2016 Student Research Case Study Challenge

Society of Actuaries

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The University of Hong Kong

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I. Executive Summary

This report intends to advise the management of the company on the most prominent disruptors that are going to increase its health expenditure in the next 5 years. After literature review on the subject, we propose the following 3 disruptors that have the greatest impact on the claim expenditure of the company, the legal risk of the Affordable Care Act (ACA) being rolled back, the mergers and acquisitions (M&As) of hospitals, the advancement in medical technology including new drugs and new medical devices. Our research suggests that the expenditure may increase by up to 40% from the baseline level with a 1-in-200 chance. Among the 3 disruptors, the legal factor and the M&A factor have the most prominent impact in the 5-year period, contributing about 40% and 30% towards the total risk level.

II. Purpose and Background

This section describes how the team decides on the most prominent disruptors in the next 5-year period and the overall logic behind the model.

2.1 Disruptor I: Rolling back the Affordable Care Act under a Republican government

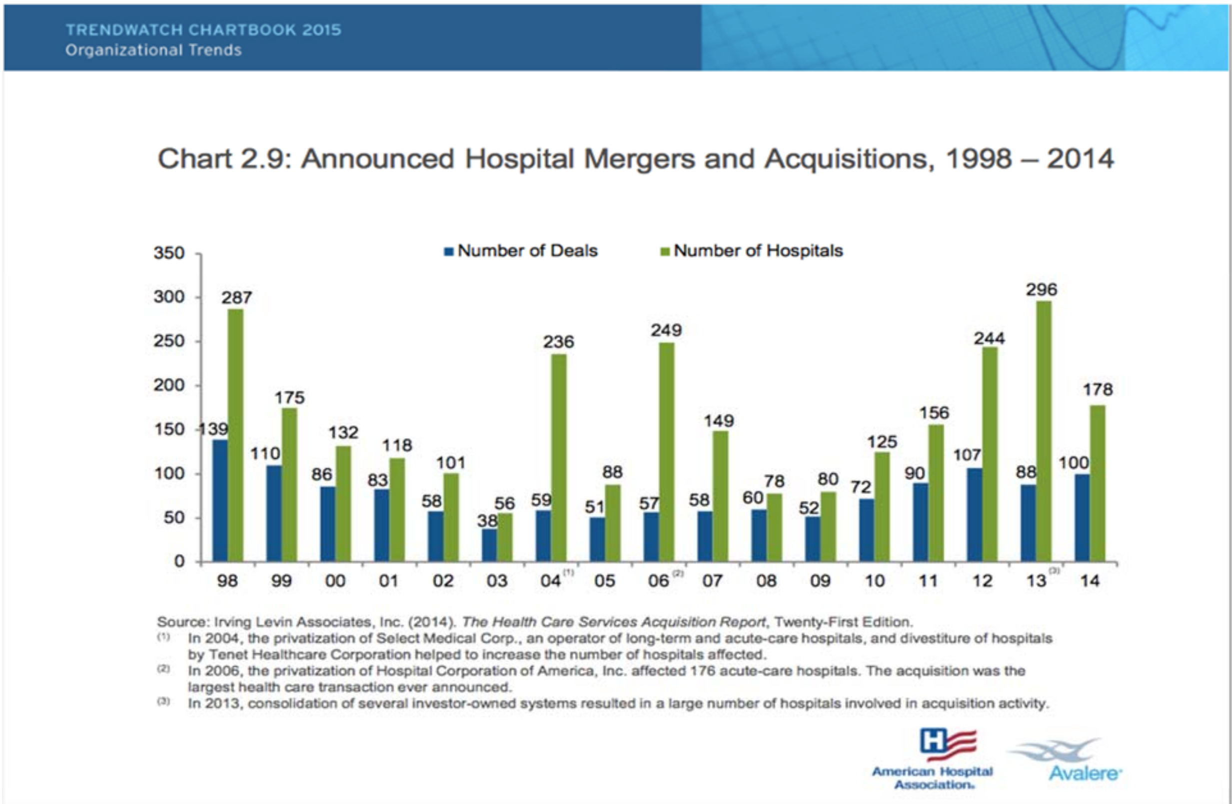
Laws and regulations directly affect private insurance. In 2010, the launch of the *Affordable Care Act* – commonly referred to as Obamacare – aimed at expanding public healthcare including *Medicare* and *Medicaid*. Thus, the U.S. government projects that public expenditure will crowd out private insurance expenditure, causing the latter to decrease over time.

However, the baseline projections are premised on the implementation of Obamacare on schedule. This itself is dependent on the Democrats being able to maintain or strengthen their political standing in the ongoing 2016 presidential elections. On the contrary, if the Republican nominee wins the presidency and the Republicans keep their firm control over the senate, it is highly likely that Obamacare would be scaled down, or even completely abolished in the next few years. Thus, we believe Republican control of the government is a relevant risk factor.

2.2 Disruptor II: The M&A of hospitals and the increase in medical cost

Several major mergers have taken place between US hospitals, such as Tenet Healthcare's acquisition of USPI in early 2015. This implies an increasing desire for hospitals to merge together (Healthcare Appraise, 2015). While consolidation brings down the operation cost, it inevitably increases their market power and the bargaining power when negotiating with insurance companies. The average medical costs of post M&A hospitals are 10% - 50% higher than those in other hospitals (Gaynor & Town, 2012).

The trend of M&A among hospitals is primarily driven by the decreasing inpatient revenue owing to preventative care encouragement and price cap under Medicaid and Medicare. According to Juniper Advisory’s report (2012), other factors including increasing treatment expense, R&D requirements and administration cost resulting from the legislation have also been driving the hospitals to merge with one another, which is also pointed out in DHG Healthcare’s research (2013). For example, the ACA directly encourages integration through the Accountable Care Organization (ACO) (Murray & Suzanne F. Delbanco).



(Source: http://www.aha.org/research/reports/tw/chartbook/2015/chart2-9.pdf)

2.3 Disruptor III: Frequent technological innovation in medical devices and drugs

New technological innovation in medical devices and drugs is chosen as another key disruptor, which will contribute to the increase of the company's health expenditure significantly.

The advancement in medical devices and drugs impacts the company's claim cost in the following two ways. On one hand, the ever increasing cost of new drugs and devices, thanks to high R&D cost and market power of patents, has driven up the medical expense by replacing the lower-cost cures for patients with higher-cost ones (Robert Wood Johnson Foundation, 2011). On the other hand, the improving diagnostic ability brought by the introduction of new devices increases the probability of early discovery of diseases, and hence drives up the number of claims and claim cost. Admittedly, some improvement brought by technological innovation may reduce the medical cost. However, empirical studies find strong positive correlations between technological innovation of medical devices and drugs with health care expenditure. It is estimated that new devices and drugs have accounted for 36% of the growth of health expenditure (Willeme & Dumont, 2015).

III. Data

3.1 Baseline Growth Rate

After locating the disruptors to be examined, we still need to find an indicator for the company medical expense. We assume the market is competitive and the company has similar product mix to the industry. The private health insurance benefits data for the entire nation is adopted as an indicator for the trend of the company's expenditures.

In addition, we recognize that some factors are either difficult to quantify, such as the societal trend towards health expenditure, or are not expected to deviate significantly from the previous development period such as the aging rate of the population, the economic growth rate and the inflation rate. Hence a baseline growth rate is adopted to reflect that upward trend of medical expense in US.

To get the baseline growth rate of the U.S. health expenditure, we make use of the *Table 2 National Health Expenditures; Aggregate, Annual Percent Change, Percent Distribution and Per Capita Amounts, by Type of Expenditure: Selected Calendar Years 1960-2014* from the Centers for Medicare and Medicaid Services (CMS) website. The data set chosen is the national health expenditure from 1960-2014. One point worth noting is that the team opt for the national health expenditure instead of the private health insurance benefits data to inference the baseline growth rate of U.S. private health expenditure growth rate because private health insurance benefits are exposed to the risk of regulatory changes, which will be captured by the legal risk factor in the model.

The team intend to use the baseline growth rate to capture the long run trend of U.S. health expenditure. The national health expenditure and average annual growth rate are summarized below.

National Health Expenditures, Selected Calendar Years 1960-2014 (Amount in Billions)			
1960	27.2	2006	2157
1970	74.6	2007	2296.2
1980	255.3	2008	2402.6
1990	721.4	2009	2496.4
2000	1369.7	2010	2595.7

2001	1486.7	2011	2696.6
2002	1629.2	2012	2799
2003	1768.2	2013	2879.9
2004	1896.5	2014	3031.3
2005	2024.5		

Table 3.1.1 - U.S. National Health Expenditures, Selected Calendar Years 1960-2014 (Source: Table 2 National Health Expenditures; Aggregate, Annual Percent Change, Percent Distribution and Per Capita Amounts, by Type of Expenditure: Selected Calendar Years 1960-2014)

Average Annual National Health Expenditures Percentage Change, Selected Calendar Years 1960-2014			
1960-1970	10.09%	2005-2006	6.34%
1970-1980	12.30%	2006-2007	6.25%
1980-1990	10.39%	2007-2008	4.53%
1990-2000	6.41%	2008-2009	3.83%
2000-2001	8.20%	2009-2010	3.90%
2001-2002	9.15%	2010-2011	3.81%
2002-2003	8.19%	2011-2012	3.73%
2003-2004	7.00%	2012-2013	2.85%
2004-2005	6.53%	2013-2014	5.12%

Table 3.1.2 - U.S. Average Annual National Health Expenditures Percentage Change, Selected Calendar Years 1960-2014
(Source: Table 2 National Health Expenditures; Aggregate, Annual Percent Change, Percent Distribution and Per Capita Amounts, by Type of Expenditure: Selected Calendar Years 1960-2014)

From the average growth rate of annual national health expenditures, we can see a steady growth rate during the 2000 to 2007 period. This period has relatively stable economic growth and demographic evolvement. The growth rate of national expenditures dropped significantly since 2007, most likely due to the financial crisis. The strong upward momentum of national health expenditure in 2013-2014 makes us believe that the economic development will return to the pre-crisis level in the next 5-year period. Hence the team will use the average growth rate of 6.81% during the period 2000 to 2007 as the baseline growth rate.

3.2 Year 2015 national expenditure level

The model uses the data from the private health consumption expenditure level as the indicator of current year company expenditure level. Since the expenditure data for 2015 is not readily available, we assume that the figure of $991 billion in 2014 has increased at the baseline growth rate to $1068.5 billion in 2015 (source: Table 20 Private Health Insurance Benefits and Net Cost; Levels, Annual Percent Change and Percent Distribution, Selected Calendar Years 1960-2014).

3.3 Legal risk

We assume the probability of an ACA rollback to be equal to that of the Republican Party winning the election. Based on the projection markets, the probability of a Republican president is around 30% (PredictIt, 2016).

Event	Probability	Impact on private insurance expenditures, 2015-19
A Democratic president	70%	Baseline – Obamacare continues as planned
A Republican president	30%	Compared to baseline – a $180.1 billion increase

Table 3.3.1 - Estimating the severity and probability of the legal disruptor

The impact of the ACA rollback is to reduce the savings of private health insurance expenditure should the Obamacare continue to exist (U.S. Centers for Medicare & Medicaid Services, 2010). We adopt the projections of the U.S. government, namely that private health insurance would decrease by a total of $360.2 billion from 2015 to 2019, with the estimated decrease per year to be $28.4 billion, $48 billion, $70.7 billion, $102.2 billion and $110.9 billion respectively (Appendix A).

We further assume that if rollback happens, then the effects of Obamacare on private health insurance would be reduced by 50%. That is to say, compared with the base case, private health insurance spending would increase by 50% * $360.2 = $180.1 billion from 2015 to 2019. Despite the efforts of Republicans to abolish Obamacare completely, even under a Republican presidency, we do not think that Obamacare will be scaled down nationwide. This is due to two factors. First, each state has relative autonomy over the adoption or rejection of the policy. Furthermore, the political battle between the two parties may lengthen the time for any regulation to be put into effect.

3.4 Merger and Acquisition

When a hospital consolidates with other health care provider entities, it becomes part of a hospital network. We use the proportion of community hospitals that have joined hospital networks as an indicator of the trend of consolidation (Gaynor & Town, 2012).

Year	In health system	Independent	Proportion of community hospitals in hospital networks	Growth rate of community hospitals in health system
1999	2524	2432	51%	/
2000	2542	2373	52%	2%
2001	2580	2328	53%	2%
2002	2606	2321	53%	1%
2003	2626	2269	54%	1%
2004	2668	2251	54%	1%
2005	2716	2220	55%	1%
2006	2755	2172	56%	2%
2007	2730	2167	56%	0%
2008	2868	2142	57%	3%
2009	2921	2087	58%	2%

2010	2941	2044	59%	1%
2011	3007	1966	60%	2%
2012	3101	1898	62%	3%
2013	3144	1830	63%	2%

Table 3.4.1 - U.S. M&As of hospitals, 1999-2013
(Source: Trendwatch Chartbook 2015: Organization Trend)

The proportion of hospitals that have joined hospital networks in the U.S. is growing at an average rate of 1% per annum from 1999 to 2010. Though the most updated data is from 2013, we exclude the data after 2010 in our analysis because of the introduction of the ACA. Therefore, we use the growth rate of 1% per annum as the baseline of the consolidation trend.

To further validate the existence of the trend, we also analyzed the Herfindahl-Hirschmann Index (HHI) which measures the concentrated share within the hospital market (Gaynor, US Department of Health & Human Services, 2011). The HHI of US has been increasing at a steady rate of 2% per year since 2010 and hit 2,821 in year 2013, implying growing concentration in hospital market (U.S. Department of Health & Human Services., n.d.).

We define the M&A shock emerges when the growth rate of M&A surpasses the baseline rate. Based on the calculation in table 3.4.2, the probability of shock taking place in the period of 1999 to 2010 is 45% which we assume to be the frequency of the M&A shocks occurring in the next 5-year period. We assume that the duration of the disruptor is one year, since insurance companies may renegotiate contracts with hospitals afterwards. Once consolidation happens, it will usually result in the increase of medical costs (see section 2.2), which will ultimately cause an increase of 3% in private insurers' expenditures (Murray & Suzanne F. Delbanco).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Growth rate	2	2	1	1	1	1	2	0	3	2	1	1
Assignedvalue(>1)	1	1	0	0	0	0	1	0	1	1	0	0.45

Table 3.4.2 – Calculation of M&A Frequency
(Source: Trendwatch Chartbook 2015: Organization Trend)

3.5 Technological innovation in medical devices and drugs

To quantify this disruptor, we propose using the total numbers of new drugs and medical devices launched as a proxy. New drugs and medical devices are modeled as two separate categories. We will evaluate the aggregate impact of these categories, without going into the specifics of the impact of individual drugs or devices. It is not feasible to assess the impact of each technology, let alone the possible inter-correlations, and therefore we assume that each new drug or device produces the same effect, which is appropriate when data nationwide is taken into consideration.

The database from the US Food and Drug Administration (FDA) is used based on our proxy defined above. It is legally required that each newly introduced drug and medical device should gain FDA approval before entering the market, so the database from FDA can be considered as credible and comprehensive. Thus, we believe the data on NME and PMA could directly reflect the application of new technology in a specific year.

The number of new drugs is measured by the number of New Molecular Entity (NME) Drug Approvals. New drugs containing active moieties are categorized as NMEs, which require FDA review, and those products frequently provide important new therapies for patients. In addition, the number of new devices is measured by the number of devices that gained Premarket Approval (PMA), which is a private license granted to the applicant for marketing a particular medical device.

An alternative dataset for drugs from the FDA is New Drug Application (NDA). However, we believe NME data is more appropriate. On one hand, NDA includes generic drugs, which are expected to lower drug expenditures due to their lower prices. On the other hand, drugs in the NME list are mostly ‘radically’ innovative, which are expensive and increase private health expenditures.

Data is aggregated on a yearly basis and only successfully approved drugs and devices are included. The following charts are a glimpse of the numbers of PMA and NME approvals from 1980 to 2015.

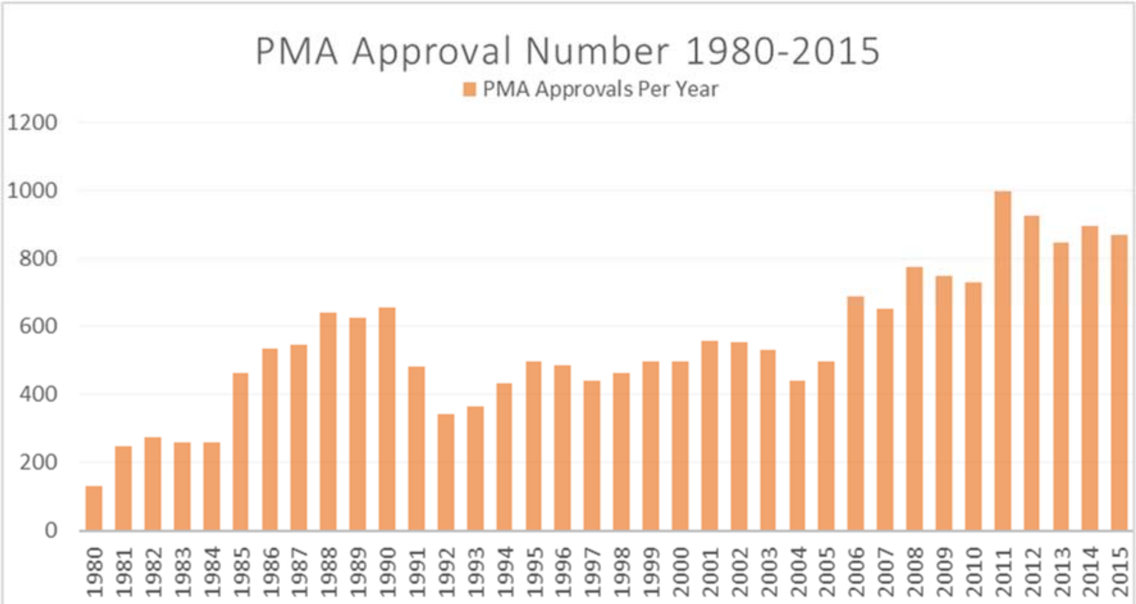


Chart 3.5.1 – Number of PMA approvals 1980-2015
(Source: FDA medical device database)

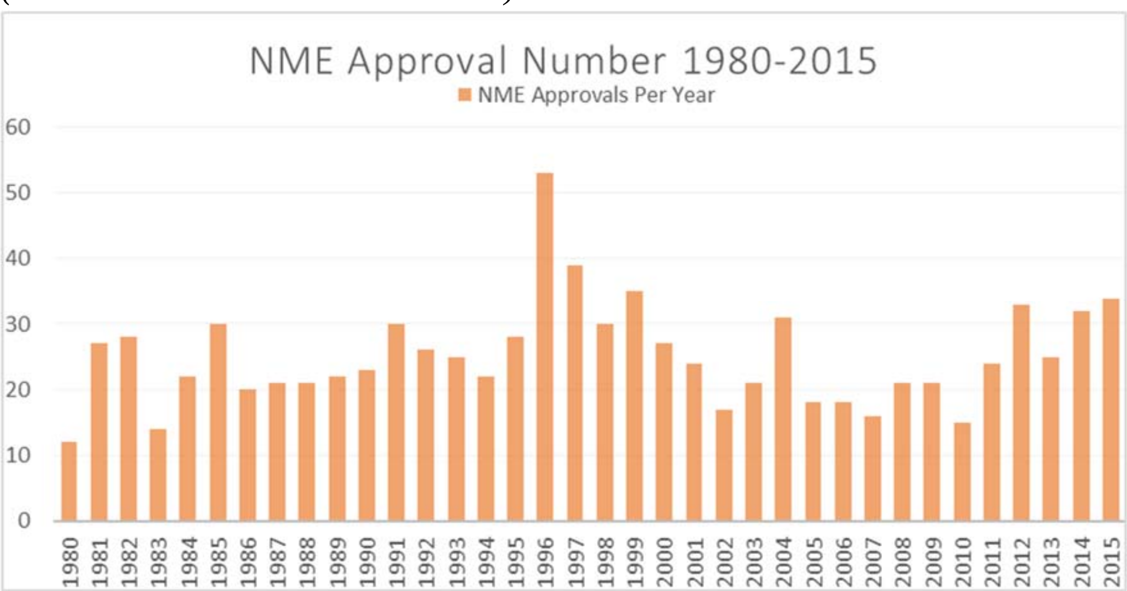


Chart 3.5.2 – Number of NME approvals, 1980-2015
(Source: FDA drug databases)

The tables below summarize the data of incremental and cumulative numbers of PMA and NME for the past five years, which will be used in our model for frequency projection in section IV.

PMA Data Summary for 2011-2015

Year	PMA Approvals Per Year	Cumulative No. of PMA Approvals	Growth Rate

NME Data Summary for 2011-2015

Year	NME Approvals Per Year	Cumulative No. of NME Approvals	Growth Rate

2011	998	16408	6.1%
2012	928	17336	5.4%
2013	846	18182	4.7%
2014	896	19078	4.7%
2015	869	19947	4.4%
5-year Average	907		

2011	24	1494	1.6%
2012	33	1527	2.2%
2013	25	1552	1.6%
2014	32	1584	2.0%
2015	34	1618	2.1%
5-year Average	30		

Table 3.5.1 – PMA and NME Data Summary

(*Source: FDA medical device database and FDA drug databases*)

Data preparation for Severity Modelling

There has been much literature studying the correlation between medical technological advancements and rising health expenditure. Although health economists have achieved a wide consensus that medical technology contributes to the growing health expenditures in U.S. and many other developed economies, there are differences in quantifying the severity of this impact. According to Willeme et al (2015), the per-capita total health expenditure increases by 0.313% and 0.331% when PMA and NME grow by 1% respectively. Inferring from the data of U.S. National Health Expenditure Accounts, we find the private health insurance expenditure takes up a constant proportion of the total health expenditure, as indicated in the table below. Therefore, following the per-capita total health insurance expenditure, the per-capita private health insurance expenditure also increases by 0.313 % and 0.331 % in response to 1 % growth in PMA and NME approvals respectively. Thus, the severity factors used in our model for PMA and NME are 0.313 and 0.331.

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Total Health Expenditure in billion $	1369.7	1486.7	1629.2	1768.2	1896.5	2024.5	2157	2296.2	2402.6	2496.4	2595.7	2696.6	2799	2879.9	3031.3
Private Health Insurance Expenditure in billion $	458.5	502.5	561.5	615.7	658.8	701.7	737.5	776.4	804.7	832.7	863.1	902.5	934.1	949.2	991
Proportion	33%	34%	34%	35%	35%	35%	34%	34%	33%	33%	33%	33%	33%	33%	33%

Table 3.6.1 - U.S. national health expenditures levels and annual percent change

(Source: Table 3 National Health Expenditures; Levels and Annual Percent Change, by Source of Funds: Selected Calendar Years 1960-2014)

IV. Model Specification

The following model intends to use simulation method to project the private health insurance expenditure development in the next 5-year period (Appendix B), the VaR of the expenditure with different significance levels is then reported to the CEO for active management. The baseline growth rate is 6.81% as stated above. We assume the company sets the premium based on the baseline development of expense so that all the deviation of expense from the baseline level caused by the disruptors can only be covered by the shareholder capital. The 3 disruptors are legal factors, the M&A cost, and new technology advancement in medical devices and drugs. We assume that all disruptors are both independent from each other and stationary to avoid the impact of correlation between shocks on the overall results.

For each simulation run, we loop through each shock factor and different shock mechanism is applied depending on the characteristic of the disruptor. For the legal factor, if the generated random number following uniform distribution over [0,1] falls below the frequency 30%, we assume the shock takes place and the increased cost due to rollback of ACA is stored in the variable addition. For the M&A disruptor, we assume the shock factor is in effect if the random number is smaller than the frequency (45%) than the preshock variable storing the previous year shocked value is adjusted upward by severity (3%).

For the factors of new drugs and new devices, we first simulate the increment in the numbers of PMA and NME. Since each discovery of new devices and drugs is relatively random and independent in the five year horizon, we assume the annual number of PMA and NME approvals both follow Poisson distribution in the actual model (the incremental number for PMA is approximated by the Central Limit Theorem because λ is too large). Further assuming that the rate of launching new devices and drugs remains unchanged in the five year horizon, which is supported by Okunade's study (2004), we chose average numbers of PMA and NME approvals in the past five years as the means of the Poisson distribution.

$$N_{NME} \sim \text{Poi}(\lambda_{NME} = 30)$$
$$N_{PMA} \sim \text{Poi}(\lambda_{PMA} = 907)$$

We regard only the additional number of new drugs and devices relative to their means. The shocks take place only when the simulated numbers of PMA and NME approvals exceed their means, i.e. 907 for PMA and 30 for NME, because the impacts of the fast-developing medical technology in drugs and devices have already been included in our baseline growth rate.

We evaluate the severity of the shocks in the following steps. We first try to calculate the annual growth rates of new devices and drugs from our simulated data, then multiply them by the annual growth rates of PMA and NME by the severity factors of PMA (0.313) and NME (0.331) respectively, and the results are the percentage increase in per-capita private health insurance expenditure. We use the growth rate of per-capita private health insurance expenditure instead of the growth rate of total private health insurance expenditure, because their difference, the population growth, has been included in our model's baseline projection.

The number of simulations is decided by adjusting up 100 until the percentage increase of 1-in-200 shocked level from baseline at year 5 don't have deviation of more than 0.5% from one another in the 5 consecutive runs. 1000 simulations are performed for the aggregate shock scenario and 500 simulations are performed for the standalone scenario.

V. Results and Suggestions

5.1 Results

After the simulation is performed, we extract the absolute shocked expense level of each scenario at $VaR_{99.5}$ (1-in-200), VaR_{99} (1-in-100), VaR_{95} (1-in-20), average and median level for each period. We also calculate the percentage increase of shocked expense level from baseline for each period. We summarize our model result in the following models and charts.

Absolute national private health insurance expenditure(billions $) increase by year					
	2016	2017	2018	2019	2020
Baseline	1141.265	1218.985	1301.998	1390.664	1485.368
Median	1170.505	1293.957	1437.203	1612.902	1808.375
Average	1168.399	1284.1	1429.338	1600.226	1790.147
1-in-20	1205.205	1349.972	1514.598	1713.446	1925.704
1-in-100	1214.029	1360.517	1540.635	1746.51	1962.495
1-in-200	1214.859	1366.573	1548.16	1755.022	1975.609

Table 5.1.1 - Absolute national private health insurance expenditure increase by year

Percentage increase in national private health insurance expenditure by year					
	2016	2017	2018	2019	2020
Median	2.58%	5.91%	10.23%	16.00%	21.84%
Average	2.75%	6.10%	10.15%	15.36%	20.89%
1-in-20	5.62%	10.77%	16.33%	23.21%	30.09%
1-in-100	6.30%	12.15%	18.79%	25.63%	33.67%
1-in-200	6.38%	12.80%	19.02%	26.99%	34.58%
Max	6.50%	13.51%	21.06%	30.67%	39.82%
Min	0.00%	0.00%	1.20%	1.30%	1.99%

Table 5.1.2 - Percentage national private health insurance expenditure increase by year

We can see from the Table 5.1.2 that the medical expenditure may inflate by 34.58% in a 1-in-200 scenario, even at a less stringent level of VaR_{95} we are expecting a 30% increase in cost level for the company by the end of 5 year period. Hence, we do suggest the company to increase its reserve or adjust its rate when underwriting to reflect the potential increase of the expense.

Further, we simulate the expenditure level for each risk stand-alone to try to reveal the relative urgency of each risk factor (Appendix C). We measure the risk contribution of each risk factor as the percentage of incremental shocked expense at 1-in-200 level relative to baseline expense for each risk factor out of the total increased expense, and the results are summarized below.

We can see that the M&A factor poses the greatest threat in the short term, contributing close to 50% of the total risk amount the company is facing. While the shock size tends to reduce in the long run, which is in line with our assumption that the company manages to negotiate new terms with hospitals or adjust the rate to reflect the increased cost in 1-year time. The impact from the legal shock is moderate in the beginning, but gradually increases in the 5-year period and is expected to increase further in the years afterwards. The total impact of advancement in diagnostic technology and the new treatment on the medical expense is relatively stable over the years, amounting to 30% of the total unexpected expense.

Based on the contribution of each risk factor to the total unexpected increase in health expense, the team suggests the management to put their priority on the M&A disruptor and legal disruptor.

5.2 Suggestions

The suggestions for each risk factor are listed below:

Mitigating the legal risk

The ACA is more likely to disproportionately affect long-term insurance products by expanding coverage to people with chronic disease. Therefore, we suggest the management to adjust their product mix by issuing much shorter term products. This strategy should provide the company with the necessary business agility to adjust their rate and premium once the legal environment has changed.

Mitigating the M&A risk

Private insurance companies mainly focus on state-wise business, making it sensitive to the merger and acquisition of hospitals in the state. Once the hospital in the system decided to raise the price charged, the claim cost paid by the company will increase considerably. To mitigate the impact, private insurance companies are suggested to enter longer term contract with their cooperating hospitals and prepare more capital for the sake of solvency issue. Moreover, companies can unite together to set up an association aimed at raising the bargaining power on behalf of private health insurance companies.

Mitigating the technological innovation risk

Another perspective is to hedge the risk by matching assets with liability. We suggest the company invest more in the biotechnology and pharmaceuticals sector, which directly benefits from technological innovation. For example, a long position of biotechnology and pharmaceuticals companies' stock may balance our company's liability side.

5.3 Future study

One important assumption made by the team while studying the full extent of 3 disruptors is that they are independent with each other. However, such assumption may be challenged in reality, for example, the mergers and acquisitions of hospitals create monopoly in medical service and reduce the pressure for doctors to search for new treatment and bring in more patients. Such correlation between disruptors may be crucial in estimating the tail risk of the company.

Second, the team left out fluctuations in economy in the modelling of the company expenditure, assuming that the economy will grow smoothly in the next 5 years. However, recent turmoil in the economic development around the globe should cast enough doubt over the soundness of such assumption. While the empirical study has revealed a huge drop in consumer demand for health service, the real issue for the company is whether its investment strategy is prudent enough to withstand another economic shock. Testing the impact of a potential economic meltdown requires the management to thoroughly examine the assets the company is holding.

Thirdly, the team doesn't incorporate the demographic disruptor or the increase in the chronic disease incidence in the modelling of the expense for primarily two reasons. First the strong advocate of a healthier lifestyle should postpone the outbreak of chronic disease. Second, part of the increase in the chronic disease related expense has already been reflected in the baseline growth rate. However the data from the census department shows that the population group aged 65 or above, which is the age group consuming most of the health related service, grew at an annual rate of 1.3% during the period of 1990-2007. The department also projected an annual growth rate of 3.31% percent in the next 5 years. This speed up of aging in the US may indeed cause trouble to some line of business with chronic disease coverage and the management should examine these lines with care.

Appendix A

Estimated Financial Effects of the "Patient Protection and Affordable Care Act," as Amended (April, 2010)
https://www.cms.gov/Research-Statistics-Data-and-Systems/Research/ActuarialStudies/downloads/ppaca_2010-04-22.pdf

	2015	2016	2017	2018	2019
Private insurance total expenditures*	-28.4	-48	-70.7	-102.2	-110.9

Private insurance total expenditures are measure as the sum of employer-Sponsored Private Health Insurance, Other Private Health Insurance and Other Private.

Appendix B

Appendix B demonstrates the code for simulation model which is developed with VBA environment.

```
Private Type factors
  name As String
  freq As Single
  sever As Variant
  Grow_Abs As String
  Duration As Integer
End Type

Function Poi_Sim(ByVal lambda As Single, ByVal rand As Double) As Integer
'to simulate the new Device/new Drug with poisson distribution
  Dim f As Double
  Poi_Sim = 0
  CDF = 0
  f = Exp(-lambda)

  While CDF < rand
    Poi_Sim = Poi_Sim + 1
    CDF = CDF + f
    f = f * lambda / Poi_Sim
  Wend

Poi_Sim = Poi_Sim - 1
End Function

Sub model_setup()

Application.Calculation = xlCalculationManual
Application.DisplayAlerts = False
Application.ScreenUpdating = False

Dim factor_arr(15) As factors
Dim duration_record(20, 5) As Integer
Dim Cumu_Device(6) As Integer 'record the cumulative Device development in the next 5 years
Dim Cumu_Drug(6) As Integer  'record the cumulative Drug development in the next 5 years
Dim legal_factor

legal_factor = Array(28.4, 48, 70.7, 102.2, 110.9)
Erase Cumu_Device
```

```
Erase Cumu_Drug
Cumu_Device(0) = 19947
Cumu_Drug(0) = 1618

' Num_factors  # number of factors in the model
' base_value   # YE 2015 base value
' baseline_growth       #basline growth rate

Set Masterbook = ThisWorkbook
Set MSheet = Masterbook.Worksheets("Model")
Set Simsheet = Masterbook.Worksheets("Simulation_Path")
MSheet.Range("Simulation_result").Clear

'input base line data
MSheet.Activate
base_value = MSheet.Range("Base_Value").Value
baseline_growth = MSheet.Range("Base_ann_growth").Value
'baseline_inflation = MSheet.Range("Base_ann_growth").Value
anchor = MSheet.Range("factor_anchor").Address

'factor input
i = 1

With MSheet

  While .Range(anchor).Offset(1, 1) <> "N/A"

    anchor = .Range(anchor).Offset(1, 0).Address

    factor_arr(i).name = .Range(anchor).Offset(0, 1)
    factor_arr(i).freq = .Range(anchor).Offset(0, 2)
    factor_arr(i).sever = .Range(anchor).Offset(0, 3)
    factor_arr(i).Grow_Abs = .Range(anchor).Offset(0, 4)
    factor_arr(i).Duration = .Range(anchor).Offset(0, 5)

    i = i + 1

  Wend

  Num_factors = i - 1
```

```
End With

Erase duration_record

anchor = MSheet.Range("Sim_Anchor").Address

For i = 1 To 500  'simulating 200 paths

  anchor = MSheet.Range(anchor).Offset(1, 0).Address
  MSheet.Range(anchor) = i
  MSheet.Range(anchor).Offset(0, 1) = base_value

  Erase duration_record 'clear the shock record

  For j = 1 To 5   'simulating 5 years

        PreShock_Value = MSheet.Range(anchor).Offset(0, j).Value
    Effectual_growth = baseline_growth

        For k = 1 To Num_factors

        Simsheet.Activate
      ActiveSheet.Calculate
      rand_N = ActiveSheet.Range("A1")   'a random number between 0 and 1

        MSheet.Activate

        Growth_or_Absolute = factor_arr(k).Grow_Abs
      shock_length = factor_arr(k).Duration

      addition = 0

        Select Case Growth_or_Absolute
      Case "a" 'if the shock is applied on the abs rate
        If duration_record(k, j) = 0 Then
        If rand_N < factor_arr(k).freq Then
                PreShock_Value = PreShock_Value * (1 + factor_arr(k).sever)

                t = j     'record the duration impact
                While (shock_length > 0) And (t <= 5)
                duration_record(k, t) = shock_length
                shock_length = shock_length - 1
```

```
            t = t + 1
        Wend
    End If
    Else
            Effectual_growth = Effectual_growth * (1 + factor_arr(k).sever)
    End If

    Case "leg"  'if the shock is applied on the absolute value additively
    If duration_record(k, j) = 0 Then
    If rand_N < factor_arr(k).freq Then
            addition = addition + legal_factor(j - 1) * factor_arr(k).sever
            t = j     'record the duration impact
            While (shock_length > 0) And (t <= 5)
            duration_record(k, t) = shock_length
            shock_length = shock_length - 1
            t = t + 1
            Wend
    End If
    Else
    addition = addition + legal_factor(j - 1) * factor_arr(k).sever
    End If

    Case "expd"  'new device impact
    'New_Device = Poi_Sim(factor_arr(k).freq, rand_N)
    'use CLT to approximate poisson distribution
    New_Device = WorksheetFunction.Norm_S_Inv(rand_N) * Sqr(factor_arr(k).freq) +
factor_arr(k).freq
    Medical_Expense_Growth_Rate = 0
    Cumu_Device(j) = Cumu_Device(j - 1) + New_Device
    If New_Device > factor_arr(k).freq Then
      Device_Growth_Rate = Log(Cumu_Device(j)) - Log(Cumu_Device(j - 1))
    Medical_Expense_Growth_Rate = factor_arr(k).sever * Device_Growth_Rate
    End If
    Effectual_growth = Effectual_growth + Medical_Expense_Growth_Rate

    Case "expm"  'new Device impact
    New_Drug = Poi_Sim(factor_arr(k).freq, rand_N)
    Medical_Expense_Growth_Rate = 0
    Cumu_Drug(j) = Cumu_Drug(j - 1) + New_Drug

    If New_Drug > factor_arr(k).freq Then
```

```
            Drug_Growth_Rate = Log(Cumu_Drug(j)) - Log(Cumu_Drug(j - 1))
            Medical_Expense_Growth_Rate = factor_arr(k).sever * Drug_Growth_Rate
            End If

            Effectual_growth = Effectual_growth + Medical_Expense_Growth_Rate

            Case Else
            MsgBox "Input error with the factor characteristic"
            Exit Sub
          End Select

            Next

            PreShock_Value = PreShock_Value * (1 + Effectual_growth) + addition

            MSheet.Range(anchor).Offset(0, j + 1) = PreShock_Value

   Next

Next

MsgBox "Simulation Complete"

Masterbook.Save

Application.Calculation = xlCalculationAutomatic
Application.DisplayAlerts = True
Application.ScreenUpdating = True

End Sub
```

Appendix C

Appendix C includes the absolute value of shocked health expense and its percentage increase relative to baseline value for each disruptor stand alone.

Legal

Absolute national private health insurance expenditure(billions $) increase by year with legal disruptor					
	2016	2017	2018	2019	2020
Baseline	1141.265	1218.985	1301.998	1390.664	1485.368
Median	1141.265	1242.985	1362.982	1506.901	1664.971
Average	1145.138	1234.576	1339.539	1465.603	1609.518
1-in-20	1155.465	1258.152	1379.182	1524.204	1683.453
1-in-100	1155.465	1258.152	1379.182	1524.204	1683.453
1-in-200	1155.465	1258.152	1379.182	1524.204	1683.453

Percentage national private health insurance expenditure increase by year with legal disruptor					
	2016	2017	2018	2019	2020
Median	0.00%	1.97%	4.68%	8.36%	12.09%
Average	0.34%	1.28%	2.88%	5.39%	8.36%
1-in-20	1.24%	3.21%	5.93%	9.60%	13.34%
1-in-100	1.24%	3.21%	5.93%	9.60%	13.34%
1-in-200	1.24%	3.21%	5.93%	9.60%	13.34%
Max	1.24%	3.21%	5.93%	9.60%	13.34%
Min	0.00%	0.00%	0.00%	0.00%	0.00%

M&A

Absolute national private health insurance expenditure(billions $) increase by year with M&A					
	2016	2017	2018	2019	2020
Baseline	1141.265	1218.985	1301.998	1390.664	1485.368
Median	1141.265	1255.555	1341.058	1475.355	1575.827
Average	1154.493	1247.418	1346.918	1459.217	1580.089
1-in-20	1175.503	1293.221	1422.728	1519.616	1671.795
1-in-100	1175.503	1293.221	1422.728	1565.204	1721.949
1-in-200	1175.503	1293.221	1422.728	1565.204	1721.949

Percentage national private health insurance expenditure increase by year with M&A					
	2016	2017	2018	2019	2020
Median	0.00%	3.00%	3.00%	6.09%	6.09%
Average	1.16%	2.33%	3.45%	4.93%	6.38%
1-in-20	3.00%	6.09%	9.27%	9.27%	12.55%
1-in-100	3.00%	6.09%	9.27%	12.55%	15.93%
1-in-200	3.00%	6.09%	9.27%	12.55%	15.93%
max	3.00%	6.09%	9.27%	12.55%	15.93%
min	0.00%	0.00%	0.00%	0.00%	0.00%

Drug

Absolute national private health insurance expenditure(billions $) increase by year with new drug					
	2016	2017	2018	2019	2020
Baseline	1141.265	1218.985	1301.998	1390.664	1485.368
Median	1147.762	1226.612	1316.863	1407.926	1506.1
Average	1145.574	1227.105	1315.015	1409.259	1508.863
1-in-20	1149.475	1235.037	1326.357	1423.013	1524.272
1-in-100	1150.33	1236.162	1328.009	1426.029	1530.904
1-in-200	1150.542	1236.613	1328.952	1426.532	1535.609

Percentage national private health insurance expenditure increase by year with new drug					
	2016	2017	2018	2019	2020
Median	0.57%	0.63%	1.14%	1.24%	1.40%
Average	0.38%	0.67%	1.00%	1.34%	1.58%
1-in-20	0.72%	1.32%	1.87%	2.33%	2.62%
1-in-100	0.79%	1.41%	2.00%	2.54%	3.07%
1-in-200	0.81%	1.45%	2.07%	2.58%	3.38%
max	0.94%	1.56%	2.09%	2.87%	3.54%
min	0.00%	0.00%	0.00%	0.00%	0.00%

Device

Absolute national private health insurance expenditure(billions $) increase by year with new devices					
	2016	2017	2018	2019	2020
Baseline	1141.265	1218.985	1301.998	1390.664	1485.368
Median	1141.265	1234.88	1320.151	1425.693	1523.948
Average	1147.821	1233.849	1327.47	1425.469	1529.683
1-in-20	1156.842	1251.389	1352.745	1445.547	1561.037
1-in-100	1157.115	1251.704	1353.174	1462.369	1579.605
1-in-200	1157.465	1251.918	1353.38	1462.44	1579.718

Percentage national private health insurance expenditure increase by year with new devices					
	2016	2017	2018	2019	2020
Median	0.00%	1.30%	1.39%	2.52%	2.60%
Average	0.57%	1.22%	1.96%	2.50%	2.98%
1-in-20	1.36%	2.66%	3.90%	3.95%	5.09%
1-in-100	1.39%	2.68%	3.93%	5.16%	6.34%
1-in-200	1.42%	2.70%	3.95%	5.16%	6.35%
max	1.44%	2.75%	3.96%	5.20%	6.37%
min	0.00%	0.00%	0.00%	0.00%	0.00%

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