R&D Project Portfolio in Research and Development, Part of a Whole in R&D Strategy

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Abstract

The proportion of resources allocated to research and product development phases play the crucial role in forming the routines of R&D companies. In such company, it is a strategic decision to focus on each of these phases, as it will affect many characteristics of the R&D operation. This model is an effort to combine a R&D strategy framework and system dynamics methodology, based on the interactions of the authors with an Iranian R&D company. A general model of R&D operation with indication of elements of R&D strategy in feedback loops is developed. Assumptions of the model are mostly based on the real world attributes of the aforementioned company. The model is then used to explain past behavior of the company over time, and examine current policies exploited by the firm.

Introduction

Present business environment is the arena of high levels of competition in almost all businesses. Attempts to reach a competitive advantage in the market, and keeping the position between rivals, has led companies to innovation in their products and processes.

In such conditions, managing the process of innovation has been a challenge for senior management. To overcome the challenge of "the appropriate model for R&D", companies have experienced several restructurings, process reengineering, management changes, goal redefinitions, etc. Despite heavy investments in R&D, many companies have not been successful in achieving acceptable performance in R&D. Reason for failure has not been lack of management effort or personal commitment in all cases. Companies invest in R&D based on a strategy, and management supports those strategies. The point is that like any other strategy, R&D strategies must reach an effective level of coherence through a variety of decisions (Pisano, 2012).

Many researchers have tried to represent important aspects of R&D Strategy, Innovation Process, and Innovation Diffusion. Roberts (1978) presented an edited collection of models of R&D projects dynamics and the connected pan-organization and resource allocation issues. Weil *et al.* considered the example of workflow bunching in which several factors (including e.g. human resource allocation, sequential dependencies of and feedback between projects) led to poorly distributed, oscillating workload within the R&D organization. Weil (1973) described the R&D performance with a focus on key characteristics of the company's technology base, R&D activities and products in the market. He also described technology programs, new product exploration programs and product development programs in terms of their "advancedness". Repenning (2000; 2001) has identified the issue of product development systems becoming trapped in a condition of poor performance due to resources not being appropriately applied to early stages developments but instead to later stage projects. Milling and Maier (Milling 1996; 2002; Milling and Maier 1993; 2001; Maier 1998) have used system dynamic models to explore the relationships between R&D activity, pricing strategy and product diffusion. Moizer and Towler (2007) developed a simulation model to explain the role R&D can play in shaping the dynamics of a firm.

Gino and Pisano (2005; 2006) viewed the R&D portfolio strategy from the information perspective. They studied R&D portfolio data from large corporates to analyze if firms are likely to diversify their R&D portfolio into products area that occupy similar information regimes. Their portfolio regime categorized

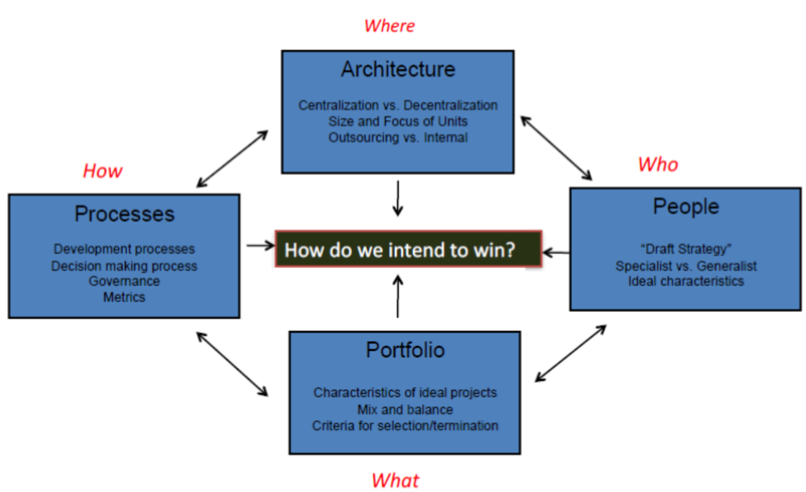

Figure 1: The R&D Strategy Framework. Source: Pisano (2012)

R&D projects to *Informationally poor* and *Informationally reach* projects. They also analyzed if this portfolio strategy is successful. Later, Pisano (2012) presented a general framework for R&D strategy. In his R&D strategy framework, Pisano describes four elements to construct a comprehensive R&D strategy: (1) architecture, (2) Processes, (3) People, and (4) Portfolio. Pisano discussed the fact that there exists a core hypothesis of win behind every strategy.

R&D performance results from the interaction of many different decisions and choices, including the size and location of R&D facilities, the division of labor between various groups, the choice of technologies used inside the R&D organization, the selection of personnel, the allocation of resources, the design of processes for managing projects, and other factors (Pisano, 2012)

This R&D strategy framework focuses on resources selection and tactics to use those resources coherently. Many important R&D strategy issues pertain to the policies which govern the acquisition of resources (Roberts, 1978). Resource acquisition and allocation decisions are intimately interwoven with aspects of technology strategy, e.g., the technical advancedness of the company's products, the mastery of the technologies used in products, the nature of new technology programs, and the priorities for assigning resources to various activities. (Weil, 2007) In the context of R&D, the ability to manage projects—specifically embodied in such decisions as project selection, resource allocation, project termination, and portfolio management—is a critical driver of competitive performance (Clark and Wheelwright, 1995).

Portfolio management and resource allocation are two intertwined issues of R&D Strategy. They play a dominant role in achieving R&D performance, due to the fact that they force other elements of R&D activity to form a coordinated environment toward the portfolio and available resources. From an Informational aspect of view, different organizational capabilities are required to manage projects in different information regimes. Managing projects in informationally poor regimes requires management capabilities and skills to deal with high levels of persistent risk and uncertainty. Because uncertainty cannot be resolved early in the development process, organizations need capabilities and approaches to manage and hedge "back-end" risks. They could conduct more parallel projects to hedge risks. They could adopt, if possible, modular design strategies to facilitate design flexibility. Their development processes themselves need to be flexible to enable significant mid-course corrections. Portfolio planning needs to be fluid in order to quickly reallocate resources across projects, and to deal with unexpected surprises (both positive and negative). And, the managers themselves need to be comfortable with a relatively high level of ambiguity (uncertainty) and risk taking.

Managing projects in informationally rich regimes requires a very different set of organizational capabilities. In an informationally rich regime, it is both feasible and desirable to make commitments to projects relatively early in the development process in order to exploit the plethora of available information. As a result, project management and portfolio management processes need to be structured around the early selection of projects early in the development cycle. Management attention should be focused on these early decision points, and on committing appropriate resources to "good prospects" while ruthlessly terminating less attractive project opportunities. Here, management needs to be comfortable in making hard decisions early, and management review processes need to be highly disciplined. In essence, the important events happen early in the life of projects belonging to an informationally rich regime, while they tend to happen late for projects belonging to an informationally poor regime (Gino and Pisano, 2006)

Much of the theorizing in strategy over the past decade has focused on the role of organizational capabilities in shaping competitive strategies and performance. (Gino and Pisano, 2006)

Many previous works of system dynamics researches are also aimed at modeling strategy issues. Gary *et al.*, (2008) studied system dynamics researches that made contribution to the strategy field and discussed that a large portion of the progress made to answer the important issue of "why are some firms more profitable than others" lie in the behavioral strategy field. However, they discussed four broad research paths they believed hold the most promise for work in the system dynamics approach to strategy: The first is laboratory experiments of individual and team decision making; the second is bootstrapping decision rules using field data; the third is variation in resource accumulation and implementation strategies; and the fourth is dynamics of competitive rivalry.

Many works in the fields related to R&D strategy lie in the third and fourth categories suggested by Gary *et al.* Many of these works in the system dynamics field focus on Innovation Performance and Innovation Diffusion (see for example Milling, 1986; 1987; 1991; 1996; Milling and Maier, 1996; 2001; Rogers, 1983; Weil *et al.*, 1987; Weil, 2007) Works in this area view R&D in dynamic interaction with the Market elements and study success of an innovation program from the aspect of a corporation. This point of view is successful in supporting managerial decision making by giving insights, and tries to substantially support decision making by formalized models and computerized inquiring systems (Milling, 1996); but it misses a view on internal dynamics of an R&D organization. They also ignore interactions between portfolio selection and R&D dynamics through time.

Schumpeter (1961) defines the innovation process as separated in three stages: (1) Invention, the phase where new products are developed (2) Innovation, i.e. the phase of introducing new products in the market, and (3) imitation or diffusion, the spreading of new products in the marketplace. Milling and Maier (2001) presented *outcome of innovation activities*

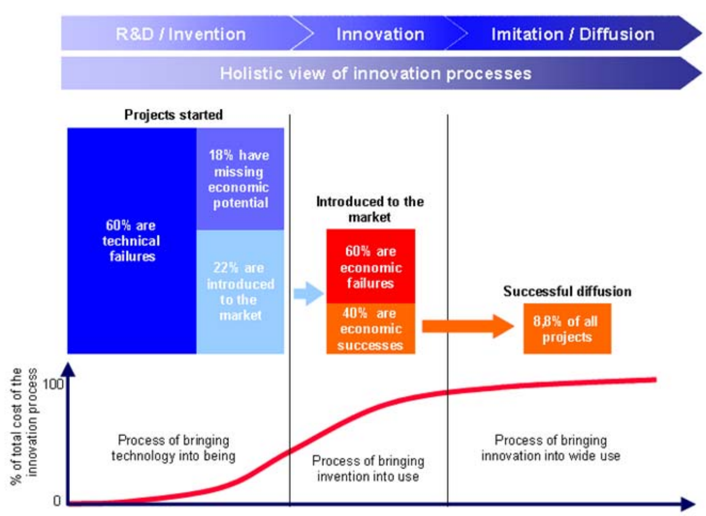

Figure 2: Invention, Innovation, Imitation. Source: Milling and Maier (2001)

as in Figure 2.

From a R&D process perspective, we see the activities of Innovation process as shown in Figure3. This schema shows the whole processes of innovation as a dynamic value chain. The main distinction of this view with respect to other viewpoints of the innovation process is that it opens up the R&D box to view its processes more precisely. The other distinction of this diagram is how it emphasizes one step before portfolio selection, i.e. idea adoption. Main issues in portfolio selection are usually attributes of the proposed project, especially leading indicators regarding outcomes of the project, and available resources versus required resources for the project, i.e. knowledge, technologies, human resources, etc.

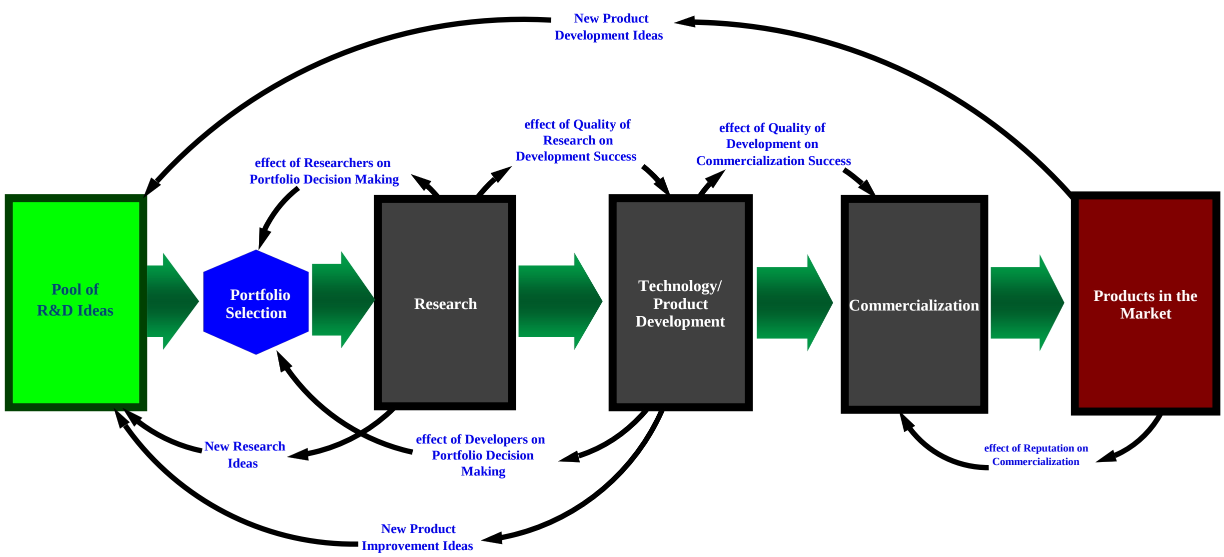

Figure 3: The R&D Processes

This paper assumes fixed conditions for the commercialization, production and market stages in the innovation process. It is assumed that these processes are performed perfectly regardless of the condition. The model in this article focuses mainly on the four steps of Idea adoption, Portfolio Selection, Research, and Development.

R&D Portfolio Selection

R&D portfolio strategy has been studied from different perspectives. Some researchers studied the issue from a risk aspect of view; some used the matrix method to develop an optimization model for R&D portfolio decision, etc. Gino and Pisano (2005; 2006) studied the issue from an information processing perspective. According to the information-processing perspective, the relationship between R&D effort (investment) and information content may vary across projects due to structural differences in the underlying knowledge bases.(Gino and Pisano, 2006) Gino and Pisano (2005) use the term “information regime” to describe the relationship between experimentation effort and the rate of decline in uncertainty over the development cycle. From this perspective, while experimentation “adds” information to projects and reduces uncertainty, the rate at which this process occurs varies across technologies due to differences in underlying scientific knowledge, the availability of predictive heuristics, and the accumulation of prior empirical knowledge. The *Information regime* concept represents a spectrum in which one end are *Informationally reach* projects, and the other end are *Informationally poor* projects.

Matheson (1997) introduces a grid analysis as a tool for R&D project portfolio selection. He used this grid to differentiate projects based on their technical difficulty and commercial potential. Technical Feasibility reflects a project’s probability of success in overcoming all hurdles (technical, financial, regulatory, etc.). The horizontal axis, Commercial Potential, reflects potential commercial value, and is measured in terms of the expected net present value of cash flows. This axis represents the magnitude of potential value creation, assuming the project overcomes all technical hurdles.

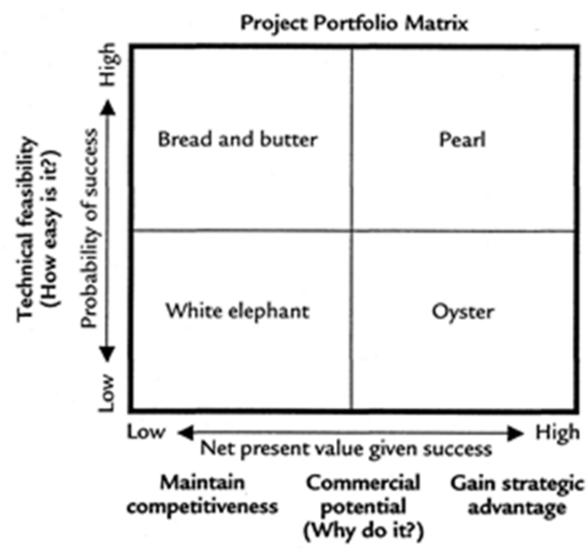

Figure 4: The R&D Portfolio Grid. Source: Matheson (1997)

What Does Actually Take Place through R&D Portfolio Selection?

One common scenario in R&D project approval is the form that senior management defines the main areas of research, mainly products that are aimed to be developed (a top-down view of portfolio selection) and R&D staffs propose new projects based on their field of work and experiences. The proposals would be analyzed in committees and will finally be approved or rejected. Also, qualified proposals might be started immediately or postponed due to capacity shortage or prioritization. This process is not isolated; it is commonly affected by willingness of people in the organization as they try to use their power to affect the process. The final list of approved projects in each section of decision making is a result of perceptions of available capacities, priorities of the company, and bargaining in committee sessions.

This scenario is a base for development of the model to analyze effects across time of this portfolio decision process on the performance of the R&D Company through time.

The R&D is modeled with two phases of Research and Development.

The Research phase consists of processes of conceptual studies, lab tests, material analyses, etc. People working in research section have commonly attributes of a researcher. Roughly saying, they are interested in lab work and research, have a grit to work in unknown conditions, and are more interested in research environment versus business environment, and their network is people with interests like them. These attributes make preferences of the research staff. Again, roughly saying, basically, researchers tend to work on projects with high knowledge gains for them, and in their previous area of study. This tendency can be changed as they get to do different jobs in different areas.

Development phase has mainly the duty of developing products and/or technologies of the firm. This phase consists of computer aided simulations, prototype making and testing, production method analysis, etc. Development staffs must have technical capabilities, experiences related and tendency to product design and manufacturing. They also must have information about or feedback from taste of the market.

Researchers and developers can take action in R&D portfolio selection with their suggestions, proposals, and standing for their proposals.

In this paper, projects in the R&D portfolio are categorized based on their sources of idea, and common attributes of projects selected from each pool of idea. This categorization is used as modeling. Also, attributes of each category is assumed to be effective during the processes of R&D. Three attributes of (1) Technical Feasibility to be performed in Research phase, (2) Technical Feasibility to be performed in Development phase, and (3) Effect of the results on the products in the Market.

Three categories of projects are analyzed in this model:

- Basic Research (BR) projects study conceptual ideas in science. These projects are assumed to lack an aim toward product development. Results of these projects can be published as papers, or presented in seminars. Also they might result in patents. These projects are proposed by researchers based on their interests and their field of work.
- Product Improvement (PI) projects are aimed at improving projects in the market based on feedback from customers and is affected by experience and willingness of development staff. Effect of results of this category of projects on the company market is increase in life cycle duration of products in the market and increase in customer satisfaction. Longer product lifetime increases lifetime value of each product.
- New Product Development (NPD) projects aim at developing new products based on market strategies of the firm. Results of these projects are new product that will be produced after their design and development, and will be introduced to market. It is assumed that these projects are proposed by senior management and have priority to other projects proposed. Source of this idea is exogenous to the model.

R&D idea category	Category Specifications	Research phase	Development phase
Basic Research	Aims at: Science Rarely enters development phase	✓	✗
Current Product Improvement	**Technical Feasibility:** High **Commercial Potential:** Low	✓	✓
New Product Development	**Technical Feasibility:** Medium **Commercial Potential:** High	✓	✓

Some factors of R&D performance are assumed given in this model to simulate more internal factors of the R&D organization. Factors such as success probability of product in the market, success probability of the projects of each category in each phase, technology relevance of new projects to past projects, etc. do affect R&D outcome performance, but are not all main factors affecting success of an R&D organization. Like any other organization, performance of an R&D organization is affected by the causal structure of internal factors. These factors make the behavior that affects them through time and this feedback loop governs the performance of the firm and results of decisions by senior management.

Of course, strategy is a unique plan for each company for each condition. Success in any strategy needs coherence through all activities and parts of the company. Porter (1996) expresses that employees need guidance about how to extend the company's uniqueness while strengthening the fit among its activities.

This model analyzes how portfolio decision is affected by (1) available capacity in R&D (2) pool of ideas for research, (3) willingness and experience of staff, (4) negotiation power of staff from each segment of the firm, and (5) plans and decision of management. This portfolio selection, in terms of rate of approval of projects and ratio of resources allocated to each type of projects, affects capacity to perform projects, staff experience, people willingness and organizational advantage.

What happens through performing projects in R&D processes?

From a stock and flow aspect of view, any project that starts in Research phase goes into a stock of research projects in hand. When any research project is finished, it is out from the stock of projects in hand.

Performing research projects needs resources such as human resources, facilities and instruments, material, place, budget, knowledge in the area, access to information resources, etc. If resources are available, the project will be finished in a normal time. These resources create a capacity to perform research projects. Each unit of capacity stands for an average amount of each resource required to perform one project. Although this concept is not accurate, it is conceptually appropriate for representing firm's capacity to perform projects. So, capacity has a unit of project.

Insufficiency of resources increase duration of projects, and hence decreases the rate of project finish. However, this deficiency is a driving force for investment in research. Investment increases amount of research capacity. Capacity is a resource that obsoletes over time. As capacity is a variable that accumulates over time, if Capacity Deficiency forces rate of investment in capacity to become more than rate of capacity obsolescence, capacity increases through time, and otherwise it will decrease or in best conditions stay unchanged.

Any research project that reaches an end, adds to the experience of the firm in research. Research staffs hold this experience with them, and with retirement of each staff, they will take their experience out with them. Experience of staff in research helps them finish project faster and with better quality. So, increase in average experience of the staff in research will decrease time to finish research projects, and reduction in average experience in research results in more time needed to perform projects. Average experience in research increases when more research projects finish per year with a same amount of capacity in research. This happens when time to finish research projects decreases with more average experience.

The same dynamic happens in development phase. More development projects in hand reduce development resource sufficiency and this increases time to finish projects, but this also forces for more investment in development, which will increase resource sufficiency with a delay. More development projects finish rate, increase average experience in development, and this leads to lower time to finish development projects and higher rate of project finish in development.

Basically, each unit of capacity used to perform each development project is composed of more resources than for research. Consequently, investment in development to increase development capacity requires more money and time.

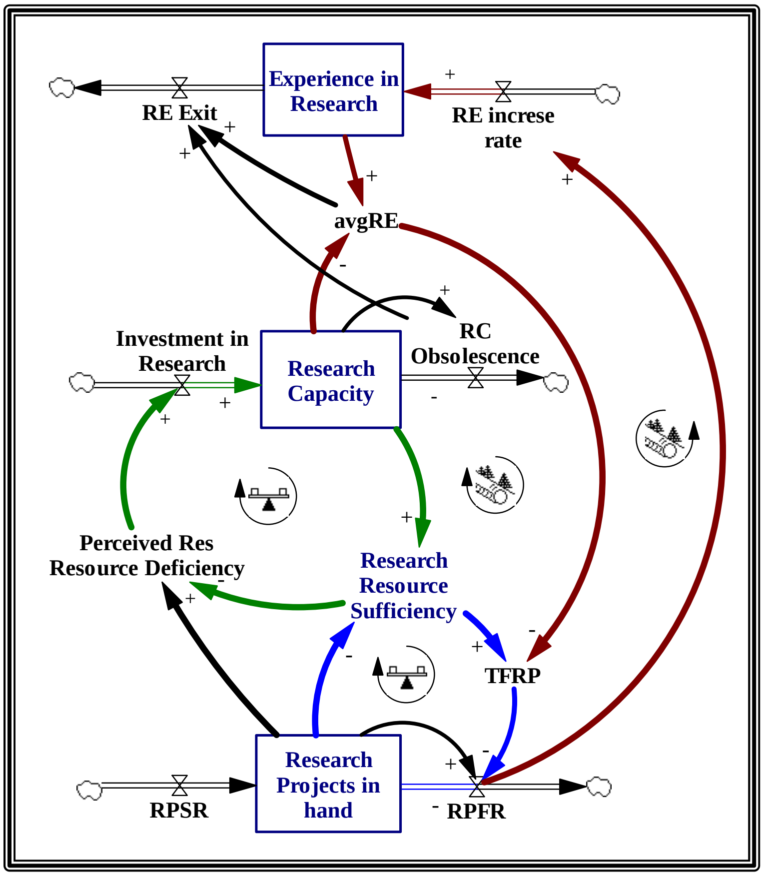

Figure 5: Stock and Flow Diagram for Research Dynamics

Abbreviations

RPSR:
Research Project Start rate

RPFR:
Research Project Finish rate

TFRP:
Time to Finish Research Projects

RE:
Research Experience

RC:
Resource Capacity

avgRE:
Average Experience in Research

Investment in capacity increases capacity for performing projects. This investment includes allocating more resources to each section. This capacity includes human resources that actively take part in actions and decisions in the firm. If more resources, including human resources, are allocated to one section, people in that section will earn more organizational advantage to influence in decisions in the organization. This includes obtaining more resources for investment in their belonging section. This mechanism is like what happens in *success for successful* archetype.

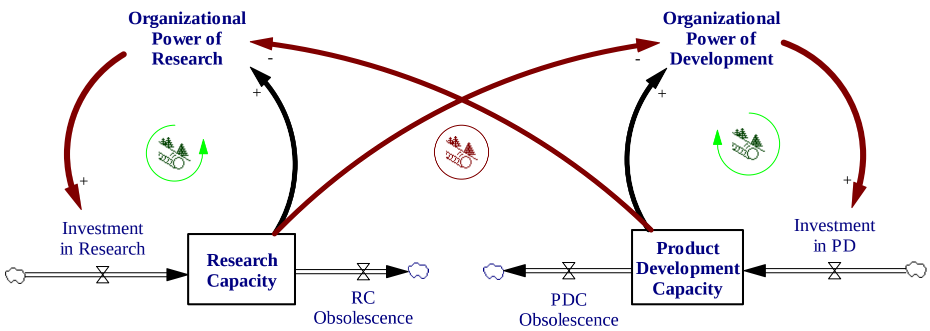

Figure 6: Stock & Flow diagram for the Power Competision

As we will see later, this effect of organizational advantage shows up again in portfolio selection.

Results of research projects might be a start point for a development project, or the work might be stopped at the end of research. As we discussed earlier, roughly estimating, Basic Research projects do not go further than research. Projects related to Product Improvement and New Product Development need to pass development processes to make results.

Tendency of researchers to perform Basic Research projects or the other types of projects is shaped as they do more from one type for a while. The more they have performed Basic Research projects recently, with respect to other types of research projects, the more they currently prefer to do more Basic research projects. The opposite is also correct. The more they perform research projects related to Product Improvement or New Product Development, the more they prefer new projects of these two types of projects.

Researchers' willingness to perform Basic Research projects results in new ideas for basic research, proposed to start in research phase. These ideas add to the pool of Basic Research Ideas. If these ideas are not approved for a while, they will be obsoleted. And if they are approved, they are moved from the pool of Basic Research Ideas to start as a new Basic Research project.

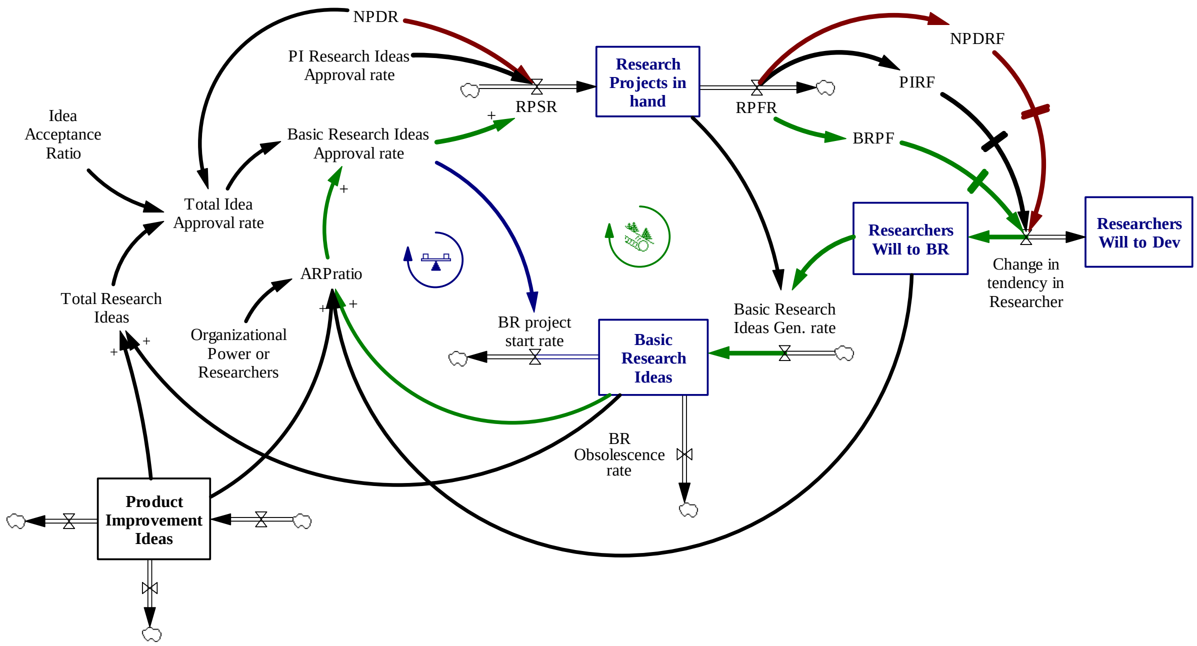

Figure 7: Stock & Flow diagram for BR Idea Generation

As figure 7 shows, Researchers' Willingness to perform Basic Research projects has effect on New Basic Research Ideas Generation rate and on portfolio selection where researchers' organizational advantage and their willingness affect the portfolio selection. Of course, developers do also have effect on portfolio selection. They tend to get approval for more proposals for Product Improvement projects.

Also, as Researchers' Experience increases, their ability to generate research ideas improves, meaning that they can suggest more research ideas.

Besides Basic Research projects, Product Improvement projects and New Product Development projects enter development phase after they are successfully finished in research. If they are not successful, they will be stopped after research finishes.

After the development phase finishes for PI projects, they result in improvement in current products in the market (if they are still in the market) and this results in customer satisfaction and also increases the probability of longer life cycle duration.

Final results of New Product Development projects after passing development phase will be design and manufacturing documents and prototypes for production of the new product. After this phase is finished for these projects, product manufacturing, advertisement campaigns, and product introduction plan phases should be successfully passed for the product to enter the market. Here we've assumed that these phases will be done perfectly. So, again we focus on the effects of new products in the market on portfolio of projects in R&D. Products in the market are resources for product improvement ideas. The more products the company offers to the market, the more product improvement ideas will be generated. Also, as development staffs have great contribution in product improvement projects, their experience in development will have positive effects on rate of idea generation in PI.

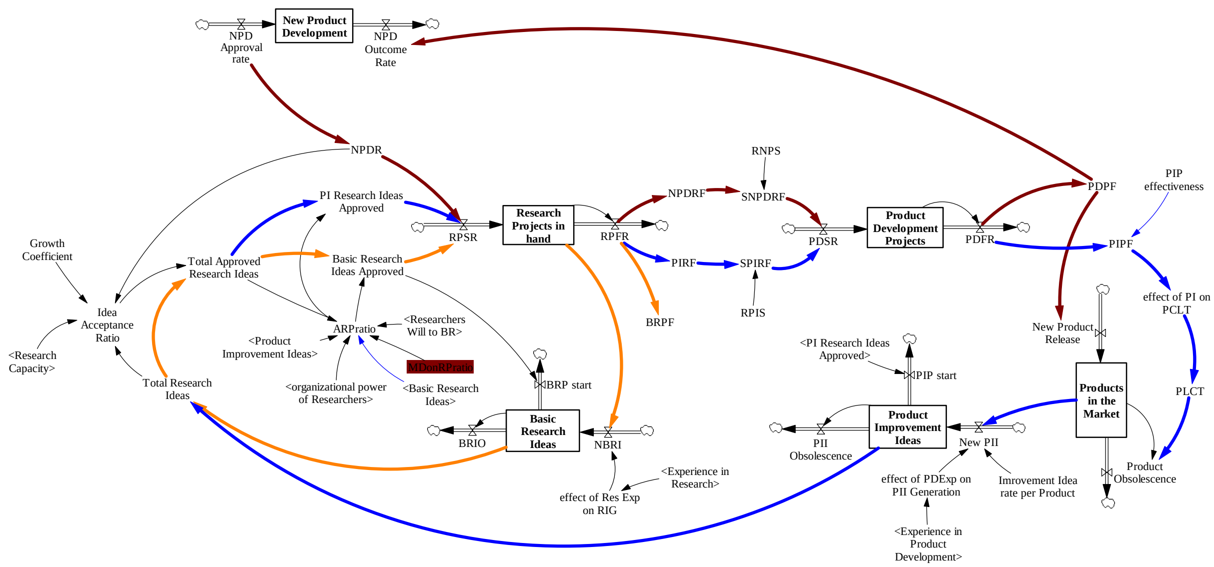

Figure 8: Stock & Flow diagram of PI Idea Generation

Model Interaction with the R&D Strategy framework

R&D strategy is a comprehensive issue. As Pisano (2012) argues, An R&D organization is like any other system: performance hinges on the coherence between the components. And, like any other system, R&D organizations cannot be designed to do all things equally well. It is because of the need for coherence and the need to manage trade-offs that R&D *strategy* is an essential ingredient for achieving superior R&D performance.

This model focuses mainly on dynamics of portfolio selection. In this model, some aspects of interaction of the portfolio decision with other issues in an R&D organization are presented. Many other aspects are poorly mentioned. However, this model is the first try to combine both system dynamics methodology with the R&D strategy framework. Pisano (2012) discusses that there is often no way to “test” hypotheses [behind every strategy] in advance. Thus, at some level, all strategies are “bets”. Despite his opinion, system dynamics delivers an appropriate ground to test the strategy in the context of R&D framework based on hypothesis behind it.

This model presents the interaction between portfolio and people. It shows how the portfolio decision changes the composition of human resources through time. Concentration of portfolio decision on every field leads to heavier investment in that field, increases need for staff in that field, and changes the composition of human resources in favor of that field. The strategy in people does also affect portfolio selection. As people in R&D organization are experienced in some fields of knowledge, the company should define projects in that field to use its human resources efficiently. Also, these people propose projects in their fields of experience, and stand for their proposals where the portfolio strategy is bottom-up.

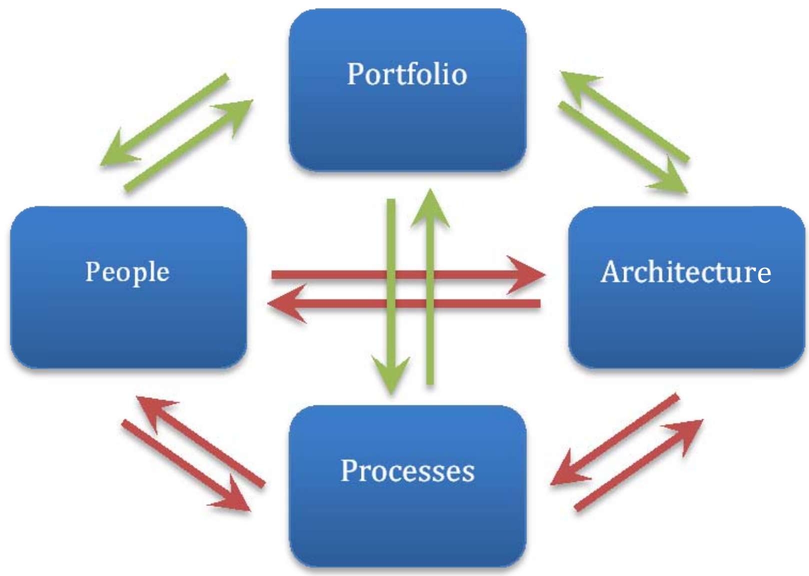

Figure٩ : Matching of the Model and R&D Strategy Framework

Also, the interaction between people and architecture is traceable in the model where network of people with outside of the organization helps them in idea generation for new projects. The architecture of the organization also affects the portfolio of the projects where a decentralized architecture can be a predictor of portfolio diversification. This fact is not shown in the model.

The interaction of portfolio decision and processes of the R&D organization can be traced in the function of *tendency to do BR or DP*. This variable can be an indicator of flexibility in the processes. Often, within a firm there are organizational processes at work that lead to "inertia" (Hannan and Freeman, 1984) or "inflexibility" (Weiss and Ilgen, 1985; Gersick and Hackman, 1990). Some aspects of this inertia are expressed in the model. This loop is completed by effects of tendency to do each type of projects on the portfolio decision this loop of interaction.

The interaction of people and processes are not directly expressed, but interaction of portfolio and processes is in dynamic interactions with people, where organizational advantage of some group of people changes the portfolio composition and this portfolio decision enforces the advantage of that group, and this portfolio does also affect the tendency of people through time, while they perform more projects in a specific field. And finally, links between processes and architecture are not explicitly presented in the model.

Model Simulation

Model Simulation was performed based on different scenarios. As the model was successfully tested as a test bench for different policies, effects of different decisions on results of the model were analyzed.

Scenario 1: No New Product Development Plan

First scenario analyzes conditions in which the senior management starts no new product development plan. This does not happen usually, and if it does in one case, it will not last long. Otherwise, the R&D organization will be closed as it will be identified as a cost center for the corporation, and it will not make returns for the investment. But this scenario was the conditions of an R&D company in Iran. The case is now a 10 years old company, and it has recently received negative signals from the corporate holding its stock.

Results from run of model with scenario 1 show that if the firm has no plans for New Product Development, rate of project finishes in R&D will grow in the first years, but starts a decline after some years. In first years, idea generation loops reinforce the number of ideas to grow, and deficiency in capacity increases investment in both research and development. After a while, with capacity reaching an amount that is almost sufficient for current projects, new projects will not make enough desires to invest in capacity, and the capacity obsolescence loop will be dominant, thus capacity will decline, forcing rate of project starts to decline.

These results show that a force to increase number of projects in hand and maximizing capacity utilization is one of the main forces for growth in a project based firm, including an R&D company.

The other factor forcing the decline in the firm is a depletion of the resource of idea that has powerful advocates in the firm. As there is no Product Development plan, number of company products in the market decreases by time, and this lessens new Product Improvement Ideas. Yet, development staffs who are dominant in the firm force the company to approve more Product Improvement projects, causing reduction in Basic Research projects approved. Lower amounts of basic research projects results in lower rate of idea generation in basic research, a reduction in the pool of idea in basic research, and the loop will be dominated by loop of obsolescence of basic research ideas.

Policy A for Scenario 1: Start NPD

In this scenario, the pool of Product Improvement Ideas becomes the dominant resource of idea, as the causal loops regarding this resource become dominant in the system. The first policy to fix problem of decline in the R&D is to charge this resource. Here we assume that the firm founds this problem in its R&D after some years, say 10 years, and the policy is executed in that section of time.

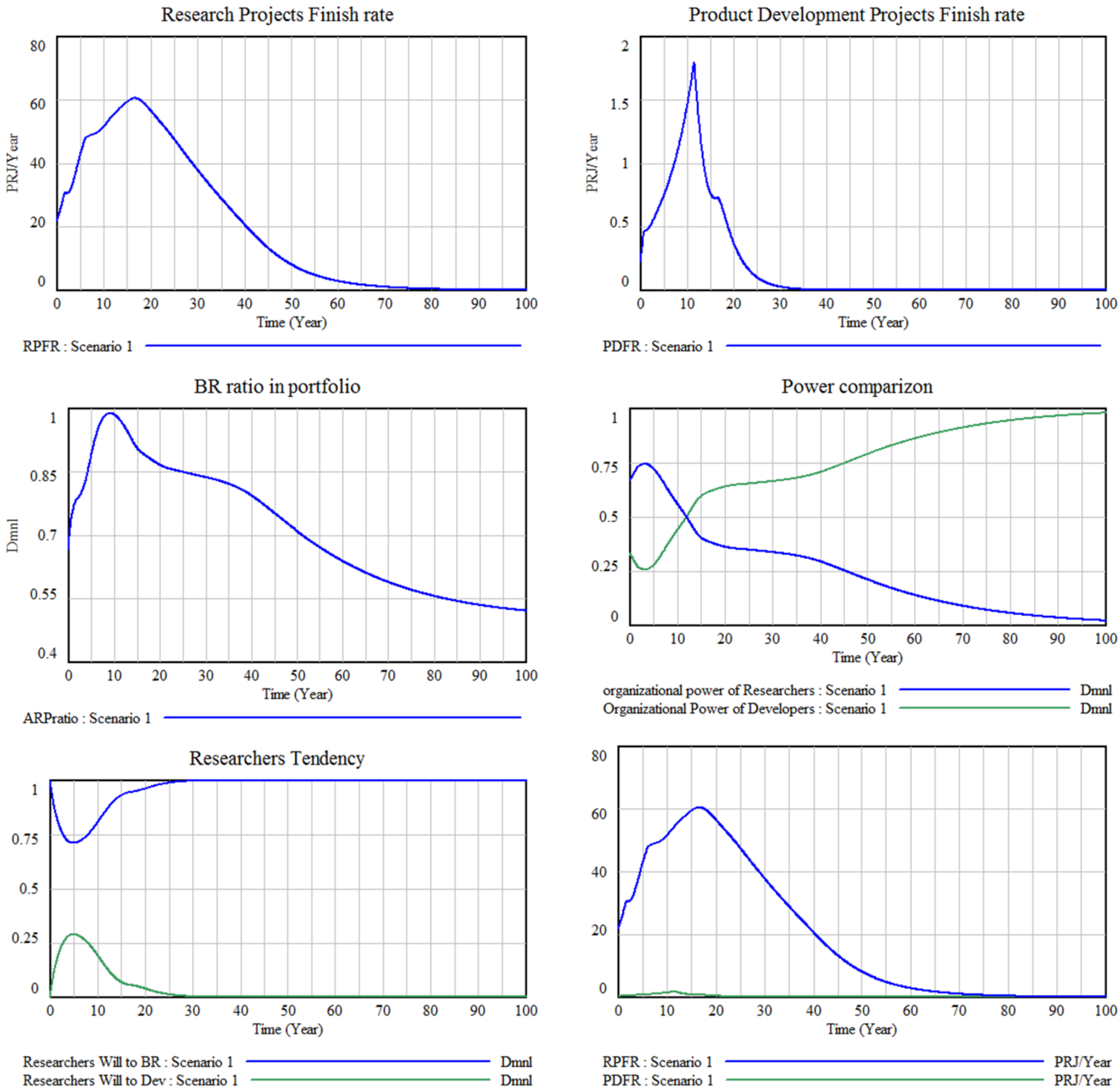

Figure 10: Model Runs for Scenario 1

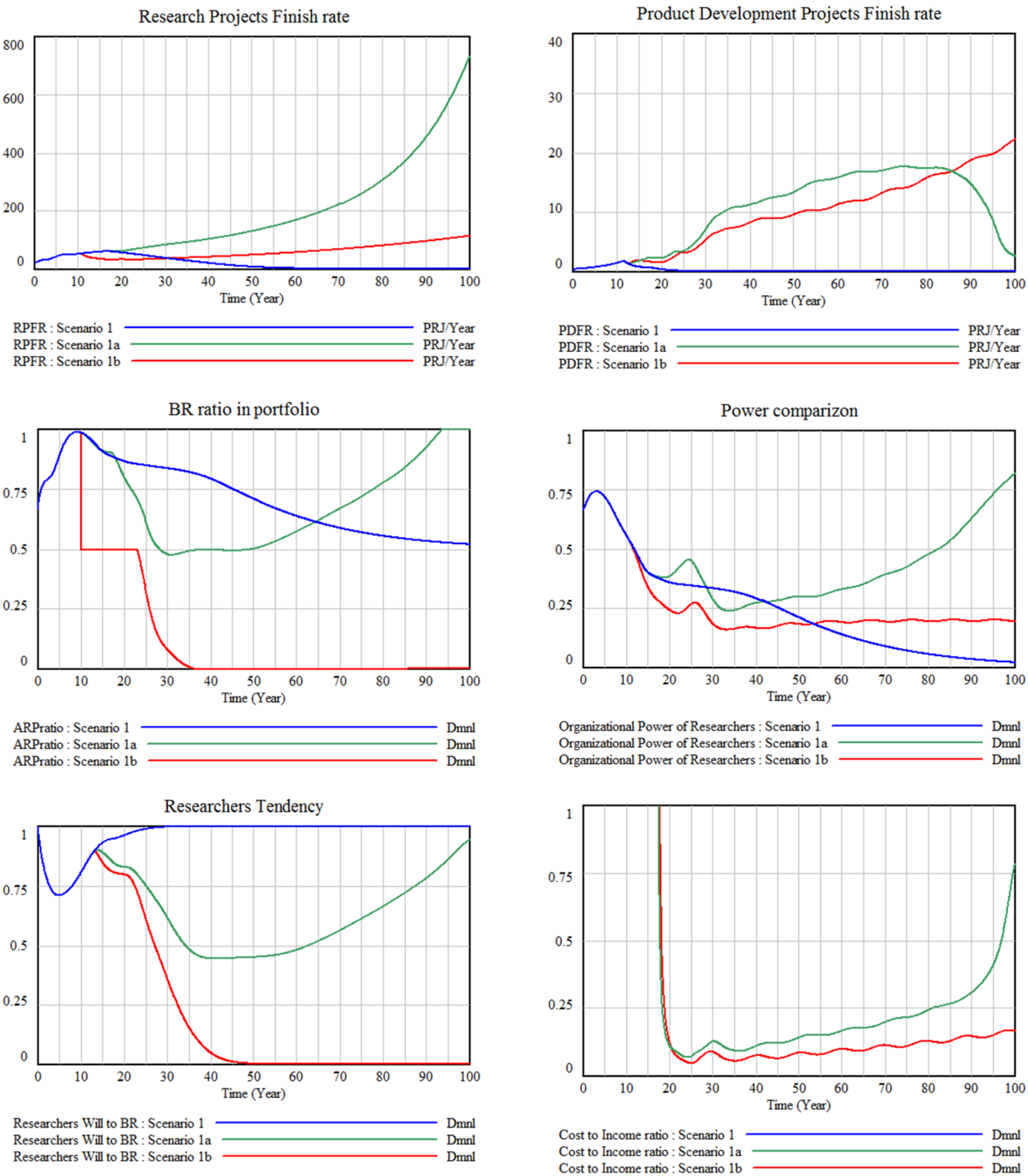

Figure 11: Model Runs for Scenario 1, Policy A and Policy B

Results show that this policy is successful in fixing the problem of decline in R&D, but it backfires as it causes in the reinforcement of loops of Basic Research. This reinforcement dominates loops related to basic research acceptance ratio after a long time, and directs the company toward an exponential growth in research projects that are not profitable for the firm. Diagrams for development projects finish rate show a trend near to logistic growth for some decades, but finally Product Improvement is stopped due to high willingness to perform basic research projects.

These results show that this policy is not an optimized decision. Policy B was implemented as a supplementary policy for the first one.

Policy B for Scenario 1: Management direct intervention

One idea is that maybe direct intervention of management can restrict unwanted growth of basic research projects. This idea was implemented into the model with a limit of 0.5 for ratio of BR to total accepted ideas, and as a supplementary policy for the policy discussed above.

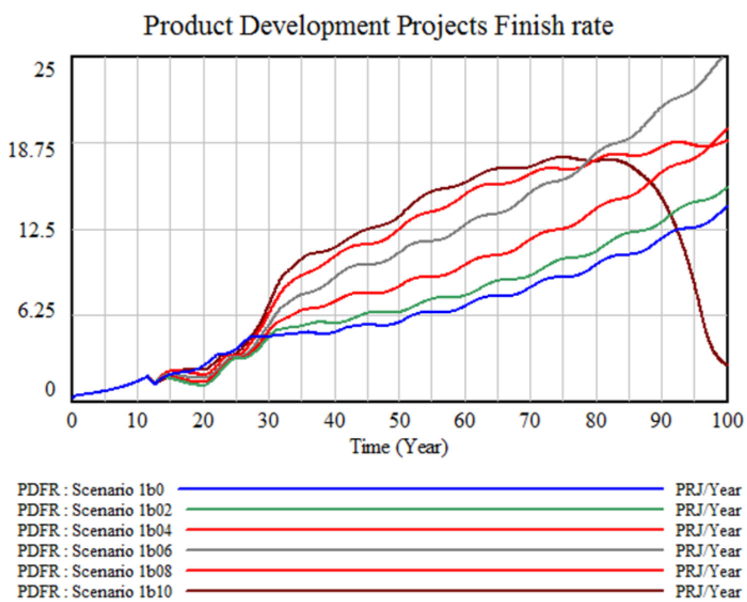

Figure 12: test results of effect of limit-Policy B

Results show that limiting ratio of accepted basic research projects works out, but a comparison between ranges of values for limits (between 0 and 1) shows that R&D performs better for short term without a limit. Also, an optimum limit for ratio of Basic Research projects was around 0.7 and 0.8. This was surprising as the prediction was that a limit near zero will be more worthwhile.

Scenario 2: Constant rate of New Product Development Plans

Scenario 2 analyzes the conditions where the company has the plan to start a New Product Development project each year. Results from this simulation show that this condition leads to a slowly growing output generation from research for first two decades, but this will change into a fast growing trend for the next several decades. This increases capacity of research, but because a great portion of the projects started in research will be Basic Research projects, this growth in research will not affect development positively.

Development outputs will experience an exponential growth for the first decade, but it changes to a goal setting growth with disordered oscillations.

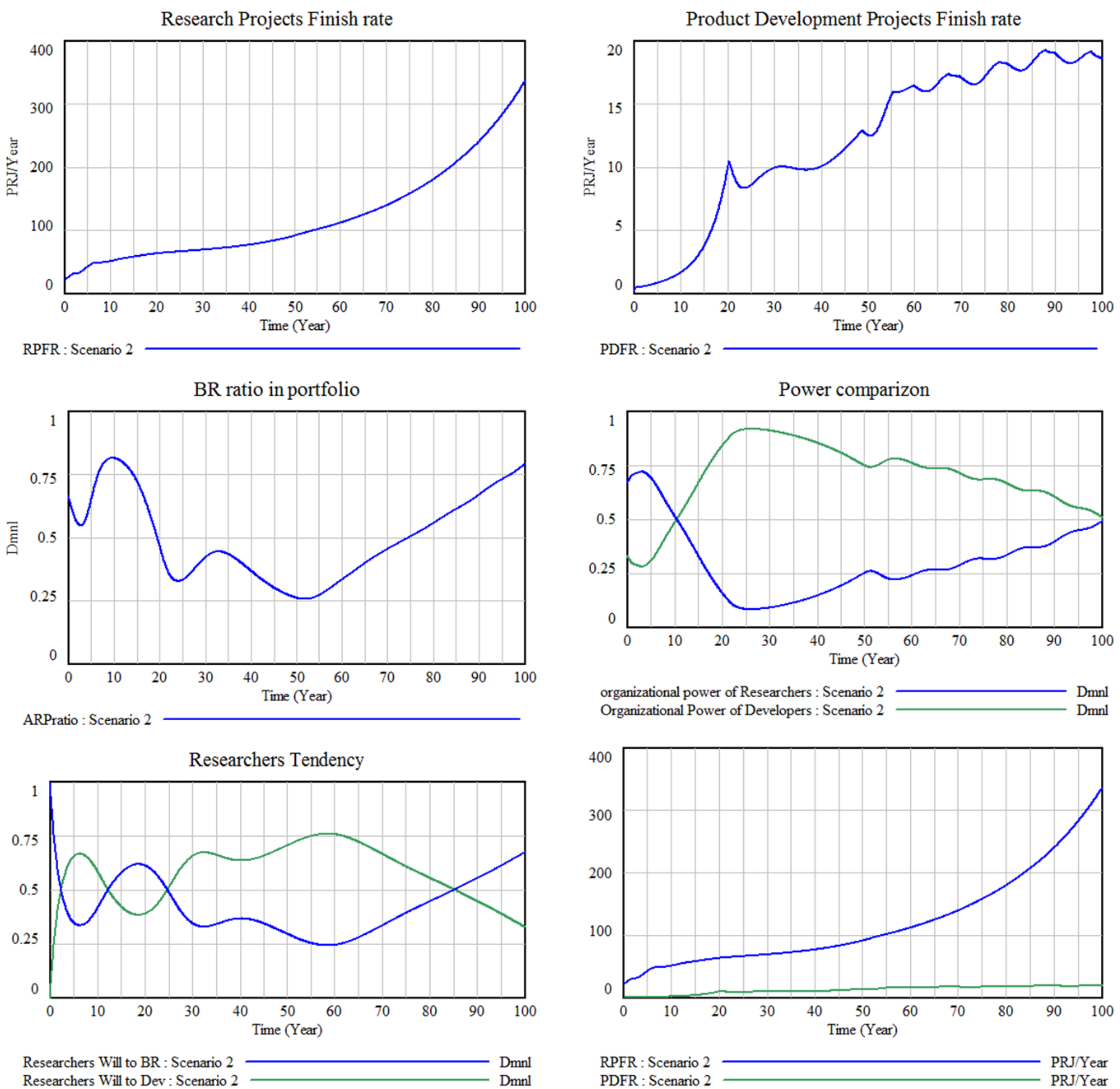

Figure 13: Model Runs for Scenario 2

Policy C for Scenario 2: Introduce Market Requirements to Researchers

Policy C suggests that the company actuate the potential within researchers for more market directed projects like Product Improvement projects. With researchers more familiarized with market requirements, the research results will be more feasible to next stages, especially in development. As performance and success probability of R&D activities are exogenous to this model, effects of this policy on them will not be viewed. But researchers will also be more effective in defining and supporting product improvement projects.

Results show that this policy would be a successful policy in increasing market related outputs of the firm. But of course, this policy increases *R&D cost* and *R&D cost to income ratio*.

Policy D for Scenario 2: Growing NPD Plan

The second policy is to plan for growth in market with strategy of growth in the number of new product development plans. Run for this policy was adjusted to get feedback from market products and plan to increase number of products, say for 20% annually. Also, the model was adjusted to start at least one plan annually.

The results are shown in comparison to base situation of scenario 2, and policy C. Results show that policy C is more powerful in controlling tendency of research to perform projects that have low technical feasibility and vague commercial potential. Both policies C and D will result in the same values over time for projects finished in development phase. But as policy D is aimed at fostering projects with high commercial potential, it gives better financial outcomes.

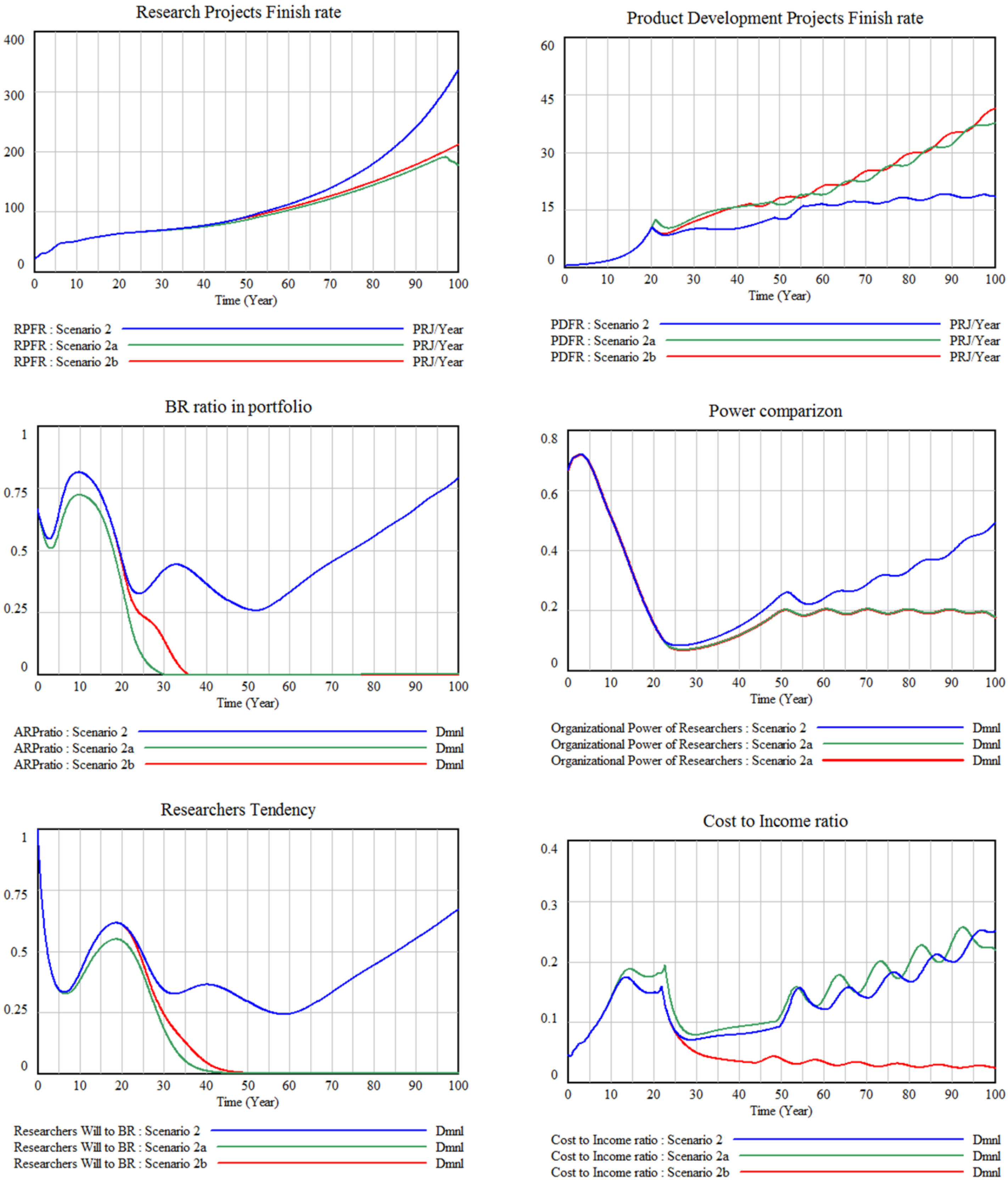

Figure 14: Model Simulation for Scenario 2, Policy C and Policy D

Conclusion

Different scenarios and policies tested in the system dynamics model showed that every exogenous intervention in a system fixes some problems and generates new problems. The main reason for this challenge inside the system lies in the nature of escalating competition inside the company. In scenarios of this model, two main sections of the R&D were in a competition to attract more resources, and get approval for more proposals of their own. The one policy that was successful was one which corrected some part of this structure, and the corrected structure led to an improved behavior. When researchers are introduced with requirements of a product for the market, they direct their attempt to more value adding projects. On the other hand, this policy led to coherence through R&D activities. Both researchers and developers aimed at improving company's products in the market and the company will be benefited from this. An R&D organization is like any other system: performance hinges on the coherence between the components. And, like any other system, R&D organizations cannot be designed to do all things equally well. (Pisano, 2012)

New Product Development plans were not taken endogenous in this model. We predict that the model which simulates endogenous new product development plans will show how the organization benefits from a more market directed R&D environment in the organization, and better trained staff will take more parts in the success of the company.

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