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On the Formulation of a Multi-dimensional Indicator of the Sustainability of Production

Hamed Fazlollahtabar*[1]

[1]*Department of Industrial Engineering, School of Engineering, Damghan University, Damghan, Iran*
**Corresponding author, email address: h.fazl@du.ac.ir*

Abstract

Concerns regarding the environment and social challenges have led to the evolution of a three-dimensional concept of sustainable development, which is based on costs and benefits in the domains of the economy, environment and society. This article presents such a multi-dimensional evaluation of business development based on data regarding indicators of sustainability. Such a procedure is required to determine whether development is balanced and where development strategies are malfunctioning. The sustainability measure proposed takes into account economic elasticity and pricing parameters, in order to handle the most important element of sustainability, namely macro-economic functions. The implementation of this method and assessment of sustainability are illustrated using data from an agricultural company.

Keywords: *Sustainability, sustainable value, sustainability measurement, pricing*

1. Introduction and literature review

In the past, companies have focused only on economic issues and their development strategies were mainly based on shareholder's expectations. Firms often were judged based on their financial performance, while the social and environmental effects of their businesses were usually not reflected in traditional financial statements. Therefore, sustainable development in the 1980s emerged in response to destructive social and environmental effects of a perspective that focused solely on economic growth [1]. According to a study by the Economist Intelligence Unit (EIU), about 75 percent of large international organizations were under pressure to report on their social and environmental performances alongside financial measures [9]. Measuring corporate's sustainability is important, as anything that cannot be measured, becomes unmanageable [3]. The role of firms in achieving sustainable development has been widely discussed in past decades [21]. To date, a large number of indicators for measuring a firm's contribution to sustainability have been introduced. Current approaches to measure sustainable performance of firms, consider external costs caused by social and environmental damages or focus on the ratio of the

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value creation to the use of resources[16], and in some cases multi objective mathematical programming models have been used to maximize economic and social benefits and minimize negative environmental impacts [8, 25, 28].

Our research provides a model for measuring sustainable development at the firm level by using pricing concept and modifying the Sustainable Value (SV) approach. The SV approach is chosen as it is the only value-based assessment approach of sustainability performance [22]. Two unique features of SV, which is the simultaneous consideration of the three aspects of sustainability as well as measuring firms' contributions to sustainability in monetary terms, have resulted in this approach to be adopted by many firms.

SV approach was developed first by Figge and Hahn [14]; it is created by an organization, when the resources are used more efficiently. Although SV is a relative efficiency indicator, it is arisen from strong sustainability [20]. SV approach is based on an assumption, which reallocate resources from firms with less efficiency in sustainability performance to ones that are more efficient in order to achieve a strong sustainability [14]. In the following, the inherent shortcomings of the assumptions made by Figge and Hahn in reallocating resources from one firm to another have been demonstrated and an alternative has been suggested.

Despite being developed and proposed recently, the SV approach [13–16] has attracted considerable attention and sparked at times lively debate[19, 23, 26, 28]. By conducting a productive efficiency analysis, Kuosmanen and Kuosmanen [20] claimed to propose novel insights into how SV is developed and formulated. The concept of sustainable production is closely related to the concept of sustainable development. The main cause of environmental destruction is the unsustainable pattern of production and consumption, especially in industrialized countries. While green and sustainable consumption targets consumers, sustainable production deals with companies and organizations that produce products and provide services. Although the concept of sustainability is still a nebulous concept, there is a growing consensus on this. That is, moving from trying to define it, to developing real and practical tools to promote and measure necessary achievements. Therefore, at the same time, there was an interest in sustainable development and the internal challenges related to it. This conflict introduced the concept of industrial ecology and industrial symbiosis to sustainable production [22]. Currently, production systems use methods and technologies that are generally not sustainable, as a result, sustainable production is considered an important issue for manufacturing organizations. Most companies have concluded that in order to be sustainable in production, it is necessary to measure and control the indicators of sustainable production, and it is also important to identify the obstacles that hinder the implementation of sustainable production. Costanza et al. [6] provided an integrated view of the concept of customer value by using the communication between the strategic view (customer value from the company's perspective) and the marketing view (customer value from the customer's perspective). Another goal was to determine the priorities of sustainable value creation based on the intelligent marketing information system based on the diagramming theory. The SV method developed by Figge and Hahn [13, 14] has been widely recognized as a promising approach for measuring corporate contributions to sustainability. In today's competitive and changing business environment, the competition in providing the expected value of the stakeholders has replaced the competition in providing quality products to the customers. The value created by businesses is a perceptual concept that is formed according to the knowledge, feelings and experiences of the stakeholders and undergoes changes over time and under the influence of various external and contemporary factors. On the other hand, paying attention to areas such as the environment, to reduce poverty, improve health and issues of this kind in the form of social responsibility is very effective as one of the main components of the identity of businesses [11]. The integration of environmental and social aspects with economic considerations, known as the triple-bottom-line (TBL), as dimensions of organizational sustainability [4], has continuously gained relevance for managerial decision making in general and for supply chain management (SCM) [10] and operations management in particular [5]. From a process-oriented or cross-functional perspective, SCM comprises planning, sourcing, production, and distribution logistics but is not exclusively focused on one of these areas [27]. Measuring sustainable production indicators is becoming an important environmental activity due to government orders and increasing people's awareness to protect the environment and reduce waste. Sustainable production indicators can be used to evaluate the effect of various management and production activities and thus provide a suitable mechanism to monitor the performance of sustainable production in order to move towards the sustainability of the company [17]. In particular, it should be that there are different ways to measure sustainable development.

Life cycle assessment (LCA) is a valuable tool not only for analyzing the environmental impact of a product but also for assisting in early-stage product development before incurring scaling-up costs. When validating a new process or project, it may be constrained to align with existing regulations or standards. Therefore, combining LCA with other applicable standards is essential to demonstrate the project's feasibility [18].

In today's engineering industries, there is a growing focus on sustainable and eco-friendly products due to their recyclability, abundant availability and property variability. One key aspect of this sustainability effort is the development of eco-friendly materials, particularly bio composites derived from agricultural waste residues [24].

As the whisky industry applies circular economy principles to maximize resource utilization and minimize environmental impact, companies become exposed to several risks, which require complex assessments to ensure reliable outcomes. Researchers in [7] provided an organized framework to identify, prioritize, and rank various risk factors commonly observed in the whisky industry through the development of an analytical hierarchy process (AHP) multi-criteria analysis model. Experts from 18 small European distilleries identified five main risk criteria and nineteen sub-criteria from brainstorming workplace observations and categorized them as: environmental (5), operational (4), technological innovation (3), food safety (3), and economical (4) risks. The AHP was used to determine the weights and ranks of the main criteria and sub-criteria based on the survey responses received from experts from each distillery.

Monitoring the transition to a circular economy requires not only the measurement of circularity but also of environmental impacts, which often present trade-offs due to different perspectives when assessing a product. This article [2] proposed a novel approach, named ECI-MCDA, to combine circularity and Life-Cycle Assessment (LCA) indicators via Multi-Criteria Decision Analysis (MCDA) non-compensatory methods (Electre I and Electre TRI).

Most researches have introduced frameworks for measuring sustainability, but disabled to provide a comprehensive measurement tool or framework, i.e., results were only expressed in the form of a number, which makes it challenging for further analysis. Therefore, this study aims to consider the dynamics of valuation indices as well as the different impacts of indices on the various supply chain layers. In addition, the concept of demand and elasticity function is used in order to calculate the sustainable value (SV). Meanwhile, the importance of different indicators in different layers of supply chain is considered using the concept of elasticity. In addition, lack of a unique indicator that can, in addition to sustainability evaluation, answer the question whether the firm is sustainable and which indicators help to improve the firm's position in order to maximize participation in sustainability considering the effect of production factor is considered.

The remainder of the paper is organized as follow. In section 2, the proposed problem and modeling process for sustainable value formulation are given. In Sections 3, the implementation study is detailed. Analysis on the results and discussion on various implications are explained in Section 4. Finally, the conclusion is provided in Section 5.

2. Problem statement and modeling

The objective of the research is to provide a model to determine the impact of sustainability indicators on the layers of a supply chain. As already pointed out, in the model introduced by Fig and Hahn [15] only the profit (value obtained) was considered without any consideration for possible loss (lost value). Further, to imply the significance of each sustainability indicator in the supply chain, while expressing their economic importance, an attempt is made to establish a factor that can distinguish SV in the different layers of the chain, in which the firm have different impact in different layers of the chain.

Sustainable Value is about integration. Sustainable Value integrates the economic, environmental and social dimension of sustainability. Sustainable Value integrates environmental and social dimensions into financial analysis and investment decision making. And Sustainable Value integrates academic research and real-world application. Sustainable Value Creation (SVC) is creating value for all stakeholders in a way that contributes to a sustainable society. It is not only about economic value, but also about ecological and social value. SVC requires systems thinking, in which organizations take into account the impact of their activities on the environment, society and future generations.

The idea of sustainable value, therefore, is to show how "the multiple challenges associated with global sustainability, seen through the appropriate business lenses, can help to identify strategies and practices which improve performance in all four quadrants of the shareholder-value framework. This, in turn, facilitates the creation of sustainable value for the firm."

Interestingly, they begin by looking at the basic components of shareholder value, which they illustrate through a matrix with four quadrants. The two axes represent time (today versus tomorrow, i.e. the short-term versus the long term) and place (internal versus external, i.e. within the firm versus beyond the firm). This results in four distinct dimensions of performance crucial to generating shareholder value: cost and risk reduction (today, internal); reputation and legitimacy (today, external); innovation and repositioning (tomorrow, internal); and growth path and trajectory (tomorrow, external).

Therefore, in this research, the linear demand function is applied for the pricing purpose. Pricing is included to express the value of each sustainability indicator in relation to the demand for different sustainability dimensions in the supply chain. In addition, to analyze the resilience of sustainability indicator in supply chain layers, price elasticity of demand has been adopted. Sustainability indicators have a wide range of dimensions and scales. In order to measure the SV, in this research a non-proportional approach is used. To achieve maximum value in three dimensions of sustainability, parameters including economic growth, normalization factor, indices elasticity, value added and linear demand function are adopted.

2.1. Sustainable value evaluation

One of the longest ongoing debates in the business world in terms of economic, political and human development involves the evolution of sustainable development. Throughout his life, humans have caused the environment to be endangered by using nature excessively. For this purpose and to minimize environmental impacts, a concept called sustainable development emerged in the past few decades. Global population growth and lack of resources are the two main categories damaging the sustainability of the environment. Such growth in population and economic activity has the potential to significantly increase the pressure on natural resources and natural systems. These damages to agricultural lands and the global atmosphere are very high and it may seem that there is no way to provide the resources of this population. Sustainable development and its goals can provide solutions for today's people for tomorrow's people. This study develops a mathematical model to measure sustainable value in a supply chain using the concept of demand-based pricing formulation. The purpose of the pricing is to investigate the impact of demand on each sustainability indicator in each layer of the supply chain. In addition, price elasticity is considered to express the relative importance of sustainability indicators and their impact on prices.

Price elasticity is used to understand how the supply and demand for a product change when its price changes. Like demand, supply also has an elasticity known as the price elasticity of supply. As is well known, the price elasticity of supply refers to the relationship between a change in supply and a change in price. Both of these elasticities are considered for price changes. The two elasticities are combined to determine what goods are produced at what prices. Knowing the price elasticity of demand for a product allows the seller of that product to make informed decisions about pricing strategies. This measure provides information to sellers about the price sensitivity of consumers. It is also important for manufacturers to determine production schedules and for governments to assess how to tax the product.

Finally, the introduction of relations between elasticity and pricing is an appropriate tool to calculate SV. Equation (1) is used to measure SV and then by using mathematical modelling and its relevant constraints, the optimum SV is obtained.

$$SV_{ij} = EG - \frac{K_{ij}}{\sum_i K_{ij}}[(-\frac{Elast_{ij}}{Elast_i} + \frac{VA_{ij}}{VA_i}) * P_{ij}] \quad (1)$$

SV_{ij}: The sustainable value of the *i*-th index in the *j*-th layer.

EG: Economic Growth.

$\frac{K_{ij}}{\sum_i K_{ij}}$: The *i*-th sustainable index value in the *j*-th layer.

$\frac{Elast_{ij}}{Elast_i}$: elasticity of each index relative to the dimensional sustainability.

$\frac{VA_{ij}}{VA_i}$: Value-added of each *i*-th index in the *j*-th dimensional / value added of each dimension of sustainability.

$p = \alpha + \beta D_{ij}$: The inverse function of the demand of each index in each sustainability dimension.

D_{ij}: Demand for the *i*-th index in the *j*-th layer.

2.2. The linear demand function

In this paper linear demand function is expressed as below. The pricing model is given in equation (2):

$$P_{ij} = \alpha_{ij} - \beta_{ij} D_{ij} \forall i, j \tag{2}$$

P_{ij} is a reverse linear demand function that takes into account elastic coefficients and uses the amount of demand to estimate the price. Also, β_i is the slope of the estimated price line, which is based on demand and is given by equation (3):

$$\beta_{ij} = \frac{-\sum_i \sum_j (de_{ij} - \bar{d})(p_{ij} - \bar{p})}{\sum_i \sum_j (p_{ij-\bar{p}})^2} \forall i, j \tag{3}$$

α_{ij} is the intercept of the estimated price line, based on demand and obtained by (4):

$$\alpha_{ij} = \bar{d} + \beta_{ij}.\bar{p} \forall i, j \tag{4}$$

$\bar{p}$ is the average price of all indicators of three dimensions of sustainability in all layers of the supply chain, given by (5):

$$\bar{p} = \frac{\sum_i \sum_j p_{ij}}{R} \forall i, j \tag{5}$$

$\bar{d}$ is the average demand for all indicators of three dimensions' sustainability in all supply chain layers (6).

$$\bar{d} = \frac{\sum_i \sum_j d_{ij}}{R} \forall i, j \tag{6}$$

It should be noted that alpha and beta in equation (2) are the intercept and slope in the regression line for price. The purpose is to use past data for demand price estimates.

3. Implementation

To study sub-groups of sustainability impacts, the sustainability indicators values are required to obtain SV over 5 years. Using the elasticity formula (the difference in the value of each indicator over 5 years, divided by the average). The elasticity values of each indicator are calculated and then using the valuation formula (1), the value of the SV for each index is calculated.

3.1. Sustainability ratio

In order to indicate the amount of SV obtained or lost by a firm, one can use equation (1). However, this amount alone cannot indicate that the firm is in a sustainable state or not. To this end, the concept of sustainability ratio (SR) has been introduced in this research. This ratio, which is represented by , indicates the ratio of the SV obtained by a firm to its revenues. If the obtained value is less than one, the firm is in an unsustainable state, while the values of one and higher, indicates the firm's sustainability.

$$SR = \frac{SV}{I} \tag{7}$$

The indicator values of each sustainability dimension as input data are shown in Table 1 (the values are extracted from [?]. The sum of the elasticity values associated with the sustainability dimensions are shown in Table 2. It should be noted that the layers of supply chain are supply, production and consumption; in each layer, the sustainability indicators are differently identified. Then,

$$Elast_{ij} = \frac{\Delta K_{ij}}{\Delta P_{ij}} \tag{8}$$

Using equation (8) and data given, elasticity is computed for each dimension of sustainability in Table 2.

Indicator type		Value obtained /(Lost)
Social	The number of female personnel	4.09
	the number of male personnel	5.04
	the amount of educational courses	7.56
	distribution of educational and promotional publications	-4.02
	the unit of protection	3.65
	guilty person	1.49
Economic	value-added share of agriculture	4.62
	the investment amount from the public budget	4.52
	production value	4.37
	the request capacity created for processing industries	4.73
	the performed projects related to the bio-environmental responsibility	4.48
Environmental	the products resulted from recycled materials	4.42
	the processing rate of the products	4.61
	the area of natural and unnatural water resources usage	-19.57

Table 1. The indicator values of each sustainability dimension [27]

Environmental Elasticity	Economic Elasticity	Social Elasticity
5.7316	5.8337	2.9884

Table 2. Elasticity of each dimension of sustainability

The values of all selected indicators, which respectively correspond to parameters given in equation (1) follows here. Economic growth in the agricultural sector is 4.52, average value added ratio is 0.090806, the normalized elasticity value for each layer of supply chain are -0.25077, 0.631816 and 0.705439, respectively. The demand function values are 40093.54, 51910.29 and 53216.1 for different layers of supply chain.

3.2. Calculating indicator value

Using the equation (1) and the information given above, the value received or lost for all sustainability indicators and the related SV for the agricultural industry have been calculated as shown in Table 3.

Indicator type	Value obtained/(Lost)
Social	-548.127
Economic	-106.214
Environmental	-3.05526

Table 3. The output Total values

4. Analysis and Discussions

Figge and Hahn [15] provided a new approach for measuring firm's participation in sustainability which is called sustainable value added (SVA). Benefit is created when the interests cover costs. This paper shows that sustainable development measurements based on the opportunity cost are more practical. SVA is a measurement index, which indicates that how much more value, added would the company create? If a company is more efficient than the pattern entity (benchmark) and consequently the resources are assigned to that company instead of the pattern entity (benchmark).

One of the topics that has gained special importance today is sustainability in various industries. The agricultural industry is also considered one of the most important industries in the world and accounts for a large part of the country's exports. So, research on a topic such as industrial sustainability can help you succeed and increase production. This term has become very widespread in recent years and is used for a variety of topics. Agriculture will have a major impact on water scarcity, deforestation, land degradation and climate change. Agriculture not only affects environmental change, but is also affected by it. Sustainable agriculture will minimize these changes. Sustainable food systems can also help sustain human populations. For example, they offer new solutions for feeding populations in changing environmental conditions and help agricultural systems. In general, sustainable agriculture is carried out with three goals: environmental protection, economic justice, and socio-economic benefit. As mentioned in the section What is sustainable agriculture, sustainability in agriculture measures the ability of nature and meets our needs based on it. Therefore, one of the goals of sustainable agriculture is to monitor natural and human resources. In addition, sustainable agriculture helps you to use a minimum of synthetic and chemical materials and have the least inappropriate impact on the environment. Soil erosion and pollution, water pollution, reduction in biodiversity, endangerment of wildlife, endangerment of human health, increase in plant diseases, etc. are among the most important reasons that have attracted the attention of most people to sustainable agriculture.

In this paper, two widely used approaches namely; the absolute indicators and the relative indicators are used to measure the enterprise sustainability. Based on these two approaches two questions of "whether" and "how" have been raised and discussed. These two questions form the framework of their model.

Absolute Sustainable Value Added:

Value Added = - external environmental and social cost + relative SVA

This means that if the resources are allocated to the more efficient firm and the covering of the costs by the created interests is considered, the absolute SVA will be created. Conceding that the access to significant results for estimating the numerous environmental and social external costs is difficult or even impossible due to their external nature which is not reflected by the market price, Figge and Hahn's article [12] mostly emphasizes the second question (where) and the presented model tries to obtain the relatively SVA.

The SV added and the indicator presented in Figge and Hahn's article [15], adopts a very cautious situation. On one hand, they have considered the resources as irreplaceable in their model. From this perspective, only the organization, which can simultaneously improve the economic, environmental and social effectiveness, can participate in sustainability. On the other hand, it is assumed that if a firm is more efficient than the benchmark firm is, then it can sell its resources to a firm, which is less efficient than the benchmark.

4.1. Challenges and limitations of the proposed framework

Due to the intense and growing competition between institutions and the lack of efficient control by the benchmark company over other institutions, the Figg and Hahn's assumption that the benchmark company can purchase resources from other firms, and create a strong sustainability on macro-level, faces serious doubt. In other words, the assumption that buying resources from less efficient companies would create sustain consumable resources on macro-level and creates additional value. Due to many factors such as competition between companies, the lack of control of the benchmark company over less efficient firms, the lack of assurance on behalf of other companies to accept this condition and even when accepted, no guarantee to oblige, clearly limits the applicability of this assumption and creates an unfeasible prospect. However, in the provided model by Figge and Hahn [15], only the negative effects of a firm on its society and environment have been considered. Another weakness of their model in obtaining the SV is the exclusion of the importance of various indicators for different social and industrial contexts. Due to the geographical diversity of human being and its natural environment as well as the different laws and norms in various societies and industries, the same sustainability indicator could have opposite impact in these varied circumstances.

4.2. Improvement matrix

The sustainable value developed by Figge and Hahn [15], takes a very prudent stance and is based on reallocating resources assumption. To improve the inadequacies and weaknesses posed by Figge and Hahn model, in this research it is suggested instead of asking "where?" the question of "how much?" can be raised. It means, how much and to what degree each firm can conduct their activities (how much is the product or service?) in order to achieve optimal SVA. Therefore, the matrix shown in Figure 1 can provide more realistic and tangible assumptions to assess the degree of firm's participation in sustainability.

Value added: value added is the difference between the proceeds from the sale of a firm and the total cost of the components, materials and services purchased over a period (usually one year). This represents the firm's share of gross domestic product (GDP). In other words, value added means the creation of economic value through optimal production, without any consideration for the possible environmental and social impacts.

Optimal value added: The maximum value that a firm can achieve without considering the possible environmental and social impacts.

Sustainable value added: The value the firm achieves in three dimensions of sustainability regardless of whether this amount is optimal or not.

		Can the benefits cover costs? (If Question)	
		Considered	Not-considered
Maximize the value? (How much Question)	considered	Optimal Sustainable Value Added	Optimal Value Added
	not considered	Sustainable Value Added	Value Added

Figure 1. Improvement matrix

Optimal SVA: The maximum value a firm can achieve in three dimensions of sustainability is called optimal SVA. In other words, the optimal SVA allows the firm to achieve optimal production while enjoying a maximum participation in sustainability.

4.3. Sensitivity Analysis of Elasticity and Economic Growth on SVA

Based on the discussion of the elasticity and economic growth, this paper introduces SVA as a proposed method to measure sustainability of the supply chain. This will include both Value Obtained / Lost and the Missing value. As depicted in Figure 2, an increase in elasticity can lead to increase in SVA. As illustrated, by increasing or decreasing the elasticity of each indicator, the corresponding SVA will increase or decreases accordingly. In other words, the improvements in elasticity might be over-compensated by a rebound effect. As illustrated in Figure 2, elasticity fluctuation is shown for upper and lower sustainable value for different sustainability dimensions.

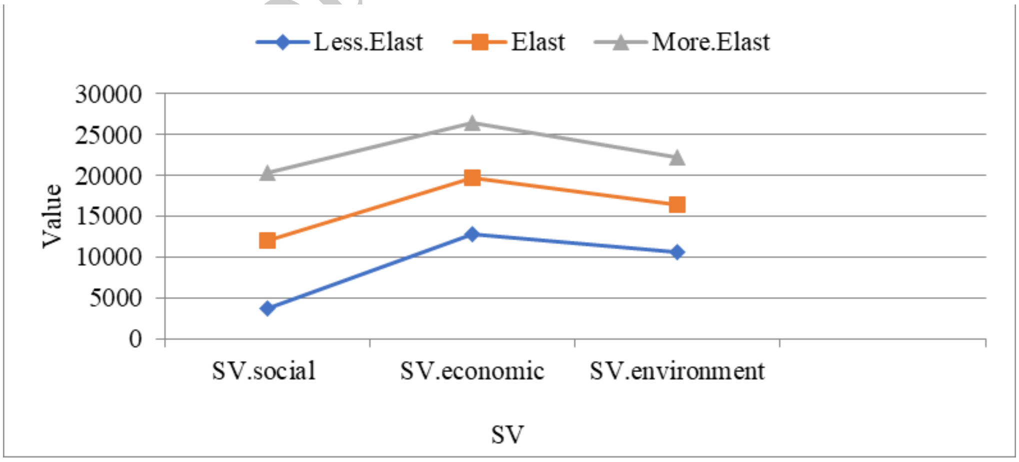

Figure 2. Corporate elasticity and economic growth

However, as an emphasis, to investigate the impact of sustainability on supply chain performance, economic growth must be considered. However, there are also some non-economic factors such as: natural resources, technology advancement, capital concentration, production organization, division of labor, production scale, social, humanitarian, organizational and political issues that could lead to economic growth and increased productivity.

As shown in equation (1), the economic growth has profound effect on SV. The sensitivity of variation in economic growth on SV for sustainability indicator is presented in Figure 3.

The interpretation of the results between economic growth and SV using the logarithmic graph shows a short-term relationship between the studied variables. The results indicate that long-term economic growth will have a significant effect on SV. The sensitivity analysis indicates any decrease in economic growth has profound negative impact on SV for sustainability indicators while its increase is less prominent.

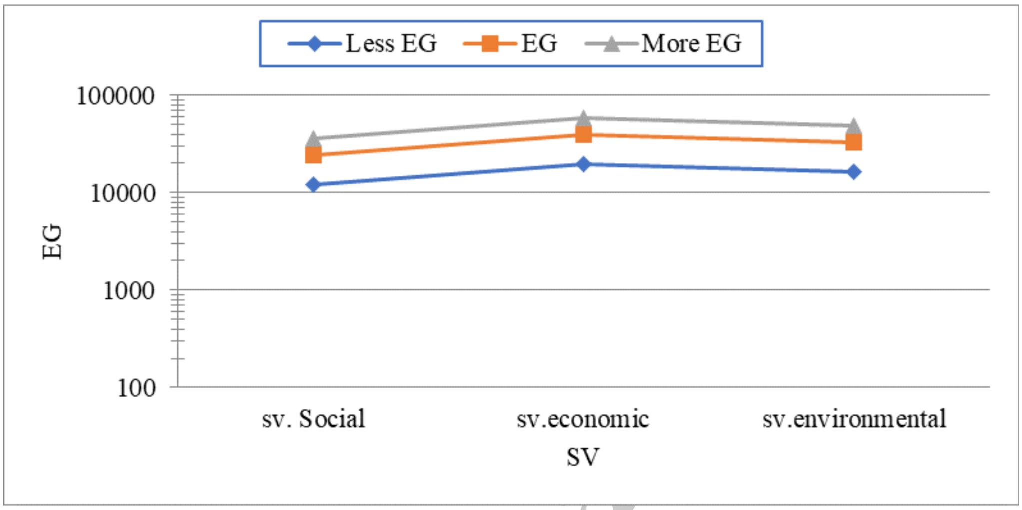

Figure 3. Corporate SV and economic growth

5. Conclusions

The SV developed by Figge and Hahn [15], takes a very conservative stance and is based on assumption of reallocating resources. The developed index (SV) in this article was focused on measuring firm's contribution to sustainability and its optimization. The index considers the distinct importance of indicators in different social and industrial contexts and also provide the possibility of applying reward and punishment by regulatory bodies through using dynamic coefficient. The proposed SV index indicates the firm's contribution to sustainability in current situation to answer to the question " how much resources (human resources, raw material, capital and environment) should be used by the firm to have maximum contribution to sustainability". Since the firms use a resource to produce products or provide services, the optimum SV is determined by using mathematical models and the result is presented as 'optimum SV'. The developed model was implemented in agricultural industry as a case study, The SV and sustainability ratio in the current situation are -657,397 billion unit of currency and 77% respectively. The impact of variation in elasticity and economic growth on SV for various sustainability indicators were analyzed. As for future research directions, one can use the proposed SV evaluation model to determine the optimal sustainability indices being employed by policy makers. In addition, implementing the model for different industries could be another useful research area.

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