Exploring Fragility and Antifragility under Uncertainty through Discrete Event Simulation

APPENDIX

Table 1 - Attributes, entities and variables (continues)

Type	Name	Function	Observation
Attribute	Bike_Type	Determines the bike material.	Value 0 for steel, 1 for aluminum and 2 for titanium.
Attribute	Work_Needed	Determines the path within the workstations that each bike will take	Discrete values from 0 to 5, with equal probability of occurrence.
Attribute	Defect	Determines the occurrence of a defect. The probability varies according to the material of the bike.	-
Attribute	Bike_Cost	Cost of the total material used to make the bike.	Varies daily according to a lognormal distribution and the material of the bicycle.
Attribute	Order_Price	Selling price of each bike.	Varies daily according to a lognormal distribution and the material of the bicycle.
Entity	Bike_Part	Non-metallic material used in the manufacture of a bicycle.	-
Entity	Bike_Frame	Metal material used to make a bicycle.	-
Entity	Bike_Order	Individual order placed by the customer.	The arrival of orders follows a Poisson distribution, and the quantity follows a standard demand curve.

Source: Author.

Table 1 - Attributes, entities and variables (continues)

Type	Name	Function	Observation
Variable	Fator_Preco_0	Multiplier factor on steel bicycle prices.	Defined by the user at the start of the simulation.
Variable	Fator_Preco_1	Multiplier factor on aluminum bicycle prices.	Defined by the user at the start of the simulation.
Variable	Fator_Preco_2	Multiplier factor on titanium bicycle prices.	Defined by the user at the start of the simulation.
Variable	Fator_Custo_0	Multiplier factor on the total material cost of steel bicycles.	Defined by the user at the start of the simulation.
Variable	Fator_Custo_1	Multiplier factor on the total material cost of aluminum bicycles.	Defined by the user at the start of the simulation.
Variable	Fator_Custo_2	Multiplier factor on the total material cost of titanium bicycles.	Defined by the user at the start of the simulation.
Variable	Fator_Demanda	Multiplier factor on the level of demand.	Defined by the user at the start of the simulation.
Variable	Fator_Frete	Multiplier factor on the freight time of metal materials for production.	Defined by the user at the start of the simulation.
Variable	Fator_Frete_Partes	Multiplier factor on the freight time of non-metallic materials for production.	Defined by the user at the start of the simulation.
Variable	Fator_Expectativa_Dias	Period of days between each production run. The quantity of bikes demanded in this period is the quantity sent into production.	Defined by the user at the start of the simulation. Only exists in the mass model.
Variable	Finished Bikes	Total number of bicycles produced.	-
Variable	Initial Stock	Quantity of bicycles in safety stock. It depends on the value of the "Fator_Expectativa_Dias" variable.	Only exists in the mass model.
Variable	Fulfilled Orders	Number of orders placed by customers that have been delivered.	-
Variable	Wait List	Number of orders placed by customers that have not yet been delivered.	-
Variable	Total_Revenue	Total sales revenue.	Revenue is counted when each order is delivered.

Source: Author.

Table 1 - Attributes, entities and variables (ending)

Type	Name	Function	Observation
Variable	Total_Costs	Total cost of production.	The cost is incurred when the metallic and non-metallic materials are purchased. It only includes raw material costs.
Variable	Total_Profit	Total profit.	
Variable	Average_Resource_Utilization	Average percentage of resource utilization during the simulation.	- It was also calculated according to the material of the bike, in the lean model.

Source: Author.

Table 2 - Simulation scenarios (continues)

Scenario	Demand_ Factor	Freight_ Factor	Part_Frei ght_Fact or	Cost_ Factor _0	Cost_ Factor _1	Cost_ Factor _2	Price_ Factor _0	Price_ Factor _1	Price_ Factor _2	Forecastin g_ Factor
Base Scenario	1	0	0	1	1	1	1	1	1	7
Symmetrical Change in Freight Times 1	1	0,5	0,5	1	1	1	1	1	1	7
Symmetrical Change in Freight Times 2	1	0,75	0,75	1	1	1	1	1	1	7
Symmetrical Change in Freight Times 3	1	1	1	1	1	1	1	1	1	7
Symmetrical Change in Freight Times 4	1	1,25	1,25	1	1	1	1	1	1	7
Asymmetric Change in the Freight Term for Metal Parts 1	1	0,5	0	1	1	1	1	1	1	7
Asymmetric Change in the Freight Term for Metal Parts 2	1	0,75	0	1	1	1	1	1	1	7
Asymmetric Change in the Freight Term for Metal Parts 3	1	1	0	1	1	1	1	1	1	7
Asymmetric Change in the Freight Term for Metal Parts 4	1	1,25	0	1	1	1	1	1	1	7
Asymmetric Change in Freight Times for Non-Metallic Parts 1	1	0	0,5	1	1	1	1	1	1	7
Asymmetric Change in the Freight Term for Non-Metallic Parts 2	1	0	0,75	1	1	1	1	1	1	7
Asymmetric Change in Freight Time for Non-Metallic Parts 3	1	0	1	1	1	1	1	1	1	7
Asymmetric Change in the Freight Time for Non-Metallic Parts 4	1	0	1,25	1	1	1	1	1	1	7

Source: Author.

| Scenario	Demand_Factor	Freight_Factor	Part_Freight_Factor	Cost_Factor_0	Cost_Factor_1	Cost_Factor_2	Price_Factor_0	Price_Factor_1	Price_Factor_2	Forecasting_Factor
Symmetrical Change in Cost 1	1	0	0	0,5	0,5	0,5	1	1	1	7
Symmetrical Change in Cost 2	1	0	0	0,75	0,75	0,75	1	1	1	7
Symmetrical Change in Cost 3	1	0	0	1,25	1,25	1,25	1	1	1	7
Symmetrical Change in Cost 4	1	0	0	1,5	1,5	1,5	1	1	1	7
Symmetrical Change in Price 1	1	0	0	1	1	1	0,5	0,5	0,5	7
Symmetrical Change in Price 2	1	0	0	1	1	1	0,75	0,75	0,75	7
Symmetrical Change in Price 3	1	0	0	1	1	1	1,25	1,25	1,25	7
Symmetrical Price Change 4	1	0	0	1	1	1	1,5	1,5	1,5	7
Asymmetric Change in Fator_Custo_0 1	1	0	0	0,5	1	1	1	1	1	7
Asymmetric Change in Fator_Custo_0 2	1	0	0	0,75	1	1	1	1	1	7
Asymmetric Change in Fator_Custo_0 3	1	0	0	1,25	1	1	1	1	1	7
Asymmetric Change in Fator_Custo_0 4	1	0	0	1,5	1	1	1	1	1	7
Asymmetric Change in Fator_Custo_1 1	1	0	0	1	0,5	1	1	1	1	7
Asymmetric Change in Fator_Custo_1 2	1	0	0	1	0,75	1	1	1	1	7
Asymmetric Change in Fator_Custo_1 3	1	0	0	1	1,25	1	1	1	1	7
Asymmetric Change in Fator_Custo_1 4	1	0	0	1	1,5	1	1	1	1	7
Asymmetric Change in Fator_Custo_2 1	1	0	0	1	1	0,5	1	1	1	7
Asymmetric Change in Fator_Custo_2 2	1	0	0	1	1	0,75	1	1	1	7
Asymmetric Change in Fator_Custo_2 3	1	0	0	1	1	1,25	1	1	1	7
Asymmetric Change in Fator_Custo_2 4	1	0	0	1	1	1,5	1	1	1	7
Asymmetric Change in Fator_Preco_0 1	1	0	0	1	1	1	0,5	1	1	7
Asymmetric Change in Fator_Preco_0 2	1	0	0	1	1	1	0,75	1	1	7
Asymmetric Change in Fator_Preco_0 3	1	0	0	1	1	1	1,25	1	1	7
Asymmetric Change in Fator_Preco_0 4	1	0	0	1	1	1	1,5	1	1	7
Asymmetric Change in Fator_Preco_1 1	1	0	0	1	1	1	1	0,5	1	7
Asymmetric Change in Fator_Preco_1 2	1	0	0	1	1	1	1	0,75	1	7

Source: Author.

Table 2 - Simulation scenarios (ending)

Scenario	Demand _Factor	Freight_ Factor	Part_Frei ght_Fact or	Cost_ Factor _0	Cost_ Factor _1	Cost_ Factor _2	Price_ Factor _0	Price_ Factor _1	Price_ Factor _2	Forecastin g_ Factor
Asymmetric Change in Fator_Preco_1 3	1	0	0	1	1	1	1	1,25	1	7
Asymmetric Change in Fator_Preco_1 4	1	0	0	1	1	1	1	1,5	1	7
Asymmetric Change in Fator_Preco_2 1	1	0	0	1	1	1	1	1	0,5	7
Asymmetric Change in Fator_Preco_2 2	1	0	0	1	1	1	1	1	0,75	7
Asymmetric Change in Price_Factor_2 3	1	0	0	1	1	1	1	1	1,25	7
Asymmetric Change in Fator_Preco_2 4	1	0	0	1	1	1	1	1	1,5	7
Change in Demand 1	0,5	0	0	1	1	1	1	1	1	7
Change in Demand 2	0,75	0	0	1	1	1	1	1	1	7
Change in Demand 3	1,25	0	0	1	1	1	1	1	1	7
Change in Demand 4	1,5	0	0	1	1	1	1	1	1	7
Change in Forecasting Factor 1	1	0	0	1	1	1	1	1	1	1
Change in Forecasting Factor 2	1	0	0	1	1	1	1	1	1	4
Change in Forecasting Factor 3	1	0	0	1	1	1	1	1	1	17
Change in Forecasting Factor 4	1	0	0	1	1	1	1	1	1	30

Source: Author.

Figure 1 - Profit and freight times in the mass model
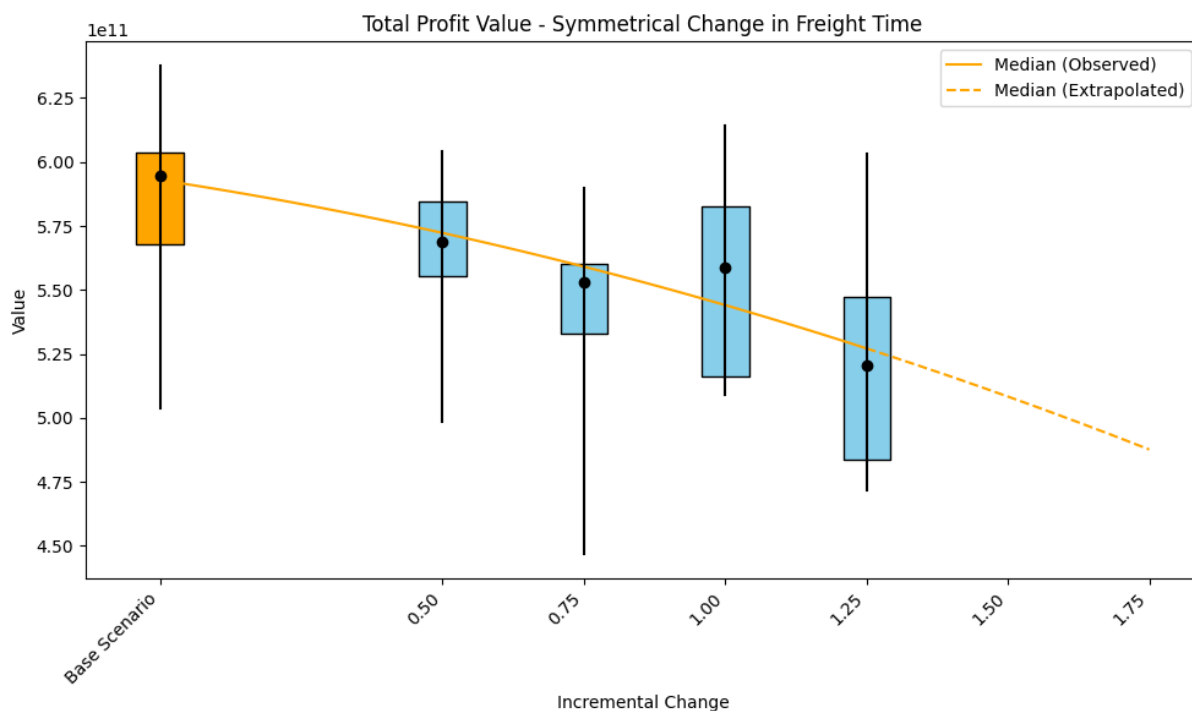
Source: Author.

Figure 2 - Profit and freight times in the lean model

Total Profit Value - Symmetrical Change in Freight Time
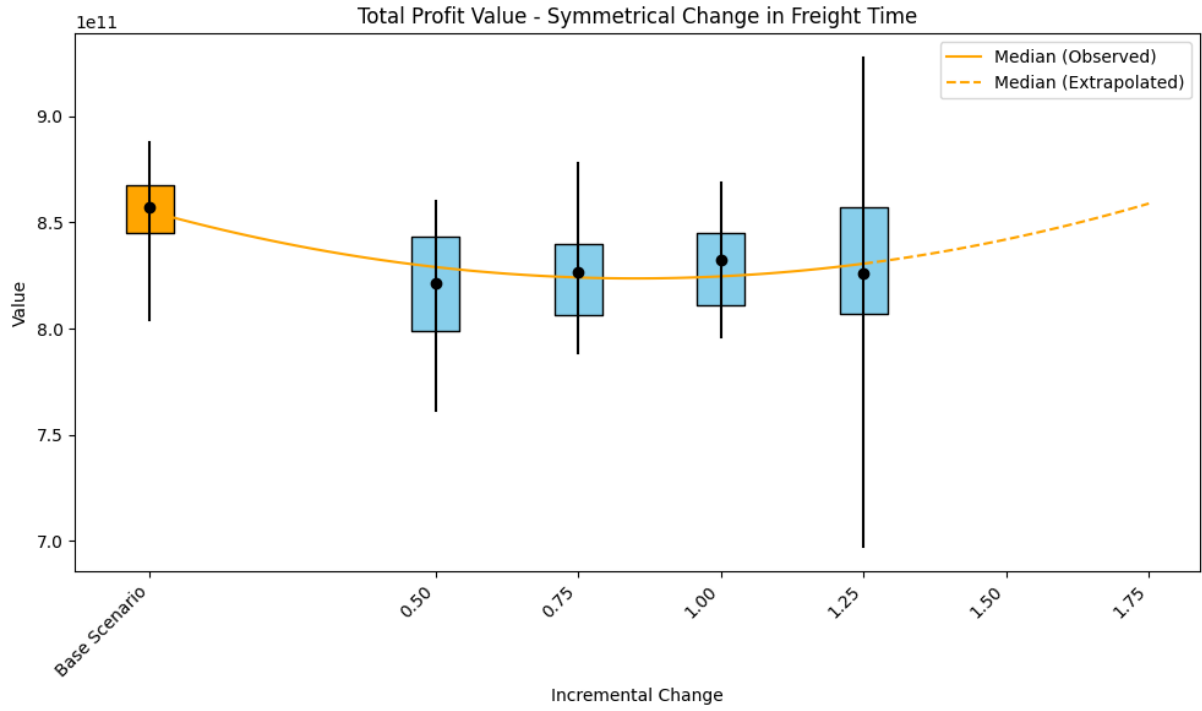
Source: Author.

Figure 3 - Profit and cost changes, mass and lean model

Total Profit Value - Symmetrical Change in Cost
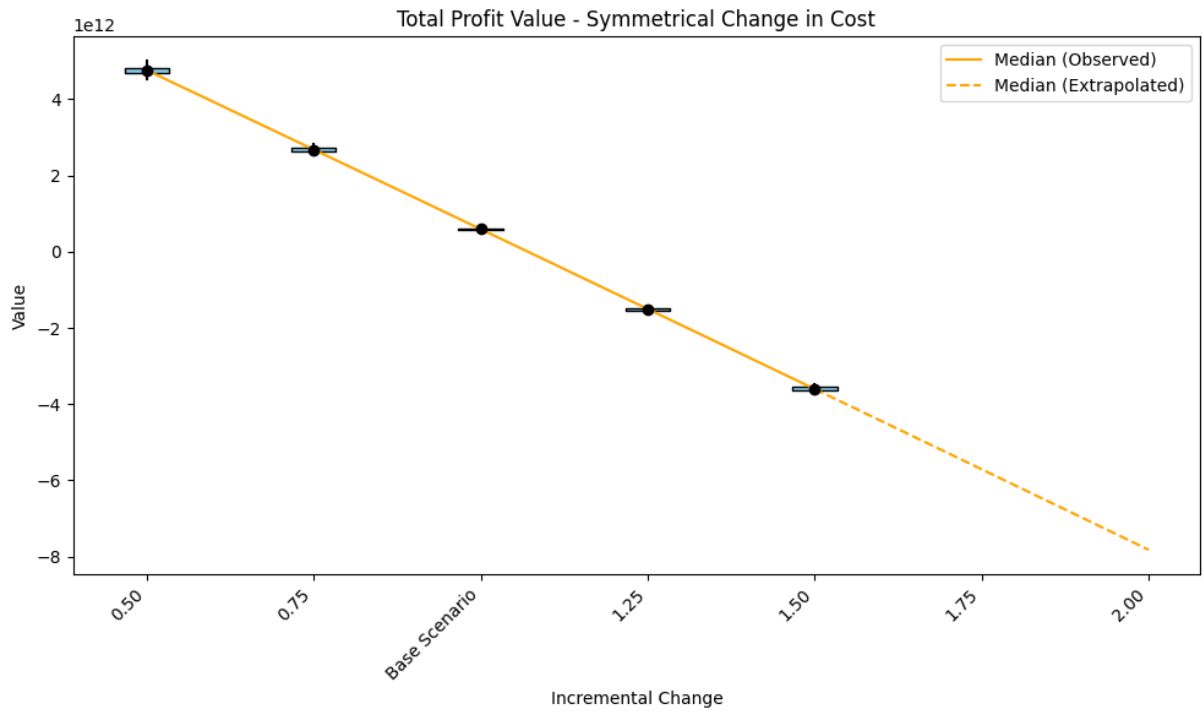
Source: Author.

Figure 4 - Profit and price changes, mass and lean model
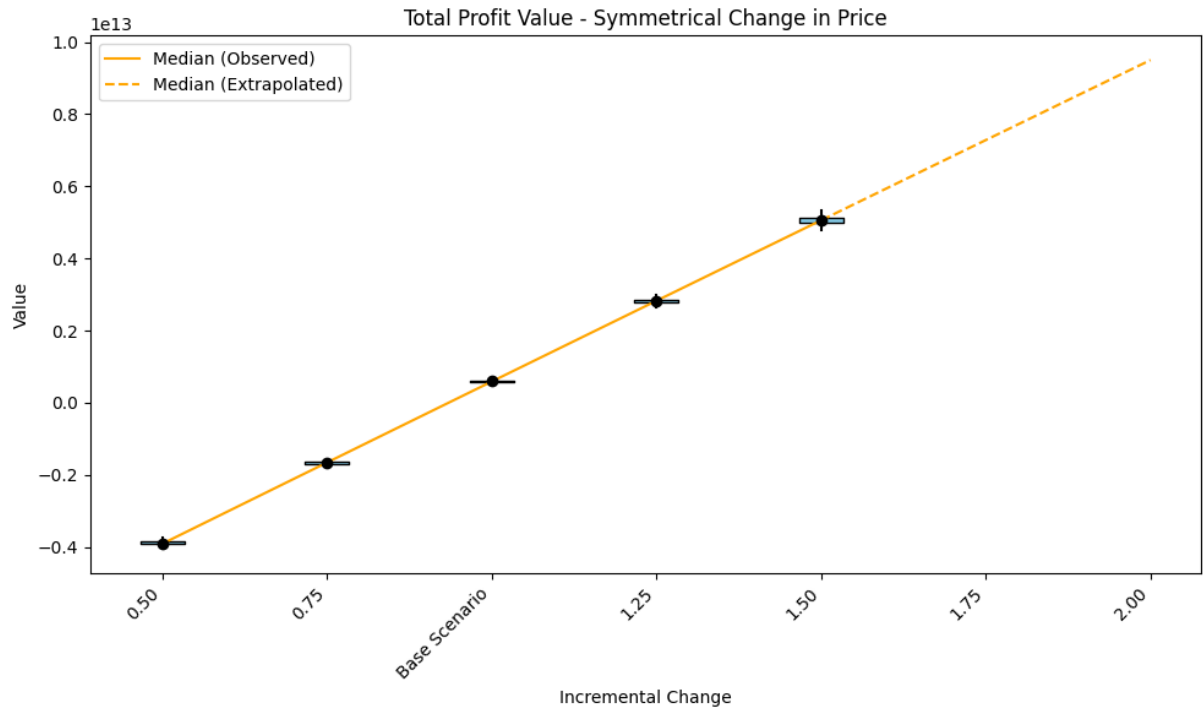
Source: Author.

Figure 5 - Profit and asymmetric price change in the mass model
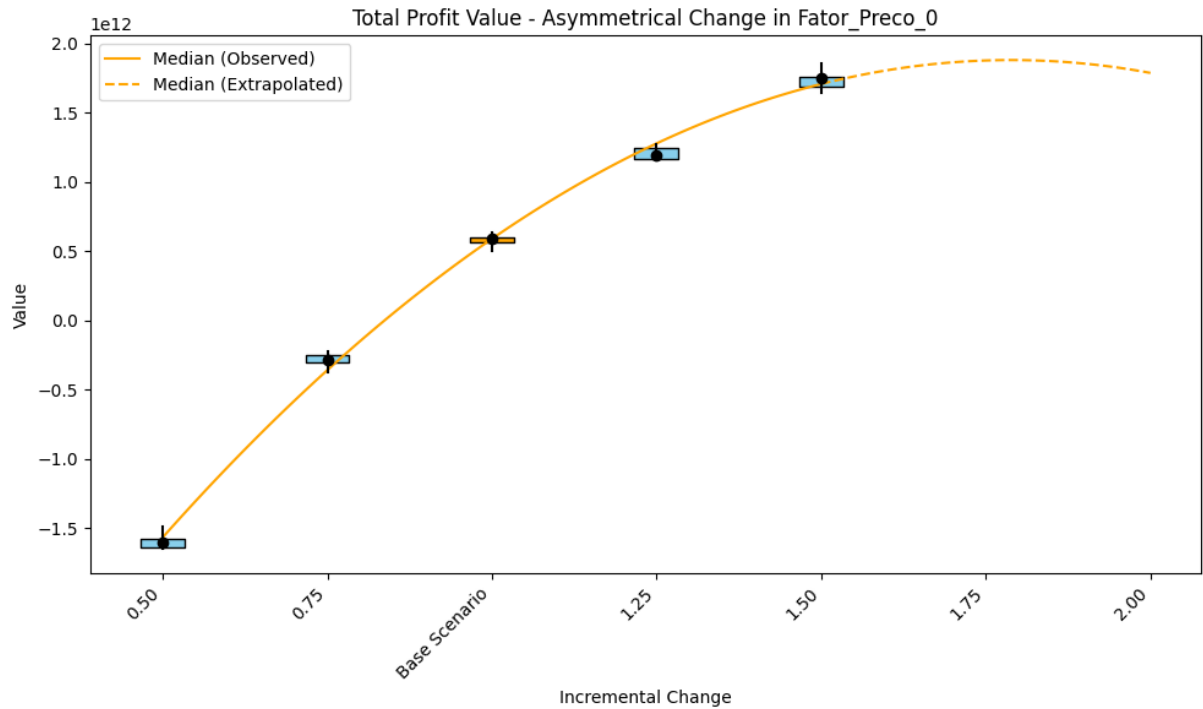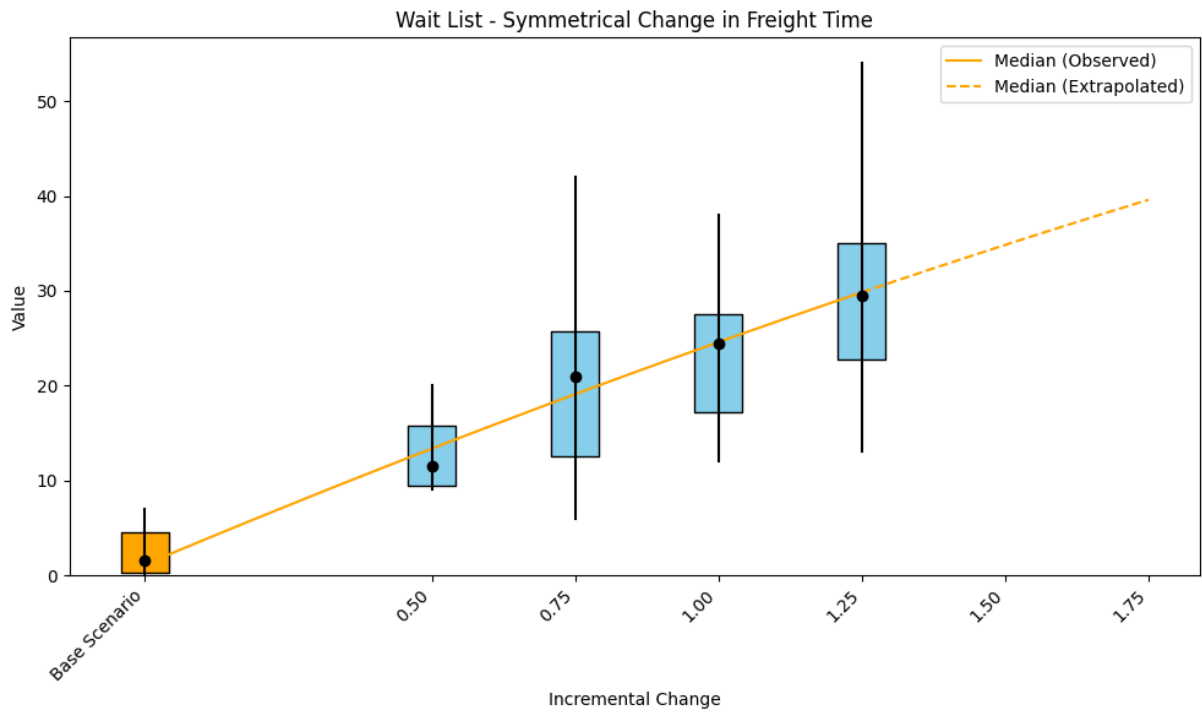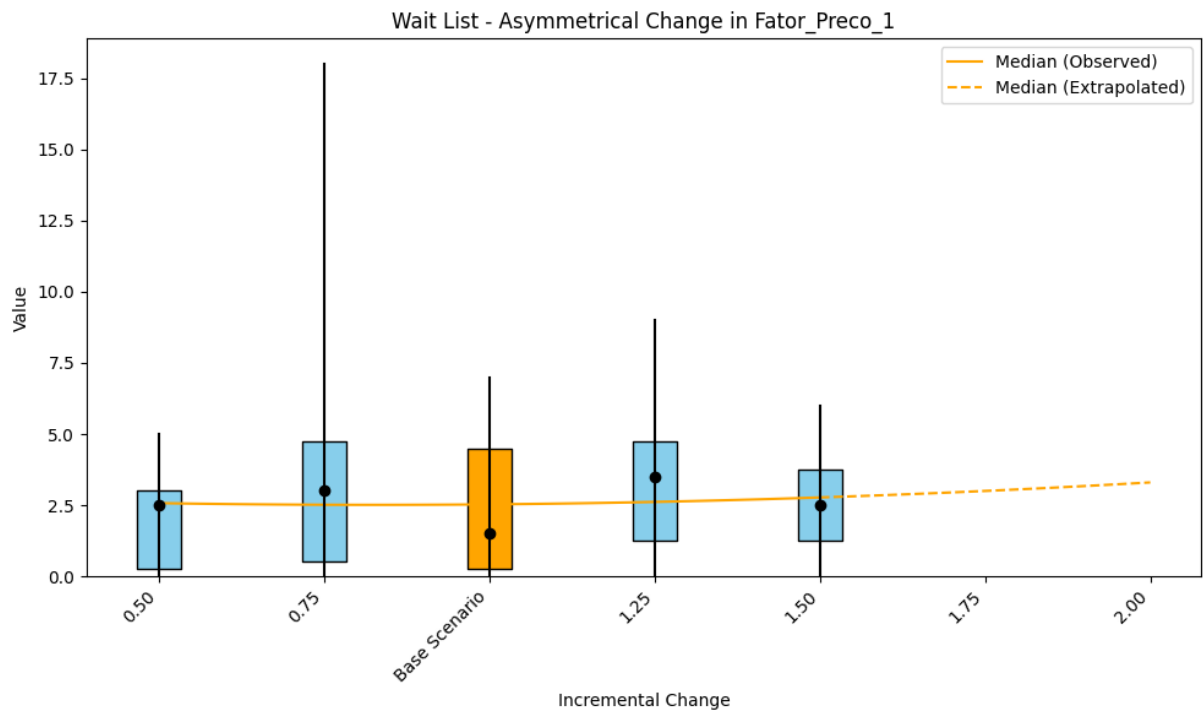

Source: Author.

**Figure 6 - Profit and asymmetric price change in the lean model**

Total Profit Value - Asymmetrical Change in Fator_Preco_0
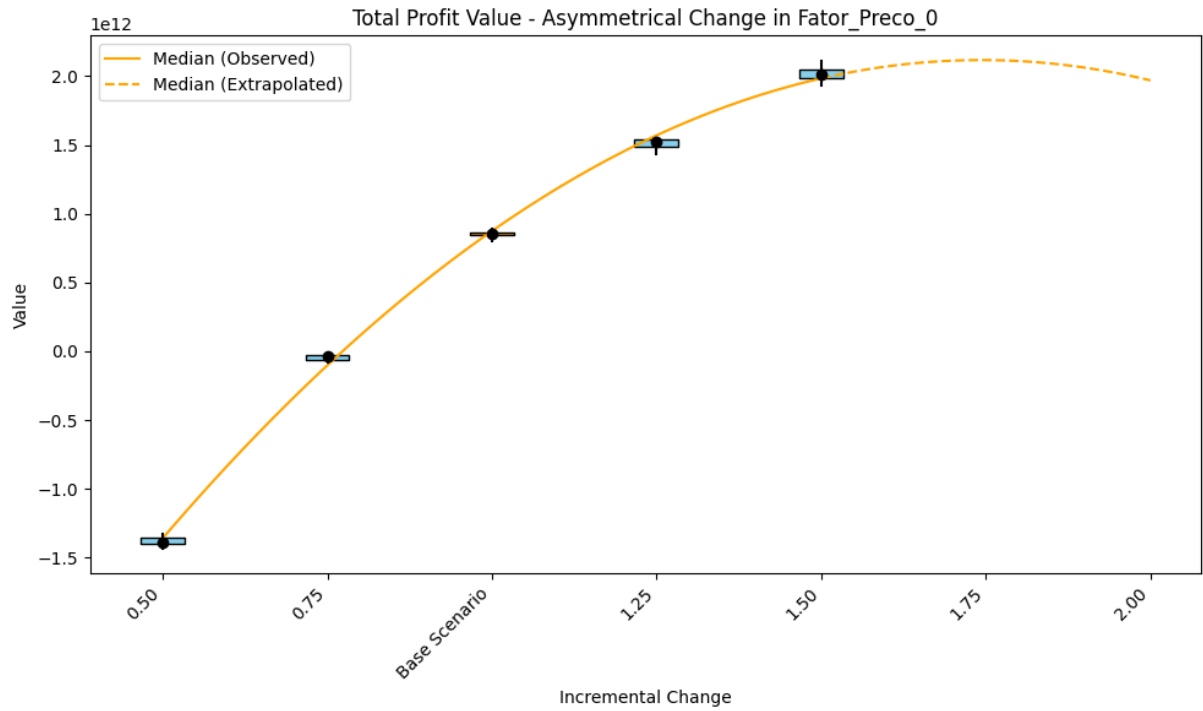
Source: Author.

Figure 7 - Profit and change in demand in the mass model

Total Profit Value - Change in Demand
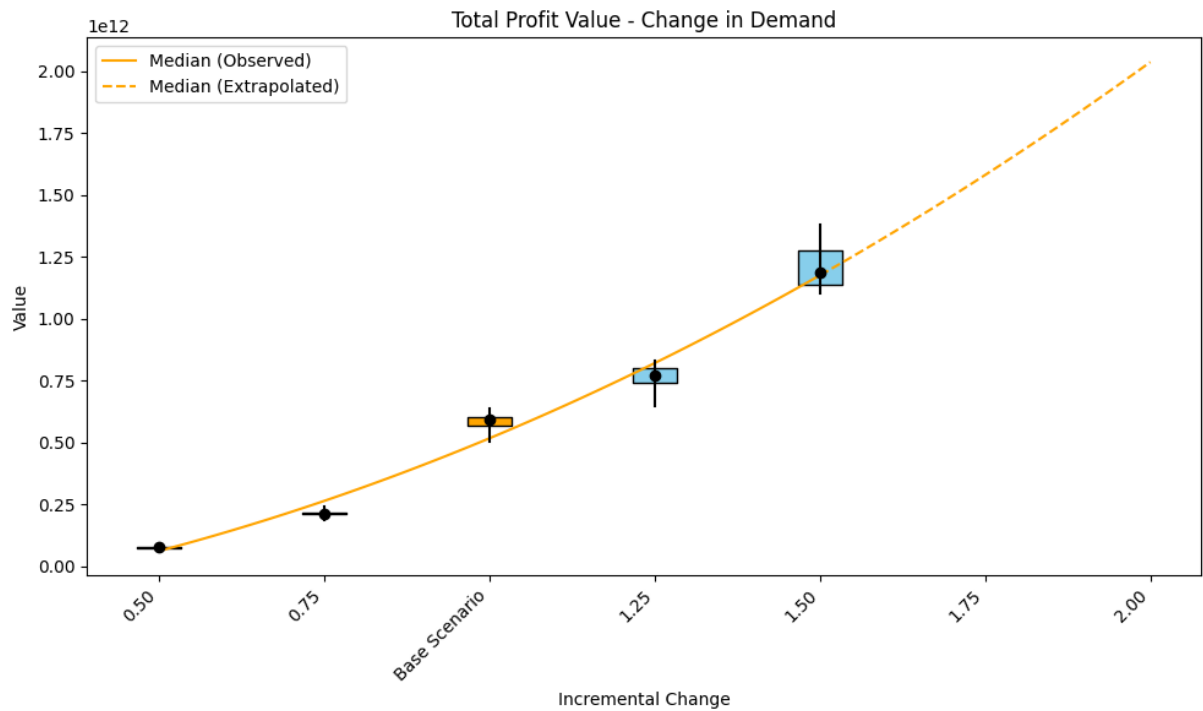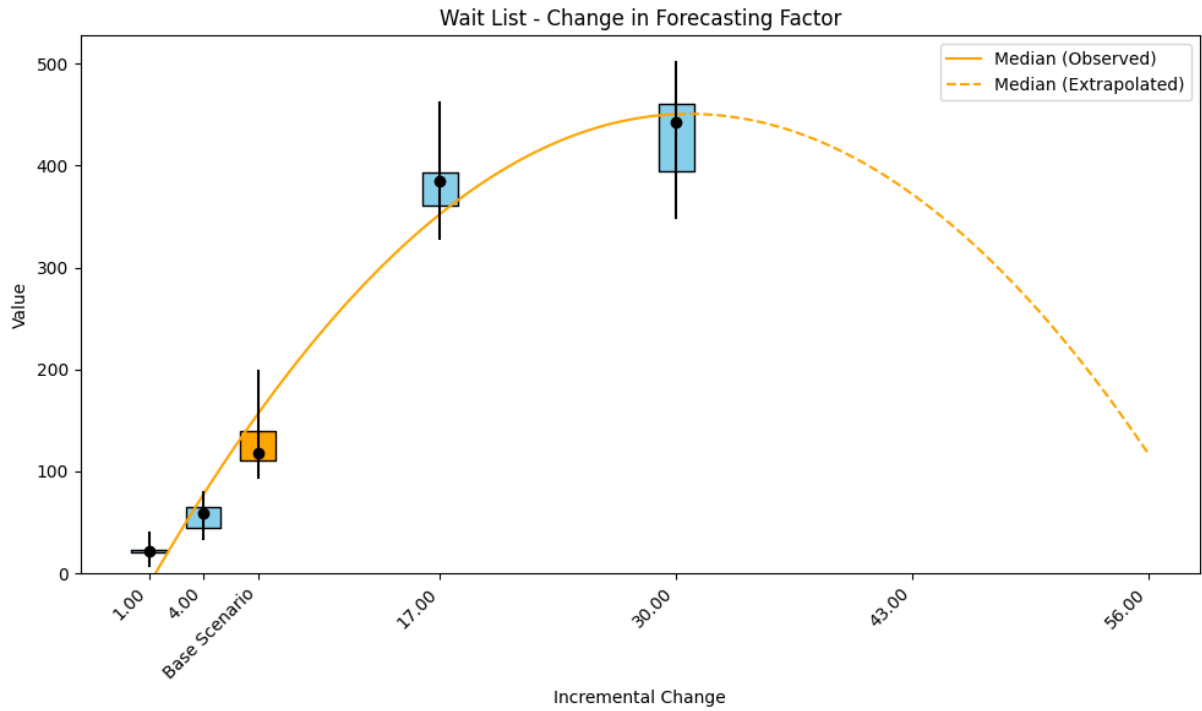

Source: Author.
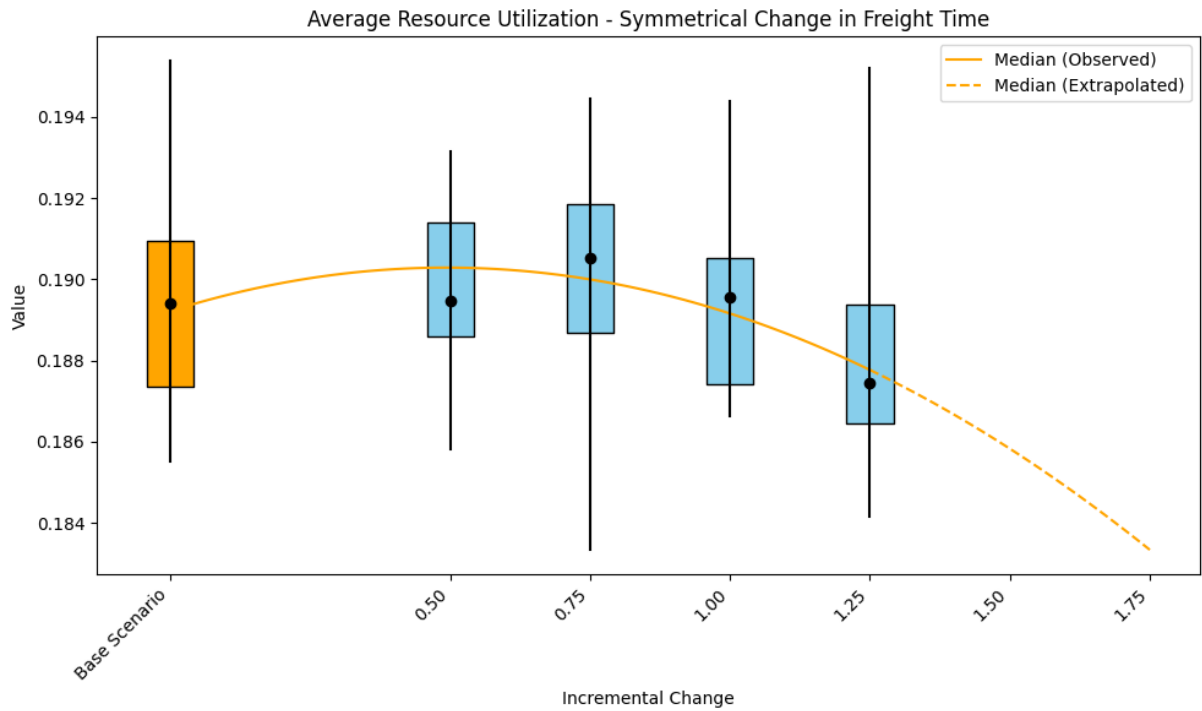
Figure 8 - Profit and change in demand in the lean model
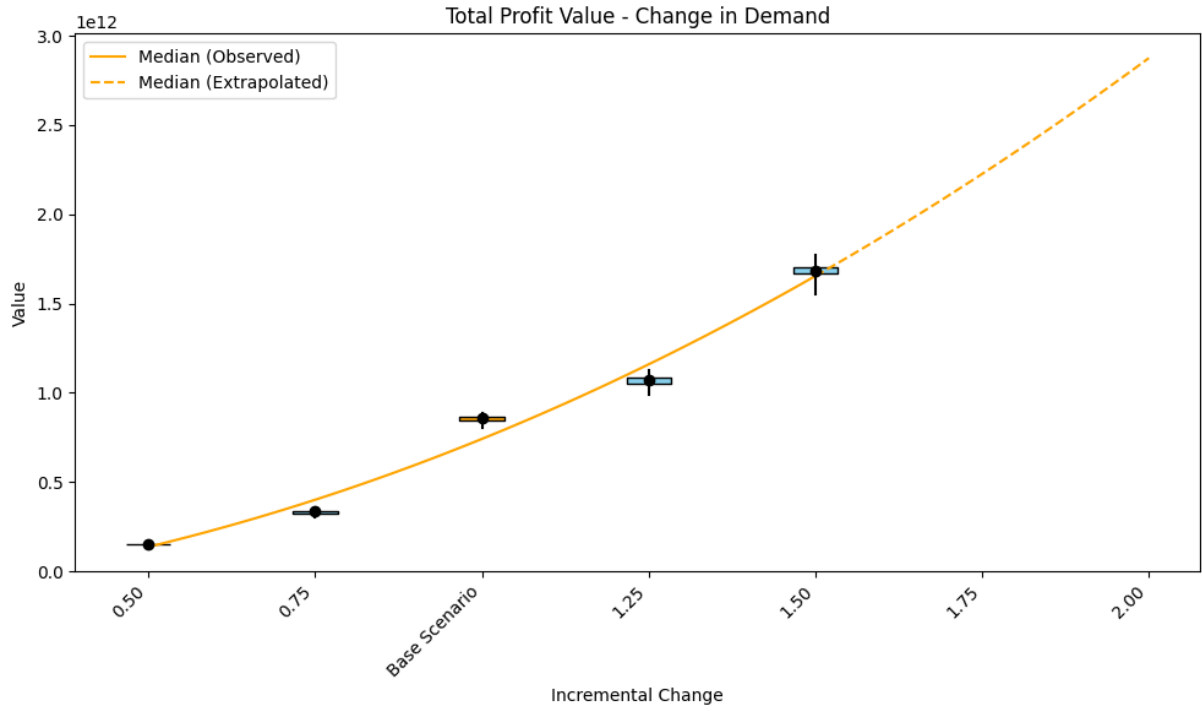
Source: Author.

Figure 9 - Profit and change in forecasting factor in the mass model
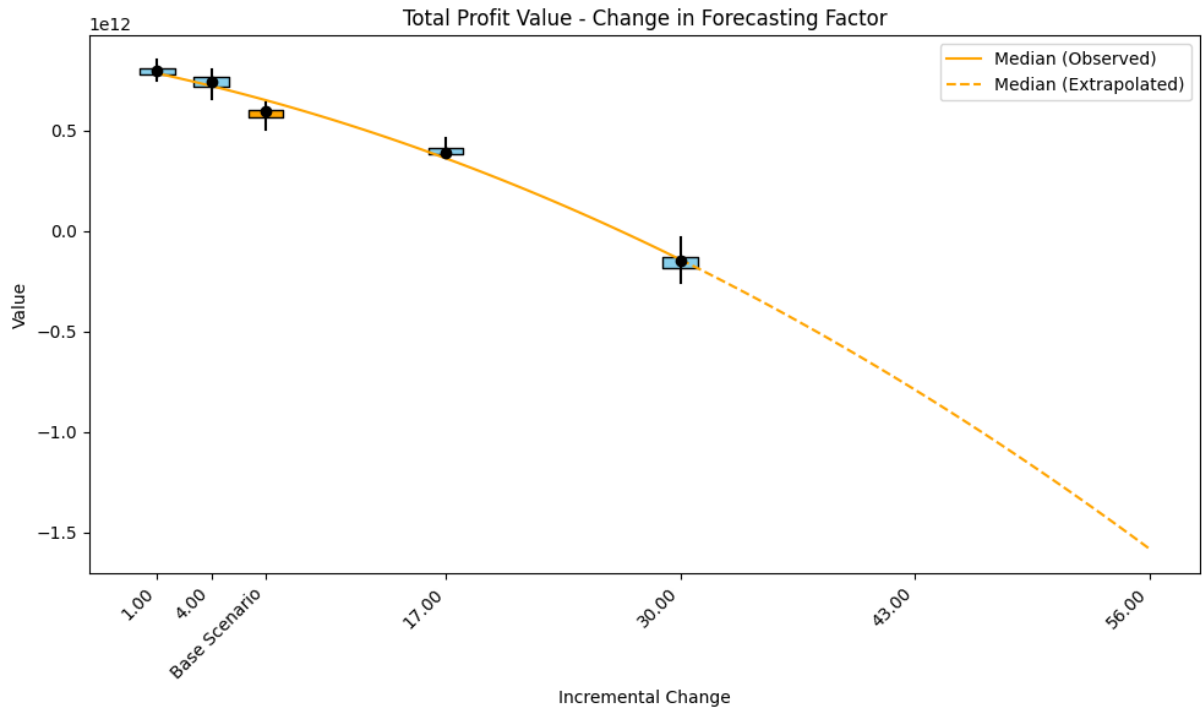
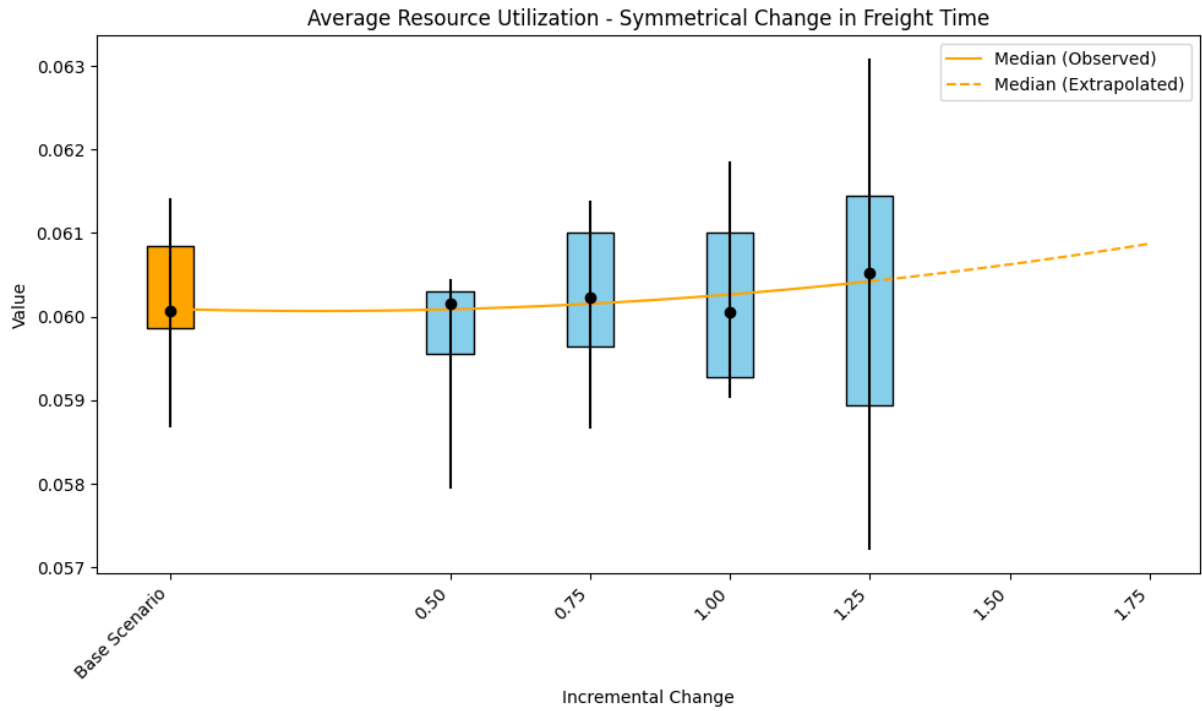Source: Author.

Figure 10 - Wait list and freight times in the mass model
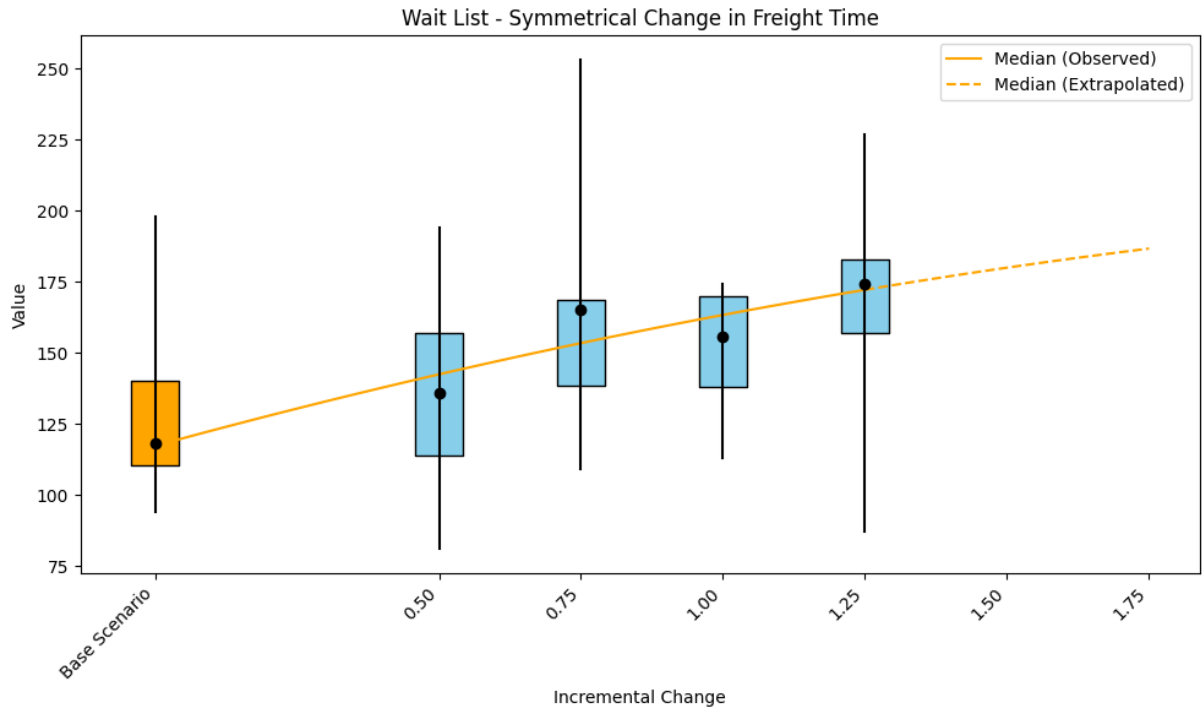
Source: Author.
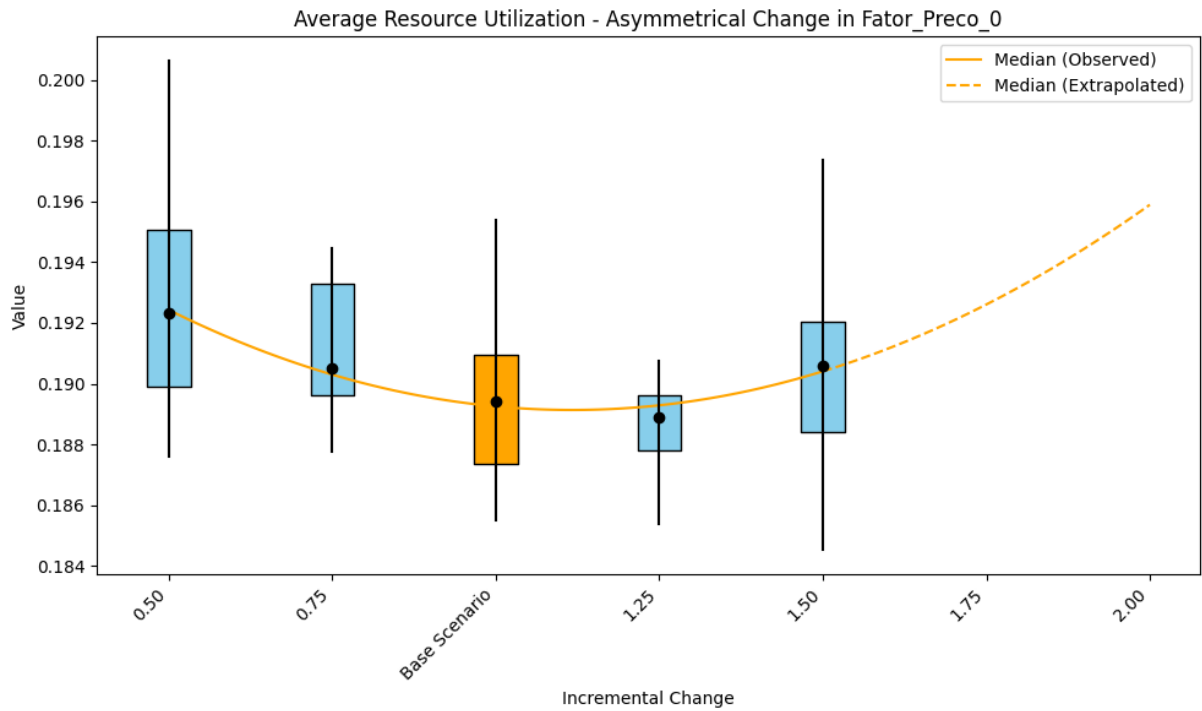
Figure 11 - Wait list and freight times in the lean model

Source: Author.

Figure 12 - Wait list and asymmetric price change in the mass model
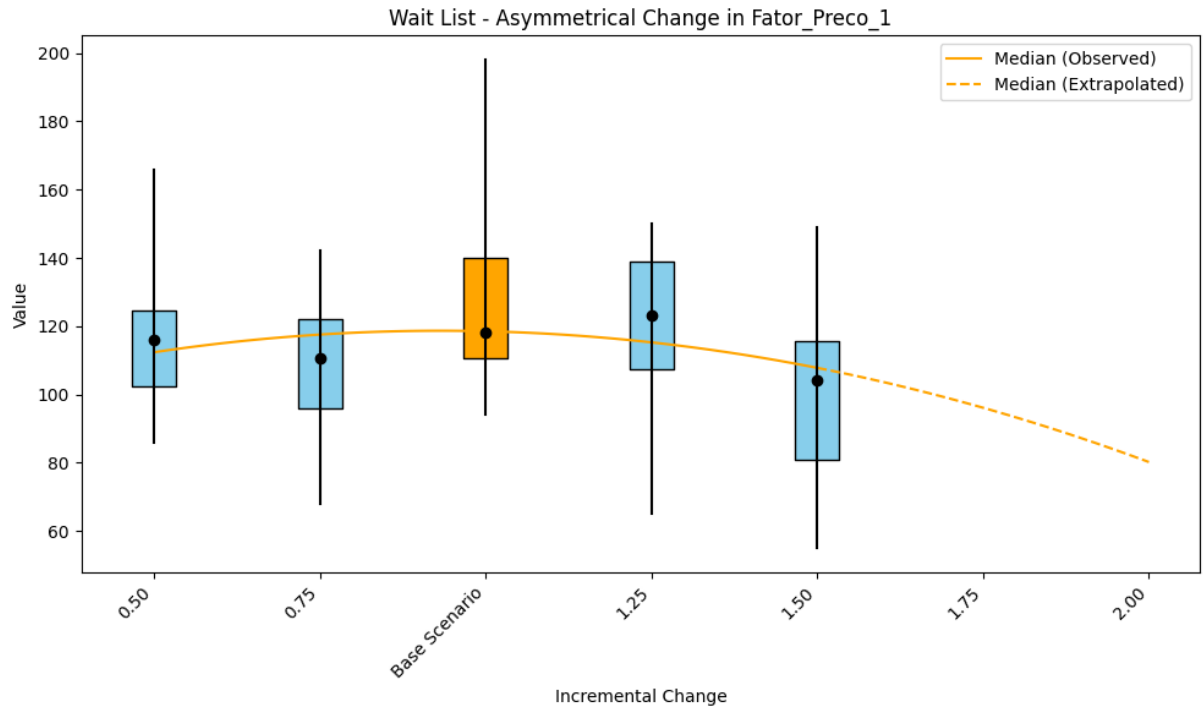
Source: Author.

Figure 13 - Wait list and asymmetric change in prices in the lean model

Source: Author.

Figure 14 - Wait list and change in demand in the mass model
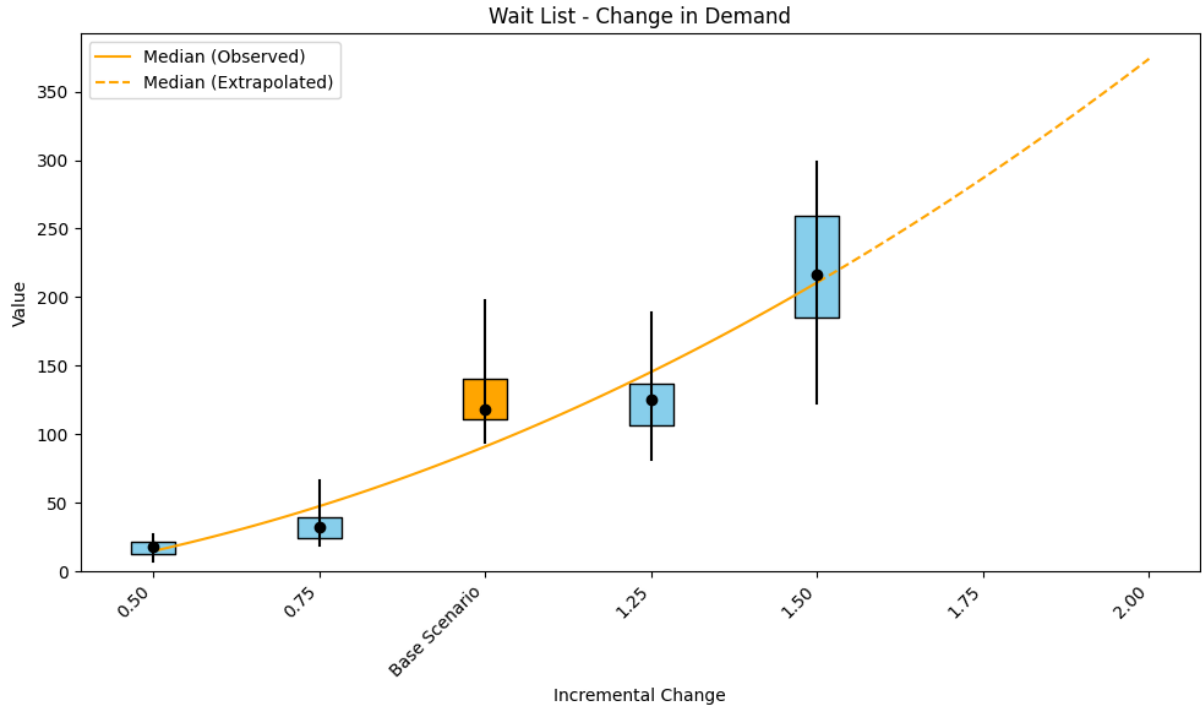
Source: Author.

Figure 15 - Wait list and change in demand in the lean model
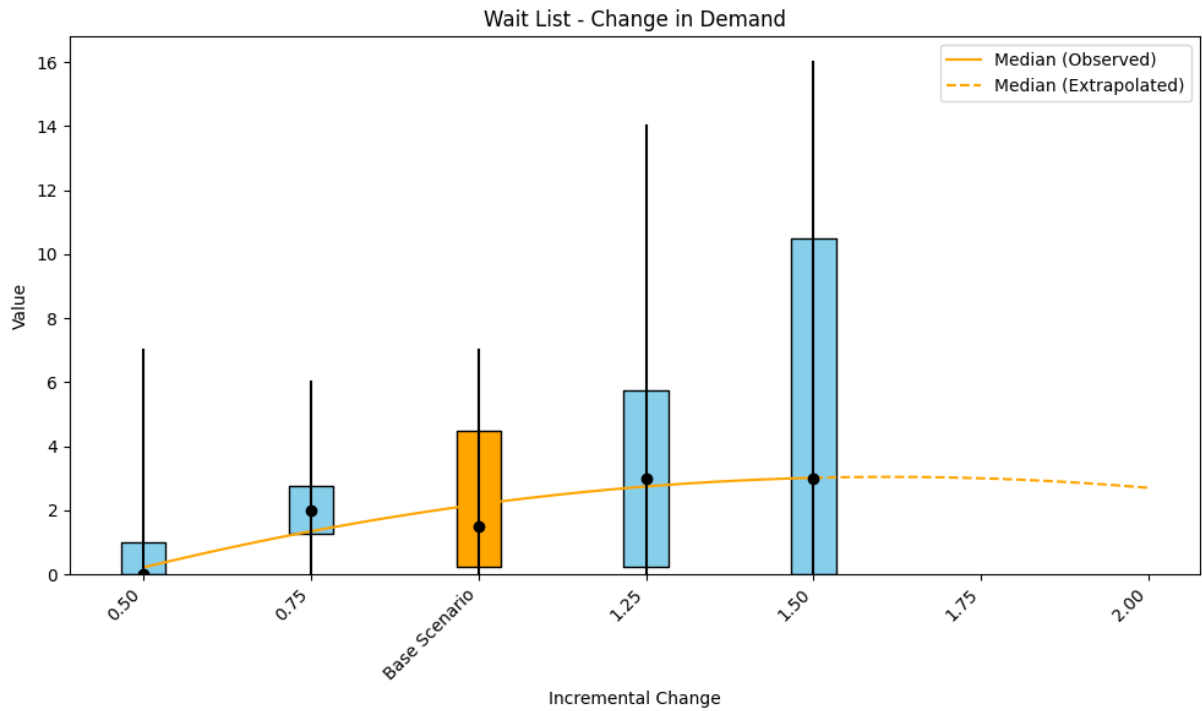
Source: Author.

Figure 16 - Wait list and change in forecasting factor in the mass model

Source: Author.

Figure 17 - Resource utilization and freight times in the mass model

Source: Author.

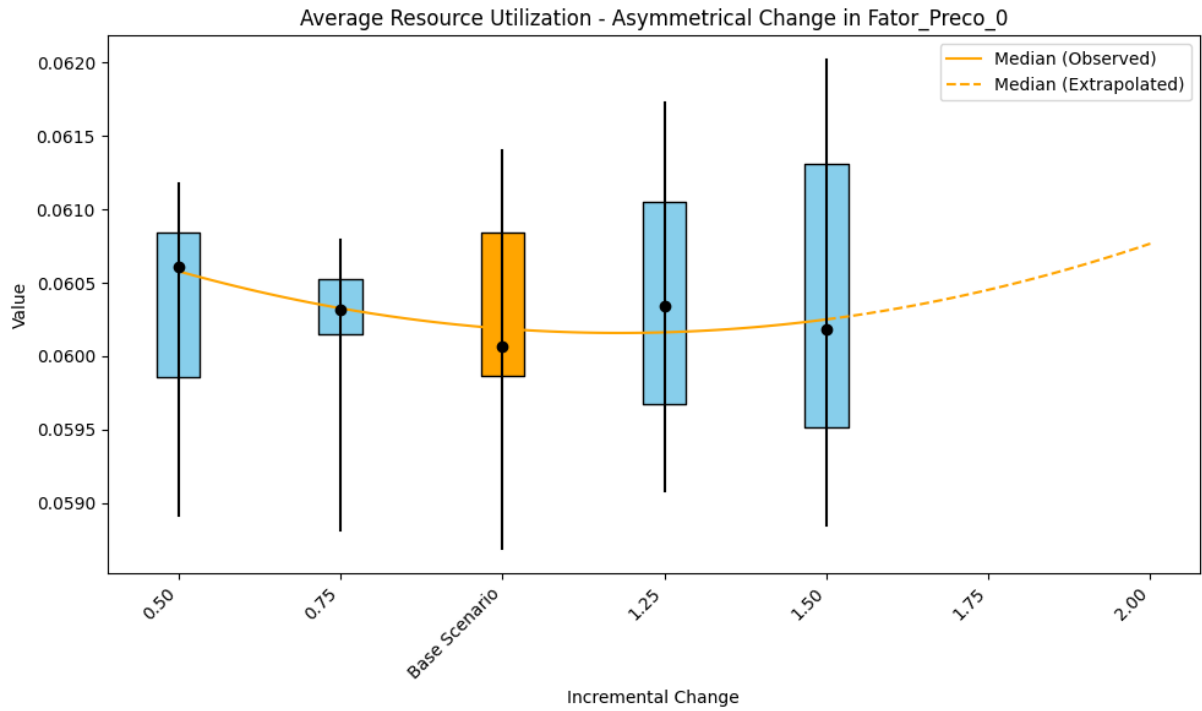**Figure 18 - Resource utilization and freight times in the lean model**

Source: Author.

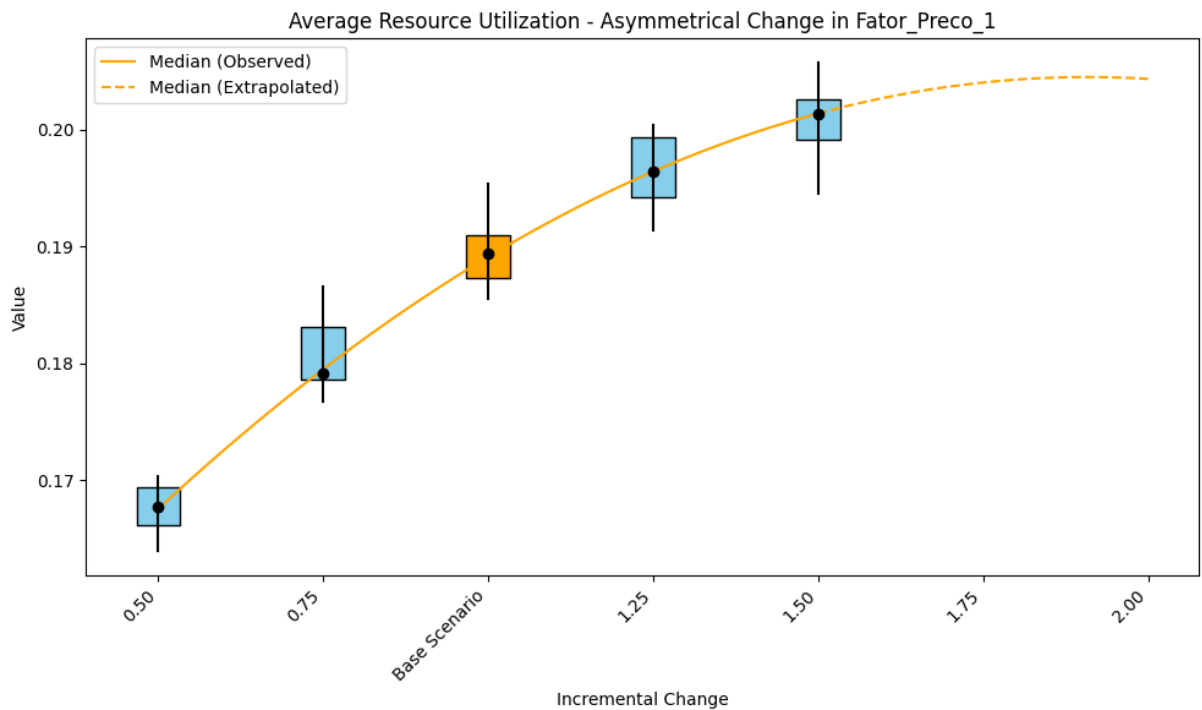**Figure 19 - Resource utilization and asymmetric price changes in the mass model**

Source: Author.

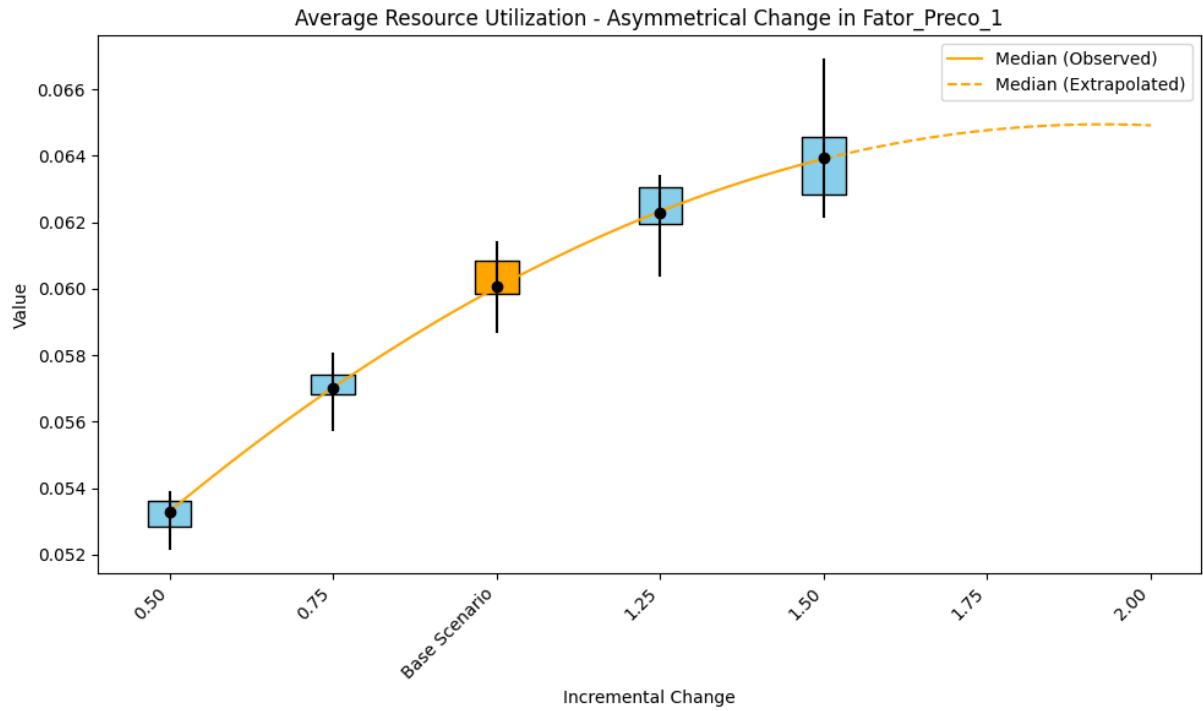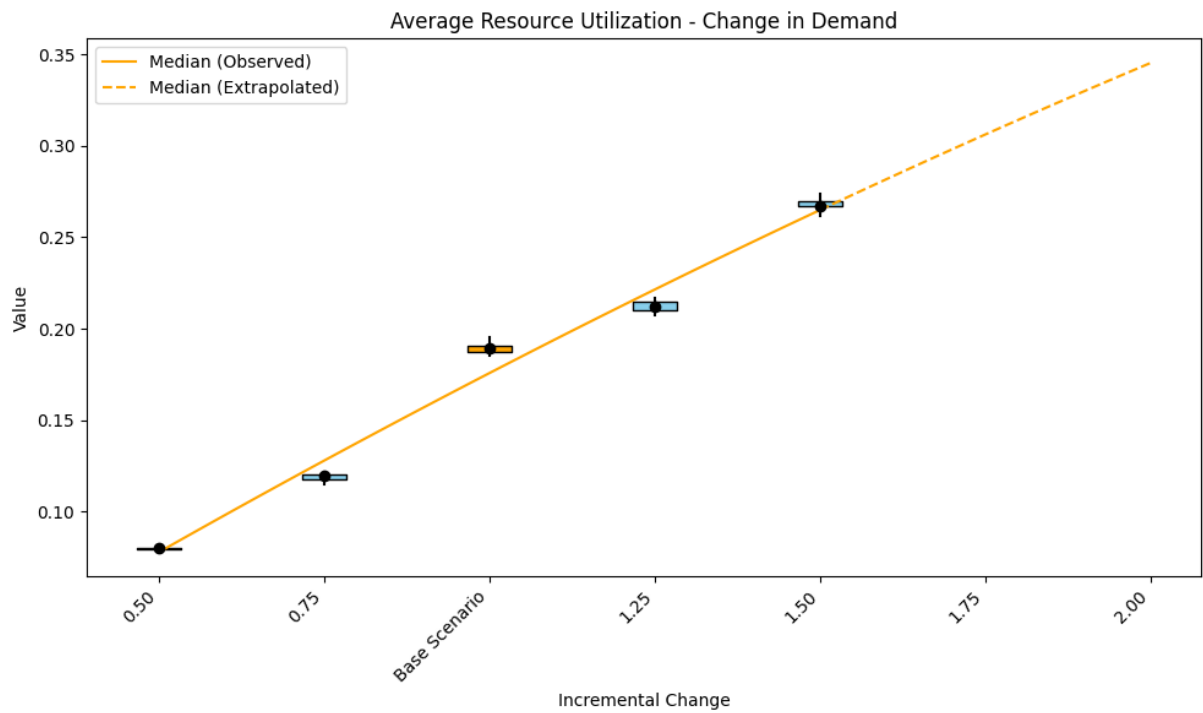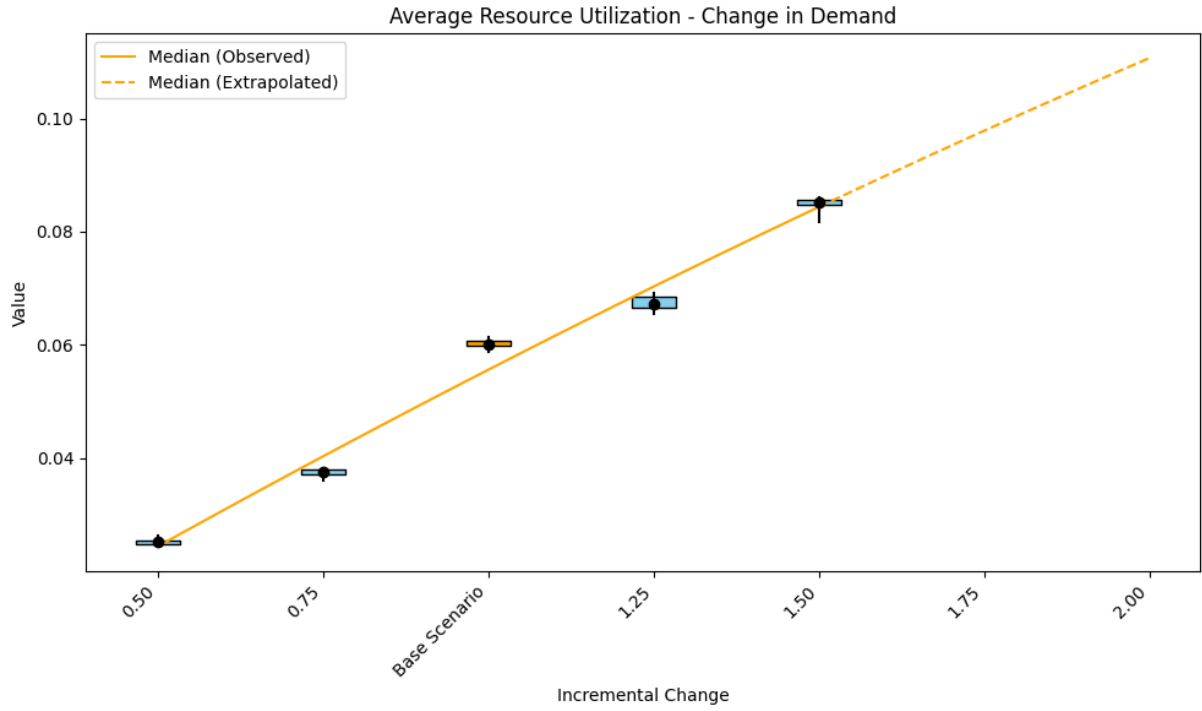**Figure 20 - Resource utilization and asymmetric price change in the lean model**

Average Resource Utilization - Asymmetrical Change in Fator_Preco_0

Source: Author.

Figure 21 - Resource utilization and asymmetric price changes in the mass model

Average Resource Utilization - Asymmetrical Change in Fator_Preco_1

Source: Author.

Figure 22 - Resource utilization and asymmetric price change in the lean model

Average Resource Utilization - Asymmetrical Change in Fator_Preco_1

Source: Author.

Figure 23 - Resource utilization and change in demand in the mass model

Average Resource Utilization - Change in Demand
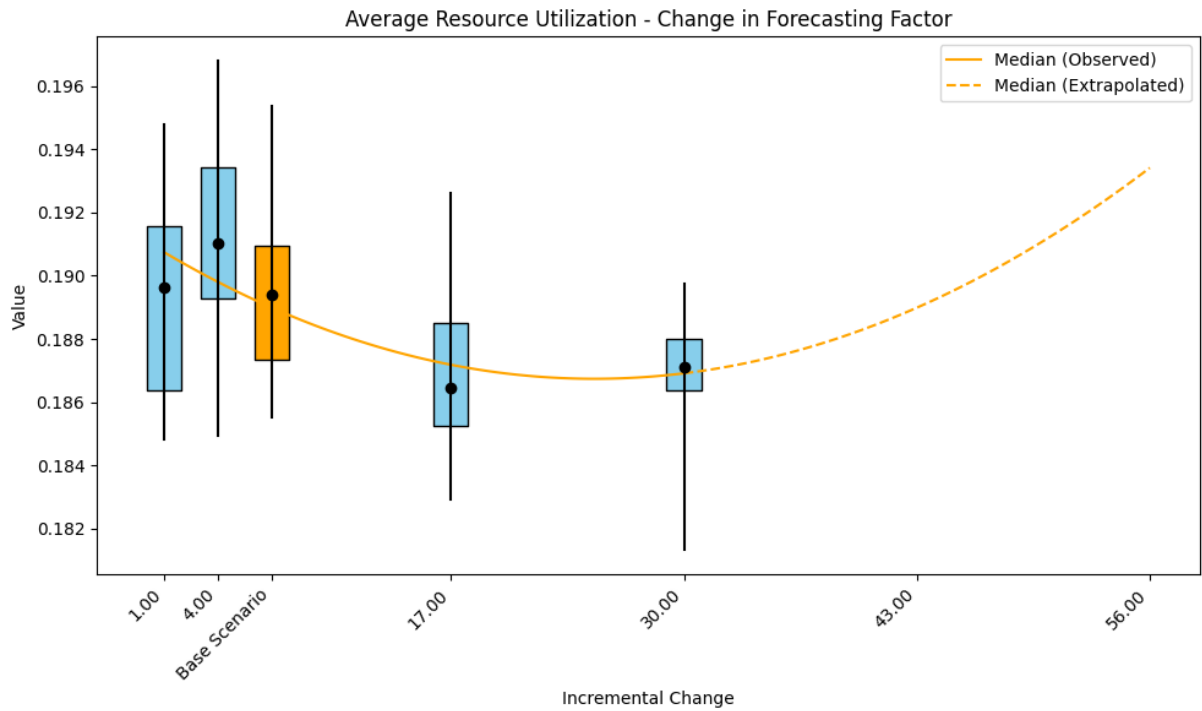
Source: Author.

Figure 24 - Resource utilization and change in demand in the lean model

Source: Author.

Figure 25 - Resource utilization and change in forecasting factor in the mass model

Source: Author.