Submission to International System Dynamics Conference (ISDC) 2025

Title: Investigating the Valley of Death and Dynamics of Deep Tech Commercialization from the Firm's Perspective

Appendix A-C

Appendix A: Model Structure

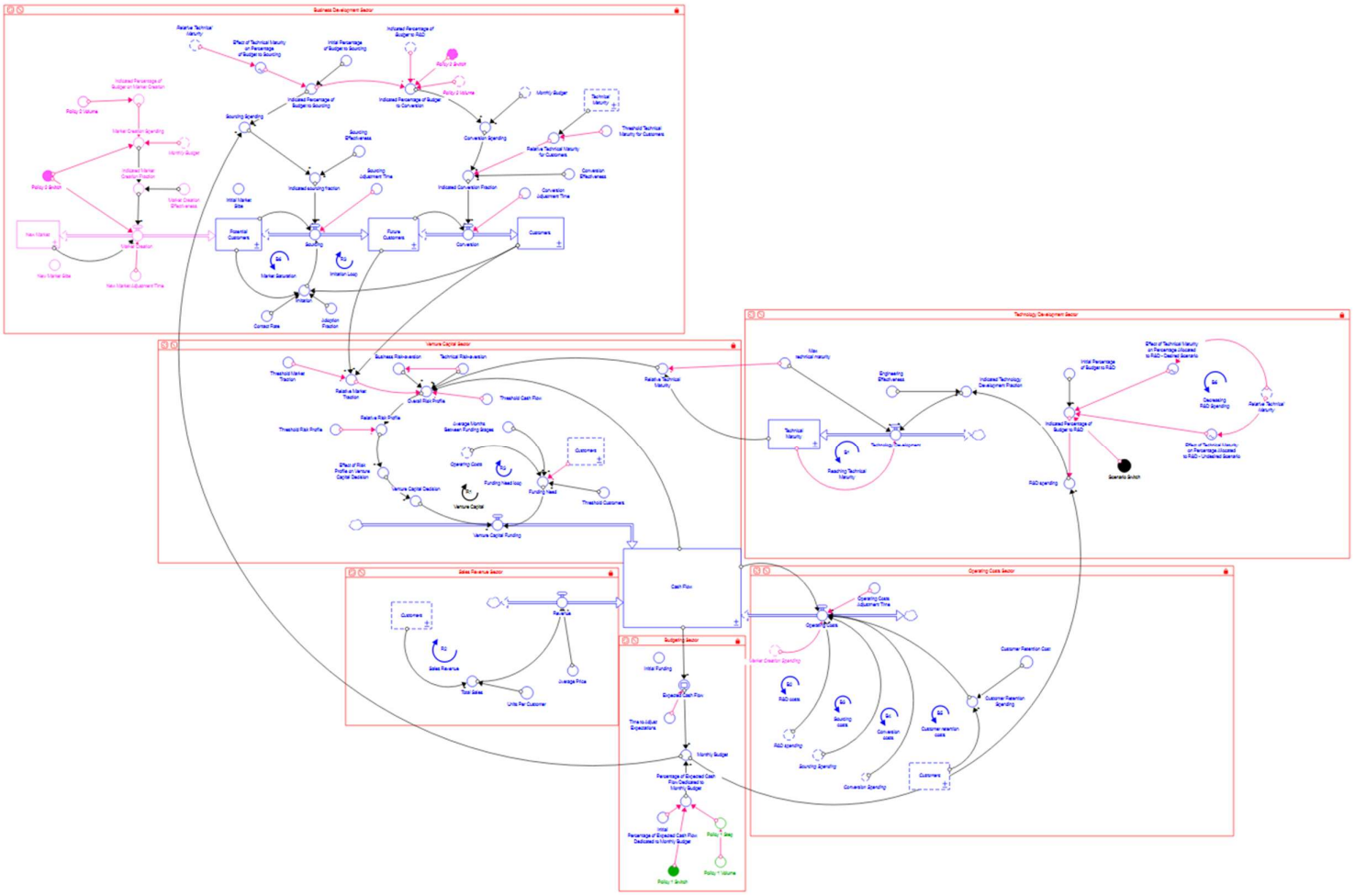


Figure 1. Formal model structure used for the study of the dynamics of technology commercialization from the perspective of a startup firm.

Appendix B: Documentation

Documentation of model according to Reporting guidelines for simulation-based research in social sciences (Rahmandad, H., & Sterman, J. D., 2012, 396-411).

Simulation Experiment Report

- Modelling Software: Stella 3.57.3
- Start Time: 0
- End Time: 120
- Integration Method: Euler
- Time Units: Months
- DT: 1/64

Table 1. Model documentation of all variables in model structure.

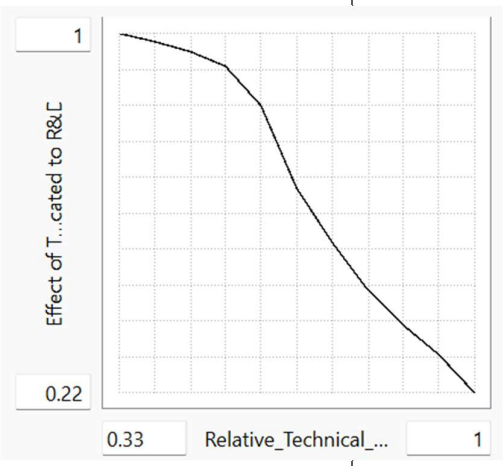
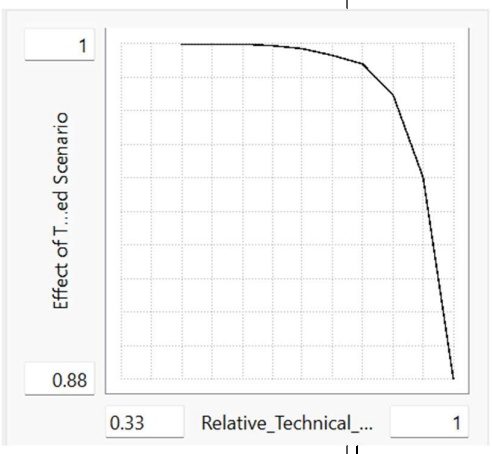
Variable	Equation	Properties	Units	Documentation
Cash_Flow(t)	Cash_Flow(t - dt) + (Revenue + Venture_Capital_Funding - Operating_Costs) * dt	INIT Cash_Flow = Initial_Funding	dollar	This is a stock which indicates the amount of dollars in the company's account. It is determined by an increase from the inflow of revenue or venture capital funding and the outflow of operating costs. The initial value of this stock is determined by initial funding.
Customers(t)	Customers(t - dt) + (Conversion) * dt	INIT Customers = 0	customer	This stock indicates the amount of customers the company has. It is determined by an increase from the inflow of conversion.
Future_Customers(t)	Future_Customers(t - dt) + (Sourcing - Conversion) * dt	INIT Future_Customers = 0	customer	This stock represents the amount of letters of intent to buy the technology from the company once the technical maturity has surpassed the threshold technical maturity for customers. It's value is determined by the inflow of sourcing from potential customers and the outflow of conversion to customers. Some investors judge traction based signals such as letters of intent or pilots that are likely to convert and demonstrate a market need and ability for future monetization (Speedinvest, 2020).
New_Market(t)	New_Market(t - dt) + (- Market_Creation) * dt	INIT New_Market = New_Market_Size	customer	This stock is the amount of customers in the new market. When Policy 2 switch is on, it's value is determined by the outflow of customers through the market creation outflow.

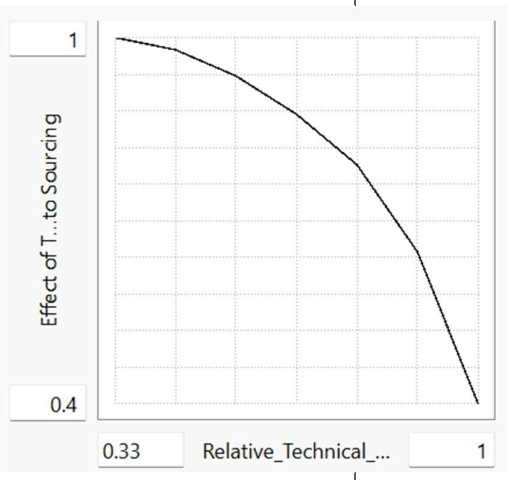
Potential_Customers(t)	Potential_Customers(t - dt) + (Market_Creation - Sourcing) * dt	INIT Potential_Customers = Initial_Market_Size	customer	This stock represents the amount of potential adopters of the new technology in the marketplace. The stock depletes as potential customers are sourced. It's value is determined by the outflow of sourcing to future customers. The initial value of the stock is set at the initial market size. When Policy 2 switch is on, there is an inflow from new market stock through the market creation inflow.
Technical_Maturity(t)	Technical_Maturity(t - dt) + (Technology_Development) * dt	INIT Technical_Maturity = 3	TRL unit	This stock represents the maturity level of the technology that the company is developing. It's value is determined based on the inflow of technology development. The maturity level is based on the technology readiness level (TRL) scale, originally defined by NASA as a means for measuring or indicating the the maturity of a given technology, from a paper sketch to its entry into the market. New technologies go through the various stages of the TRL scale, from 1-9 in their life cycle and thus it helps to evaluate project progress of different technologies. Horizon Europe uses the TRL scale as an indicator to position proposals and projects in the program (BRIDGE2HE, 2022). The initial value is estimated as 3 based on that the European Commission and National Science Foundation both award grants to companies in this development stage of the TRL scale (European Innovation Council, n.d; National Science Foundation, n.d.).
Conversion	MIN(Indicated_Conversion_Fraction, Future_Customers/Conversion_Adjustment_Time)		customer/Months	This is an outflow from the future customers stock and inflow to the customers stock. It indicates the rate at which the company converts future customers into customers. It is determined by the minimum value of the indicated conversion fraction or the future customers stock divided conversion adjustment time, because the value can never be positive if the future customers stock is 0.
Market_Creation	IF Policy_2_Switch=0 THEN 0 ELSE 0+STEP(MIN(New_Market/New_Market_Adjustment_Time, Indicated_Market_Creation_Fraction), 78)		customer/month	This flow represents the rate at which customers can be moved from new market stock into potential customers stock, when Policy 2 switch is turned on. When Policy 2 switch is off then it's value is 0.

Operating_Costs	MIN(R&D_spending+Conversion_Spending+Sourcing_Spending+Customer_Retention_Spending+Market_Creation_Spending, Cash_Flow/Operating_Costs_Adjustment_Time)		Dollar Per Month	This is a flow that depletes the stock of cash flow. It is the rate at which dollars leave the cash flow. It is determined by the minimum value of addition of R&D spending, sourcing spending, conversion costs and customer retention costs; and the value of cash flow divided by operating costs adjustment time, thus controlling the flow from going negative, an unrealistic scenario.
Revenue	Total_Sales*Average_Price		dollar/month	Revenue flow represents the inflow of dollars into the stock of cash flow. It is the rate of accumulation of the cash flow stock. It is determined by the multiplication of total sales and average price.
Sourcing	MIN(Indicated_sourcing_fraction+Imitation, Potential_Customers/Sourcing_Adjustment_Time)		customer/Months	Sourcing rate represents the rate at which potential customers move to be future customers. The rate is determined by the sourcing effectiveness which is relative to the amount of potential customers and the amount of dollars allocated to sourcing.
Technology_Development	(1-Technical_Maturity/Max_technical_maturity)/(1+EXP(-Indicated_Technology_Development_Fraction))		TRL unit/month	This flow represents the rate of inflow into the technical maturity stock. Its value is determined by a variation of the sigmoid logistic growth function, with which grows asymptotically towards its maximum of 9. The numerator indicates how far the technology is from reaching its max level. The denominator determines the steepness of growth; a higher value representing a faster rate of technology development. According to Christensen, in its mature stages, a technology will asymptotically approach a limit, which requires that ever greater periods of time or inputs of engineering effort be be expended to achieve increments of technology development improvement (Christensen, 1992). Woamy representatives reiterate that the rate of technology development decreases as the technology matures (Elamir & Partanen, personal communication, December 12, 2024).
Venture_Capital_Funding	PULSE(Venture_Capital_Decision*Funding_Need, 24, 24)		dollar/month	This is a flow that accumulates dollars into the cash flow stock at a specified volume of dollars, at a first pulse time and at specified intervals throughout the simulation. The volume is determined by funding need and whether the venture capitalist's decision to invest. The first pulse is and interval are estimated value of 24 months based on data of average time between funding rounds for deep tech companies (Boston Consulting Group, 2023).

Adoption_Fraction	0.1		dmnl/customer	This variable represents the likelihood of adopting the new technology when hearing about it from a customer. The value is estimated at to represent that there is a lengthy process to adopt a new technology and several factors in play such as existing value chains, contracts with existing technology providers, etc.
Average_Months_Between_Funding_Stages	24		month	This variable represents the amount of months between funding stages. It is an estimated value of 24 months based on data of average time between funding rounds for deep tech companies (Boston Consulting Group, 2023).
Average_Price	20000		dollar/unit	This variable represents the per unit price of the technology the company sells to customers. The value is estimated based on value-based pricing methodology, in which customer's perceived value of the product and costs incurred to the company are used to set the price (Investopedia, n.d.; Rappold, 2020). Prices of deep tech products can vary greatly based on the technology and thus a value was chosen based on the assumption that the company is producing something perceived to be very valuable and at a price higher than the set customer retention costs.
"Business_Risk-aversion"	1-"Technical_Risk-aversion"		risk unit	This variable represents how much weight of the company market traction has on the overall risk profile. Literature suggests that investors assess business-related risks in their decision-making process (Murphy & Edwards, 200, pg. 14). The value is uncertain and thus assumed in the base run scenario to be 0.5. Investors may be more or less averse to business risks.
Contact_Rate	0.2		dmnl/month	Contact Rate represents the likelihood that a Potential Customer comes into contact with a Customer in a month and speaks about the new product. The value is set at 0.2 to reflect that there is a 20% chance of this happening. Customers and Potential Customers operating in the same industry have a good chance of coming in contact with eachother during industry events, meetings and general knowledge sharing where new technologies and general business activities are discussed. Furthermore, word about a very beneficial technology is relatively likely to spread throughout an industry, thus it's reasonable to assume a 20% Contact Rate. Value is uncertain so +-50% yields min of 0.1 and max of 0.3
Conversion_Adjustment_Time	1		month	This variable represents the amount of time it takes the company to adjust to when the future customers stock goes to a lower number than indicated conversion fraction.

Conversion_Effectiveness	0.00001		customer/dollar	This variable represents how many customers the company can convert per dollar of conversion spending. The value is estimated at 0.00001 meaning that for every 100,000 dollars the the company spends they can move one customer from the future customers stock to customers stock. The estimation is based on data that sales leaders at the early stage deep tech companies earn an average salary of $78,000 (XAnge, 2024). Factoring in other possible expenses such as sales software and tools the value of $100,000 is a fair estimation.
Conversion_Spending	Monthly_Budget*Indicated_Percentage_of_Budget_to_Conversion		dollar/month	This variable represents the amount of dollars per month the company will allocate towards conversion from their monthly budget. It is determined by multiplying the total monthly budget by the indicated percentage of budget to conversion.
Customer_Retention_Cost	10000		dollar/customer/month	This variable represents the amount of dollars per month it costs the company to retain its customers. The value is estimated based on the total cost of customer retention teams and initiatives, such as personalized customer experiences, customer support, product improvement, value-add services and data security and compliance (Userpilot, 2024; TD Shepherd, 2024). The company is adopting a value-based pricing methodology and thus the average price set by the company is also a factor in estimating this variable's value (Investopedia, n.d.; Rappold, 2020).
Customer_Retention_Spending	Customers*Customer_Retention_Cost		dollar/month	This variable represents the total amount of dollars per month the company spending on retaining its customers. It is determined by multiplying customers by the customer retention cost.
Effect_of_Risk_Profile_on_Venture_Capital_Decision	IF Relative_Risk_Profile >= 1 THEN 1 ELSE 0		dmnl	This variable represents the effect of the relative risk profile on the venture capital decision. The value is either 0 or 1, which is determined by whether the relative risk profile is above or below 1.
"Effect_of_Technical_Maturity_on_Percentage_Allocated_to_R&D_-_Desired_Scenario"	GRAPH(Relative_Technical_Maturity) Points: (0.3300, 1.0000), (0.3970, 0.9821), (0.4640, 0.9607), (0.5310, 0.9286), (0.5980, 0.8429), (0.6650, 0.6643), (0.7320, 0.5464), (0.7990, 0.4434), (0.8660, 0.3666), (0.9330, 0.3024), (1.0000, 0.2200)		dmnl	This converter represents how the company shifts their monthly budget allocation from R&D spending to business development spending, such as sourcing and conversion. The converter's limits and points on the graph are estimated based on stakeholder interview with Woamy. The limits and points of the between TRL 1-5, nearly 90% of the company's total monthly budget is focused on technology development. As the company begins investing more into sourcing future customers at TRL 6 or 0.66 relative technical maturity, this figure drops to about 60%. As the company gets past TRL 7 costs shift more towards commercial activities and percentage dedicated to R&D drops to 20%. Lower limit 0.22 at relative technical maturity

				level is normalized to the initial percentage of budget of 0.9 (Elamir & Partanen, personal communication, December 12, 2024). ANALYTICAL FUNCTION LOGISTICBOUND("Effect_on_R&D_<yfrom>", "Effect_on_R&D_<yto>", Relative_Technical_Maturity, "Effect_on_R&D_<xmiddle>","Effect_on_R&D_<xspeed>", "Effect_on_R&D_<xstart>", "Effect_on_R&D_<xfinish>") <xfinish>=1.62 <xstart>=0.37 <xspeed>=11.9 <xmiddle>=0.831 <yfrom>=0.978 <yto>=0.15
"Effect_of_Technical_Maturity_on_Percentage_Allocated_to_R&D_-_Undesired_Scenario"	GRAPH(Relative_Technical_Maturity) Points: (0.3300, 1.0000), (0.390909090909, 1.0000), (0.451818181818, 0.9999), (0.512727272727, 0.9999), (0.573636363636, 0.9997), (0.634545454545, 0.9992), (0.695454545455, 0.9981), (0.756363636364, 0.9957), (0.817272727273, 0.9926), (0.878181818182, 0.9817), (0.939090909091, 0.9520), (1.0000, 0.8800) 		dmnl	This converter represents how the company shifts their monthly budget allocation from R&D spending to business development spending, such as sourcing and conversion. The converter's limits and points on the graph are estimated based on stakeholder interview with Woamy. The limits and points of the between TRL 1-5, nearly 90% of the company's total monthly budget is focused on technology development. As the company begins investing more into sourcing future customers at TRL 6 or 0.66 relative technical maturity, this figure drops to about 60%. As the company gets past TRL 7 costs shift more towards commercial activities and percentage dedicated to R&D drops to 20%. Lower limit 0.22 at relative technical maturity level is normalized to the initial percentage of budget of 0.9 (Elamir & Partanen, personal communication, December 12, 2024). ANALYTICAL FUNCTION LOGISTICBOUND("Effect_on_R&D_<yfrom>", "Effect_on_R&D_<yto>", Relative_Technical_Maturity, "Effect_on_R&D_<xmiddle>","Effect_on_R&D_<xspeed>", "Effect_on_R&D_<xstart>", "Effect_on_R&D_<xfinish>") <xfinish>=1.62 <xstart>=0.437 <xspeed>=12.7 <xmiddle>=1.15

				<yfrom>=1 <yto>=0.0612
Effect_of_Technical_Maturity_on_Percentage_of_Budget_to_Sourcing	GRAPH(Relative_Technical_Maturity) Points: (0.3300, 1.0000), (0.441666666667, 0.9800), (0.553333333333, 0.9371), (0.6650, 0.8743), (0.776666666667, 0.7914), (0.888333333333, 0.6486), (1.0000, 0.4000) 		dmnl	This converter represents how the company shifts their monthly budget allocation away from sourcing and to other commercialization activities such as conversion as their technology matures. The converter's limits are estimated based on stakeholder interview stakeholder. Initially, nearly all of the company's commercialization budget is focused on sourcing leads indicated by the effect's value of 1 at 0.33 relative technical maturity. During TRL 3-6 stage, or relative technical maturity 0.33-0.66, Woamy's focus is on generating interest through pilots, which is represented as future customers in my model and thus the effect remains well above 0.5. However from TRL 7-8 the focus becomes about securing contracts with early adopters and thus the effect decreases increasingly. Once TRL 9 is reaches 80% of budget allocation is on business development, of which 40% is on sourcing, equal to 32%. (Elamir & Partanen, personal communication, December 12, 2024). ANALYTICAL FUNCTION EXPBOUND("Effect_on_Sourcing_<yfrom>", "Effect_on_Sourcing_<yto>", Relative_Technical_Maturity, "Effect_on_Sourcing_<exponent>", "Effect_on_Sourcing_<xstart>", "Effect_on_Sourcing_<xfinish>") <xfinish>=12.61 <xstart>=0.357 <exponent>=-3.09 <yfrom>=1.04 <yto>=0.269
Engineering_Effectiveness	0.000001		TRL unit/dollar	This variable represents the how much the company can develop the technology for every dollar of R&D spending. The value is estimated at 0.000001 meaning that for every $1,000,000 of R&D spending they can gain one TRL unit into the technical maturity stock. However the value is very uncertain ans thus a large uncertainty range. The development of deep tech is characterized as technologically complex and highly capital intensive due to budgets for purchasing equipment and lab space, regulatory approvals and each TRL level presenting new technology development challenges (Hatch, 2023).

Expected_Cash_Flow	SMTH1(Cash_Flow, Time_to_Adjust_Expectations)		dollar	This variable represents the company's expectation about the cash flow which happens at a delay specified by the time to adjust expectations. A company makes investment decisions into B&D and R&D based on what they expect the cash flow to be.
Funding_Need	IF Customers>Threshold_Customers THEN 0 ELSE Operating_Costs*Average_Months_Between_Funding_Stages		dollar	This variable represents the volume of the PULSE function in the venture capital funding flow. It is determined by multiplying operating costs by the average months between funding stages. Based on working experience as a consultant for deep tech companies I know that covering a company's operating expenses until the next fundraising goes into the calculation of funding need, however there are many other factors, such as EBITDA, valuation and capitalization tables, to consider when determining the amount of funding a company should raise from private investors, and thus the value should be scrutinized. The endogenous nature of this variable based only on operating expenses is not ideal, because when operating costs are low due to a low cash flow, the amount of funding need will also be low, and thus not represent the true funding need. Literature review on the valley of death suggests that a funding need does exist for companies in this phase of development (Murphy & Edwards, 2003, page 1).
Imitation	Potential_Customers*Customers*Contact_Rate*Adoption_Fraction		customer/month	This variable represents the the amount of potential customers that go into the sourcing flow from being in contact with customers. It's value is determined by multiplying potential customers, customers, contact rate and adoption fraction. Literature on adoption and diffusion of new technologies cites imitation as having a strong effect for the early majority, late majority and laggards to adopt (
Indicated_Conversion_Fraction	IF Relative_Technical_Maturity_for_Customers<1 THEN 0 ELSE Conversion_Spending*Conversion_Effectiveness		customer/month	This variable represents the amount of customers per month the company can convert from the future customers to customers stock. If relative technical maturity for customers is less than 1 then the value of the variable is 0, otherwise it is determined by multiplying conversion spending by conversion effectiveness.
Indicated_Market_Creation_Fraction	Market_Creation_Spending*Market_Creation_Effectiveness		customer/month	This variable represents the amount of customers per month the company can source from new market to potential customers stock. It's value is determined by multiplying market creation effectiveness by market creation spending.
Indicated_Percentage_of_Budget_on_Market_Creation	Policy_2_Volume		dmnl	This variable represents the indicated percentage of the company's total monthly budget that they will allocate towards sourcing spending when Policy 2 switch on. It is determined by multiplying the initial percentage of budget to sourcing by the effect of technical maturity on percentage of budget to sourcing. When Policy 2 switch is off the value is 0.

Indicated_Percentage_of_Budget_to_Conversion	IF Policy_2_Switch=0 THEN (1-Indicated_Percentage_of_Budget_to_Sourcing-Indicated_Percentage_of_Budget_to_R&D) ELSE (1-Indicated_Percentage_of_Budget_to_Sourcing-Indicated_Percentage_of_Budget_to_R&D)+STEP(Policy_2_Volume*-1, 78)		dmnl	This variable represents the indicated percentage of the company's total monthly budget that they will allocate towards conversion spending. It is determined by subtracting the indicated percentage of budget to R&D and sourcing from a value of 1. The value of 1 represents 100% of the monthly budget and is used in order that the total value of the indicated percentages to R&D, sourcing and conversion never exceeds the total monthly budget.
Indicated_Percentage_of_Budget_to_R&D	IF Scenario_Switch=0 THEN (Initial_Percentage_of_Budget_to_R&D*"Effect_of_Technical_Maturity_on_Percentage_Allocated_to_R&D_-_Desired_Scenario") ELSE (Initial_Percentage_of_Budget_to_R&D*"Effect_of_Technical_Maturity_on_Percentage_Allocated_to_R&D_-_Undesired_Scenario")		dmnl	This variable represents the indicated percentage of the company's total monthly budget that they will allocate towards R&D spending. It is determined by multiplying the initial percentage of budget to sourcing by the effect of technical maturity on percentage of R&D to sourcing.
Indicated_Percentage_of_Budget_to_Sourcing	Initial_Percentage_of_Budget_to_Sourcing*Effect_of_Technical_Maturity_on_Percentage_of_Budget_to_Sourcing		dmnl	This variable represents the indicated percentage of the company's total monthly budget that they will allocate towards sourcing spending. It is determined by multiplying the initial percentage of budget to sourcing by the effect of technical maturity on percentage of budget to sourcing.
Indicated_sourcing_fraction	Sourcing_Spending*Sourcing_Effectiveness		customer/month	This variable represents the amount of customers per month the company can source from potential customers to future customers stock. It's value is determined by multiplying sourcing effectiveness by sourcing spending.
Indicated_Technology_Development_Fraction	Engineering_Effectiveness*R&D_spending		TRL unit/month	This variable adjusts the rate at which the technology development grows towards the max technical maturity level. It determines the steepness of growth with a higher value representing a faster rate of technology development. It is determined by multiplying engineering effectiveness and R&D spending.
Initial_Funding	3000000		dollar	This variable represents the initial amount of dollars in the cash flow stock. The value is estimated based on data from public funding instruments in US and Europe (U.S. Small Business Administration, n.d.; European Commission, n.d.-a).
Initial_Market_Size	1000		customer	This variable represents the total initial market size of customers that the company is looking to sell their technology to. It's value is estimated based on that deep tech companies may initially look to niche markets with less customers and a higher price point. Stakeholder interview with Woamy supports this (Woamy, personal communication, 2024).

Initial_Percentage_of_Budget_to_R&D	0.85		dmnl	This variable represent the initial percentage of the company's total monthly budget that they will allocate towards technology development. The value is estimated based on stakeholder interview with Woamy, who reported allocating nearly 90% of their total budget to technology development in early stages between TRL 1-5 (Elamir & Partanen, personal communication, December 12, 2024).
Initial_Percentage_of_Budget_to_Sourcing	0.15		dmnl	This variable represent the initial percentage of the company's total monthly budget that they will allocate towards conversion spending. The value is estimated as 15% because the initial percentage of budget to R&D is a value of 85%.
Initial_Percentage_of_Expected_Cash_Flow_Dedicated_to_Monthly_Budget	0.1		1/month	Tis variable represents the initial percentage of expected cash flow dedicated to monthly budget. The value is estimated at 0.1 to reflect that the firm is spending 10% of the cash flow in each month.
Market_Creation_Effectiveness	0.00005		customer/dollar	The parameter represents the effectiveness of market creation per dollar spent when Policy 2 switch is on. The number is chosen as 0.0005 to represent that the company can move 1 customer per $20,000 spent from new market to potential customers.
Market_Creation_Spending	IF Policy_2_Switch=0 THEN 0 ELSE 0+STEP(Monthly_Budget*Indicated_Percentage_of_Budget_on_Market_Creation, 78)		dollar/month	When Policy 2 switch is on this variable represents the amount of dollars per month the company will allocate towards market creation from their monthly budget. It is determined by multiplying the total monthly budget by the indicated percentage of budget to sourcing. If Policy 2 switch is off the value is 0.
Max_technical_maturity	9		TRL unit	This variable represents the maximum technical maturity level of 9, based on the TRL scale (TRL Assessment Tool Guide, 2022).
Monthly_Budget	Expected_Cash_Flow*Percentage_of_Expected_Cash_Flow_Dedicated_to_Monthly_Budget		dollar/month	This variable represents the amount of dollars the company will invest in a month. It is determined by multiplying the expected cash flow by the percentage of expected cash flow dedicated to monthly budget.
New_Market_Adjustment_Time	1		month	This variable represents the amount of time it takes the company to adjust to when the new market stock goes to a lower number than indicated market creation fraction.
New_Market_Size	2000		customer	This variable represents the total new market size of customers that the company could sell their technology to. It's value is estimated based on that deep tech companies may look towards larger markets as the company develops and proves their technology in initial markets.
Operating_Costs_Adjustment_Time	1		month	The variable represents the time it takes to adjust if cash flow is at zero and cannot be depleted. It is used to control the operating cash flow stock from going negative.

Overall_Risk_Profile	IF Cash_Flow<Threshold_Cash_Flow THEN 0 ELSE (Relative_Technical_Maturity *"Technical_Risk-aversion")+("Business_Risk-aversion"*Relative_Market_Traction)		risk unit	This variable represents the risk profile of the company. The value is determined by the sum of technical risk-aversion multiplied by relative technical maturity and business-risk aversion multiplied by relative market traction. Literature suggests that companies are assessed based on their risk level (Murphy & Edwards, 200, pg. 4-5). If cash flow is below the threshold cash flow then the value of this variable yields 0. Based on my experience as a consultant for deep tech companies, companies should have sufficient runway, or months until money runs out to warrant an investment, usually of about 6 months. If the company has a cash flow lower than the threshold than it is a signal that the company is mismanaging resources and may run out of cash flow (BBVA Spark, 2023).
Percentage_of_Expected_Cash_Flow_Dedicated_to_Monthly_Budget	IF Policy_1_Switch=0 THEN Initial_Percentage_of_Expected_Cash_Flow_Dedicated_to_Monthly_Budget ELSE Initial_Percentage_of_Expected_Cash_Flow_Dedicated_to_Monthly_Budget+Policy_1_Step		1/month	This variable represents the percentage of the expected cash flow the company will dedicate to the monthly budget. The value is calibrated so that the company can invest sufficiently into improving technical maturity and to gain future customers and customers. If Policy 1 switch is off, its value is equal to the initial percentage of expected cash flow dedicated to monthly. If the Policy 1 switch is off then it's value is determined by adding the value of the STEP Function
Policy_1_Step	STEP(Policy_1_Volume, 62)		1/month	
Policy_1_Switch	0		dmnl	This is the Policy 1 switch. When the value is 0, Policy is off is off and when the value is 1, the Policy 1 is activated.
Policy_1_Volume	0.05		1/month	This variable represents the percentage increase of the Policy 1 switch when it is activated.
Policy_2_Switch	0		dmnl	This is the Policy 2 switch. When the value is 0 Policy 2 is off and when the value is 1, the Policy 1 is activated.
Policy_2_Volume	0.2		dmnl	This variable represents the volume of Policy 2. It is set as 0.2 meaning if Policy 2 scenario is activated 20% of the monthly budget is dedicated to market creation. The 20% is shifted from percentage of budget to conversion in order to ensure 100% of the total monthly budget is not exceeded.
R&D_spending	Monthly_Budget*Indicated_Percentage_of_Budget_to_R&D		dollar/month	This variable represents the amount of dollars per month the company will allocate towards technology development from their monthly budget. It is determined by multiplying the total monthly budget by the indicated percentage of budget to R&D.

Relative_Market_Traction	IF Customers>1 THEN 1 ELSE MIN(Future_Customers/Threshold_Market_Traction, 1)		dmnl	This variable represents the ratio of future customers stock relative to a threshold value of future customers and thus the MIN function limits the value from going above 1. It factors into the overall risk profile of the company, representing the business risks of the company. However, if the company has one customer then the value of the variable is 1. This is because for the purposes of this model, it represents whether the technology that the company is developing is wanted by customers. Based on my experience as consultant future customers and customers are indicators for market traction for a deep tech company.
Relative_Risk_Profile	Overall_Risk_Profile/Threshold_Risk_Profile		dmnl	This variable represents the company's overall risk profile relative to the threshold risk profile. The value is determined by dividing the overall risk profile by the threshold risk profile.
Relative_Technical_Maturity	Technical_Maturity/Max_technical_maturity		dmnl	This variable represents the company's technical maturity relative to the threshold technical maturity. The value is determined by dividing technical maturity stock by the threshold technical maturity. It factors into the overall risk profile and eventually the venture capital funding decision, as well as the indicated conversion fraction. According to literature and my own work experience, technical maturity factors into the decision-making process of investors (Murphy & Edwards, 200, pg. 4). Since threshold risk represents a full technology readiness for the market and customers, this variable functions to indicate how close to market readiness the technology is.
Relative_Technical_Maturity_for_Customers	Technical_Maturity/Threshold_Technical_Maturity_for_Customers		dmnl	This variable represents the maturity level of the technology relative to the threshold technical maturity for customers. The value is determined by dividing the technical maturity by the threshold technical maturity for customers.
Scenario_Switch	0		dmnl	This is a switch which can be used to switch between the two base run simulations; the desired scenario and the undesired scenario. A value of 0 for the switch corresponds to the desired scenario and a value of 1 corresponds to the undesired scenario.
Sourcing_Adjustment_Time	1		month	This variable represents the amount of time it takes the company to adjust to when the potential customers stock goes to a lower number than indicated conversion fraction.
Sourcing_Effectiveness	0.00005		customer/dollar	The parameter represents the effectiveness of sourcing per dollar spent. The number is chosen as 0.0005 to represent that the company can move 1 customer per $20,000 spent from Potential Customers to Future Customers.
Sourcing_Spending	Monthly_Budget*Indicated_Percentage_of_Budget_to_Sourcing		dollar/month	This variable represents the amount of dollars per month the company will allocate towards sourcing from their monthly budget. It is determined by multiplying the total monthly

				budget by the indicated percentage of budget to sourcing.
"Technical_Risk-aversion"	0.5		risk unit	This variable represents how much weight technical maturity of the company has on the overall risk profile. Literature suggests that investors assess technical risk in their decision-making process (Murphy & Edwards, 200, pg. 4). The value is uncertain and thus assumed in the base run scenario to be 0.5. Investors may be more or less averse to technical risk.
Threshold_Cash_Flow	30000		dollar	The variable represents the threshold amount of cash flow that the company should have to have a non-zero risk profile and potential of an overall risk profile above the investor's threshold risk profile. The value is a minimal assumption based on data of average salaries for early-stage deep tech ranging from $60000-$65000 (XAnge, 2024). When factoring in equipment, office, lab and other expenses, $50000 would hardly keep a company running, let alone send a signal of good financial management to an investor.
Threshold_Customers	100		customer	This variable represents an amount of customers that indicate the company can generate revenues without external investment, but on sales revenues. If the company's customers stock is above this threshold, then they determine that they do not have a need to raise external funding at the timing of the PULSE. The value is estimated at one tenth of the market size.
Threshold_Market_Traction	10		customer	This variable represents a threshold amount of future customers stock. According to literature review, investors assess companies with a technological edge but who manufacture market-focused products based on those technologies and strategies to develop markets and distribution channels for those products (Murphy & Edwards, 200, pg. 15). Investors often want to see initial sales or market traction before investing (Murphy & Edwards, 200, pg. 21). Market traction is a signal to the investor that this company is market-focused. The value is an assumption based on that if 1% of the total market would be future customers then the company has been sufficiently market-focused in their early development phase.
Threshold_Risk_Profile	0.85		risk unit	This variable represents the threshold risk profile that the company must be above in order to get a positive venture capital decision. Literature suggests that investors assess risk of startups when making a decision about whether to invest into a deep tech startup or not and that they have a personally or institutionally determined acceptable risk level (Murphy & Edwards, 200, page 4). The value is estimated based on that investors scrutinize firms intensively before providing capital and go to great lengths to lower the risk of their investments and thus a high bar

				is chosen (Murphy & Edwards, 2003, pg. 5; Gompers & Lerner, 2001, pg. 155).
Threshold_Technical_Maturity_for_Customers	8		TRL unit	This variable represents the technical maturity level at which customers can begin implementing the technology that the company is developing. According to Horizon Europe, once a technology reaches TRL 8 according to the technology readiness level scale they can be commercial (TRL Assessment Tool Guide, 2022).
Time_to_Adjust_Expectations	3		month	This variable represents the time for the company to adjust their expectations about cash flow. It is an estimated value based on that the company plans their budget allocation every 3 months.
Total_Sales	Customers*Units_Per_Customer		unit/month	This variable represents the total amount of units per month a customer buys. It is determined by multiplying the amount of customers by the amount of units per customer.
Units_Per_Customer	1		unit/customer/month	This variable represents the amount of units per month the customer is purchasing. The value is estimated based on the assumption that the company is selling to other businesses in R&D intensive industries to enhance efficiency and productivity and thus a licensing or service contract would be typical (Murray, Porter, & Raff, 2024).
Venture_Capital_Decision	Effect_of_Risk_Profile_on_Venture_Capital_Decision		dmnl	This variable represents the decision of the venture capital investor to investor or not invest in the company at the time of the first pulse and intervals of the PULSE function. The value is equal to the effect of risk profile on venture capital decision variable. There are many other factors that go into the venture capital decision, such as management team, technology competitiveness and defensibility, liquidity opportunities and company structure, to invest which are not part of the model structure. (Murphy & Edwards, 200, pg. 14)

Appendix C: Sensitivity Analysis

Section 1. Local Sensitivity Analysis: Undesired Scenario

For this model, all parameters were tested that were uncertain values using Stella's sensitivity analysis tool using Sobol Sequence of 50 runs with uniform distribution. Table 2 showcases all the parameters that were tested and the sensitivity of those parameters.

Table 2. Local sensitivity analysis overview of undesired scenario.

Model Sector	Parameter	Range	Sensitivity
Technology Development Sector	Engineering Effectiveness	0.000001-0.0001	Numerical
	Initial Percentage of Budget to R&D	0.75-0.9	Numerical
	Sensitivity Effect of Technical Maturity on Percentage Allocated to R&D	(+-0.25)	Not Sensitive
Business Development Sector	Adoption Fraction	0.05-0.15	Not Sensitive
	Contact Rate	0.1-0.3	Not Sensitive
	Conversion Adjustment Time	0.5-1.5	Not Sensitive
	Conversion Effectiveness	0.000005-0.000015	Numerical
	Initial Market Size	500-1500	Numerical
	Initial Percentage of Budget to Sourcing	0.05-0.1	Numerical
	Sourcing Adjustment Time	0.5-1.5	Not Sensitive
	Sourcing Effectiveness	0.000025-0.000075	Not Sensitive
	Sensitivity Effect of Technical Maturity on Percentage Allocated to Sourcing	(+-.5)	Numerical
Venture Capital Sector	Average Months Between Funding Stages	20-28	Not Sensitive
	Threshold Cash Flow	50,000-75,000	Not Sensitive
	Threshold Customers	50-150	Not Sensitive
	Technical Risk-Aversion	0.25-0.75	Not Sensitive
	Threshold Market Traction	50-150	Not Sensitive
	Threshold Risk Profile	0.75-0.95	Not Sensitive
Sales Revenue Sector	Average Price	10,000-30,000	Numerical
	Units per Customer	1.0-5.0	Numerical
Budgeting Sector	Initial Funding	2,000,000-4,000,000	Numerical
	Percentage of Expected Cash Flow Dedicated to Monthly Budget	0.05-0.15	Behavioral
	Time to Adjust Expectations	1.0-6.0	Numerical
Operating Costs Sector	Customer Retention Cost	5,000-15,000	Numerical
	Operating Costs Adjustment Time	1.0-3.0	Not Sensitive

The parameters to which KPIs were behaviorally sensitive are expanded on further below.

Parameter: Percentage of Expected Cash Flow Dedicated to Monthly Budget

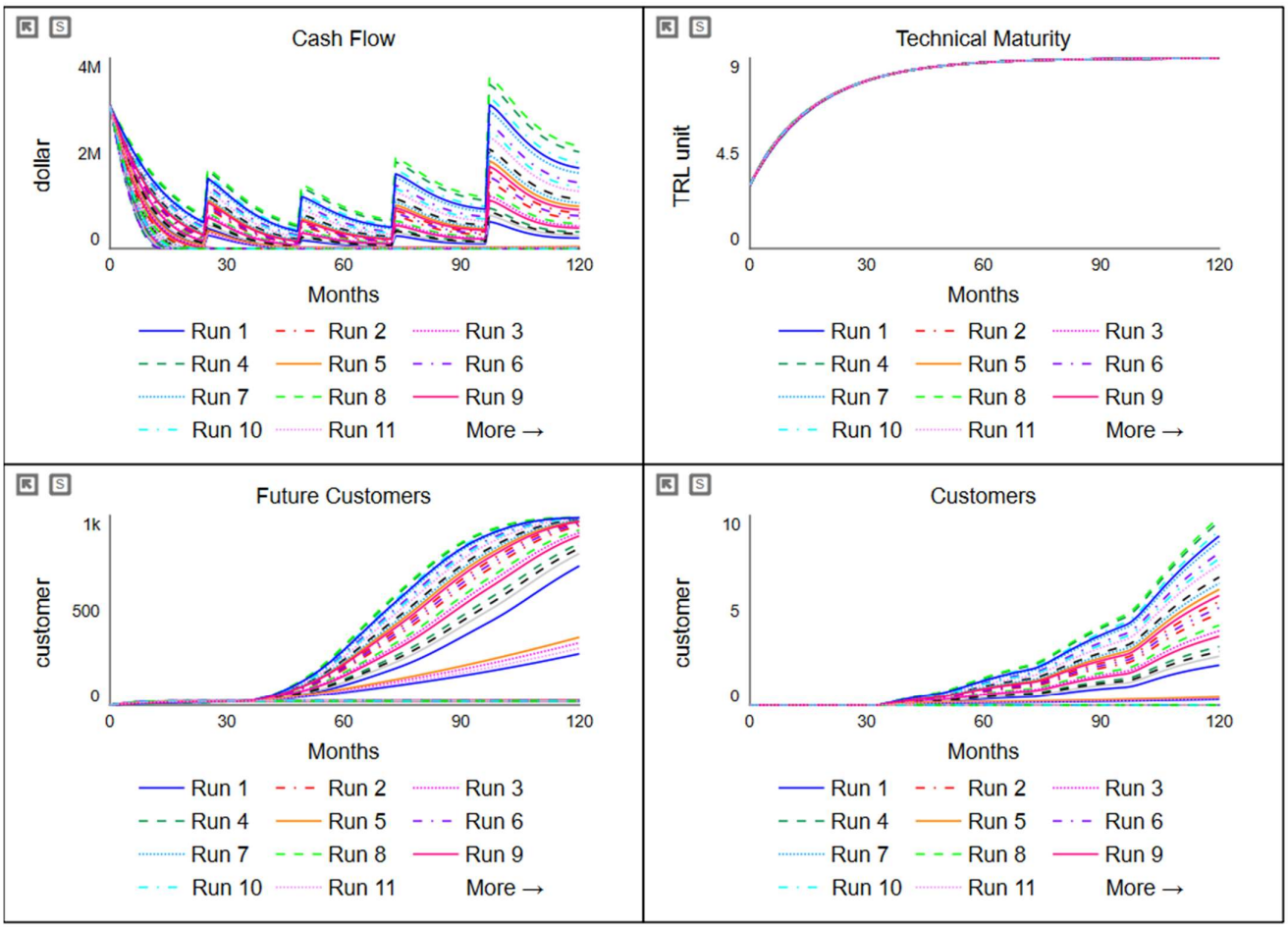


Figure 2. Comparative line graphs for the effect of randomized values of percentage of expected cash flow dedicated to monthly budget, an uncertain variable, on KPIs in the undesired scenario simulation.

Figure 2 shows that cash flow is sensitive to this parameter. This sensitivity analysis reveals a flaw in the model structure of the undesired scenario simulation. The PULSE function firing increases the strength of the balancing costs loops and the reinforcing sales loop does not have time to gain strength and generate enough customers for the firm to no longer have a funding need under the parameters in the simulation before the PULSE fires again at the next interval, setting off the same chain of structural dynamics.

Section 2. Global Sensitivity Analysis: Undesired Scenario

A global sensitivity analysis on Sobol sequence across 1000 runs of random variations was performed to determine the confidence in the model creating different modes of behavior with random variations of uncertain parameters. Confidence intervals graph for cash flow in figure 3 suggests that we can be confident about the behavior of Cash Flow between months 0 to 60. However, there is significant variation in model output from month 60 to 120 during the simulation time horizon.

For a stock such as cash flow, which measures the financial success of a firm, it is not surprising that there is such widespread model outputs as shown in figure 3. This is a model with a lot of uncertainty in model output, at least in the later stages of the firm. This finding is aligned with the real world scenario – the longer the time horizon of a firm the greater the uncertainty of cash flow. As the global sensitivity analysis points to, the cash flow can be over $1.5 billion or it can be zero. The global sensitivity analysis gives some confidence that model is structurally valid because it can produce multiple plausible reference modes and the trajectory of the company is slowly growing over a relatively long time horizon.

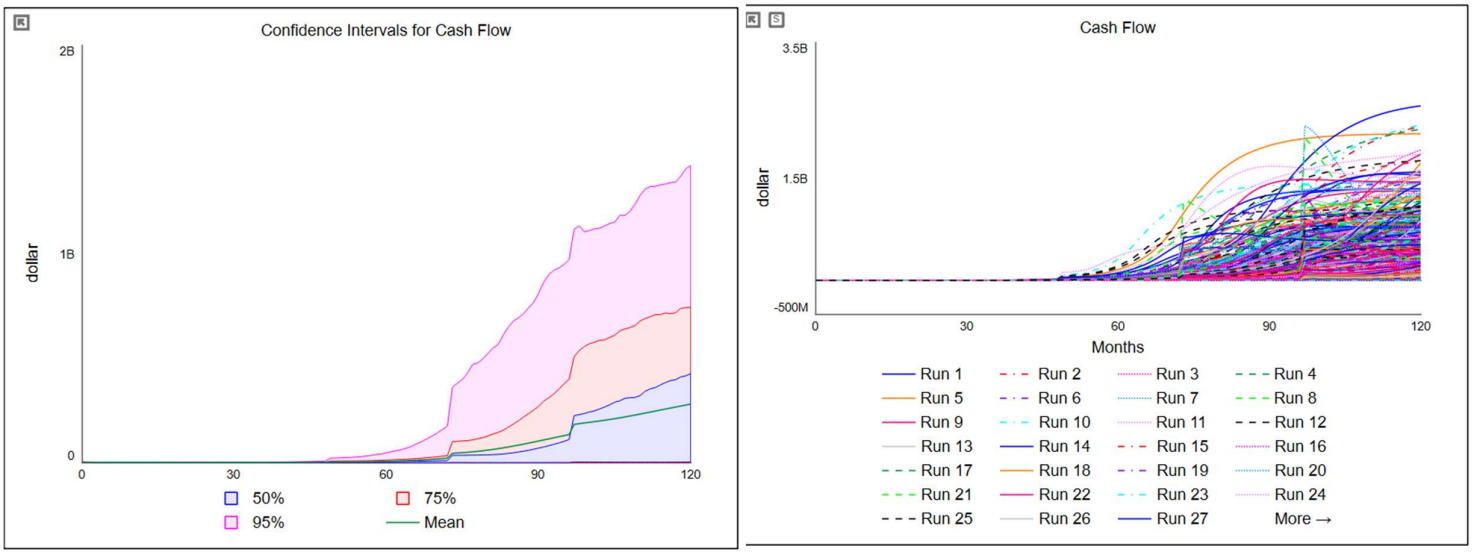


Figure 3. Confidence intervals output of Global Sensitivity analysis for the Cash Flow KPI in the undesired behavior simulation (left). And Comparative line graphs output of Global Sensitivity analysis for the Cash Flow KPI in the undesired behavior simulation (right).

Section 3. Local Sensitivity Analysis: Desired Scenario

For this model, all parameters were tested that were uncertain values using Stella's sensitivity analysis tool using Sobol Sequence of 50 runs with uniform distribution. Table 3 showcases all the parameters that were tested and the sensitivity of those parameters.

Table 3. Local sensitivity analysis overview of desired scenario.

Model Sector	Parameter	Range	Sensitivity
Technology Development Sector	Engineering Effectiveness	0.0000001-0.000002	Numerical
	Initial Percentage of Budget to R&D	0.75-0.9	Numerical
	Sensitivity Effect of Technical Maturity on Percentage Allocated to R&D	(+-0.25)	Numerical
Business Development Sector	Adoption Fraction	0.05-0.15	Not Sensitive
	Contact Rate	0.1-0.3	Not Sensitive
	Conversion Adjustment Time	0.5-1.5	Not Sensitive
	Conversion Effectiveness	0.000005-0.000015	Numerical
	Initial Market Size	500-1500	Numerical
	Initial Percentage of Budget to Sourcing	0.07-0.21	Numerical
	Sourcing Adjustment Time	0.5-1.5	Not Sensitive
	Sourcing Effectiveness	0.000025-0.000075	Not Sensitive
	Sensitivity Effect of Technical Maturity on Percentage Allocated to Sourcing	(+-.5)	Numerical
Venture Capital Sector	Average Months Between Funding Stages	20-28	Numerical
	Threshold Cash Flow	50,000-75,000	Numerical
	Threshold Customers	50-150	Not Sensitive
	Technical Risk-Aversion	0.25-0.75	Not Sensitive
	Threshold Market Traction	50-150	Numerical
	Threshold Risk Profile	0.75-0.95	Numerical
Sales Revenue Sector	Average Price	10,000-30,000	Behavioral
	Units per Customer	1.0-5.0	Numerical
Budgeting Sector	Initial Funding	2,000,000-4,000,000	Numerical
	Percentage of Expected Cash Flow Dedicated to Monthly Budget	0.05-0.15	Behavioral
	Time to Adjust Expectations	1.0-6.0	Numerical
Operating Costs Sector	Customer Retention Cost	5,000-15,000	Numerical
	Operating Costs Adjustment Time	1.0-3.0	Not Sensitive

The parameters to which KPIs were behaviorally sensitive are expanded on further below.

Parameter: Average Price

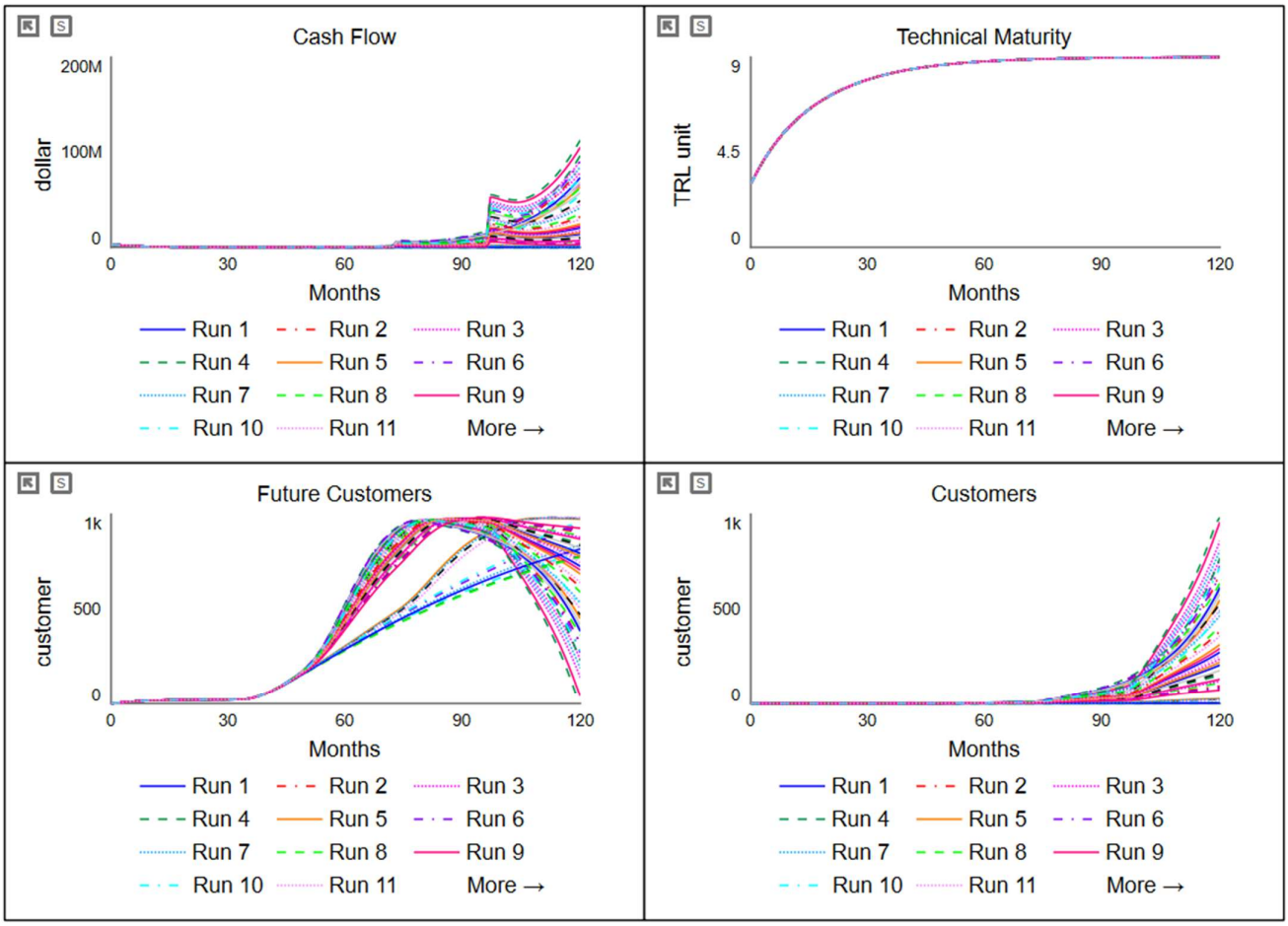


Figure 4. Comparative line graphs for the effect of randomized values of average price, an uncertain variable, on KPIs in the desired scenario simulation.

Figure 4 shows that the model is sensitive to this parameter in the desired behavior simulation. Cash flow shows differing behaviors at the end of the time horizon. In some runs the balancing cost loops (B6 to B9) continue to dominate the system and in others the reinforcing sales loop (R2) dominates. Most interesting about the KPIs is the behavior of future customers in some of the runs. If average price is low enough then the reinforcing sales loop (R2) does not offset the balancing cost loops (B6 to B9) due to a decreased amount of conversion in the undesired scenario.

Parameter: Percentage of Expected Cash Flow Dedicated to Monthly Budget

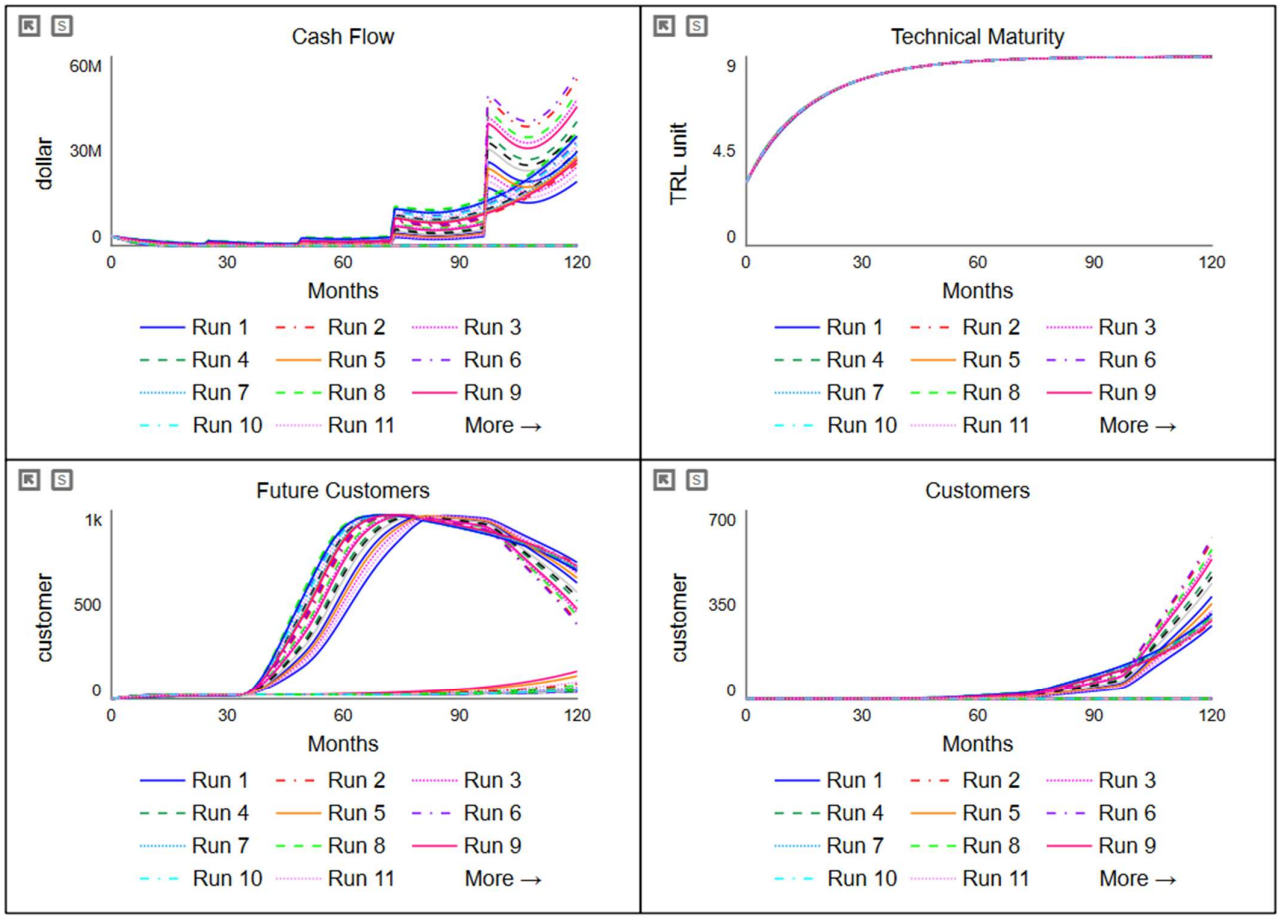


Figure 5. Comparative line graphs for the effect of randomized values of percentage of expected cash flow dedicated to monthly budget, an uncertain variable, on KPIs in the desired scenario simulation.

Figure 5 shows that the model is sensitive to this parameter in the desired scenario simulation. Once again it is the behavior of future customers which is slightly surprising. The slow growth of future customers with low levels of monthly budget limits the amount of customers stock because technical maturity is not reaching the customers threshold and thus the powerful imitation loop (R7) is not activated until the end of the time horizon. This sensitivity analysis reveals that the output of the desired scenario simulation is uncertain – it can produce the undesired scenario behavior mode as well.

Imitation is responsible for most of the sourcing of future customers, and it relies on the conversion of customers. When the budget does not shift sufficiently to sourcing and conversion, the reinforcing imitation loop does not have a chance to gain as much strength, underscoring the problem causing the valley of death.

Section 4. Global Sensitivity Analysis – Desired Scenario

A global sensitivity analysis on Sobol sequence across 1000 runs of random variations was performed to determine the confidence in the model creating different modes of behavior with random variations of uncertain parameters.

Figure 6 shows that the cash flow stock has an even wide range of potential outputs for the desired scenario as compared to the undesired scenario, which is to be expected. This is a model with a lot of uncertainty in model output, at least in the later stages of the firm. The global sensitivity analysis gives some confidence that model is structurally valid because it can produce multiple plausible reference modes and the trajectory of the company is slowly growing over a relatively long time horizon.

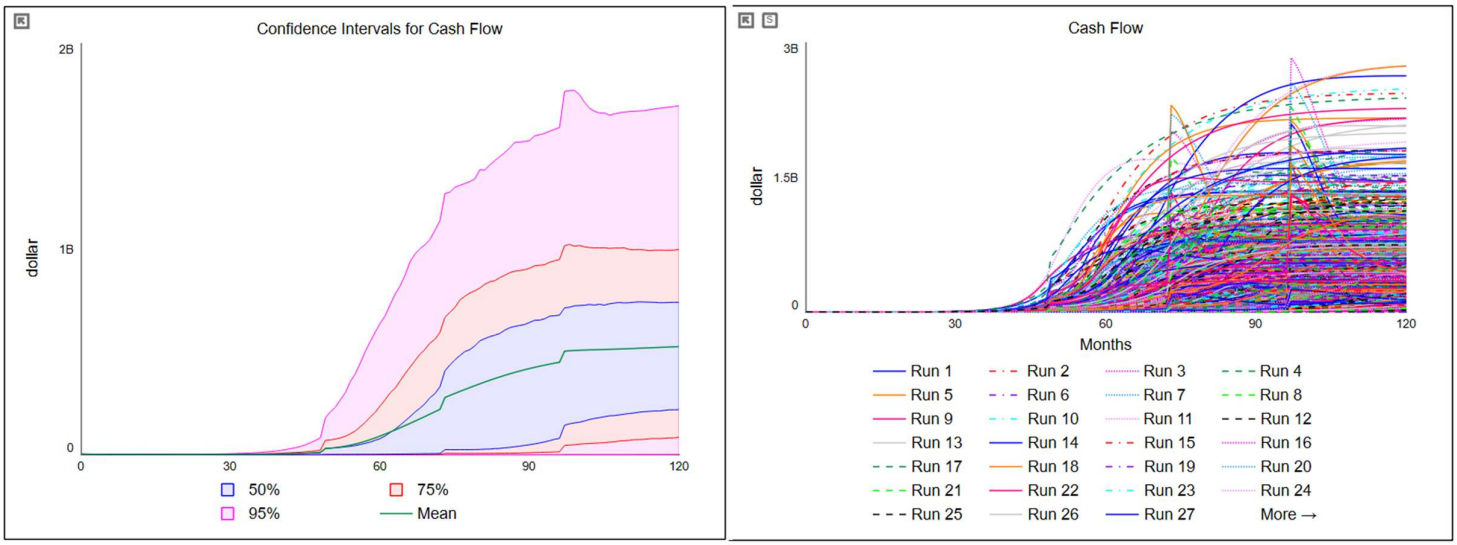


Figure 6. Confidence intervals output of Global Sensitivity analysis for the Cash Flow KPI in the desired behavior simulation (left). And Comparative line graphs output of Global Sensitivity analysis for the Cash Flow KPI in the desired behavior simulation (right).

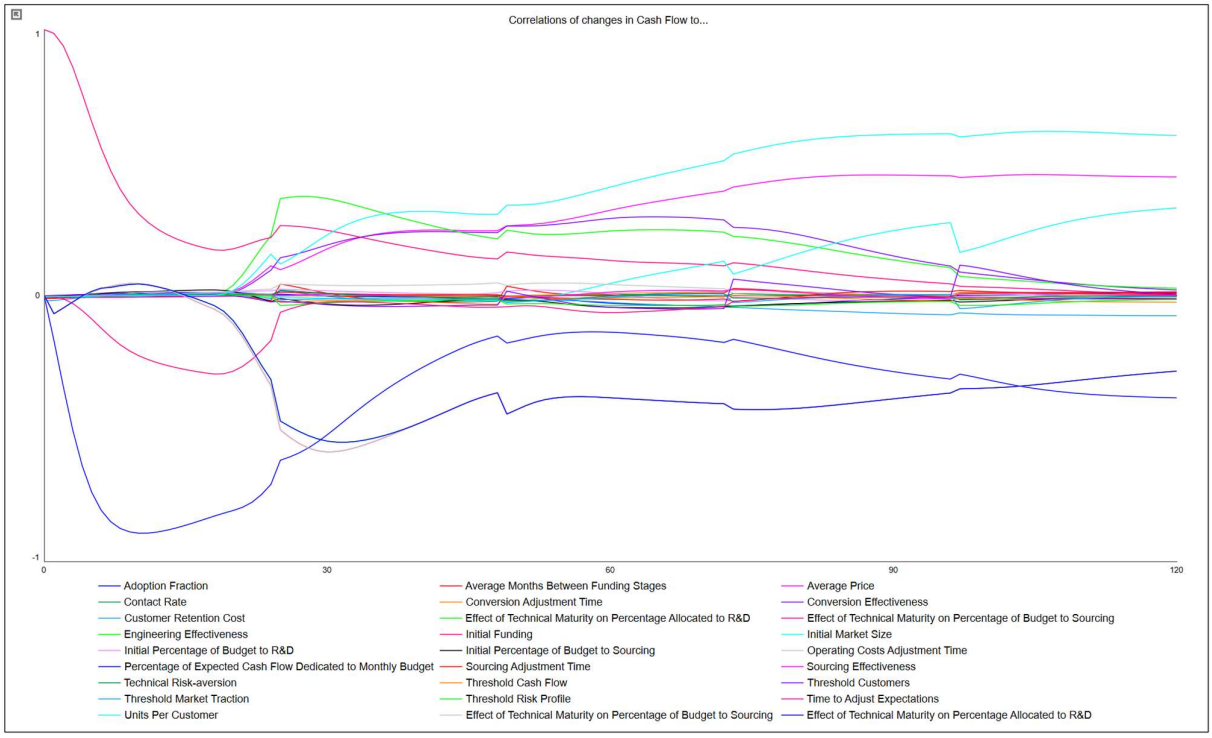


Figure 7. Correlation across runs output of Global Sensitivity analysis for the Cash Flow KPI for all model input variables in the desired behavior simulation

Figure 7 shows that initially cash flow is most positively affected by changes in initial funding and negatively affected by the percentage of cash flow dedicated to monthly budget. However, as the simulation progresses more interesting insights can be inferred with potential policy implications, for example at month 24, changes in engineering effectiveness have a relatively large impact on the cash flow output. It can be inferred from the increase in the correlation that with stronger engineering effectiveness the firm's technical maturity could be closer to customer threshold faster and thus activate the reinforcing sales loop and the decrease after results from the simultaneously activated balancing customer retention cost loop. However, it may not be feasible to increase engineering effectiveness.

After month 30, units per customer, average price and initial market are high leverage points due to a high correlation with output of cash flow. Expanding to new markets is a common tactic of deep tech startups once they have broken into one market and thus a potential policy could be implemented.

Furthermore, the percentage of expected cash flow dedicated to monthly budget and effect of technical maturity on percentage allocated to R&D have the highest negative correlation and thus limiting the growth in cash flow. Out of these two variables the percentage of expected cash flow dedicated to the monthly budget yields a more feasible policy implication. Once a firm gets to a healthy cash flow and has a large stock of future customers ready to be converted into paying customers, especially if they want to expand to new markets and increase their customer base, they may want to invest more into this growth expansion; thus increasing the monthly budget is a potential policy measure to maximize cash flow growth.

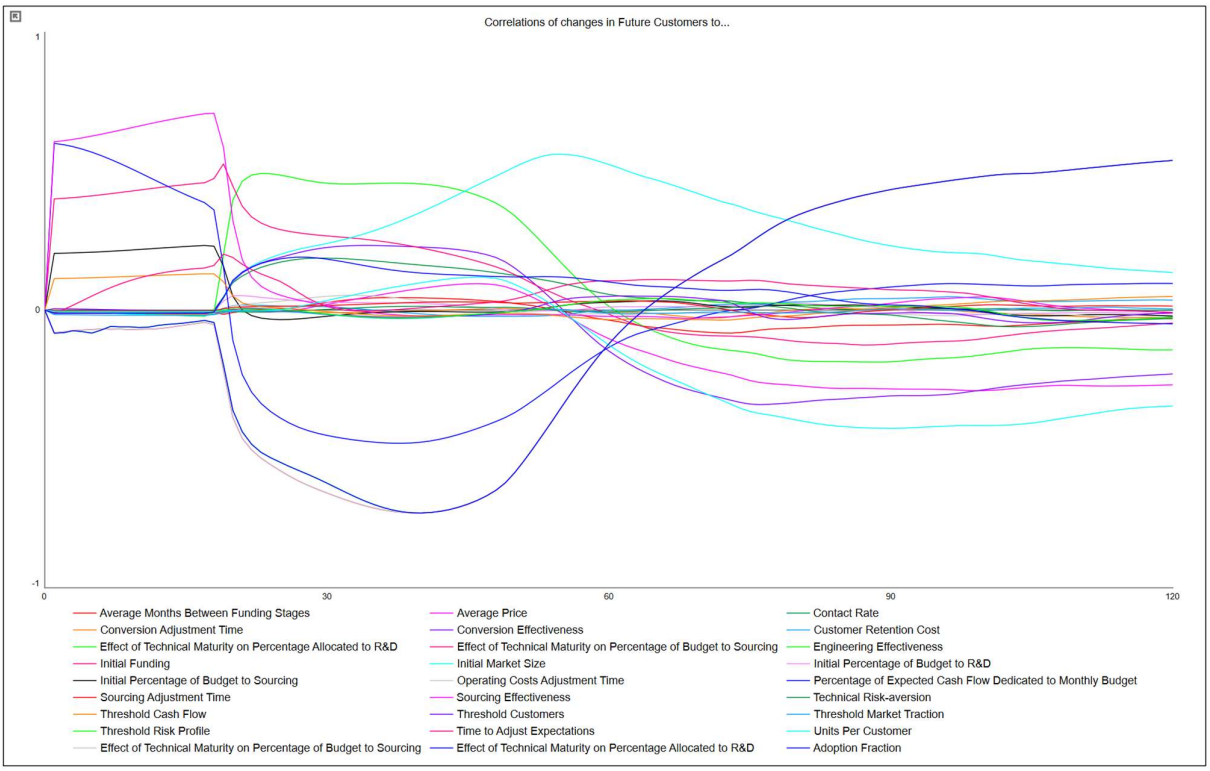


Figure 8. Correlation across runs output of Global Sensitivity analysis for the Future Customers KPI for all model input variables in the desired behavior simulation.

Figure 8 shows that future customers has the highest positive correlation with adoption fraction which emphasizes the importance of the reinforcing imitation loop (R7). This underscores the importance of conversion on the future customers stock.

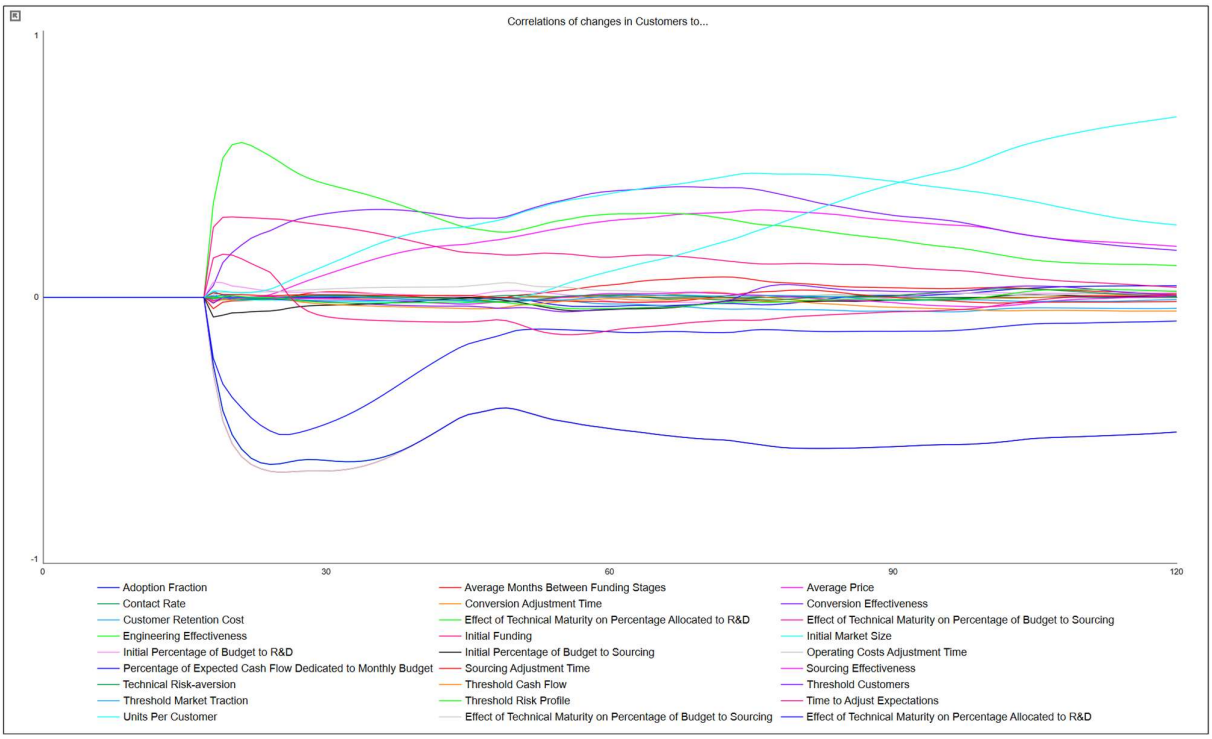


Figure 9. Correlation across runs output of Global Sensitivity analysis for the Customers KPI for all model input variables in the desired behavior simulation.

Figure 9 shows that customer stock is eventually most positively correlated with initial market size, which adds more validity to the potential policy implication of expanding to new markets to increase the market size. Effect of technical maturity on percentage allocated to R&D has the highest negative correlation thus limiting the growth in customers. However, there is not a feasible policy implication on that variable since the company must continue to invest in R&D at the minimal level of 20% even once the tech is mature. Woamy representatives highlighted that after TRL 9 the company still dedicates 20% of their budget to R&D.

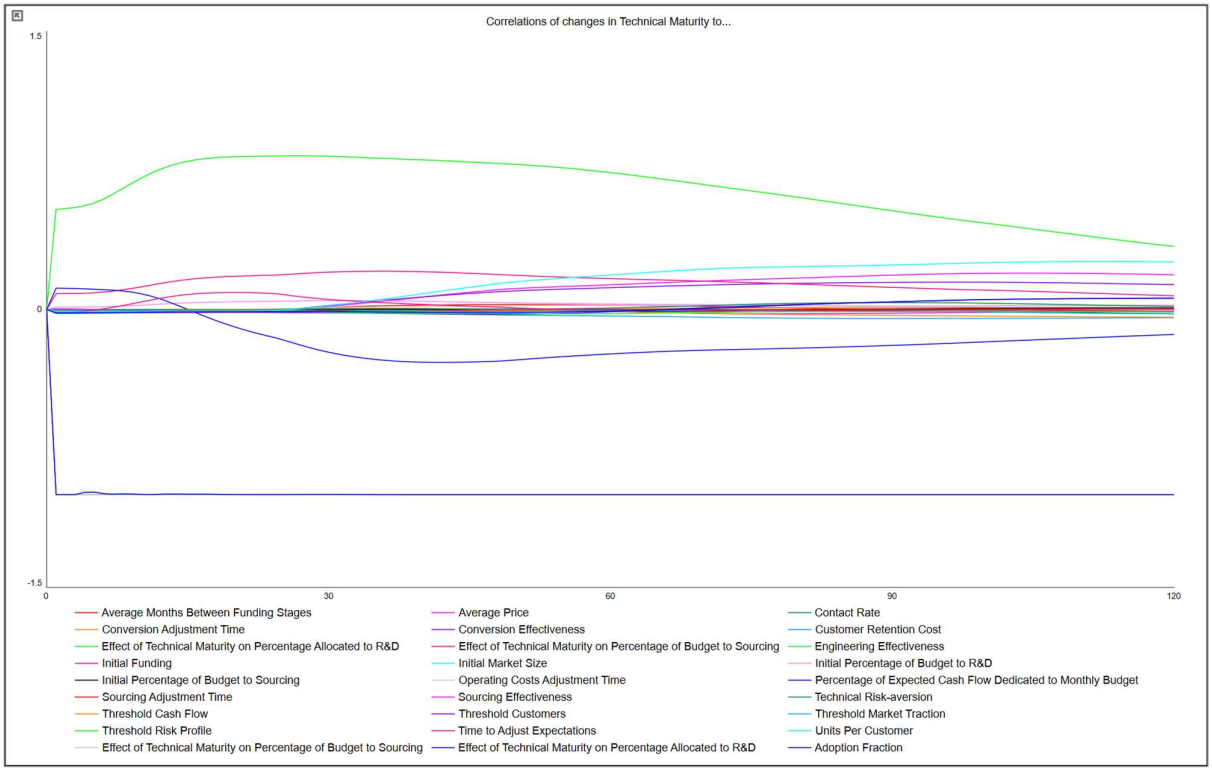


Figure 10. Correlation across runs output of Global Sensitivity analysis for the Technical Maturity KPI for all model input variables in the desired behavior simulation

Figure 10 shows that the output technical maturity is most positively correlated with the input, engineering effectiveness throughout the simulation and most negatively correlated with the input, initial percentage of budget to sourcing. These findings do not yield any feasible policy implications.