Sensitivity Analysis in Pension Expenditure Model

Hasimah Sapiri, Anton Abdulbasah Kamil, and Razman Mat Tahar

Abstract—This paper describes a dynamics model of pension expenditure with particular case on Malaysia public employees’ pension plan. We analyzed pension expenditure due to salary and demographic risk. Then, sensitivity analysis was performed in order to validate the pension expenditure model.

Keywords—Pension Expenditure, Sensitivity Analysis, System Dynamics.

I. INTRODUCTION

Due to fertility decline and increasing life expectancies, these two factors contribute to an ageing population [1]-[2]. Around the world, people are expected to live up until 74 years in 2045-2050 while in developed countries, life expectancy will rise to 82 years [3]. In a developing country like Malaysia, the population of people aged 60 years and above, was estimated at about 1 million in 1999, and is expected to increase to 4 million by the year 2025 [4], while the life expectancy for an aging population has increased to 71.9 years for males and 76.4 years for females in the year of 2007 [5]-[6]. These demographic trends are believed to give pressure on the public pension system and also, it could have a major impact on the government’s economic position [7]. For these reasons, pension has become one of the most important issues for policymakers where in most countries, pension spending is projected to grow substantially as populations’ age and the number of retirees increases. An aging population also creates concern about the sustainability of public pension systems [8]-[9]. As workers reach their retirement age and their longevity happens to be high, then they will be entitled to draw pension for a much longer time. Therefore, the burden on the pension fund will be heavy.

Due to this phenomenon, pension systems around the world are in flux conditions [10]. This condition is caused by uncertainties or inherent risk that affects the pension scheme.

The existence of risk will also affect pension expenditure. Among the risk that the sponsor of pension plan particularly in Defined Benefit plan is exposed to, are demographic risk and salary risk [11]. Demographic risk is defined as the increasing risk due to population aging while salary risk refers to the salary growth affecting the cost of providing pension benefits [11]. Hence, this study attempts to develop a dynamics model which analyzes pension expenditure as a result of demographic risk and salary risk.

II. PENSION AT A GLANCE

Around the world, pension systems are generally classified on how they are financed and managed (funded or unfunded—financial resources to provide retirement benefit either financed by employer’s contribution, employee’s contribution or both, private or public—mandated by government or by an employer’s of a specific company, defined benefit or defined contribution [12]. According to reference in [5], [13] and [14], generally there are three pillars of pension systems which are public pay as you go plan, private pension plan, and personal saving and annuity pension plan. Table 1 indicates the characteristics for each pension plan.

<table>
<thead>
<tr>
<th>Type of Pension System</th>
<th>Characteristics</th>
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</thead>
<tbody>
<tr>
<td>Public pay as you go plans</td>
<td>• This is the most popular pension scheme in most countries.</td>
</tr>
<tr>
<td></td>
<td>• This is a mandatory pension scheme which is generally mandated by the government.</td>
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<tr>
<td></td>
<td>• Some countries have changed their type of financing to funded system.</td>
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<tr>
<td></td>
<td>• Generally, it operates based on defined benefit plan.</td>
</tr>
<tr>
<td></td>
<td>• Usually, employees in the government sectors are covered with this plan.</td>
</tr>
<tr>
<td>Private pension plans</td>
<td>• It is typically offered by employers of specific industrial sectors or companies.</td>
</tr>
<tr>
<td></td>
<td>• The objective of this pension scheme is to attract and retain workers in companies.</td>
</tr>
<tr>
<td></td>
<td>• It is also known as occupational pension scheme.</td>
</tr>
<tr>
<td></td>
<td>• In the past, this pension scheme is based on defined benefit plan. However, due to the burden of</td>
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</tbody>
</table>

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If the worker chooses DB plan, he/she has to be in service not less confirmed in the service. After confirmation, the public employees public workers who have met certain requirements and being government budget. This pension plan is available for permanent contributions and investment rate. Both of the plans are calculated based on their (employee’s and employer’s) salary and length of service, while, defined contribution plan retirement benefit is generally calculated based on final basic salary and duration of services at compulsory retirement age and the pension annuity for all pensioners is adjusted to the same rate as in salary adjustment. Yearly salary increment is an even salary increment for all workers which ranges between 3% - 9% from their basic salary while salary adjustment is defined as an adjustment in a worker’s basic salary announced by the policy makers every 5 years period depended on the government’s financial capability or when there is a need in doing so, such as due to increasing living cost and etc. Between years of 1995 until 2008, the public workers had received 4 salary adjustments which are in 2000, 2002, 2003 and the latest in 2007 (table I). The salary adjustment rate in 2000 and 2002 is a 10% increment from basic salary for all groups of service. In 2003, salaries have been adjusted not according to the percentage. The salary increment is in amount of RM110 (for top management group), RM65 (for management & professional group) and RM15 (for supporting group). Then, most recently in 2007, the salary adjustment is made by group of service as shown in the table 2. Workers in top management group received an increment of 7.5% from their basic salary while workers in management & professional group and supporting group received an increment of 15% and 25%-35% from their basic salary, respectively. Every time the salary adjustment is announced, the pension annuity for all pensioners is adjusted to the same rate as in salary adjustment.

Due to Malaysia’s public pension system whereby the percentage of pension annuity is depended on the amendment of maximum duration of service as well as the existence of derivative pension, in this study, the demographic risk is defined as the risk that the public workers is attaining the maximum duration of service. Hence, effective July, 2008, public workers who have been in service for 30 years and above are eligible to receive 60% pension annuity from their last basic salary.

There are three groups of employees in Malaysia’s public sector which are top management group, management & professional group and supporting group (supporting group is divided to supporting I and supporting II group). Each group is classified by salary schemes also known as scheme of service; which indicate the priority in establishment and level of salary. In Malaysia’s public sector, there are two types of salary changes involved; the salary increased due to yearly salary increment and salary adjustment. Yearly salary increment is an even salary increment for all workers which ranges between 3% - 9% from their basic salary while salary adjustment is defined as an adjustment in a worker’s basic salary announced by the policy makers every 5 years period depended on the government’s financial capability or when there is a need in doing so, such as due to increasing living cost and etc. Between years of 1995 until 2008, the public workers had received 4 salary adjustments which are in 2000, 2002, 2003 and the latest in 2007 (table I). The salary adjustment rate in 2000 and 2002 is a 10% increment from basic salary for all groups of service. In 2003, salaries have been adjusted not according to the percentage. The salary increment is in amount of RM110 (for top management group), RM65 (for management & professional group) and RM15 (for supporting group). Then, most recently in 2007, the salary adjustment is made by group of service as shown in the table 2. Workers in top management group received an increment of 7.5% from their basic salary while workers in management & professional group and supporting group received an increment of 15% and 25%-35% from their basic salary, respectively. Every time the salary adjustment is announced, the pension annuity for all pensioners is adjusted to the same rate as in salary adjustment.

In developed countries like United Kingdom, United States, and European Union, there are many private pension schemes provided by the company employers. The pension scheme is purposely set up to hire higher quality workers and to encourage excellent workers to continue working in the same company. Meanwhile, the public pension system is designed for workers in the state and local governments. For an Asian country like Malaysia, there are basically two pension plan types, which are final salary pension plan (also known as defined benefit plan) and personal saving and annuity plans or money purchase plan (also known as defined contribution plan). Defined benefit plan is a pension plan where the retirement benefit is generally calculated based on final basic salary and length of service, while, defined contribution plan is a pension plan where the retirement benefit is generally calculated based on their (employee’s and employer’s) contributions and investment rate. Both of the plans are mandatory pension plans designed for government employees and private sector employees. In Malaysia, employees in state and federal governments can choose their own pension plan as either final salary pension plan or money purchase plan, but for workers in the private sector, they are only eligible for money purchase plan.

### III. The Structure of Malaysian Employees Public Pension Plan

In this research, Malaysia public pension plan is studied to analyze pension expenditure due to salary and demographic risk. In Malaysia, public pension plan is also exposed to demographic risk and salary risk since the public pension plan is based on unfunded Defined Benefit (DB) plan. In this pension plan, the employees’ benefits after retirement are determined by their final basic salary and duration of services which is the maximum duration of services is 25 years (300 months). Also, the retirement benefits are paid through government budget. This pension plan is available for permanent public workers who have met certain requirements and being confirmed in the service. After confirmation, the public employees get to choose their desired pension plan between two plans offered. If the worker chooses DB plan, he/she has to be in service not less than 10 years in order to be eligible to receive 2% of pension benefit from his/her last basic salary for every accumulated services. Workers who have worked for at least 25 years and above are eligible to receive 50% pension annuity from their last basic salary. The pension annuity will be paid until the worker pass away and the annuity is continuously paid to the eligible family members. The pension benefit received by eligible family member is known as derivative pension. The compulsory retirement age in this pension plan is 55 years old, but the retirement age has been raised up to 56 years old in October, 2001 and then to 58 years old effective on July, 2008. However, the increment of retirement age does not indicate that the maximum duration of service will also change. The maximum duration of service can also be amended without increasing the retirement age. Therefore, the percentage of pension annuity is depended on the amendment of maximum duration of service. Hence, effective July, 2008, public workers who have been in service for 30 years and above are eligible to receive 60% pension annuity from their last basic salary.

There are three groups of employees in Malaysia’s public sector which are top management group, management & professional group and supporting group (supporting group is divided to supporting I and supporting II group). Each group is classified by salary schemes also known as scheme of service; which indicate the priority in establishment and level of salary. In Malaysia’s public sector, there are two types of salary changes involved; the salary increased due to yearly salary increment and salary adjustment. Yearly salary increment is an even salary increment for all workers which ranges between 3% - 9% from their basic salary while salary adjustment is defined as an adjustment in a worker’s basic salary announced by the policy makers every 5 years period depended on the government’s financial capability or when there is a need in doing so, such as due to increasing living cost and etc. Between years of 1995 until 2008, the public workers had received 4 salary adjustments which are in 2000, 2002, 2003 and the latest in 2007 (table I). The salary adjustment rate in 2000 and 2002 is a 10% increment from basic salary for all groups of service. In 2003, salaries have been adjusted not according to the percentage. The salary increment is in amount of RM110 (for top management group), RM65 (for management & professional group) and RM15 (for supporting group). Then, most recently in 2007, the salary adjustment is made by group of service as shown in the table 2. Workers in top management group received an increment of 7.5% from their basic salary while workers in management & professional group and supporting group received an increment of 15% and 25%-35% from their basic salary, respectively. Every time the salary adjustment is announced, the pension annuity for all pensioners is adjusted to the same rate as in salary adjustment.

Due to Malaysia’s public pension system whereby the percentage of pension annuity is depended on the amendment of maximum duration of service as well as the existence of derivative pension, in this study, the demographic risk is defined as the risk that the public workers is attaining the maximum duration of services at compulsory retirement age and the
pensioners (or pension recipients) will live longer. Also, the salary risk is focusing on the increment of salary when the basic salary is adjusted.

### TABLE 2: PERSONNEL ACCORDING TO GROUP OF SERVICE AND SALARY ADJUSTMENT RATE

<table>
<thead>
<tr>
<th>Group of Service</th>
<th>Salary Adjustment Rate</th>
</tr>
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<tbody>
<tr>
<td>Top Management</td>
<td>10%</td>
</tr>
<tr>
<td>Management &amp; Professional</td>
<td>10%</td>
</tr>
<tr>
<td>Supporting I</td>
<td>10%</td>
</tr>
<tr>
<td>Supporting II</td>
<td>10%</td>
</tr>
</tbody>
</table>

### IV. RESEARCH METHODOLOGY

In this research, system dynamics simulation will be applied in order to analyze pension expenditure. The research methodology (Fig. 1) is divided into three main sections, which are the personal interview section, development of simulation model of pension expenditure section, and model validation section. The research procedure started with personal interview with several officers in the public sector then continued with the process of system dynamics methodology which is the development of dynamics hypothesis and system dynamics model. Next, by using a sample of actual data obtained from the Public Service Department, the proposed model was validated. Modeling is a feedback process which acts like an iterative cycle [15]. In conducting this research, we followed the iteration (for section (A) and (B)) and the process went through these steps many times.

In this research, an interview session was arranged with the Departmental Head of Actuary in Ministry of Finance to investigate the factors that affect pension expenditure and how they are interrelated. The next interview session was carried out with the Director of Pensions Division in Malaysia Public Service Department (PSD) in order to gain in depth information regarding the pension system for public workers. After that, few visits were conducted with the senior officers in pension division and deputy accountant of PSD to further discuss the pension system, available data and related information. Through the literature review in [16]-[21] and from the interview sessions, Fig. 2 presents the summary of numerous factors influencing pension expenditure.

![Fig. 1: Research methodology](image)

![Fig. 2: Summary of numerous factors that affect pension expenditure](image)

Also, there are a few assumptions that will be used in model construction. The assumptions used are to simplify and form the model structure, and the assumptions still capturing the...
essential aspects of the real world system, which are as follows:
i. the compulsory retirement age in the simulation model starts at 55 years old,
ii. life expectancy for retired public workers in Malaysia is 74 years old. (Department of statistics, 2008),
iii. all retired worker reach the maximum salary in theirs’ salary scheme,
iv. all workers in each service group have been in service for 25 years and are eligible to received 50% pension annuity from their last basic salary, and
v. in the simulation model, all retired workers will only be classified by their salary scheme.

V. DEVELOPMENT OF SYSTEM DYNAMICS MODEL

In this research, all factors presented in figure 2 were transformed into system dynamics model of pension expenditure and the mathematical equations in the model are as follows. The system dynamics model of pension expenditure contains 3 main sectors which are the population sector, salary scheme sector and pension expenditure sector.

A. The Population Sector

The population sector illustrates the dynamics that are involved in various population categories. The number of public workers is depended on an appointment rate and the numbers of new workers. The public workers consist of top management group, management and professional group and supporting group. Therefore, the total number of retired workers is from each of this group is then will affect maturity rate. Maturity rate represents the ratio of workers that reach compulsory retirement age and become pensioners. Also, due the existence of derivative pension, the cessation workers in each group of service represent number of pensioners that is no longer received pension annuity. The equations in the population sector are:

\[ P(t) = P(t - dt) + M \ast dt \]  
\[ M = MR \ast PW \]  
\[ MR = \sum R_{T,P,S} \]  
\[ PW(t) = PW(t - dt) + (NW - M) \ast dt \]  
\[ NW = PW \ast AR \]  
\[ RW_{T,P,S}(t) = \]  
\[ RW_{T,P,S}(t - dt) + (R_{T,P,S} - CW_{T,P,S}) \ast dt \]  
\[ R_{T,P,S} = RR_{T,P,S} \ast W_{T,P,S} \]  
\[ W_{T,P,S} = PW \ast F_{T,P,S} \]  

where \( P \) = pensioners, \( M \) = maturity, \( MR \) = maturity rate, \( PW \) = public workers, \( NW \) = new workers, \( AR \) = appointment rate, \( RW_{T,P,S} \) = retired workers in top management, management & professional and supporting group, \( R_{T,P,S} \) = retirement in top management, management & professional and supporting group,

\[ W_{T,P,S} = \text{workers in top management, management & professional and supporting group}, \]

\[ F_{T,P,S} = \text{fraction of workers in top management, management & professional and supporting group}, \]

\[ R_{T,P,S} = \text{retirement rate in top management, management & professional and supporting group}, \]

\[ RR_{T,P,S} = \text{retirement rate,} \]

\[ SA_{V1-V7} = \text{salary adjustment rate based on percentage,} \]

\[ ADRP = \text{adjustment rate based on non percentage,} \]

\[ TLBS_{T} = \text{total last basic salary in top management group,} \]

\[ LBSR = \text{last basic salary rate.} \]

B. The Salary Scheme Sector

Salary scheme sector shows the retirement in top management group (similar procedures applies to management & professional and supporting group) which is categorized by salary cohort also known as scheme of services. Retirement in top management group depended on workers in top management group and top management retirement rate. In top management group, there are 7 salary schemes ranging from V1 until V7. The numbers of retired workers in each salary schemes is depended on retirement in top management group and retirement rate. Then, total salary in each salary scheme is influenced by the number of retired workers and the last basic salary in each salary scheme. The last basic salary in each salary scheme is affected by two types of adjustment rate which are based on percentage and non-percentage. Lastly, total salary for all salary schemes determines the last basic salary rate and total last basic salary for top management group. The equations in the salary scheme sector are:

\[ R_{T} = W_{T} \ast RR_{T} \]  
\[ RW_{V1-V7} = R_{T} \ast RR_{V1-V7} \]  
\[ TS_{V1-V7} = LBS_{V1-V7} \ast RW_{V1-V7} \]  
\[ LBS_{V1-V7}(t) = \]  
\[ LBS_{V1-V7}(t - dt) + (SA_{V1-V7}) \ast dt \]  
\[ SA_{V1-V7} = (LBS_{V1-V7} \ast ADRP) + ADRNP \]  
\[ TLBS_{T}(t) = TLBS_{T}(t - dt) + LBSR \]  
\[ LBSR = \sum TLBS_{V1-V7} \]  

where \( R_{T} \) = retirement in top management group, \( W_{T} \) = workers in top management group, \( RR_{T} \) = retirement rate of top management group, \( TS_{V1-V7} \) = total salary in scheme V1-V7, \( LBS_{V1-V7} \) = last basic salary in scheme V1-V7, \( RW_{V1-V7} \) = retired workers in scheme V1-V7, \( SA_{V1-V7} \) = salary adjustment in scheme V1-V7, \( ADRP \) = adjustment rate based on percentage, \( ADRNP \) = adjustment rate based on non percentage, \( TLBS_{T} \) = total last basic salary in top management group, \( LBSR \) = last basic salary rate.

C. Pension Expenditure Sector

The pension expenditure sector is the focus of this study because it is the main interest of the proposed model and related to all other sectors. In pension expenditure sector, the pension expenditure is calculated for top management group.
(similar procedures applies to management and professional and supporting group) by referring to the principles used in [20]-[21]. From the total last basic salary in top management group, the expected pension expenditure is determined by the total last basic salary and accrual rate. The calculation of pension expenditure includes pension adjustment too. It means when the salary adjustment is announced, the pension annuity for all pensioners is adjusted to the same rate as in salary adjustment. The pension adjustment consists of two types of adjustment rate which are based on percentage and non-percentage. Pension adjustment based on percentage adjustment rate is influenced by the pension expenditure and the percentage of adjustment rate. While, pension adjustment based on non-percentage adjustment rate is determined by the total numbers of pensioners and the non-percentage adjustment rate, RM 110. Simultaneously, pension expenditure is affected by benefit cessation rate. The equations of this sector are:

\[
PE_T(t) = PE_T(t - dt) + (EPE + PA - BC) \cdot dt
\]

\[
EPE = TLBS_T \cdot ACR
\]

\[
PA = (PE \cdot ADRP) + TANP
\]

\[
TANP = RW_T \cdot ADRNP
\]

where \(PE_T\) is pension expenditure for top management group, \(EPE\) = expected pension expenditure, \(PA\) = pension adjustment, \(BC\) = benefit cessation, \(TLBS_T\) = total last basic salary for top management group, \(ACR\) = accrual rate, \(TANP\) = total adjustment based on non percentage, \(ADRP\) = adjustment rate based on percentage, \(ADRNPD\) = adjustment rate based on non percentage.

Pension expenditure for management & professional group and supporting I & II group is calculated as similar procedures applies to top management group. In management & professional group, the salary schemes are ranging from scheme 41 until scheme 54 while in supporting group, the salary schemes are ranging from scheme 1 until scheme 16 for supporting II group and scheme 17 until scheme 40 for supporting I group.

VI. SIMULATION AND RESULTS

An actual data provided by Public Service Department is used to simulate the system dynamics model of pension expenditure from 1995 to 2027. In the base-run simulation, we assume the initial value of accrual rate is 0.5. This rate implies that all workers have been in service for 25 years and eligible to received 50% pension annuity from their last basic salary. We also assume starting 2008, the pension annuity will be paid continuously to the eligible family member if the pensionable officer died. The base-run simulation results of pension expenditure for top management group, management & professional group and supporting I & supporting II group were presented in fig. 3. Along with the time, it is shown that pension expenditure for all group of service increased.

VII. SENSITIVITY ANALYSIS

Next, sensitivity analysis was performed. In order to further validate and analyze the simulation model of pension expenditure, the sensitivity analysis tests for the total pension expenditure (total pension expenditure is the summation of pension expenditure for all groups of services) was performed. Sensitivity analysis test is the procedure of changing the assumption about parameter values in the model and examining the resulting output. The purpose of the sensitivity analysis test is to examine whether the conclusion changes in ways important to the stated purpose when the assumptions of parameter are varied under a reasonable range of uncertainty. The sensitivity analysis tests include behaviours mode sensitivity. The behaviour mode sensitivity exists when a parameter around which no uncertainty exists [22]-[23]. On the other hand, no tests are required for a parameter as the sensitivity test should also consider changes in the way people are assumed to make decisions. Also, reference in [24] suggested in conducting a sensitivity test, the parameter can be changed to be lower and higher than the
original value. Therefore, as suggested by reference in [22]-[24], there are three scenarios that were employed in conducting sensitivity analysis test in this research. In the first scenario, the values of the parameter were set to the values most favourable to the policies that are to be tested, and in the second scenario, the values of the parameters were set to values least favourable to the policies that are to be tested. Meanwhile, in the third scenario, the values of the parameters were set to values that the policymakers wanted to change in the coming future. Since this research focuses on the risk that public workers attain with the maximum duration of service at the compulsory retirement age, therefore the value of accrual rate should be in incremental value. For each scenario, 100 simulations were conducted in order to obtain the final results. A total of 100 simulations were selected because it would produce two significant figures for pension expenditure. The sensitivity analysis tool in the I-think software was used to simulate the three scenarios.

Scenario I

In the first scenario, the parameter values were set to the values most favourable to the policies are want to be tested, i.e. most favourable for policymakers to make decisions. As previously stated in the base-run scenario, it was assumed that the accrual rate is 0.5, which implies that all workers in the top management group have been in service for 25 years and are eligible to receive 50% pension annuity from their final basic salary. Since the policy makers have amended the maximum duration of service to 30 years, will the pension expenditure vary if the sponsor has to pay 60% pension annuity from the workers’ final basic salary? The researcher simultaneously simulated the accrual rate for top management group, management and professional group, also support group. Since the maximum percentage of annuity that the workers may obtain is 60%, therefore the maximum boundary for accrual rate is 0.6. It was also assumed the accrual rate is in incremental value and there was no replication of the simulated value. Fig. 4 describes the changing graphs of total pension expenditure along with time in a different accrual rate (starting at 0.5 and ending at 0.6). It shows that the graph is slightly widened during the growth of total pension expenditure.

Scenario II

In the second scenario, the parameter values were set to the values least favourable to the policies that are to be tested. In this scenario, the outcomes when the accrual rate is less than 0.5 are to be observed. Therefore, the researcher simultaneously changed the value of accrual rate for all the groups of services (i.e. top management group, management and professional group, and support group) to between 0.4 and 0.5. It was also assumed that the accrual rate is in incremental value and there was no replication of the simulated value. From the simulation result (Fig. 5), it is observed that the total pension expenditure also produced significant change and it is also sensitive to the amendment of accrual rate.

Scenario III

In the third scenario, the values of the parameter are set to the values that the policymakers want to change in the coming future. Therefore, it was assumed that the policymakers will increase the retirement age to 60 years old. Then, we also assumed the maximum duration of service is 32 years which means that the value of accrual rate will change to 0.64. Then, the researcher simultaneously changed the value of accrual rate for all the groups of services (i.e. top management group, management and professional group, and support group) from 0.5 to 0.64. Scenario III also followed the same assumptions in scenario I, which are the accrual rates is in incremental value and there is no replication of the simulated value. Fig. 6 depicted the graphs of total pension expenditure along with time, with different accrual rates (starting at 0.5 and ending at 0.64). It is observed that the total pension expenditure graph varies as there are different inputs of accrual rate. Also, the graph of total pension expenditure is slightly widened during the growth of pension expenditure. Therefore, this shows that the total pension expenditure is also more sensitive to higher accrual rates.
The sensitivity analysis for all the three scenarios showed that the total pension expenditure graphs had slightly widened and had produced significant change when the accrual rate values are amended. Also, the results showed that the control parameter can influence the total pension expenditure where there is also a significant change in the numerical values of the outputs in the scenarios.

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