX Price*.
* ***minimum hospital operating margin* –** This is a fixed value representing the minimum margin the hospital must reach to continue providing care.
	+ shared by all three hospital venues
* ***stretch margin on (ER/OP/IP) cost*** – Unlike the constant minimum margin, stretch margin is inversely proportional to demand: the more demand, the more leverage hospitals have to raise prices, for example. This is in line with standard supply-demand theory and interviews with hospital administrators, but runs contrary to some empirical findings regarding physician price-setting behavior. See sector recommendations.
	+ *stretch margin on XX cost* = *nm stretch margin on XX cost* \* *XX capacity utilization rate* / *desired average XX utilization rate*
* ***Cumul*[ative] *MMO Premium Effect on Price* –** Higher medical malpractice insurance premiums cut into the net revenue received by providers. They are assumed to respond by increasing their desired price. Similarly, declining premiums engender a lower desired price. The relationship between the real (inflation-adjusted) premium trend and price trend effect is specified by the lookup function shown in Figure 22. This relationship specifies that providers are assumed to pass on a greater share of cost increases than they do savings. Unlike the malpractice premium effect on visit rate or physician price, which depends on the smoothed trend (a flow), the *MMO premium effect on hospital price* depends on the cumulative trend effect (the corresponding stock). There are no adjustments for changes in number of providers or visits, though such changes could be tested in the future.
	+ Shared by all three hospital venues.
	+ Trend flow uses first-degree SMOOTH of lookup function.

Figure 26: MMO premium effect on price f lookup function

Insurance initiatives may reduce the actual amount the hospital receives. *XX Price* is altered through the following bi-flow:

*chg XX Price* = ( ( *Desired XX Price* - *weight on XX price initiative* \* *XX Price Initiatives* \* *XX Price initiative effectiveness* ) - *XX Price* ) / *time to change XX price*

* ***(ER/OP/IP) Price Initiatives –*** MCO efforts to reduce required reimbursement cost. Because co-pays/co-insurance are included in the modeled price, the *Price Initiatives* variable does not include schemes which simply shift payment responsibility without changing total cost.
* ***(ER/OP/IP) Price initiative effectiveness*** – In contrast to the various visit initiative effectiveness variables present in the model, hospital price initiative effectiveness is dynamic. Normal effectiveness is modified by the ratio of current to desired venue utilization rate. When utilization increases, insurers are assumed to enforce coverage restrictions more strenuously. This is modeled as an increase in price initiative effectiveness, which in turn will put downward pressure on price. The effect also works in reverse.

## Inputs:

### From other sectors:

* ***Average XX Operating Cost*** [HOSPITAL COSTS]
* ***ER/OP capacity utilization rate / IP occupancy rate*** [XX CAPACITY]
* ***Cumul MMO Premium Effect on Price*** [MMO PREMIUMS]
* ***XX Price Initiatives*** [XX PRICE INITIATIVES]

### Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Value / Restrictions** | **Source** | **Notes** |
| *desired (ER/OP) utilization rate* / *desired IP occupancy rate* | **ER** | 0.476… |  | 1 / ( 1 + *desired XX capacity reserve* ) |
| **OP** | 0.476… |
| **IP** | 0.588… |
| *minimum hospital operating margin* | 0.2 |  | Shared. |
| *nm XX Price initiative effectiveness* | non-negative | Calibration |  |
| *nm stretch margin on XX cost* | non-negative |  |
| *time to change desired XX price* | positive |  |
| *time to change XX price* | positive |  |
| *tune MMO premium effect on hospital price* | non-negative | Shared. |
| *weight on XX price initiative* | non-negative |  |
| last updated 11/29/20 |

## In Isolation (Example Venue: OP Price):

### Initial values for equilibrium:

* *Desired OP Price* [Initial] = *Average OP Operating Cost* \* ( 1 + *minimum hospital operating margin* + *stretch margin on OP cost* + *MMO premium effect on hospital price* )
* *OP Price* [Initial] = *Desired OP Price* - *weight on OP price initiative* \* *OP Price Initiatives* \* *OP Price initiative effectiveness*

### Test 1: *Average OP Operating Cost*

#### Expectations:

Price is ultimately based off the cost of providing care. A change in *Average OP Operating Cost* should produce movement in the same direction in both *Desired OP Price* and, with a delay, in *OP Price.*

#### Testing:[[9]](#footnote-9)

*Average OP Operating Cost* = 500 + STEP(± 50, 2)



Figure 27: Effect of STEP in *Average OP Operating Cost* on *Desired OP Price* and *OP Price*

#### Results:

As expected, positive and negative step inputs in *Average OP Operating Cost* caused asymptotic growth or decline, respectively, in both *Desired OP Price* and *OP Price*, with the latter adjusting more slowly.

### Test 2: *Cumul MMO Premium Effect on Price*

#### Expectations:

MMO premiums are an expense and thus accounted for in the desired price. *Cumul MMO Premium Effect on Price* reflects the price level of premiums, so a change in the variable should produce movement in the same direction in both *Desired OP Price* and, because *OP Price Initiatives* is fixed, in *OP Price* as well*.*

#### Testing:

*Cumul MMO Premium Effect on Price* = STEP (± 0.2, 2)



Figure 28: Effect of step change in *Cumul MMO Premium Effect on Price* on *Desired OP Price* and *OP Price*

#### Results:

Both *Desired OP Price* and *OP Price* react to a change in *MMO premium effect on price* with asymptotic movement in the same direction, as expected.

### Test 3: *OP Price Initiatives*

#### Expectations:

*OP Price Initiatives* aim to decrease outpatient visit price. Thus, *OP Price Initiatives* and *OP Price* should move in opposite directions. *Desired OP Price* is unaffected by initiative changes.

#### Testing:[[10]](#footnote-10)

*OP Price Initiatives* = 100 + STEP(+/-10, 2)



Figure 29: Effect of step changes in *OP Price Initiatives* on *Desired OP Price*, *OP Price*, and *chg OP price*

#### Results:

An increase in *OP Visit Initiatives* causes a decline in *OP Price*, and a decrease in the former produces an increase in the latter. The adjustment path is asymptotic. As predicted, there is no effect on *Desired OP Price*.

### Test 4: *OP capacity utilization rate*

#### Expectations:

An increase in demand will increase hospitals’ perceived ability to charge more, and vice versa, in line with traditional supply-demand theory and with interviews with hospital administrators (the demand effect). Thus, a change in *OP capacity utilization rate* will produce movement in the same direction of *Desired OP Price*. With a delay, this will be transmitted as a proportional change in *OP Price.* However, changes in utilization also affect the initiative effectiveness parameter, ultimately causing movement of *OP Price* in the opposite direction (the enforcement effect). Because there is no delay in the enforcement effect, *OP Price* will initially move opposite to the change in *OP capacity utilization rate*. Over time, the demand effect may come to dominate the change in *OP Price* and reverse its direction of movement. The net effect on *OP Price* is indeterminate, as it depends on the value of other variables and parameters.

#### Testing:

*OP capacity utilization rate* = 0.5 + STEP(±0.1, 2)



Figure 30: Effect of step changes in *OP capacity utilization rate* on *Desired OP Price*



Figure 31: Effect of step changes in *OP capacity utilization rate* on *OP Price*

#### Results:

Because the *Desired OP Price* is only affected by the “demand effect,” it moves monotonically in the same direction as utilization, as demonstrated in Figure 30. Conversely, *OP Price* first moves in the opposite direction from the change in utilization (the “enforcement effect”), but the “demand effect” eventually comes to dominate and the price change reverses direction. In the pair of runs shown in Figure 31, by the time a new equilibrium is reached, the cumulative effects of the enforcement and demand effects are almost equal, returning *OP Price* to its original value. However, depending on the value of other variables, most notably *Average OP Operating Cost, OP Price Initiatives, weight on OP price initiative,* and *MMO premium effect on hospital price*, the relative strength of the two effects can vary greatly. As a result, a positive step change in *OP capacity utilization rate* can result in a new equilibrium where *OP Price* variously increases, returns to the original value, or decreases.

### Conclusion:

All expectations were confirmed – the sector operates according to its intended design.

## Verification of other venues:

* ER PRICE: 🗹
* OP PRICE: 🗹

## Recommendations and suggestions for further work:

* Some previous research has found that physicians *increase* prices when demand falls in order to maintain a desired income level (Ratanawijistrasin, 1993). This works because third parties (insurers) bear most of the cost. Such a finding suggests that perhaps the direction of demand influence on *stretch margin* should be reversed. More investigation is likely warranted. The direction and magnitude of such an effect may depend on type of insurance (traditional fee-for-service vs PPO, for instance).

# Module: Price Initiatives

## **Purpose:**

Managed Care Organizations (MCOs) would like to decrease the average price they reimburse for a health care visit. They employ a number of tactics in pursuit of this goal, including step therapy – requiring use of a generic drug before authorizing a patented medicine – excluding high-priced physicians from coverage networks, implementing a capitation payment scheme instead of fee-for-service. The Price Initiatives sectors track such initiatives by venue: physician office (PO), emergency department (ER), outpatient (OP), and inpatient (IP) settings.

## Uses:

* PO PRICE INITIATIVE
* ER PRICE INITIATIVE
* OP PRICE INITIATIVE
* IP PRICE INITIATIVE

## Diagram:



Figure 32: Diagram of *XX Price Initiatives* structure

## **Summary:**

MCOs determines a target price based on a fixed percentage reduction of an exponential smooth of historical prices, then adjust their initiative development capacity to meet that target. The model simulates initiative development as reactionary rather than proactive; insurers allocate resources to develop initiatives when increasing medical prices result in higher-than-anticipated payouts. However, no development capacity is allotted to replace initiatives which are “losing effectiveness”, meaning that initiatives rarely accomplish their full targeted price reduction. Development capacity takes time to adjust, and initiatives take time to be implemented. Initiatives also lose their effectiveness after a period of time, representing, among other possibilities, patients or providers finding work-arounds or the insurer terminating an initiative due to unpopularity or a large administrative burden.

## Decision Points:

* ***target XX Price –*** Medical care organizations are assumed to target price levels are based off the historical price level.
	+ Price initiatives create a reinforcing feedback loop where success in limiting *XX Price* leads to a further fall in *target XX Price*. However, the structure also creates an additional balancing loop that restrains this effect. In most cases, these feedback loops should be of minor importance.
* ***target XX price initiative capacity* –** Implementing initiatives requires organizational resources, represented by the *XX Initiative Development Capacity*. Target capacity is determined by the gap between the target and actual prices. Target capacity is translated into actual capacity over time, as MCOs adjust the amount of resources directed towards initiatives. It is important to note that target capacity does not take into account existing initiatives and the capacity that will be needed to replace expiring programs. This is intended to model the reactive nature of these initiatives: if an initiative is successful and reimbursement outlays decline, the loss of financial urgency will tend to cause the insurer to lose focus on sustaining the initiative, even if it is responsible for the improvement.
	+ *target XX price initiative capacity* cannot be negative (MAX function). A negative initiative capacity would represent insurers making efforts to increase the price of care. Because insurers pay the majority of this cost, such a scenario is unlikely.
	+ *target XX price initiative capacity* uses the normal initiative effectiveness, not the demand-influenced actual effectiveness. There are two justifications for this decision. First, initiative effectiveness is forecasted based on actuarial analysis which is unlikely to be significantly affected by temporary shifts in ongoing initiative effectiveness. Secondly, this formulation avoids a case where MCOs would sabotage themselves in a manner unlikely in the real world. As explained in detail under the Hospital Price section, initiative effectiveness is positively linked to utilization; it is presumed that high demand will stretch MCO budgets, prompting the insurers to enforce existing restrictions more stringently. Despite the increase in initiative effectiveness, total MCO outlays would likely remain high due to above-average utilization. In such a scenario, the organizations would still focus on cost-cutting, making a drop in price initiatives illogical. However, tying the target initiative capacity to the actual effectiveness would cause the former to decrease when the latter increased. Using the normal effectiveness instead avoids this situation. A more realistic formulation might base initiative development and deployment on MCO margins.
* ***XX price initiative processing* & *XX price initiative losing effectiveness***
	+ *XX price initiative processing* = *XX Price Initiative Development Capacity* / *time to develop XX price initiative*
	+ The simplifying assumption is made that initiatives do not take resources to administer once they have been developed; if development capacity instantly dropped to zero, initiatives would still remain in effect for their normal lifespan.

## Sector Inputs:

### Endogenous Inputs:

* ***XX Price*** [XX PRICE]: *target XX initiative capacity* & *Historical XX Price*
	+ *Historical XX Price* uses a 1st-order exponential delay function.

### Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value / Restrictions** | **Source** | **Notes** |
| *desired fract XX price reduction* |  | Calibration | Positive values result in reductions |
| *nm XX price initiative effectiveness* [from XX PRICE] | non-negative |  |
| *XX price initiative life* | positive |  |  |
| *time to change XX price initiative development capacity* |  |  |
| *time to develop XX price initiative* |  |  |
| *MCO accounting horizon* |  | Controls delay time for *Historical XX Price* |
| last updated 12/9/20 |

## In Isolation (Example Sector: ER Price Initiatives):

### For equilibrium:

* *ER Price Initiatives* [Initial] = *ER Price* \* *ER price initiative effectiveness* \* *ER price initiative life* /

( *time to develop ER price initiative* \* *desired fract ER price reduction*)

* *ER Price Initiative Development Capacity* [Initial] = *target ER price initiative capacity*

### Test 1: *ER Price*

#### Expectations:

Because initiatives are modeled as having an additive impact on price but insurers are assumed to target percentage decreases, an increase in price will require stronger initiatives, and vice versa. In other words, *ER Price Initiatives* will move in the same direction as the change in *ER Price*. However, because the target price is calculated based on a lagged price variable, the adjustment path will not be perfectly smooth. After a positive step increase in *ER Price*, for instance, *target ER price initiative capacity* will lose part of its initial gain once *Historical ER Price* catches up to *ER Price*.

#### Testing[[11]](#footnote-11):

*ER Price* = 200 + STEP( ±20, 2)



Figure 33: Effect of positive and negative STEP in *ER Price* on *ER Price Initiatives*

#### Result:

**Increase in *ER Price*** 🡪 increase in *ER Price Initiative Development Capacity* 🡪 **increase in *ER Price Initiatives***. Adjustment path depends on relative delay sizes; positive and negative changes may produce asymmetrical paths. Nevertheless, once a new equilibrium is reached, the respective differences from the original equilibrium are symmetrical (see Figure 33).

### Conclusion:

All expectations were confirmed – the sector operates according to its intended design.

## Verification of other sectors:

PO Price Initiatives: 🗹

OP Price Initiatives: 🗹

IP Price Initiatives: 🗹

## Recommendations and suggestions for further work:

* Duplicate Consumer Response structure for all venues and integrate into Price Initiatives structure (3).
* Consider linking MCO margins to desired initiatives (5).

# Module: Hospital Revenue

## Purpose:

The Hospital Revenue sector produces national aggregate values for hospital costs and revenue.

## Uses:

* HOSPITAL REVENUE

## Diagram:



Figure 34: Diagram of the Hospital Revenue sector.

## Summary:

This sector is almost purely computational, with no decision or behavior modeling. All costs are summed to produce *total hospital cost*, all income sources contribute to *total hospital revenue*, and the difference is *hospital net revenue*. Related to these are *Average Hospital Operating Cost*, *Average Hospital Revenue*, and *net average hospital revenue*, respectively, which correspond to the delayed “measured” values. All these values represent totals, not per visit or per bed day figures.

## From other sectors:

* ***annual emergency operating cost*** [HOSPITAL COSTS]: *total hospital treatment costs*
* ***annual ER visits*** [ER VISIT RATE]: *total hospital revenue*
* ***annual inpatient operating cost*** [HOSPITAL COSTS]: *total hospital treatment costs*
* ***annual IP bed days*** [IP VISIT RATE]: *total hospital revenue*
* ***annual OP visits*** [OP VISIT RATE]: *total hospital revenue*
* ***annual outpatient operating cost*** [HOSPITAL COSTS]: *total hospital treatment costs*
* ***Cumulative Non Treatment Cost Inflation*** [HOSPITAL COSTS]: *total hospital treatment costs*
* ***ER Price*** [HOSPITAL PRICE]: *total hospital revenue*
* ***initial annual non treatment operating cost*** [HOSPITAL COSTS]: *total hospital treatment costs*
	+ Constant
* ***IP Price*** [HOSPITAL PRICE]: *total hospital revenue*
* ***OP Price*** [HOSPITAL PRICE]: *total hospital revenue*

## Notable calculation variables:

* ***total hospital treatment cost*** = *emergency operating cost* + *outpatient operating cost* + *inpatient operating cost*
* ***non treatment operating cost*** = *annual non treatment operating cost* \* *Expected Non Treatment Cost Inflation Effect*
* ***total hospital cost*** = *total hospital treatment cost* + non treatment operating cost
* ***total hospital revenue*** = *annual OP visits* \* *OP Price* + *annual ER visits* \* *ER Price* + *annual IP bed days* \* *IP Price*
* ***hospital net revenue*** = *total hospital revenue* – *total hospital cost*

## Parameters & Exogenous Inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value / Restrictions** | **Source** | **Notes** |
| *time to measure hosp cost* | positive |  | Also used in HOSPITAL COSTS sector. |
| last updated: 11/10/20 |

## For equilibrium:

* *Average Hospital Revenue* = *total hospital revenue*
* *Average Hospital Operating Cost* = *total hospital cost*

# Module: Physicians

## Purpose:

The physicians module tracks the number of practicing physicians.

## Uses:

* PHYSICIANS

## Diagram:



Figure 35: Diagram of the Physicians sector

## Summary:

There is one stock – *Physicians in Practice*. Physicians can enter either by graduating from medical school or by immigrating. As the name of the stock implies, both these inflows only include those individuals who go into practice – the model does not include people with medical degrees who are not practicing. The single outflow accounts for all physicians leaving active practice. All flows in this sector are fully exogenous.

## Sector Inputs:

### From other sectors:

None

### Parameters & Exogenous inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value / Restrictions** | **Source** | **Notes** |
| *average practice life* | positive |  |  |
| *physicians graduating* | Data-type input (optional) |  | Effectively an inflow to *Physicians in Practice* with a delay time of 1 |
| *physicians immigrating* | Data-type input (optional) |  | Inflow to *Physicians in Practice* |

## In Isolation

### For Equilibrium:

* *physicians graduating* = *Physicians in Practice* / *average practice life* - *immigrating physicians in practice*

## Recommendations and suggestions for further work:

* Physician flows (both entering and leaving) could be linked to physician price or another measure of financial success. (6)

# Module: Medical Technology

## Purpose:

Technology is one of the most important dynamic influences on health diagnosis, care delivery and outcomes. This sector tracks “Medical Technology Solutions,” both pharmacological and non-pharmacological in nature. While the value of *Medical Technology Solutions* is not meaningful in and of itself, the cumulative trend can be tracked to create an index of technological progress.

## Uses:

* MEDICAL TECHNOLOGY

## Diagram:



Figure 36: Simplified diagram of the Medical Technology sector, with selected feedback loops labeled

## Summary:

At its core, the medical technology sector is driven by the trend in prescription revenue (here, prescriptions refer to doctor’s orders, whether for pharmaceuticals or other tests or procedures). Moreover, because the number of prescriptions written is proportional to *Medical Technology Solutions,* a pair of feedback loops is created within the sector (**B1** & **R1**).[[12]](#footnote-12) The labels **B1** and **R1** actually represent three loops each, but the aggregate effect can be captured by thinking of a reinforcing loop and a delayed balancing loop. More prescriptions produce more industry revenue, some of which is re-invested in research and development. As industry revenue grows, more players join and there is a greater reward for innovation, speeding up the rate of new discoveries and development. It is worth emphasizing that industry size has **no** effect on innovation rate – only the trend matters. To illustrate the difference, consider that a one-time step increase in revenue will initially produce in increases in both revenue value and trend, but will eventually settle into a new equilibrium where the amount of revenue remains elevated but the trend returns to zero. In this scenario, both the innovation rate and the level of technology would return to their original values – the latter because the stock of technology depreciates over time (**B3**).

In the model, there are three categories of medical needs: “unidentified”, “unmet” but identified, and those both identified and addressed by medical technology solutions. The more identified unmet needs, the faster the innovation rate (**B4**). This represents the declining efficiency of innovation as “low hanging fruit” becomes progressively rarer, an effect documented in the real world (McConaghie, 2018). The pool of unmet needs can be replenished by identifying new needs (**R2**), a process whose rate is affected by the industry revenue growth trend in a similar manner to the innovation rate. The sum of all medical needs (identified and not) is modeled as finite via the *max medical needs* parameter.

As the medical market becomes more saturated, the average new technology is assumed to target a more specialized market and thus have a smaller impact on aggregate medical decisions (**B5**). Market saturation is determined by the ratio of medical technology solutions to unmet medical needs. The latter is chosen over *max medical needs* to represent the new market opportunities produced by needs identification.

### Decision points:

* ***trend in medical technology solutions*** – As the name implies, this variable calculates the proportional change in *Medical Technology Solutions*. However, the value is modified by the *market fraction affected by new tech*. The flow into *Cumulative Medical Technology Trend* is the 1st order delay of *trend in medical technology solutions*, with a delay time equal to the parameter *med tech diffusion time*.
* ***prescriptions written*** – The total number of prescriptions written is the product of two factors: medical visits and prescriptions per visit. Relative technology level is assumed to affect both; however, the effect on visit rate is handled by the respective visit rate sectors. The relationship of technology to *prescriptions written* thus represents the effect on prescriptions per visit. New technology expands the options physicians have when ordering tests or procedures or prescribing medicines, which is assumed to create a positive relationship between technology and prescriptions per visit. Each visit type has an associated normal scripts per visit parameter.
* ***Research Dollar Resources* –** The money directed at research and development of new technologies or treatments, expressed in real dollars. The targeted *fraction of revenue to research* is constant, but there is an adjustment time (*time to chg research fract*) in the event of a change in income. In other words, *Research Dollar Resources* is a smoothed function of *prescription revenue*.
* ***Pressure to Increase Medical Market*** – When the medical technology industry is experiencing revenue growth, there is fiercer competition and a greater incentive to “win” through innovation. If industry revenue is declining, *Pressure to Increase Medical Market*, which is the ratio of *Research Dollar Resources* to *Lagged Research Dollar Resources*, impacts both the *time to innovate* and *time to identify needs*.
* ***identification of needs*** – This flow into *Identified Medical Needs* represents the identification of new medical conditions and the development of tests to identify disease. The concept encompasses the identification of distinct new conditions as well as advances in knowledge about known conditions that expand the understanding of potentially valuable treatment avenues.
* ***unmet medical needs* –** Medical needs that have been recognized but are not (fully) treated by current technology.
	+ *unmet medical needs* = *Identified Medical Needs – Medical Technology Solutions*

## Sector Inputs:

### From other sectors:

* ***annual PO Visits*** [PO Visit Rate]: *prescriptions written*
* ***annual ER Visits*** [ER Visit Rate]: *prescriptions written*
* ***annual OP Visits*** [OP Visit Rate]: *prescriptions written*
* ***annual IP Visits*** [IP Visit Rate]: *prescriptions written*

### Parameters & Exogenous inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value** | **Source** | **Notes** |
| *fraction of revenue to research* | 0.052 | Calibration |  |
| *max medical needs* |  | Calibration | Theoretical value. |
| *med tech diffusion time* |  |  |
| *medical solution life* |  |  |
| *min needs id time* | 10 |  |  |
| *nm market fraction* |  | Calibration |  |
| *nm time to identify needs* |  |  |
| *nm scripts per ER visit* | 2 |  |  |
| *nm scripts per IP visit* | 4 |  |  |
| *nm scripts per OP visit* | 3 |  |  |
| *nm scripts per PO visit* | 1 |  |  |
| *nm time to innovate* |  | Calibration |  |
| *script inflation rate function* | Data input  |  |  |
| *time to chg research fract* |  | Calibration | research fract = fraction of revenues to research |
| *time to feel pressure* |  | time to feel competitive market pressure to innovate |
| *time to lag value of research dollars* |  |  |
| last updated 12/7/20 |

## In Isolation:

### Initial values for equilibrium:

* *Fraction Market Affected by Adopted Medical Technology* [Initial] = *fraction market affected by new medical technology*
* *Identified Medical Needs* [Initial] = *max medical needs*
* *Lagged Research Dollar Resources* [Initial] = *Research Dollar Resources*
* *Medical Technology Solutions* [Initial]= *medical solution life* \* *max medical needs* / ( *medical solution life* + *nm time to innovate* )
* *Pressure to Increase Medical Market* [Initial] = 1
* *Research Dollar Resources* [Initial] = *fraction of revenue to research* \* *prescription revenue*
* *script inflation rate* = 0

Note: Because initial *Identified Medical Needs* = *max medical needs*, *identification of needs* = 0 and the needs identification loops (**R2** and its unlabeled balancing counterpart) are inactive. Unfortunately, there is no other way to put the sector in equilibrium.

------------------------------------------------------------------------------------------------------------------------------------------

All endogenous inputs into this sector modify *prescriptions written*; therefore, demonstrating that changes in one input produce the desired results is sufficient to verify all inputs. Thus, verification will only be demonstrated for the *annual PO visits* input. For Tests 1-4, the equation is as follows:

*annual PO visits* = 1000 + STEP(500, 2)[[13]](#footnote-13)

Due to the complexity of this sector, validation will begin with the least complex core structure and other elements will be added on in steps. After each addition, the results will be compared with expectations. Figure 37 displays the structural components, while Figure 38 lists the components used in each run. The results of negative step changes are not shown, but in all cases they run roughly symmetrical to positive step changes.

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### Test 1: No major feedback loops

For the first test, the only feedback loop is the depreciation effect (**B3**). This means that the cumulative technology trend has no effect on the number of prescriptions written and *unmet medical needs* is a constant, in turn isolating the behavior of *research dollar trend*. The run is labeled “No Major Feedback” in Figure 39 and is cyan in color.

#### Expectations:

When the number of physician visits increase, more prescriptions will be written and medical technology revenue will also rise, though with a delay. A positive revenue trend creates greater market pressure and speeds up innovation, but as *Lagged Research Dollar Resources* catches back up to *Research Dollar Resources*, *Pressure to Increase Medical Market* will trend back towards 1. Without the major feedback loops, *prescription revenue* will remain constant after the initial step, so the *research dollar trend* should peak soon after the step time and then return to zero. Because depreciation is proportional to the stock value, *Medical Technology Solutions* should decay to its original value.

#### Results:

The model results for the “No Feedback Run” confirm expectations. The path closely follows the shape of a right-skewed bell curve, exhibiting S-shaped growth until it peaks around year 20, after which it slowly declines until it settles at the original equilibrium value.



Figure 37: Simplified diagram showing testing progression

**Run Key:**

(1) No Major Feedback: 

(2) Primary Loops Only: 

(3) Primary + Low Hanging: 

(4) Primary + Low Hanging + Specialization: 

(5) All loops: 

Figure 38: Testing run key



Figure 39: Graph of *Medical Technology Solutions,* runs 1 - 4

### Test 2: Primary Loops Only

In Test 2, the connection between *Cumulative Medical Technology Trend* has been reestablished, activating **R1** and **B1** loops (these labels technically represent three loops each, but the effect can be reasonably approximated as a reinforcing loop and a delayed balancing loop). In Figure 38 and Figure 39 this run is labeled “Primary Loops Only” and is colored brown.

#### Expectations:

Due to the activation of the reinforcing feedback loop, *Medical Technology Solutions* should increase more than in Test 1. However, as *Lagged Research Dollar Resources* catches up to *Research Dollar Resources,*  the new loops will virtually cancel each other out, resulting in temporary dominance of depreciation loop **B3**. Therefore, *MTS[[14]](#footnote-14)* will once again return to its original equilibrium position.

#### Results:

As shown in Figure 39, *Medical Technology Solutions* indeed reaches a higher maximum in Run 2 (“Primary Loops Only”) compared to Run 1 (“No Major Feedback”), and both eventually return to their original value, although Run 2 experiences mild damped oscillation. Note that Run 2 declines more rapidly; this is due to the new feedback loops accelerating the downward trend.

### Test 3: Adding Diminishing Returns

In this test, *unmet medical needs* is no longer a constant, although *Identified Medical Needs* is. This means that *unmet medical needs* decreases as *MTS* increases, activating loop **B4**. Thus, innovation becomes less efficient the larger *Medical Technology Solutions* is, representing a diminishing returns or “low hanging fruit” effect. This test run is labeled “Primary plus Low Hanging” and is orange in color.

#### Expectations:

Because *innovation rate* is inversely proportional to unmet needs, this addition should curtail the growth in *MTS* compared to Run 2 (“Primary Loops Only”). As before, it should return to its original equilibrium value over time.

#### Results:

As expected, the introduction of loop **B4** limits growth in *Medical Technology Solutions* quite severely compared to Run 2. As before, *MTS* returns to its original value via damped oscillation.

### Test 4: Adding Specialization

In this run, *market fraction affected by new tech* is no longer constant; instead, it decreases as *MTS* increases. As explained in the Summary section, this simulates the narrowed impact of average new innovation as the market becomes more saturated. Run 4 is labeled “Primary plus Low Hang plus Specialization” and is represented by a thick blue line in Figure 39.

#### Expectations:

With *market fraction affected by new tech* free to adjust, an increase in *MTS* will cause a smaller increase in *trend in MTS* than in previous runs. This will dampen the effect of the **R1** feedback loop. Thus, *MTS* should peak lower in Run 4 than in Run 3 (Primary + Low Hanging Fruit).

#### Results:

At the scale of Figure 39, the trajectories of Runs 3 and 4 are indistinguishable, but Run 4 in fact peaks slightly lower than Run 3; because of this, Run 4 also experiences slightly larger amplitude dampened oscillation.

### Test 5: Ramp and Exponential Inputs

To confirm that an exponential increase in *annual PO visits* is needed to keep *MTS* from returning to its original equilibrium value, the same active structure as in Test 4 was run twice more: once with a sustained ramp increase and once with an exponential increase in *annual PO visits*.



Figure 40: Comparison of input pattern effect on *Medical Technology Solutions*

#### Results:

As shown in Figure 40, a constant ramp increase in *annual PO visits* is not sufficient to avoid decline in *MTS*. It takes a very long time (over 1000 years), but eventually it returns to the original equilibrium. An exponential input results in a monotonically increasing trend in *MTS*, but *MTS* nevertheless settles into a new equilibrium far below the value of *Identified Medical Needs*, which in these runs was 10,000. This is an important finding: in this model, constant exponential growth in *prescriptions written* causes *Medical Technology Solutions* to settle into an equilibrium where *unmet medical needs* is non-zero.

What happens when there is a **negative** ramp input? Figure 41 shows the results. *MTS* will decline as long as *prescriptions written* is positive and there is a sustained constant negative input change. As soon as the input levels out, however, *MTS* returns to the equilibrium value (see brown line). The exception is if *prescriptions written* reaches zero and stays there. Because this results in no prescription revenue, *Research Dollar Resources* (and consequently, *research dollar trend*) will also go to zero. With no innovation inflow, *MTS* will decay to zero (blue line).



Figure 41: Effect of negative ramp input on *Medical Technology Solutions*

### Conclusion:

All expectations were confirmed – this sector operates according to its intended design with the very important caveat that the influential Needs Identification feedback loop cannot be active in an equilibrium scenario.

## Recommendations and suggestions for further work:

As mentioned above, it is not possible for the needs identification loop to be active while in an equilibrium-based policy testing mode; *Identified Medical Needs* must equal *max medical needs* for equilibrium behavior to be maintained. Clearly, this is not ideal, as this loop is an important contributor to the overall behavior of the sector. There are two general alternatives to address this issue. First, to redesign the sector in such a way that all loops can be active while maintaining equilibrium. The other option would be to choose not to initialize the model in equilibrium for policy testing, but rather to produce a base run that can be compared to policy-testing runs. This is not ideal either, as equilibrium initialization improves the ease of tracking policy effects. In any case, it is recommended that future users of this model seriously consider following one of these paths.

Other suggestions and research questions:

* Should absolute market size (rather than solely the trend) have an impact on innovation rate?
* Consider making *needs id rate* dependent on stock of *unmet medical needs.*
* Make *unidentified medical needs* an infinite source?
* Should the research fraction of revenues be variable?
* Jim Thompson originally envisioned separating pharmaceutical development into a complementary module. This could be a possible avenue for future expansion.(9)

# Module: MMO Premiums

## Purpose:

Tracks medical malpractice premiums by modeling the basic financial structure of medical malpractice insurers or organizations (MMO). When the model was constructed, malpractice premiums had been growing rapidly for several years and were thus a significant focus of efforts to forecast (and reduce) medical cost growth. This explains the detail devoted to this sector.

## Uses:

* MALPRACTICE PREMIUMS

## Diagram:



Figure 42: Diagram of part 1 of the MMO Premium module



Figure 43: Diagram of part 2 of the MMO Premium module

## Summary:

In the model, malpractice claims are determined by the product of annual medical spending, the normal error fraction, and the error cost multiple. Because the model does not represent unsuccessful claims, the *nm error fraction* is the fraction of medical visits which result in successful malpractice suits.[[15]](#footnote-15) *MMO error cost multiple* is the estimated ratio of the average claim value to the original visit cost. In other words, for every dollar’s worth of negligent care, “*MMO error cost multiple”* dollars are claimed. Claim value is also modified by *healthcare cost index*, a measure of aggregate medical cost inflation, as measured by the aggregate*.* Furthermore, claims take time to be processed, adjudicated, and settled. The number of malpractice claims is also tracked (bottom chain in Figure 42), but only for the purpose of calculating the average claim value; for the purposes of MMO premium setting, only total claim value matters.

Malpractice insurers are assumed to set premium rates at a level which covers claim payments as well as a desired profit margin. Administrative costs are abstracted in claim payouts. Insurers also maintain an actuary reserve of invested assets which not only serves a cushion against a down period but also generates a return used to help fund operations. Because premiums cannot be changed instantaneously to account for shifts in claim payments, it is possible to have an imbalance between costs and income. Though claim payments can be covered by the actuary reserve, MMOs are assumed to attempt to recoup any cumulative shortfall by increasing future premiums. Conversely (despite the variable name), excess income reduces future premiums.

This sector includes a basic structure tracking the number of medical malpractice insurers. When MMO profits exceed targets, the industry becomes attractive and more players join. If profits are subpar, the opposite happens. Larger numbers of insurers increase the time required to adjust premiums and extends the desired time to recoup past revenue shortfalls. Smaller numbers do the opposite. When costs experience a sustained and premium revenue shortfalls appear, a decrease in *Medical Malpractice Insurers* allows premiums to adjust more quickly, narrowing the shortfall. When costs are decreasing, the increase in MMO numbers results in a slight larger profit margin as premiums take longer to fall.

### Decision Points:

* ***inflation effect on claim value* –** The purpose of this inflow to *MMO Claims in Adjudication* is unclear. It is equal to the product of that stock and *healthcare cost index*, the latter being the model’s non-cumulative measure of aggregate healthcare cost inflation. However, the *annual medical expense* off which claim value is calculated already adjusts for this cost inflation. There are two possible purposes I can think of:
	+ **1.** It is intended to model the growth of malpractice claim value *above* that of general medical cost inflation.
	+ **2**. It simulates inflation during the delay between claim filing and payout.
* ***Average Malpractice Industry Performance*** – The smoothed ratio of the actual MMO profit margin to the desired margin.
* ***companies wanting to join MMO business* –** If the industry is performing well, more players want to join. Conversely, if it is doing poorly, some existing companies look to exit the market. The “desired” number of firms in the MMO market is the initial number of insurers (*normal malpractice insurers*) multiplied by the output of the lookup function *Malpractice Insurance Industry Performance f*, shown in graphical form in Figure 44*.* The input to the lookup function is *Average Malpractice Industry Performance*. *Companies wanting to join MMO business* takes the desired number and subtracts the current number. Thus, a positive value of this variable denotes an aggregate inflow of insurers, while a negative value signals an outflow.
	+ The inflow and outflow to *Medical Malpractice Insurers*, *MMO insurer entering* and *MMO insurer attrition*, respectively, are controlled by IF THEN ELSE statements, and both cannot be active simultaneously.
	+ As shown in Figure 44, the slope above one is much shallower than the slope below. This means that insurer numbers are much more sensitive to small decreases in aggregate industry performance than they are to small increases.



Figure 44: lookup function *Malpractice Insurance Industry Performance f*

* ***effect of MMO market size*** – The ratio of current to initial *Medical Malpractice Insurers*.
* ***time to recover premium shortfall* –** Insurers would like to recover a ( 1 / *time to recover premium shortfall* )fraction of *MMO Premium Revenue Shortfall* each year. This would generate exponential decay if there were no other influences. *Time to recover premium shortfall* is inversely proportional to *effect of MMO market size*. The reasoning for this relationship has been lost to time.
* ***time to change MMO premium rev* –** Insurer count is positively correlated to the adjustment time for *MMO premium revenue*. The relationship is determined by the *effect of market size f* lookup function shown in Figure 45. The input is *effect of MMO market size* and *time to change MMO premium rev* is the output.
	+ There is a separately specified *min time to change MMO prem rev*



Figure 45: lookup function *effect of MMO market size f*

## Inputs:

### From other sectors:

|  |  |  |
| --- | --- | --- |
| * ***annual ER visits*** [PO VISIT RATE]
 | } | **:** *annual medical expense* |
| * ***annual IP visits*** [PO VISIT RATE]
 |
| * ***annual OP visits*** [PO VISIT RATE]
 |
| * ***annual PO visits*** [PO VISIT RATE]
 |
| * ***ER Price*** [ER PRICE]
 |
| * ***IP Price*** [IP PRICE]
 |
| * ***OP Price*** [OP PRICE]
 |
| * ***PO Price*** [PO PRICE]
 |

* ***healthcare cost index*** [HEALTH CARE COST INDEX]: *inflation effect on claim value*
* ***MMO investment income*** [MALPRACTICE EQUITY]: *desired premium revenue* & *MMO Premium Revenue Shortfall* & *perceived MMO margin*

### Parameters & Exogenous inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value** | **Source** | **Notes** |
| *annual CPI U* | Optional data input |  | Used in *MMO premium trend effect on price* |
| *annual fraction MMO loss discovered* | 1 | Calibration | Real-world meaning unclear (fails parameter verification test). |
| *desired malpractice insurance profit margin* | 0.2 |  |  |
| *min time to change MMO premium rev* | 0.5 |  |  |
| *MMO error cost multiple* | 1000 | JPT estimate | Ratio of claim value to original visit cost. |
| *nm error fraction* | 8.5 \* 10^(-6) |  | Fraction of care delivery resulting in a successful malpractice claim.  |
| *nm time to change MMO premium rev* | 2 |  |  |
| *nm time to recover MMO premium rev shortfall* | 2 |  | rev = revenue.  |
| *normal malpractice insurers* | 200 |  |  |
| *potential malpractice case per visit* | 1 |  | Multiplied by error fraction and visit totals to produce number of malpractice cases. |
| *switch on malpractice effect* | 0 OR 1 |  | 0 = no malpractice effect |
| *time to average MMO profit* | 2 |  | Used in determining average industry performance. |
| *time to enter MMO market* | 3 |  | for insurers joining |
| *time to exit MMO market* | 10 |  | for insurers exiting |
| *time to MMO adjudication* | 1 |  | Average time to flow from *MMO Discovered Loss* to *MMO Claims in Adjudication.* |
| *time to perceive MMO margin* | 10 |  | Used in determining average industry performance. |
| *time to perceive MMO premium trend effect on price* | 1 |  |  |
| *time to perceive MMO premium trend effect on utilization* | 2 |  |  |
| *time to settle MMO case* | 2 |  | Average time to leave *MMO Claims in Adjudication* stock. |
| last updated 12/7/20 |

## In Isolation:

### For equilibrium:

* *Average Malpractice Insurance Industry Performance* [Initial]= *fraction of MMO profit margin achieved* = 1
* *healthcare cost index* = 0
* *Medical Malpractice Insurers* [Initial]= *normal malpractice insurers*
* *MMO Case in Litigation* = *annual fraction MMO loss discovered* \* *annual medical case load* \* *time to settle MMO case*
* *MMO Case Initiated* = *annual fraction MMO loss discovered* \* *annual medical case load* \* *time to MMO adjudication*
* *MMO Claims in Adjudication* [Initial] = *annual fraction MMO loss discovered* \* *annual MMO loss* \* *time to settle MMO case*
* *MMO Discovered Loss* [Initial] = *annual fraction MMO loss discovered* \* *annual MMO loss* \* *time to MMO adjudication*
* *MMO Premium Revenue* [Initial] = ( 1 + *desired malpractice insurance profit margin* ) \* *MMO paying claims* – *MMO investment income*
* *MMO Premium Revenue Shortfall* [Initial]= 0

### Test 1: *annual medical expense* step

Expectations: *annual medical expense* and *MMO Premium Revenue* will move in the same direction. Changes in *annual medical expense* represent changes in visit rates or prices. When this value increases, MMO claims will also increase, which, after a delay, will increase MMO payouts to claimants. Faced with rising costs, insurers must augment their income by raising premiums. Because there will be short-term losses, there may be a decrease in numbers of MMOs. In the “fixed MMI” runs, changes in the number of malpractice insurers have no effect on *time to recover premium shortfall* and *time to change MMO premium rev.*

#### Testing:

*annual medical expense* = 500,000 + STEP(±100,000, 2)

#### Results:

We will begin with the positive step in *annual medical expense*. Once the change propagates through to *MMO paying claims*, the combination of *MMO investment income* (which is fixed in these runs) and *MMO Premium Revenue* is insufficient to meet expenses, so the latter must increase. By the time premium revenue is sufficient to cover immediate expenses, a debt has accumulated in *MMO Premium Revenue Shortfall* (see Figure 47). As such, premiums continue to rise for a bit, then decline to their new equilibrium via damped oscillation as the shortfall is reduced to zero. The opposite process happens when *annual medical expense* declines.



Figure 46: Effect of step changes in *annual medical expense* on *MMO Premium Revenue*

When claim costs increase, insurers initially cannot meet their targeted profit margins. As actors judge the industry to be less profitable, some insurers exit the market (see Figure 48). This reduces the premium adjustment time and also decreases *time to recover premium shortfall*; the aggregate effect is that insurers can increase premiums more rapidly than in the “fixed MMI run,” where these variables are constant. This results in a smaller peak shortfall and a quicker recovery, evident in Figure 46 and Figure 47.

In response to a fall in claims costs, insurers initially extract higher-than-normal profits, attracting more companies to the market. This increases premium adjustment time and lengthens the shortfall recovery (in this case, actually the surplus payback) horizon, leading to a slightly lower trough in *MMO Premium Revenue Shortfall* and slightly more pronounced oscillation in the variable MMI run. The difference between the variable and fixed MMI runs is much more noticeable with the positive step. This is due to the variable slope of the *effect of MMO market size f* lookup function used to determine *time to change MMO premium rev* (see Figure 45). Firms are modeled as being most sensitive to poor industry performance.

Also interesting to note is that the number of malpractice insurers drops just as low in the negative step run as in the positive step run, though it happens later in the simulation. The reason is that the industry performance calculations do not consider the *MMO Premium Revenue Shortfall.* When insurers are using their accumulated surplus to lower premiums, they are not meeting the desired margins, so companies want to exit the industry.



Figure 47: Effect of step changes in annual medical expense on MMO paying claims and MMO Premium Revenue Shortfall

Figure 48: Effect of step changes in *annual medical expenses* on *Medical Malpractice Insurers*

### Test 2: *annual medical expense ramp*

This test demonstrates the potential for the sector to exhibit steady state error when faced with a sustained increasing input, whether linear or exponential.



Figure 49: *MMO Premium Revenue Shortfall* under various input types

Figure 49 shows the *MMO Premium Revenue Shortfall* (not the *MMO Premium Revenue*) in response to ramp and exponential changes in *annual medical expense*. With both positive and negative ramp inputs, the shortfall settles into a non-zero equilibrium. Because the shortfall is the gap between actual and desired premium revenue, this is steady state error.

### Test 3: *healthcare cost index*

Expectations: Like *annual medical expense*, healthcare cost index affects claims payouts. The important difference is that *healthcare cost index* modifies the *inflation effect on claim value* flow into *MMO Claims in Adjudication*. This stock-flow pair forms a reinforcing loop which competes with the *MMO paying claims* – *MMO Claims in Adjudication* balancing loop. If *healthcare cost index* is less than 1 / *time to settle MMO case* (including if it is negative), the balancing loop will dominate and growth will be asymptotic. If greater than that value, growth will be exponential.

Testing:

*healthcare cost index* = STEP(0.1, 2) + STEP(0.1, 12)



Figure 50: Effect of double step changes in *healthcare cost index* on *MMO paying claims*

Results:

*Healthcare cost index* is the averaged trend in aggregate healthcare costs, with a value of 0.1 representing a 10% yearly increasing trend. However, a step increase in the index from 0 to 0.1 causes a nearly 25% jump in claims costs, while an increase in the index from 0.1 to 0.2 (10% to 20% annual growth), there is an increase of over 30%, for a cumulative increase of over 65%. The corresponding values for step decreases in the cost index are 16%, 15%, and 29%. The discrepancy between the change in index and the change in claim value is due to the reinforcing loop between *Inflation effect on claim value* and *MMO Claims in Adjudication*.

### Conclusion:

The sector fulfills its main objectives, but there are a few areas which need some revision.

## Recommendations and suggestions for further work:

* *MMO premium revenue trend* is currently *chg MMO premium revenue / MMO Premium Revenue*. Consider replacing the denominator with the initial value of *MMO Premium Revenue*. Currently, a change in MMO premiums from 2% to 1% of physician costs has the same effect on PO price as a change from 10% to 5%. Making the denominator constant would mean that the trend is based off absolute rather than relative changes. The true effect is likely somewhere between the two extremes, so this is a modeler’s judgement call. (2)
* Address the possibility for steady-state error when *annual medical expense* is growing exponentially. (4)
* *MMO premium trend effect on utilization* and *MMO premium trend effect on price*, along with their accessory variables, may be better suited in the utilization and price sectors, respectively. (1)
* Even though profit margins influence the number of malpractice insurers, there are no actual profits in the model: all excess income is used to decrease future premiums. Whether this is an issue likely depends on the purpose of the modeling project and the importance of the malpractice sector.
* Accumulated shortfall not factoring into industry performance calculations causes some questionable behavior. When insurers are using their accumulated surplus to lower premiums, they are not meeting the desired margins, so companies want to exit the industry. On the other hand, when revenue is greater than claim cost plus desired premiums, companies want to join, even though the “extra” revenue is being used to pay down a cumulative shortfall. This merits investigations.
* Examine real-world malpractice claim behavior to see if there is justification for the separate *inflation effect on claim value*.

# Module: MMO Equity

## Purpose:

The MMO Equity tracks the value of assets in the MMO Actuary Reserve and the income derived from those assets.

## Uses:

* MMO EQUITY

## Diagram:



Figure 51: Diagram of the basic structure of the MMO Equitymodule.

## Summary:

Like other types of insurers, malpractice insurers must maintain a reserve in case of claim costs exceeding premium income over a certain period of time. Though they can make up the loss by raising future premiums, they need an immediate source for paying the claims. In many places, governments require malpractice insurers to keep a certain fraction of annual costs in a reserve. In the model, the target value of the actuary reserve is one year’s worth of claims value. A notable simplification is that the money going in (or out) of the actuary reserve does not have to come from (or go) anywhere; *MMO Actuary Reserve* simply adjusts over time to equal *MMO Claims in Adjudication*.

Though the interest rate is set as a constant for equilibrium-based runs, it can be set up to be driven using historical data or another type of input..

## Model Inputs:

### From other sectors:

* ***MMO Claims in Adjudication*** [MMO PREMIUM]: *indicated change in MMO actuary reserve*

### Parameters & Exogenous inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable Name** | **Value** | **Source** | **Notes** |
| *ave hist MMO invst rate* | 0.06 | Calibration | The sector is currently structured such that this parameter provides the constant investment rate. |
| *time to return to ave MMO invst rate* | 2.5 |  | Currently unused. Intended to smooth transition between data input and constant when making future predictions (i.e. no further data available) |
| *time to adjust MMO actuary reserve* | 2 |  |  |
| Last Updated 12/7/20 |

## In Isolation:

### For equilibrium:

* *MMO Actuary Reserve* = *MMO Claims in Adjudication*
* *MMO ave invst rate* = *ave hist MMO invst rate*

### Conclusion:

This sector fulfills its intended purpose adequately, but there are important improvements that can be made.

## Recommendations and suggestions for further work:

* Consider linking changes in the actuary reserve to the rest of the MMO budget in the MMO PREMIUM module. Currently, an increase in claim costs will “magically” increase *MMO Actuary Reserve* (and thus investment income) at the same time as the MMOs are losing money. (3)

# Module: MCO Premium

Placeholder.

1. Where applicable, references to *… XX visit rate* variables encompass the equivalent LOS variable. [↑](#footnote-ref-1)
2. Converted from level to auxiliary type variable. [↑](#footnote-ref-2)
3. In the interest of readability and concision, “… *XX rate*” (in this case, *technology adjusted XX rate*) may be used to encompass similarly named variables from all venues listed in the “Uses” section. Unless explicitly stated otherwise, this includes the relevant length of stay variable (here, *technology adjusted LOS*) even though the name is not an exact fit. [↑](#footnote-ref-3)
4. Converted from Level to Auxiliary [↑](#footnote-ref-4)
5. Unless explicitly noted otherwise, the information given applies to the equivalent IP variable; here, *forecast annual IP bed days* [↑](#footnote-ref-5)
6. There is no analogous delay in *annual CPI U*. It is unclear why wage inflation is treated differently. [↑](#footnote-ref-6)
7. *IP bed capacity* = *IP Capacity* / 365 [↑](#footnote-ref-7)
8. Converted from Level to Auxiliary type variable [↑](#footnote-ref-8)
9. Variable converted from level to auxiliary type. [↑](#footnote-ref-9)
10. Variable converted from Level to Auxiliary. [↑](#footnote-ref-10)
11. Converted from Level to Auxiliary [↑](#footnote-ref-11)
12. **R1** and **B1** are identical except that **B1** “detours” through *Lagged Research Dollar Resources*. Because the link between *Research Dollar Resources* and *Lagged Research Dollar Resources* is negative, the loop polarity is reversed. Loops **R2** and **B5** also have corresponding loops of opposite polarity that are unlabeled in Figure 36. [↑](#footnote-ref-12)
13. For convenience, all visit numbers have been reduced by a factor of a million. [↑](#footnote-ref-13)
14. For the remainder of this module, *Medical Technology Solutions* and *MTS* will be used interchangeably. [↑](#footnote-ref-14)
15. Though this may seem like a major omission, especially given the relatively small percentage of malpractice claims settled in favor of the plaintiff, it is simply a calibration decision and does not change model behavior when compared to a structure where a fixed percentage of claims were dismissed. Modeling claim success rate endogenously would add considerable complexity in return for questionable gain. [↑](#footnote-ref-15)