# Dynamic Models of Multi-Profile Resource Provision of Information System Protection and Survivability*

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## Abstract

The paper is devoted to the topical issue of the development of methods for creating dynamic models of multi-profile resource support for information protection and survivability of information systems. Analysis of existing research on the topic of the paper revealed a contradiction between the need for practice in methods of dynamic modeling of multi-profile resource support for information protection, survivability of information systems, and the imperfection of existing theoretical and applied approaches to this issue. The purpose of the study is to increase the effectiveness of dynamic models of multi-profile resource support for information protection and survivability of information systems. A feature of the formulation of the research task is the consideration of technologies for ensuring information protection and survivability of information systems as a set of technologies that work together for a common beneficial effect. At the same time, each component technology has its separate resource, which it converts into a useful effect. The most adequate dependence for the basic models was recognized as a logistic model. The results of the research of V. Shevchenko and Y. Syvytsky were taken as basic technology models. The following classification of logistic development dependencies was used: EGEL/BiS, EL/BiS, EL/BLO, EL/BiF. Models of the interaction of component technologies were built based on additive and multiplicative convolutions. The simulation results showed that the results of both types of convolutions are very similar to logistic dependencies of EGEL or EL type. It was found that the more the symmetry points of individual logistic dependencies differ, the more the effects of steps are manifested in the results of additive convolution. The primary qualitative nature of the dependencies is most preserved in the results of additive convolution of EL-type technologies. The result of multiplicative convolution is EGEL-type dependencies regardless of the primary type of dependency. In this case, there is a clear loss of the central symmetry of the dependencies.

## Keywords

computer simulation model, information system, information protection, survivability, logistic dependence, useful effect, resource, management decision support, automation, optimization

## 1. Introduction

Information protection and ensuring the survivability of information systems is an urgent task. Without this, information systems today cannot work in principle. Information protection systems are multi-component. Therefore, they require multidisciplinary resource support. All this resource support works for a general beneficial effect, which consists of the beneficial effects of individual component technologies, each of which is provided with its resources. Individual resources and technologies can be interchangeable or non-interchangeable. A complex system is formed that depends on many factors and is not clear regarding the results of its work. To predict the beneficial effects of the implementation of multidisciplinary technologies that consume multidisciplinary resources, it is necessary to create appropriate models.

Therefore, the task of creating dynamic models of multidisciplinary resource support for information protection and survivability of information systems is urgent.

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## 2. Analysis of existing studies

The works of many authors are devoted to ensuring the information protection and survivability of information systems.

In [1], the issues of survivability of information systems are thoroughly considered, but insufficient attention is paid to the creation of dynamic models of the corresponding processes. In addition, organizational issues of information protection management are not considered. A detailed analysis of organizational issues at the project management level is considered in [2, 3], but they do not contain methods for assessing the level of information danger. The issues of assessing the level of information security are considered in [4, 5], and organizational issues of information security management are considered in [6–8]. Unfortunately, these works do not disclose the issues of creating relevant models. Methodological approaches to creating dynamic models are considered in [9], but the issues of ensuring the survivability of information systems are not considered. Modeling threats of epidemiological type computer attacks are considered in [10], but the issues of the beneficial effect of the joint use of different technologies are not considered. Cyber protection models and dynamic cybersecurity models are considered in [11, 12], but they do not contain an assessment of the results of technology sharing. Modeling the results of technology sharing is considered in [13], but only the issues of transforming the structure of projects or technologies are considered. That is, the sequential use of technologies is considered. The beneficial effect of the simultaneous use of resources or technologies is considered in [9], but the specifics of information protection technologies and ensuring the survivability of information systems are not taken into account.

Thus, during the analysis of existing research, a contradiction was identified between the need for practice in methods of dynamic modeling of multidisciplinary resource support for information protection, survivability of information systems, and the imperfection of existing theoretical and applied approaches to this issue.

The purpose of the paper: is to increase the effectiveness of dynamic models of multidisciplinary resource support for information protection and survivability of information systems.

## 3. Classification of logistic models of effectiveness of projects ensuring the survivability of information systems

In the works of Y. Syvytsky and V. Shevchenko, the use of an atomic development model is proposed, which in itself implements the simplest patterns of development, but at the same time can be part of very complex hierarchical structures (Fig. 1). In each node of such a model, an exponential or linear dependence of the growth of the useful effect on the input resource can be implemented. At the output of the model (upper node) as a useful effect, we can receive the level of cybernetic or information security, the quality of performing individual tasks regarding the security of the information system, and the profit of the organization, as the difference between economic profit and losses from cybernetic or information security incidents. Any resource or combination of resources can be supplied to the input of the system (inputs of lower-level nodes): finances, material resources, human resources, technologies, licenses, property rights, level of reputation, time, etc. In this study, the time of technology implementation or the time of project implementation to ensure information protection and the survivability of the information system is considered as an input resource. If instead of a useful effect, negative results are obtained at the output, then we will still call them a useful effect. Only this useful effect will have a negative sign. This approach allows us to develop a single technology for predicting the dynamics of the development of complex technologies that contain many different component technologies.

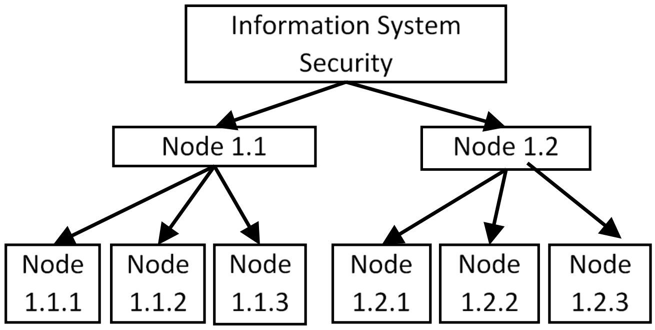


**Figure 1:** Example of Structural and logical model of information system security

It is well known that atomic models, which make up more complex models of large technologies, implement exponential and linear development dependencies. However, the processes always begin with exponential growth, in which resource consumption does not lead to a noticeable increase in the useful effect (latent period of technology implementation). Then begins a stage of sharp growth (first exponential, then linear), which corresponds to the full development of technology, in which the useful effect at the output of the system is proportional to the resources entering the system. Unfortunately, the capabilities of any technology are not unlimited. Therefore, there comes a time when the technology approaches the limit of its maximum development and any additional resources do not lead to its further growth. This stage corresponds to the model of exponential growth in the zone of approximation to the upper asymptote (saturation zone). To combine all the stages that we have considered, we use a common model based on logistic dependence.

The logistic dependence can be written as an ordinary differential equation

$$\frac{dE}{dt}=m(E-d)(a-E). \tag{1}$$

where $E$ is the useful effect at the output of the system (atomic model), $t$ is the time, $d$ is the lower asymptote of development, $a$ is the upper asymptote of development, m—coefficient that determines the growth rate of the logistic dependence, the multiplier $(E-d)$ provides slow growth along the lower asymptote, and the multiplier $(a-E)$ provides a slowing down of growth when approaching the upper asymptote. The differential form of the logistic dependence clearly shows that the fastest growth occurs at the maximum distance of the process from both asymptotes. The symmetry of the multipliers on the right-hand side of the differential equation determines the central symmetry of the logistic dependence. The result of solving the differential equation with constant coefficients is the integral form of the logistic dependence

$$E=SL(t)=d+\frac{a-d}{1+e^{\frac{-2}{T}(t-s)}}. \tag{2}$$

The following variables were added to this equation: $T$ is the constant of the logistic dependence, $s$ is the abscissa of the point of central symmetry of the logistic dependence. The abscissa of the point of central symmetry depends on the initial conditions for integrating the differential equation of the logistic dependence.

In real tasks of ensuring information protection and survivability of information systems, resources are multi-profile. That is, just as in (Fig. 1), several different resources that interact with each other enter the system input. The main types of interaction are additive and multiplicative convolutions. To study the features of such types of internal interaction of multi-profile resources, we will define a standard set of logistic dependencies that describe the effectiveness of such resources.

Let us clarify the understanding of the concept of efficiency within the framework of this study. Efficiency $E'$ is the ratio of the effect $E$ (beneficial effect) to the resources $R$ spent on its achievement

$$E' = \frac{E}{R}. \tag{3}$$

In our study, the time spent on developing individual components of technologies for ensuring information protection and the survivability of information systems is considered as resources

$$E' = \frac{E}{t}. \tag{4}$$

Note that such dependencies for efficiency occur if the dependence of the effect on resources is linear. In our case, the dependence of the effect on the input resource of time is nonlinear, namely, logistic for all components of technologies and, accordingly, for all components of multi-profile resource provision.

$$E_i = SL_i\left(t_i\right). \tag{5}$$

The subscripts denote the different types of input resources and the corresponding technologies for which they are intended.

In further modeling, we will consider multi-profile resources and the corresponding logistic dependencies of beneficial effects, which have five 5 components. We will use the classification of patterns of project and technology development, which was proposed in the studies of V. Shevchenko and Y. Syvytsky:

- EGEL—Exponential Growth without limits and Exponential growth in the zone of technology Limits (full logistic dependence).
- EL—Exponential growth in the zone of technology Limits (upper part of logistic dependence).
- BiS—Bigger technologies are Slower.
- BLO—Bigger technologies have a larger upper Limit Only.
- BiF—Bigger technologies are Faster.

The corresponding components of multi-profile resources are presented in (Figs. 2–7).

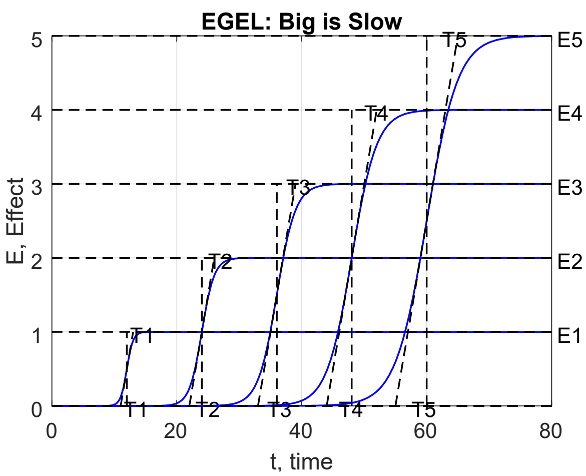


**Figure 2:** EGEL/BiS technology, $a = [1\,2\,3\,4\,5]$

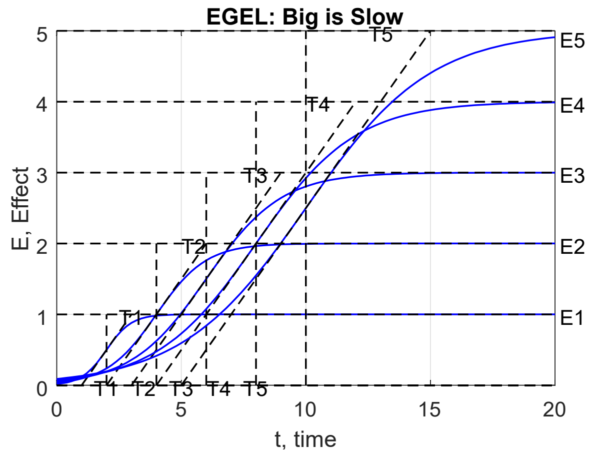


**Figure 3:** EGEL/BiS technology, $a=[1\,2\,3\,4\,5]$, $s=[2\,4\,6\,8\,10]$)

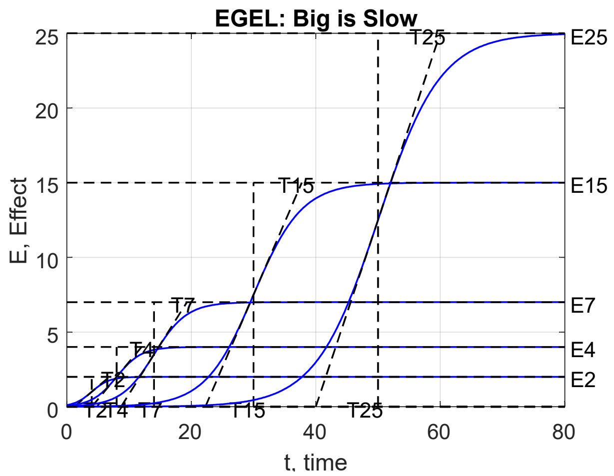


**Figure 4:** EGEL/BiS technology, $a=[2\,4\,7\,15\,25]$

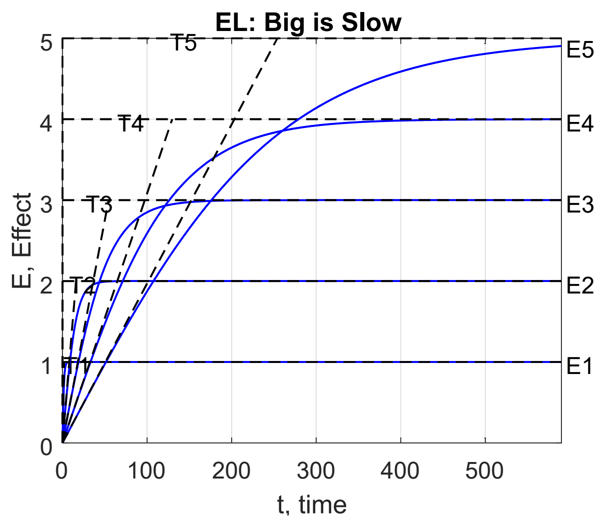


**Figure 5:** EL/BiS technology, $a=[1\,2\,3\,4\,5]$

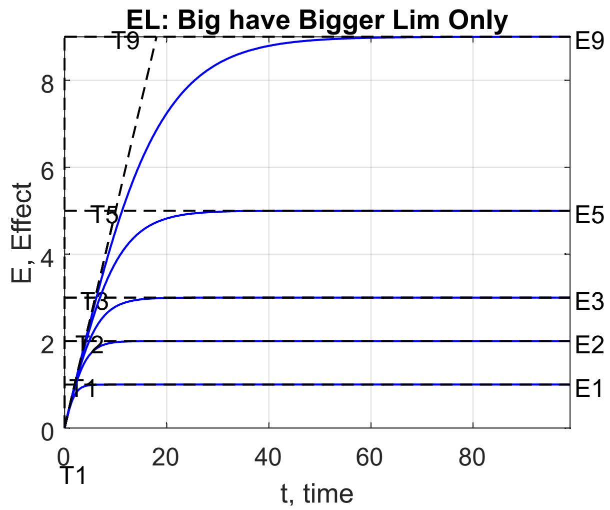


**Figure 6:** EL/BLO technology, $a = [1 2 3 5 9]$

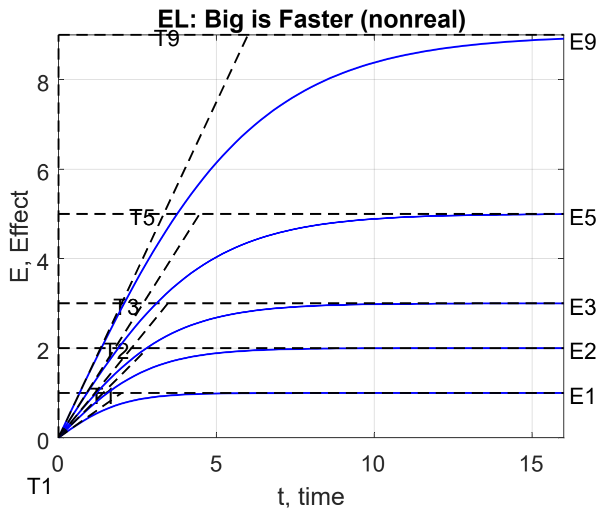


**Figure 7:** EL/BiF technology, $a = [1 2 3 5 9]$

## 4. Results of additive convolution

The most common variant of scalar convolution is additive convolution, which corresponds to a situation in which complete interchangeability of input resources or technologies located at the same level of hierarchy in the overall technology structure is possible

$$E_{\Sigma} = \sum_{i=1}^{5} SL_i(t_i). \tag{6}$$

The simulation results are presented in (Figs. 8–13).

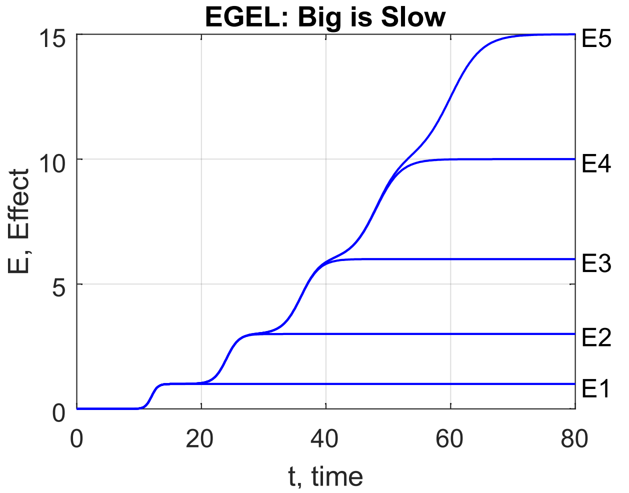


**Figure 8:** The result of additive convolution of beneficial effects of EGEL/BiS technology, $a=[1 2 3 4 5]$

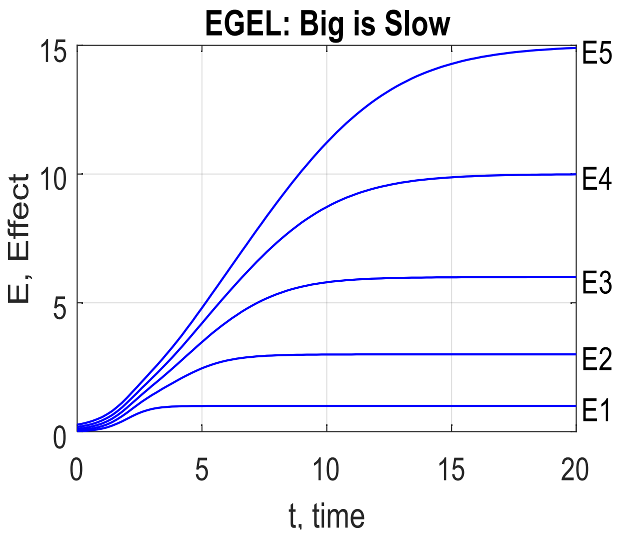


**Figure 9:** The result of additive convolution of beneficial effects of EGEL/BiS technology, $a=[1 2 3 4 5]$, $s=[2 4 6 8 10]$

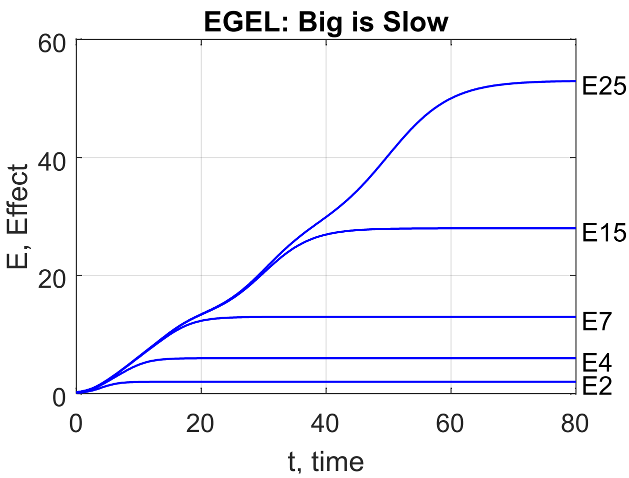


**Figure 10:** The result of additive convolution of beneficial effects of EGEL/BiS technology, $a=[2 4 7 15 25]$

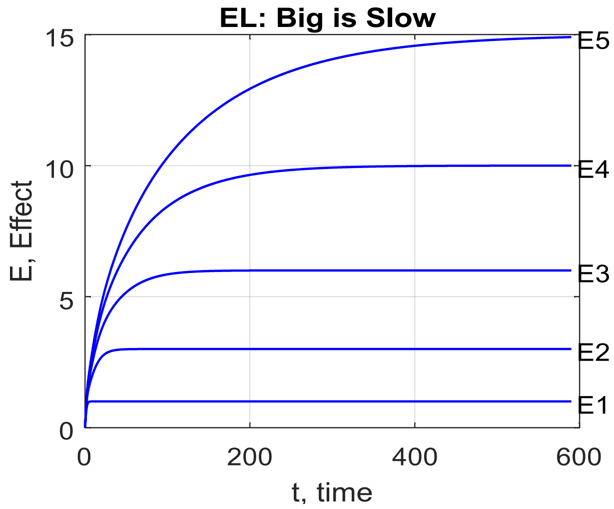


**Figure 11:** The result of additive convolution of beneficial effects of EL/BiS technology, $a=[1 2 3 4 5]$

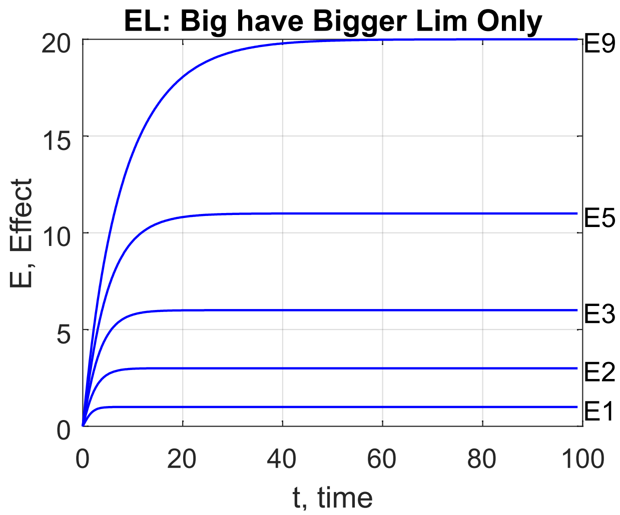


**Figure 12:** The result of additive convolution of beneficial effects of EL/BLO technology, $a=[1 2 3 5 9]$

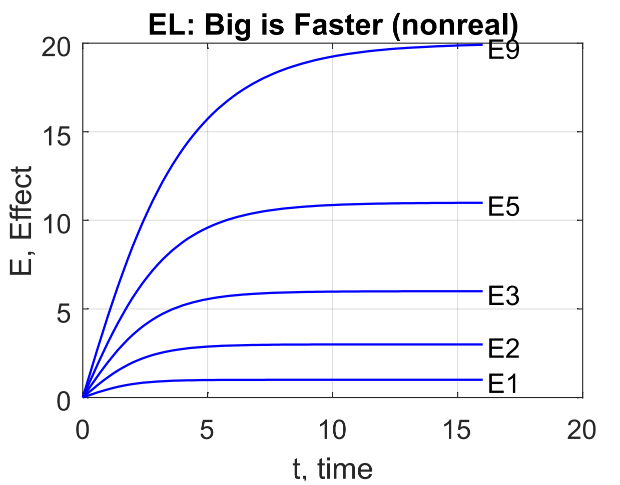


**Figure 13:** The result of additive convolution of beneficial effects of EGEL/BiF technology, $a=[1 2 3 5 9]$

The simulation results first present the graph of the smallest dependence without convolution, then the result of convolution of the two smallest dependences of beneficial effects, and then three, four, and five.

## 5. Results of multiplicative convolution

Multiplicative convolution is required in cases where the interchangeability of resources (technologies) occurs but is not complete.

$$E_{\Pi}=\prod_{i=1}^{5} SL_i(t_i). \tag{7}$$

The simulation results are presented in (Figs. 14–19).

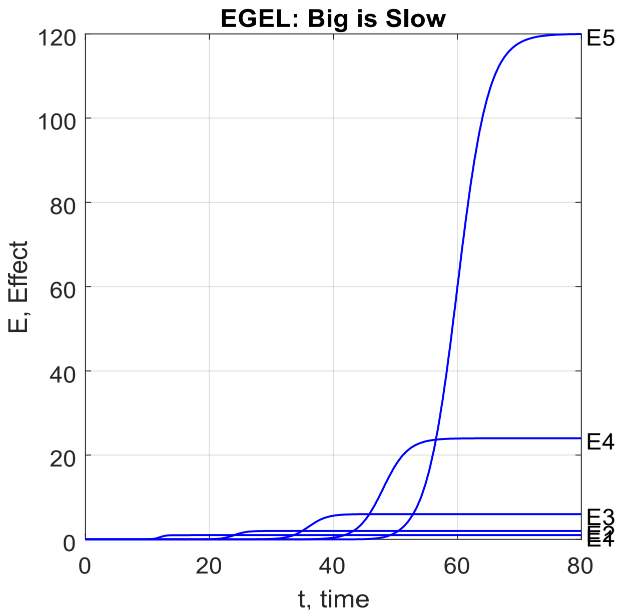


**Figure 14:** The result of multiplicative convolution of beneficial effects of EGEL/BiS technology, $a=[1 2 3 4 5]$

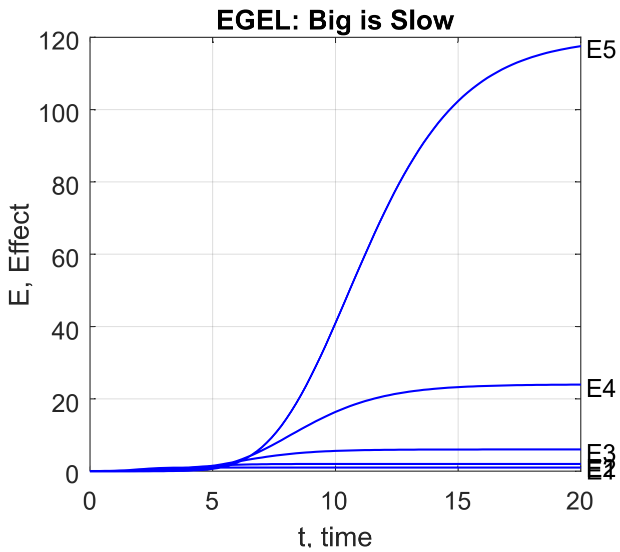


**Figure 15:** The result of multiplicative convolution of beneficial effects of EGEL/BiS technology, $a=[1 2 3 4 5]$, $s=[2 4 6 8 10]$

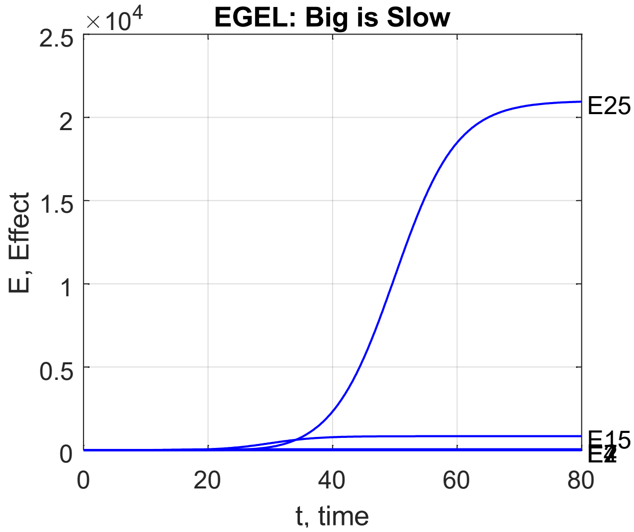


**Figure 16:** The result of multiplicative convolution of beneficial effects of EGEL/BiS technology, $a$=[2 4 7 15 25]

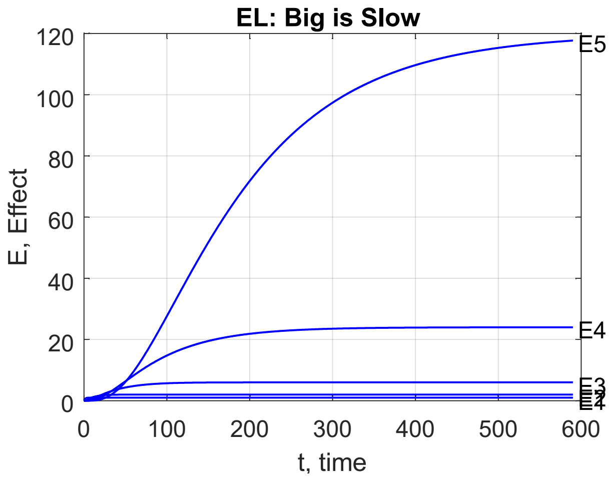


**Figure 17:** The result of multiplicative convolution of beneficial effects of EL/BiS technology, $a$=[1 2 3 4 5]

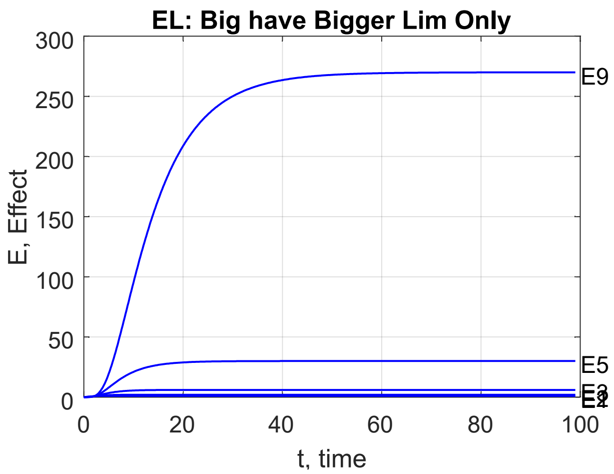


**Figure 18:** The result of multiplicative convolution of beneficial effects of EL/BLO technology, $a$=[1 2 3 5 9]

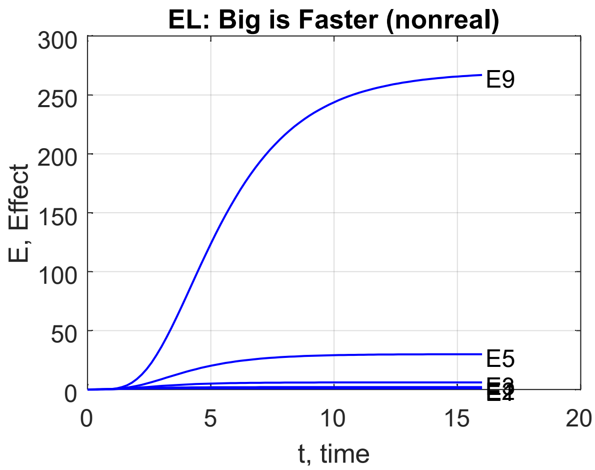


**Figure 19:** The result of multiplicative convolution of beneficial effects of EGEL/BiF technology, $a$=[12359]

As in previous cases, the simulation results first present the graph of the smallest dependence without convolution, then the result of the convolution of the two smallest dependences of beneficial effects, and then three, four, and five.

## Conclusions

The paper considers models of the useful effect of technologies consisting of separate component technologies that consume multi-profile resources. The types of joint operation of individual technologies on the overall useful effect are considered in the form of models of additive and multiplicative convolutions. The modeling results showed that the results of convolution are very similar to logistic dependencies of the EGEL or EL-type. The more the symmetry points of individual logistic dependencies differ, the more the effects of steps are manifested in the results of additive convolution. The primary qualitative nature of the dependencies is most preserved in the results of additive convolution of EL-type technologies. The result of multiplicative convolution is EGEL-type dependencies regardless of the primary type of dependency. In this case, there is a clear loss of the central symmetry of the dependencies.

## Declaration on Generative AI

While preparing this work, the authors used the AI programs Grammarly Pro to correct text grammar and Strike Plagiarism to search for possible plagiarism. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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