Untangling the origins of Strategic Innovation
A System Dynamics Approach

Support Material

Annex 1. Model equation list

Equation list includes variables description and unit of measures

init Dismissed_innovations = 0
flow Dismissed_innovations = +dt*Dismissing_rate
doc Dismissed_innovations = Innovative projects that are not integrated in the strategy of the firm are dismissed
unit Dismissed_innovations = Innovations

init Failed = 0
flow Failed = +dt*Failure_rate
doc Failed = Technical innovations that are not succesfully integrated in the strategy of the firm and enter into the stock "failed"
unit Failed = Innovations

init First_Developed_innovations = 1
flow First_Developed_innovations = -dt*Refusal_rate
-dt*Approval_rate
+dt*First_Development_rate
doc First_Developed_innovations = Technical innovations presented for the approval
unit First_Developed_innovations = innovations

init Full_developed_innovations = 0
flow Full_developed_innovations = -dt*Dismissing_rate
-dt*Integration_rate
+dt*Full_development_rate
unit Full_developed_innovations = innovations
init Innovations_approved_for_experimenting = 0
flow Innovations_approved_for_experimenting = -dt*First_Developed_Obsolescence_rate
-dt*Full_development_rate
+dt*Approval_rate
doc Innovations_approved_for_experimenting = Innovation approved to be implemeted on a small scale
unit Innovations_approved_for_experimenting = Innovations

init Innovations_Refused = 0
flow Innovations_Refused = +dt*Refusal_rate
doc Innovations_Refused = Innovations refused by top managers. These innovations are abandoned and no more examined to be developed
unit Innovations_Refused = Innovations

init Obsolete_innovative_projects = 0
flow Obsolete_innovative_projects = +dt*First_Developed_Obsolescence_rate
doc Obsolete_innovative_projects = Obsolete innovative projects that are definitely abandoned and no more examined
unit Obsolete_innovative_projects = Innovations

init Perceived_failure_rate = Failed
flow Perceived_failure_rate = +dt*Change_in_failure_rate_perception
doc Perceived_failure_rate = Strategic integrated innovations failed under competive pressure and, consequently, abandoned
unit Perceived_failure_rate = Innovations

init Perceived_integration_rate = First_Developed_innovations
flow Perceived_integration_rate = +dt*Change_in_integration_rate_perception
doc Perceived_integration_rate = The total amount of innovations integrated in the corporate strategy as percepted by top management
unit Perceived_integration_rate = Innovations

init Resourced_for_development = 0
flow Resourced_for_development = -dt*Resources_consumption_rate
+dt*Resources_accumulation_rate
doc Resourced_for_development = The stock of total resources accumulated to sustain the development of innovative projects
unit Resourced_for_development = Resources

init Strategic_integrated = 0
flow Strategic_integrated = -dt*Failure_rate
+dt*Integration_rate
doc Strategic_integrated = Technical innovations integrate successfully in the strategy of the firm.
unit Strategic_integrated = Innovations

aux Approval_rate = IF(First_Developed_innovations<0, 0,MIN(First_Developed_innovations, First_Developed_innovations*Fractional_approval_rate))
doc Approval_rate = Innovation approved by top management ecah month. These innovations will be developed on a small scale to be tested
unit Approval_rate = Innovations per month

aux Change_in_failure_rate_perception = (Failure_rate-Perceived_failure_rate)/Time_to_perceive_failure_rate_changes
doc Change_in_failure_rate_perception = The net change in the precepted failure rate. Top managers perceive how many strategic integrated innovations fail under competive pressure and must be abandoned
unit Change_in_failure_rate_perception = Innovations per month

aux Change_in_integration_rate_perception = (Integration_rate-Perceived_integration_rate)/Time_to_perceive_integration_rate_change
doc Change_in_integration_rate_perception = The net change in the perceived integration rate. Top managers perceive how many innovations are integrated in the strategy of the firm with a certain delay.
unit Change_in_integration_rate_perception = Innovations per month

aux Dismissing_rate = Full_developed_innovations*Reference_dismissing_rate*External_competitive_pressure
doc Dismissing_rate = The rate at which fully developed innovative projects are dismissed. After a certain period of time, innovative projects loose their innovative attributes for two reasons, the firm develops new innovations, rivals develop similar or alternative innovations. The rate at which projects are dismissed by top managers depends on the reference fractional dismissal level that represents the willingness of the company to maintain the fresher projects and the effect of the approval pressure that represent the intensity of rivalry.
unit Dismissing_rate = Innovations per month

aux Failure_rate = Strategic_integrated*MIN(1, Fractional_failure_rate)
doc Failure_rate = The rate at which innovations integrated fail and accumulate in the stock "failed"
unit Failure_rate = Innovations per month

aux First_Developed_Obsolescence_rate = MIN(Innovations_approved_for_experimenting,Innovations_approved_for_experimenting*Ref_obsolescence_rate*External_competitive_pressure)
doc First_Developed_Obsolescence_rate = The rate at which presented innovative projects become obsolete. After a certain period of time, innovative proposal loose their innovative attributes for two reasons, the firm generates new innovations, rivals generate similar or alternative innovations. The rate of obsolescence depend from the reference fractional level of obsolescence that represents the willingness of the company to maintain the fresher projects and the effect of the approval pressure that represent the intensity of rivalry.
unit First_Developed_Obsolescence_rate = Innovations per month

aux First_Development_rate = IF(Time_to_autonomous_initiatives=0,0,(Time_to_autonomous_initiatives*Reference_productiviy_for_unit_of_time))
doc First_Development_rate = The number of innovation that are developed to be examined by top management
unit First_Development_rate = Innovations per month

aux Full_development_rate = MIN(Innovations_approved_for_experimenting,Resources_consumption_rate/Resource_for_development_per_project,Innovations_approved_for_experimenting-First_Developed_Obsolescence_rate)
doc Full_development_rate = Innovations that come under complete development each month. These depend from the total resources that are available and from the amount of resources that each innovation requires to be fully developed.
unit Full_development_rate = Innovations per month

aux Integration_rate = MIN(Full_developed_innovations,Full_developed_innovations*(Fractional_integration_rate),Full_developed_innovations-Dismissing_rate)

aux Refusal_rate = First_Developed_innovations-Approval_rate
doc Refusal_rate = Express how many innovations presented by front line management are refused by top managers
unit Refusal_rate = Innovations per month

aux Resources_accumulation_rate = Approval_rate*Reference_resources_per_project
doc Resources_accumulation_rate = The rate at which top managers plan resource accumulation to sustain innovative projects. It is a function of reference resources that each project needs and the approval rate that represents how many innovative projects were approved.
unit Resources_accumulation_rate = Resources per month

aux Resources_consumption_rate = Resourced_for_development/Time_to_resource_absorption
doc Resources_consumption_rate = This represents the rate at which each project absorbes resources to be full developed.
unit Resources_consumption_rate = Resources per month

aux Effect_of_implementation_rate_on_resource_for_development = GRAPH(Implementation_rate,0,0.2,[2,1.8,1.6,1.4,1.2,1,0.8,0.6,0.4,0.2,0.01"Min:0;Max:2;Zoom"])
doc Effect_of_implementation_rate_on_resource_for_development = The more will be the implementation rate the more simple the implementation will be and the less will be resources destined to a single project
unit Effect_of_implementation_rate_on_resource_for_development = Dimensionless

aux Effect_of_relative_failure_rate_on_fractional_approval_rate = GRAPH(Relative_failure_rate,0,0.1,[1,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0.1,0"Min:0;Max:1; Zoom"])
doc Effect_of_relative_failure_rate_on_fractional_approval_rate = The effect of failure rate is as follow: the more it increases the more prudent will be top managers in approving innovative projects, so the less will be the approval rate.

aux Effect_of_relative_failure_rate_on_integration_rate = GRAPH(Relative_failure_rate,0,0.1,[1,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0.1,0"Min:0;Max:1; Zoom"])
doc Effect_of_relative_failure_rate_on_integration_rate = The more will be the fractional failure rate the less will be the integration rate, because top managers become more prudent and want to spend more time to integrate innovative projects
unit Effect_of_relative_failure_rate_on_integration_rate = Dimensionless

aux Fractional_approval_rate = External_competitive_pressure*Reference_fractional_approval_rate*Effect_of_relative_failure_rate_on_fractional_approval_rate
doc Fractional_approval_rate = The percentage of developed innovations that are approved by top managers to be developed on small scale each month.
unit Fractional_approval_rate = Fraction per month

aux Fractional_failure_rate = (Fractional_integration_rate*Reference_fractional_failure_rate*External_competitive_pressure)
doc Fractional_failure_rate = The strategic innovations failure rate depends firstly on the reference fractional failure rate that is influenced by two factors: fractional integration rate and external competive pressure. The higher the integration rate the less top mangers will dedicate attention to innovation integration and the higher the failure rate will be.
unit Fractional_failure_rate = Fraction per month

aux Fractional_integration_rate = Effect_of_relative_failure_rate_on_integration_rate*Reference_fractional_integration_rate
doc Fractional_integration_rate = The fraction of innovative project that are integrated in the strategy of firms and became strategic innovations
unit Fractional_integration_rate = Fraction per month

aux Fractional_time_to_new_initiatives = Implementation_rate*Reference_fractional_time_to_new_initiatives
doc Fractional_time_to_new_initiatives = The fraction of time that effectively will be allocated to new intiatives
unit Fractional_time_to_new_initiatives = Dimensionless

aux Implementation_rate = Full_developed_innovations/First_Developed_innovations
doc Implementation_rate = Express the performances in term of ability to implement innovations
unit Implementation_rate = Dimensionless

aux Relative_failure_rate = Perceived_failure_rate/Perceived_integration_rate
doc Relative_failure_rate = Performance in term of failed strategic innovations that are appreciated in relation with integrated innovations
unit Relative_failure_rate = Dimensionless

aux Resource_for_development_per_project = Effect_of_implementation_rate_on_resource_for_development*Reference_resources_per_project
doc Resource_for_development_per_project = Amount of resource effectively destined to a single innovation project
unit Resource_for_development_per_project = Resources per innovation

aux SIR_Synthetic_innovation_rate = MAX(0.00001, Strategic_integrated/Total_innovations)
aux Time_to_autonomous_initiatives = Total_time_available*Fractional_time_to_new_initiatives
doc Time_to_autonomous_initiatives = The unit of time available each month for innovative initiatives
unit Time_to_autonomous_initiatives = Unit of time per month

aux Total_innovations = Failed+Strategic_integrated
const External_competitive_pressure = 1
doc External_competitive_pressure = It express the level of competitive turbulence of the industry [D'Aveni, 1997] also called level of rivalry among firms [Porter, 1985]. It can vary from 1 that represents an industry with a low level of rivalry to 2 that is a very turbulent industry.
unit External_competitive_pressure = Dimensionless

const Ref_obsolescence_rate = 0.1
doc Ref_obsolescence_rate = The fractional rate of obsolescence is set as an independent variable and can be interpreted as the willingness of top managers to retain in the stock only a small portion of innovative initiatives
unit Ref_obsolescence_rate = Fraction per month

const Reference_dismissing_rate = 0.001
doc Reference_dismissing_rate = The fractional dismission rate is set as an independent variable and can be interpreted as the willingness of top managers to abandon older technical innovation and retain in the stock only a small and well qualified portion of them.
unit Reference_dismissing_rate = Fraction per month

const Reference_fractional_approval_rate = 0.3
doc Reference_fractional_approval_rate = The percentage of innovations that are normally approved by the firm's top management each month.
unit Reference_fractional_approval_rate = Fraction per month

const Reference_fractional_failure_rate = 0.2
doc Reference_fractional_failure_rate = Reference fractional failure rate
unit Reference_fractional_failure_rate = Fraction per month

const Reference_fractional_integration_rate = 0.30
doc Reference_fractional_integration_rate = This is the reference rate at wchich top managers wanto to integrate innovative projects. This is an ideal goal set "a priori" by top mangers.
unit Reference_fractional_integration_rate = Fraction per month

const Reference_fractional_time_to_new_initiatives = 0.3
doc Reference_fractional_time_to_new_initiatives = Percentege of total time available thta fornt line managers can allocate to autonomous initiatives
unit Reference_fractional_time_to_new_initiatives = Dimensionless

const Reference_productiviy_for_unit_of_time = 1
doc Reference_productiviy_for_unit_of_time = Express how many technical innovations can be realized in a unit of time
unit Reference_productiviy_for_unit_of_time = Innovations per unit of time

const Reference_resources_per_project = 1
doc Reference_resources_per_project = Reference amount of resources needed to each project to be developed
unit Reference_resources_per_project = Resources per innovation

const Time_to_perceive_failure_rate_changes = 4
doc Time_to_perceive_failure_rate_changes = Time to perceive the change in the failure rate. It is normally set at 4 because the reports are examined on a quarterly basis by top management
unit Time_to_perceive_failure_rate_changes = Months

const Time_to_perceive_integration_rate_change = 4
doc Time_to_perceive_integration_rate_change = Time to perceive the change in the integration rate. It is normally set at 4 because the reports are examined on a quarterly basis by top management

unit Time_to_perceive_integration_rate_change = Months

const Time_to_resource_absorption = 1.5

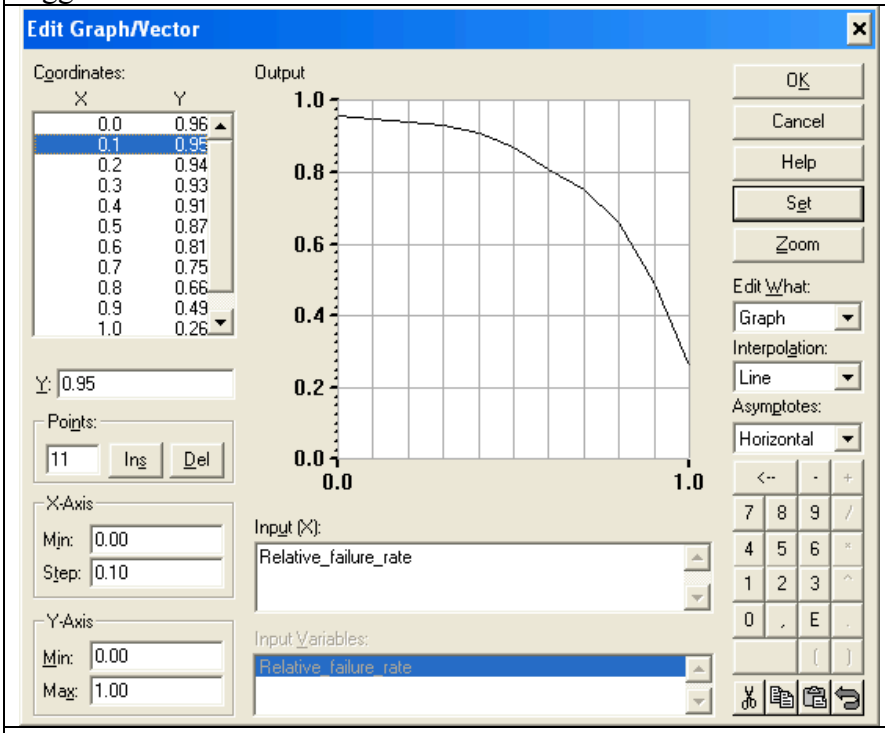
doc Time_to_resource_absorption = Time that innovative projects need to absorb resources and become fully developed
unit Time_to_resource_absorption = Months

const Total_time_available = 50
doc Total_time_available = The amount of time available each month for work. The unit of time is a conventional measurment (it can be days, hours or minutes) and indicates the total time of front line managers to work
unit Total_time_available = Time unit per month

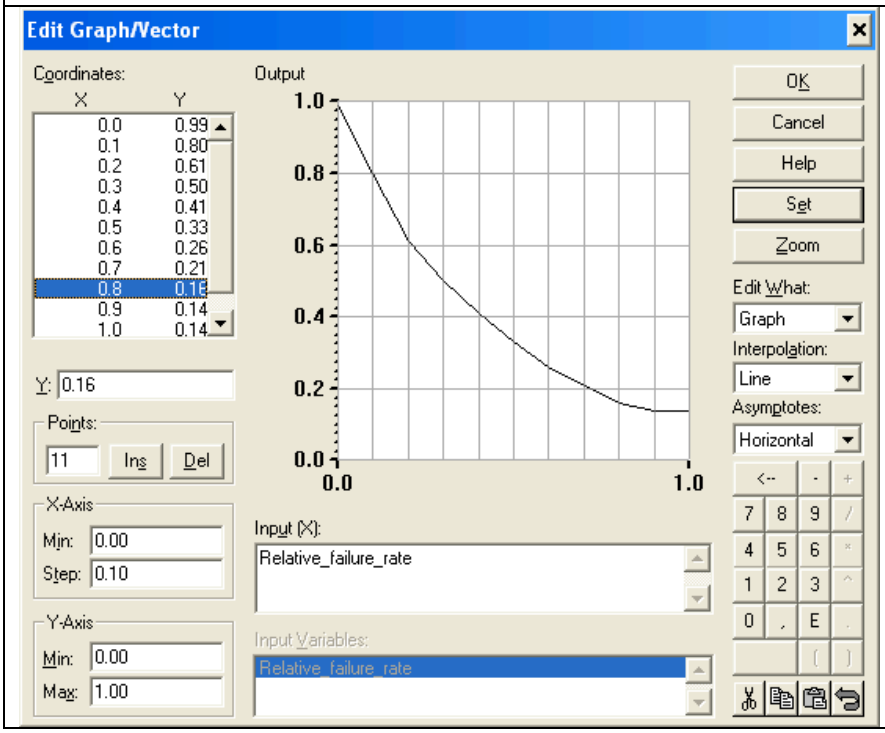
Annex 2
Characterisation of non-linear effects to represent managers' mental models

Characterisation of the effect of relative failure rate on approval rate

Aggressive mental models

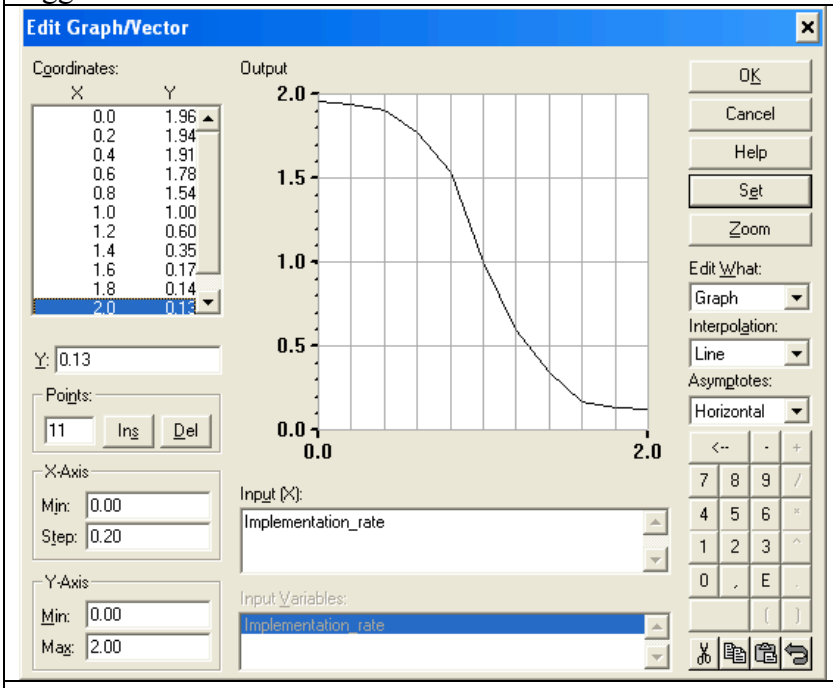


Conservative mental models

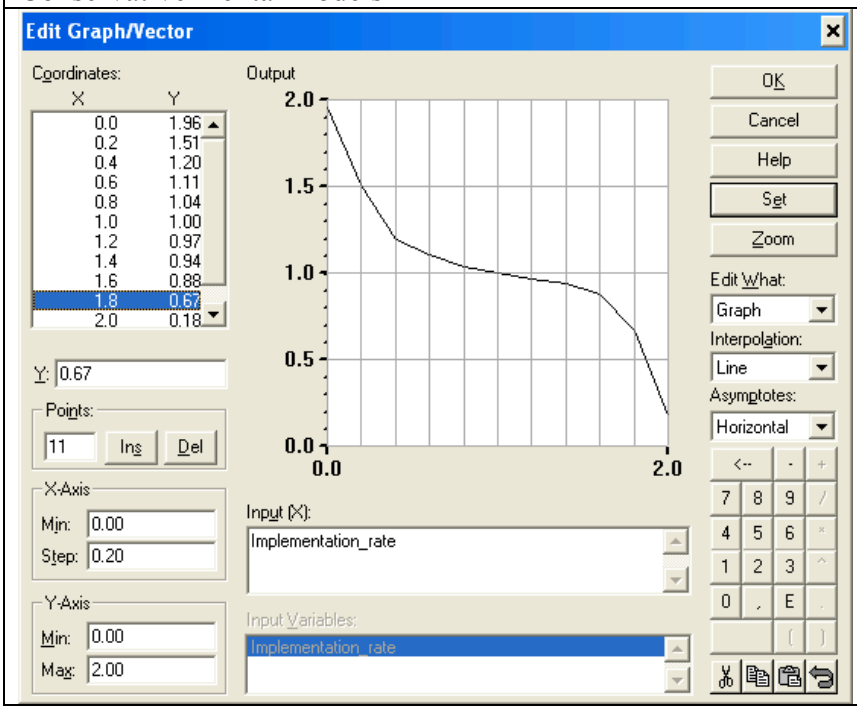


Characterisation of the effect of implementation rate on resources for development of a single project

Aggressive mental models

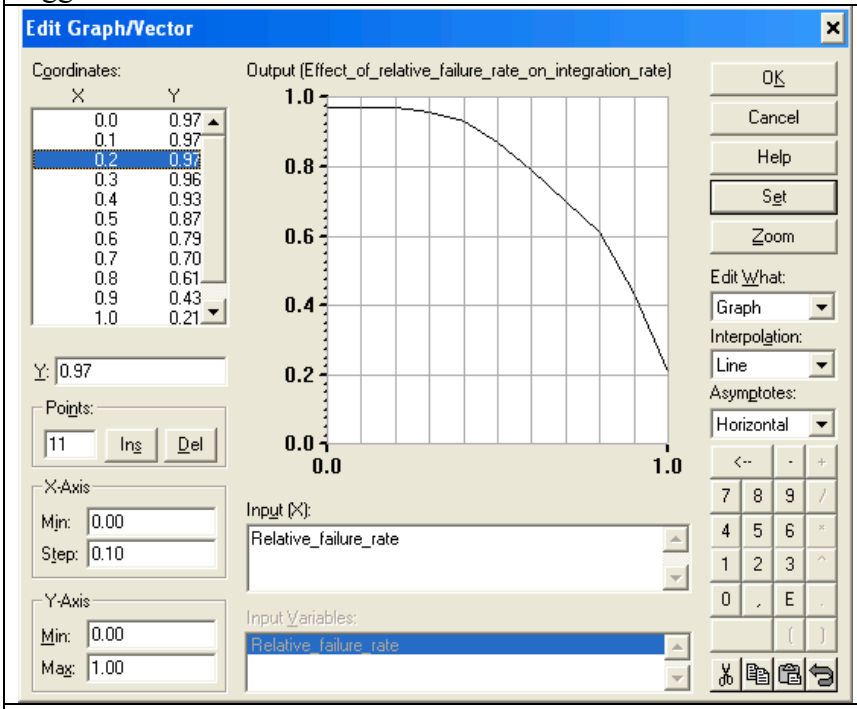


Conservative mental models

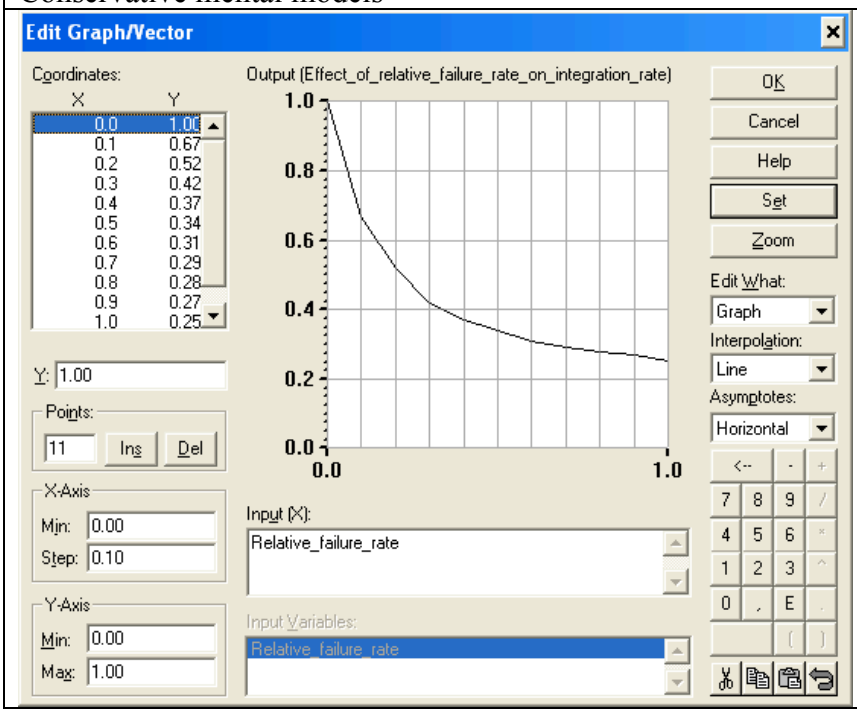


Characterisation of effect of failure rate of the integration rate

Aggressive mental models

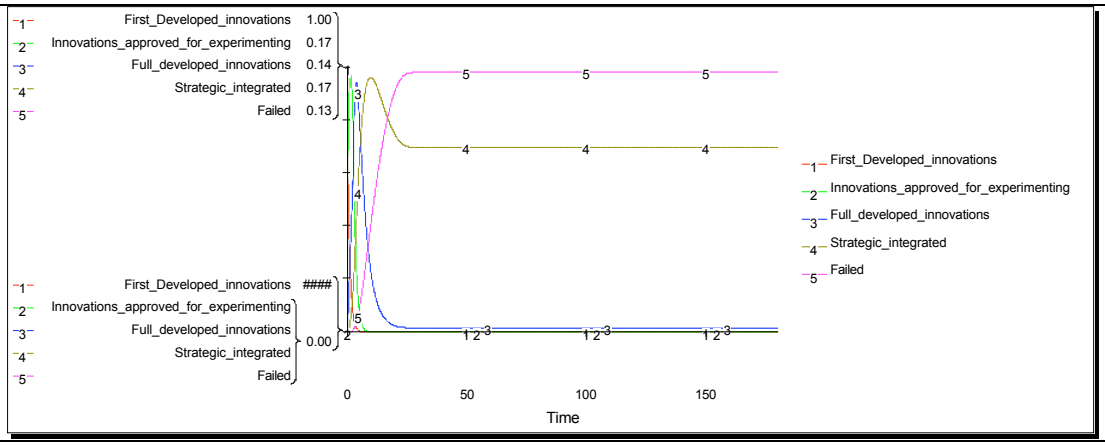


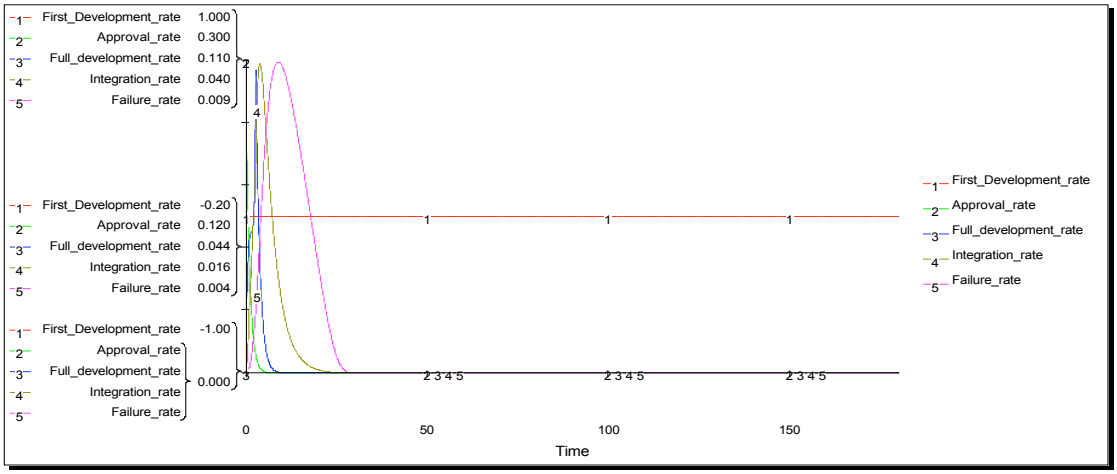
Conservative mental models

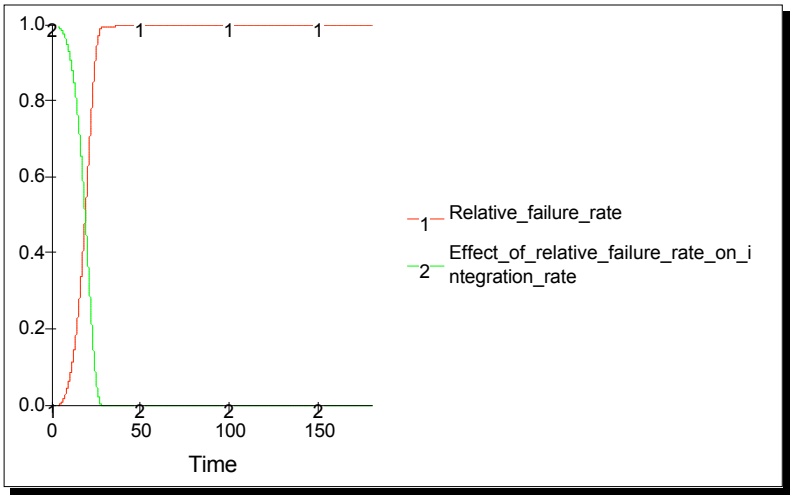


Annex 3. Selected simulation outputs for validation

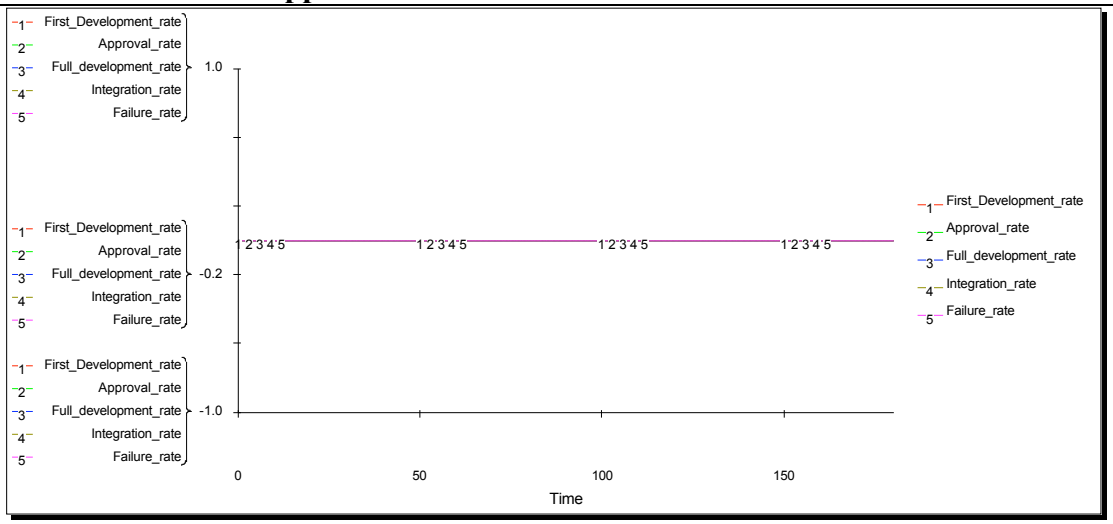
Reference fractional time to autonomous initiatives = 0



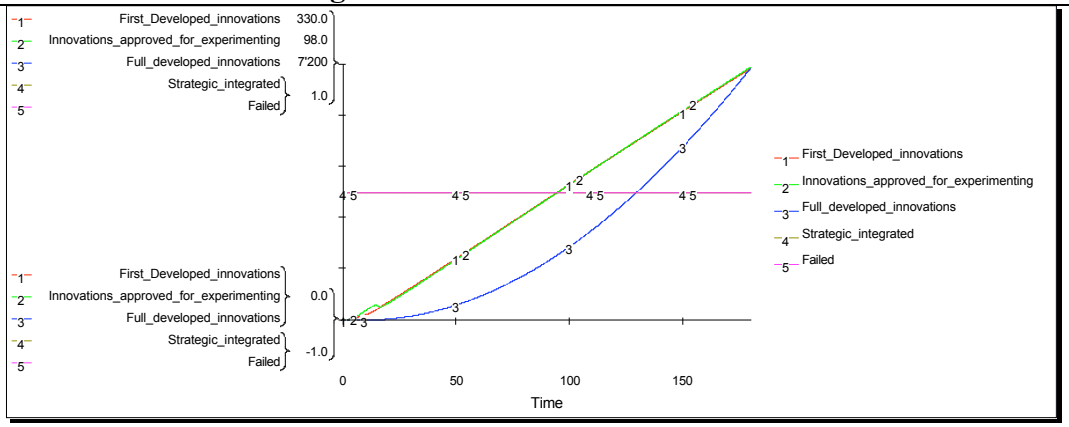


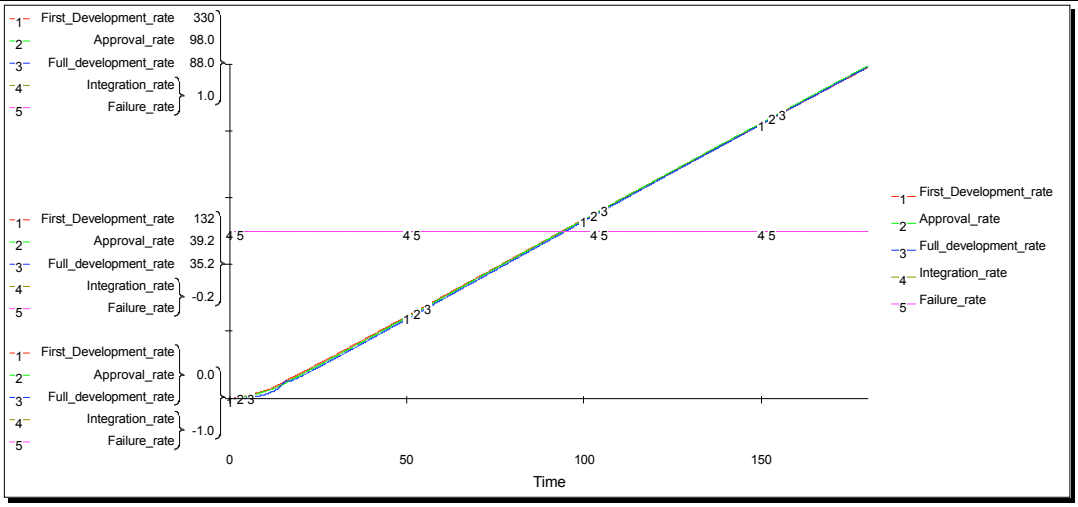


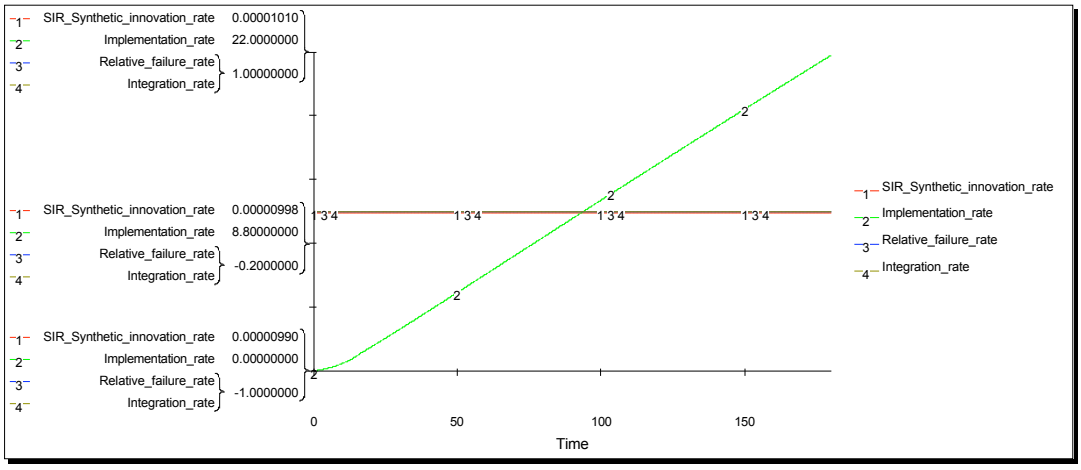
Reference fractional approval rate = 0



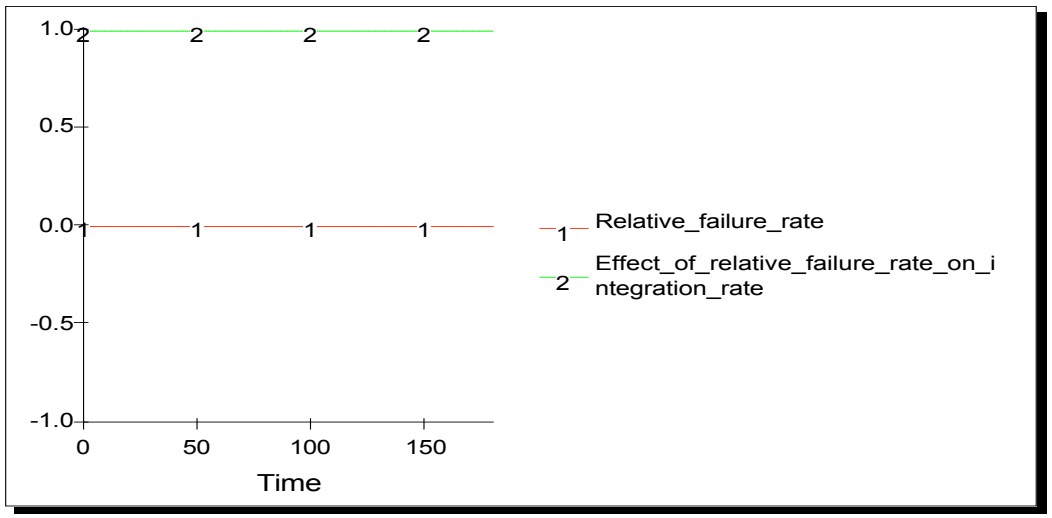
Reference fractional integration rate = 0…







…Reference fractional integration rate = 0



Annex 4. Simulation software settings

Software	Powersim constructor 2.51
Integration method	Euler (fixed step)*
Start time	0
Stop time	180
Time step	0.625

* We adopted Euler's integration method. We tested the robustness of our model by running several simulations with the Runge-Kutta method and we did not encounter any significant differences with Euler's method simulations