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Using Thermodynamics Entropy To Modelling Economic Value Added Analysis of Manufacturing Firms (Iranian Chemical Industries Case Study)

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Abstract

Based on natural Law's capabilities in the Economic modeling, this study compares the economic value added (EVA) in various groups of chemical industries by thermodynamics principles. At first the EVA per unit computed. Then by providing equivalents for thermodynamic and economic variables, the intrinsic value of economic inputs and outputs per unit was calculated by using thermodynamic equations of state (EOS) and their absolute entropy changes were determined. Next, statistical correlation of EVA with absolute entropy changes in each of the EOS was investigated. Finally, based on the obtained thermodynamic results, chemical industry groups were classified. The statistical sample contains about 61 units from 155 active Chemical Industries in Fars province, Iran and was determined using stratified random sampling. Findings indicate that despite the existence of significant correlation coefficient of EVA with Entropy changes in all equations of states (sig=0.05), Van-der-Waals equation had the highest correlation. On the other hand, the highest ratio of entropy changes to the absolute entropy of resources was observed in large and medium sized industries. It seems that the top industries in this ranking have higher technical knowledge over others. A comparison of productivity in accordance with the laws of thermodynamics confirms the obtained results.

Keywords: Economic Value Added, Equations of State, Entropy, Thermodynamics Model, Chemical Industry.

Introduction

Human remarkable growth in the development of the boundaries of knowledge and discovery of different phenomena in the Universe has been causing the formation of specialized courses in various fields of science. Extensive and in-depth studies in each field are followed by valuable results which are able to increase the depth of concepts in special fields. Along with the scientific development, some studies have focused on the relation between ontological and methodological research among different fields in which using the results of scientific findings in the development or at least solving problems of other fields is considered. Therefore, this leads to the emergence of new disciplines in science. Meanwhile, the science of thermodynamics, which has a special place in experimental science and engineering has been gradually entering the humanities, social and economic science that considers the scientific issues from a new perspective.

One of the most important topics in economics and social sciences is the analysis of the economic value added as a useful tool in understanding the overall condition of an industry is to identify the value key points in the production process and supply, optimal policymaking in the creation of infrastructures and provide facilities. Eventually, uniform industrial and service development in the region, technology management and identification of non-productive resources have a special place in this chain.

Different models have been provided and used in the value chain analysis each of which pay special attention to a part of the value chain characteristics based on the purposes of the study.

Among these practical methods is the economic Value Added method suggested by Stewart with some modification of the common methods to calculate the value added.

Accordingly, the present study is aimed at investigating the relationship between the principles of thermodynamics and economics in the analysis of value added, followed by identification of industries with high added value based on thermodynamic principles. Given the similarity of the thermodynamic and economic characteristics and using the relationship over thermodynamic systems, the economic value added is determined using equations of state. The most important feature of this study is the use of the laws of thermodynamics in economics and management, and it can help the development of models for value chain analysis in addition to the reinforcement of the connection between physics, chemistry and economics solve problems in these fields. On the other hand, in the value chain analysis, the existing quantitative models have focused chain analysis by considering specific aspects of the research. Meanwhile, the thermodynamic approach, due to the properties of physical systems, enters variables and equations in the model that makes system closer to reality.

The main steps of this study are identification of the equivalent characteristics of both thermodynamic and economic systems in the economic value added, determining economic value added using the equations of state along with Stewart model and comparison of the equations results in both approaches.

Background and literature review

Evaluation and investigation of added value are considered as a basis for various plans and policies besides the scientific development approach among the areas of interest for researchers. Among the analytical approaches, Michael Porter's value creation model is used in the areas such as preparation of differentiation strategies in emerging markets in Latin American agribusinesses (Brenes et al., 2014), achieving added value in a Knowledge-Intense organization (Marshall et al., 2014), or even at a more micro level, such as the evaluation of financial performance in Finnish large and medium-sized sawmills (Lahtinen et al., 2008). Some of these studies also used the value calculation approach based on the input-output method in the analysis of industry's value creation. Development model of industrial cluster of auto parts manufacturers in Tabriz, Iran, is based on UNIDO (Hadji et al., 2009). Value added analysis in the electricity sector in Turkey (Sohtaoglu, 1999), investigation of the impact of Chinese exports on domestic value added and employment (Xikang et al., 2012), comparing the value added of units in clusters with that of ordinary units in Ethiopia (Merima et al., 2011), comparing the performance of upstream, intermediate and downstream industries in petrochemical of Thailand Industrial center of MTPIE (Charmondusit et al., 2011) or determining the quantitative contribution of technology in Portugal (Fernandes, 2012).

By providing economic value added indices by Stern and Stewart, this index was used in the assessments of firm's performance (Xin et al., 2012). Simulation of economic systems, such as agriculture (Samson et al., 2013), value-based management in the organization (Woods et al., 2012) or even investigation of environmental issues and social costs (Ferrao et al., 2014) are among studies in which economic value added is used. In calculating the economic value added, capital costs are also considered along with operating profit. Therefore, it may be closer to reality in the actual valuation. One of the approaches that can be seen in the recent year's studies is using the findings of natural science to clarify, explain or even modelling economic and management phenomena. Among these theories, we can refer to the application of the principles and thermodynamic variables in the economy.

One of the main developers of this model was Soddy (1925) who awarded the Nobel Prize in Chemistry. He believed in similar behavior of economic and thermodynamic systems and put the energy force equivalent to the work force. Later, Fisher (1930) by the help of Gibbs considered the final utility as equivalent to the force and the utility as equivalent to energy (Leof et al., 1999). Paul Samuelson, the Economics Nobel Prize winner in the book Principles of Economic Analysis (1947) used the Le Chatelier's principle in chemistry and used this concept in the market equilibrium. According to this principle, when the system is in equilibrium, it reacts against any change in the opposite direction to remove the impacts. Though Le Chatelier believed that this principle can be used in the economics and wrote articles about the relationship between employer and employee, productivity and industry. He used principles of classical thermodynamics and Entropy concept to explain the problem of constrained maximization problem. In the Noble Prize lecture in 1970, he declared that volume and pressure in thermodynamics are comparable with volume and prices in the economy (Altmann et al., 1998). Lisman stated that utility of money in the balance of economic systems has an entropy behavior similar to that of thermodynamic systems (Lisman, 1949). Later, Pikler considered the circulation of money equal to the temperature (Pikler, 1954). Also, the relationship between thermodynamic energy and economics in the book entitled the law of entropy and economic processes by Georgescu Roegon published in 1979 as a famous book by Harvard University, provided the functional similarities of the exchange of energy and materials in the thermodynamic and economic systems (Georgescu-Roegon, 1986).

Among the recent studies is the evaluation of the economic performance of the Netherlands on the basis of thermodynamic parameters in which thermodynamic parameters are used in the form of Exergy for the economic evaluation of three stages of the energy chain (Ptasinski et al., 2008). In another study, thermodynamics principles are used to model stress management and innovation. In this study, energy rules are defined as heat and work for stress analysis in which organization is considered as a thermal engine that receives input (heat), while performs the work (W) with the change of energy (U). In this enthalpy (H) study, the amount of staff stress and temperature (T) is interpreted as resources per worker (Pati, 2009). In the same year, another study used thermodynamic entropy that refers to the energy and materials tendency to waste or becoming unhealthy substances during the economic activities (Čiegis, 2008). In another article, the thermodynamic statistical relationship and Gibbs Boltzmann distribution was used to model linear, nonlinear and complex economic systems. In this study, money function is obtained as a quantitative economic reality for the mentioned systems based on which all thermodynamic parameters are simulated (Quevedo et al., 2011). Bryant (2011) used thermodynamic principles and processes of constant volume, constant pressure, constant temperature and constant entropy explain economic problems. He used (Q) as the amount of money entering into or out of the system, (T) for temperature equal to commercial value, (P) for pressure equal to market price, (C) for specific heat equal to a function of specific economic value, (S) for equivalent to changes in economic value.

According to literature review of previous studies, it seems possible to calculate production system of economic value based on laws of thermodynamics.

Material and methods

In the first section of this study, the descriptive research method is used. One of the issues that is considered important for researchers in this study (and other similar studies) is that based on Boulding's classification the social systems at the level eight in the systems. However, the research method in this study is based on the natural system at the fourth level of this classification. According to Boulding's theory, the research method for each level of classification should be consistent with the same level. Some researchers believe that the natural sciences can be considered a good model for the development of science. Problems of social studies and research, excessive complexity of research topics, lack of separation of scholar, phenomenon, etc. to obtain social theories lead to natural methodology in the social sciences. Hobbes beliefs about social physics, Descartes works, Francis Bacon and D'Alembert in the seventeenth century, Spinoza quantitative oriented approach, Kenneth research methods, supporting the "naturalistic" social science of Herbert Spencer and research methods of logical realism in the nineteenth century, Boulding views on description of system level and finally, the naturalistic paradigm theorists such as Homans, Kuzort, Friedman, Nicebet are the result of such a space (Ahranjani, 2007).

Value chain analysis is also a social–economic issue. Therefore, because there are limited efficient tools for its objective analysis, which require simplification, this issue will be examined in the framework of the laws of thermodynamics as a natural issue. In another point of view, the value chain is a systematic issue at eighth level of Boulding's classification. However, according to Boulding, in the analysis of such systems the researcher has to use the natural class rules, and thus provide a philosophical basis for the present study.

In the economic discussions, value added is calculated using FAO, IOA, SAM, EVA methods. In this study, Stern and Stewart's method is used for calculating the economic value added to consider capital costs in addition to functional profits as follows:

$$EVA = Operating\ profit - Capital\ charge, \quad EVA = NOPAT - (c \times capital) \tag{1}$$

Where c is the weighted average cost of capital (WACC).

EVA of jth unit, calculated as Eq. 2:

$$\begin{aligned} EVA_j &= NOPAT_j - Capital\ charge_j \\ &= I_p + I_w - (C_m + C_{E,PM} + C_l + C_d) \\ &- [r_s.K + D.r_d.(1-T)] \end{aligned}$$

where:

I_p : Income from products,
I_w : Income from wastes,
C_m : Material cost,
$C_{E,PM}$: Energy and Preventive maintenance,
C_d : Depreciation Cost,
r_s : Shareholder equity rate,
K : Shareholder equity,
D : Debt, r_d : Debt rate,
and T : Tax rate , (2)

Required data were gathered from profit loss statement and open interview results.

In this study, each economic unit consists of the economic system with a behavior equivalent to the ideal behavior of air gas. According to the laws of thermodynamics, entropy can be considered as a function of temperature, volume and fluid pressure as Eq. 3:

$$\begin{aligned} dS(T,v) &= \frac{\partial S}{\partial T}dT + \frac{\partial S}{\partial V}dv = \frac{1}{T}(dE(T,v) + p(T,v)dv) \\ dS(T,v) &= \frac{1}{T}\frac{\partial E}{\partial T} + \frac{1}{T}\left(\frac{\partial E}{\partial v} + p\right)dv \end{aligned} , \tag{3}$$

Where p is pressure, v is the volume, T is temperature, E is energy and S is entropy (Cengel, 2011). According to the second law of thermodynamics, dW=dY-T Ln(S), work force decreases entropy value. In economics, working decreases capital distribution because the investment is through sales to customers. This means that the capital injection like Carnot cycle can lead to economic growth. Work has a similar meaning in both thermodynamics and economics. In the

Carnot cycle, the integral of heat pack dQ is not zero, and Q value depends on the integration path. The same issue arises in the economy. Investments in different countries results in different profits in each case. In other words, the amount of the profit depends on the investment method.
According to what mentioned before, in this model resources with thermodynamic properties such as raw material, capital, labor force, energy, and maintenance and repair services are entered the production unit with properties of Ti, pi and Si change into a production with Tp, pp and Sp properties or wastes with Tw, pw and Sw properties (Fig. 1).

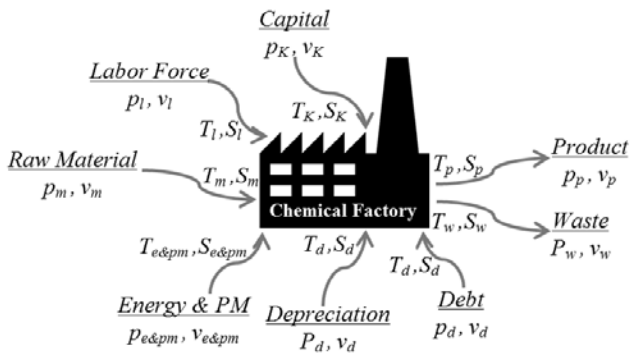

Figure 1: Schematic of Inputs and Outputs properties of a chemical factory

During the process of value creation in this production unit, the amount of resources is equal to the volume and their value is equal to the entropy. Resources and products price is considered equivalent to pressures. The pressure is assumed as the force on the surface obtained as the conflict between the internal force (Molecular Movement) and the external surface.

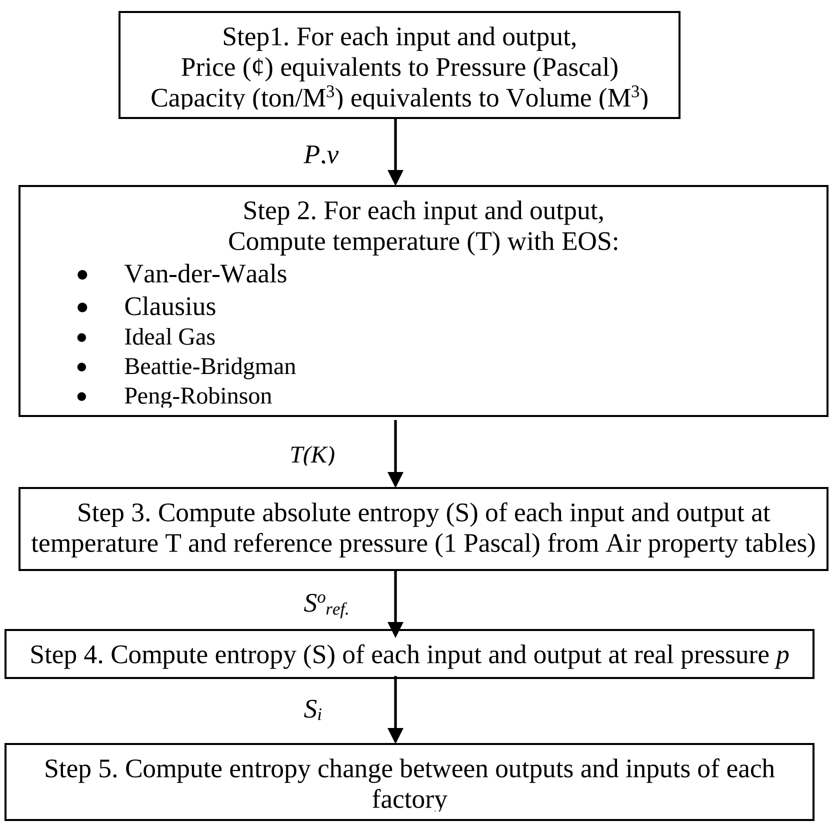

Figure 2: Flowchart of Added Value computation based on thermodynamics analogy

Therefore, the price is affected by mechanisms such as supply and demand of goods and products and alternative products, income elasticity, demand and market conditions in addition to internal factors such as product cost and unit strategies. Meanwhile, intrinsic value is equal to the thermodynamic temperature that in isolated systems, it is independent of the environment and at the microscopic level is due to the internal movement of molecules. The flowchart of added value computation based on thermodynamics analogy is shown on Fig. 2. In order to determine the intrinsic value of resources and products equivalent to temperature variable (T), thermodynamic equations of state are used. In other words, in order to determine the entropy change in each of the industrial units, resource and product prices equal to the thermodynamic pressure (one cent market price equals to one Pascal pressure) and volume (Each Metric ton of solid and liquid or each Cubic Meter of gaseous products equals to one cubic meter of an ideal gas in thermodynamics), and value equivalent to thermodynamic absolute entropy considered in International Units System (SI). Then parameters of ideal gas in the air were used to put available data in the equations of state and the thermodynamic temperature of inputs and outputs were used to determine absolute entropy (step 2, Fig. 2). Investigations of equations of state included Van-der-waals, Clausius, Ideal Gas, Beattie-Bridgeman and Peng-Robinson equations (as shown in Table 1).

Table 1:Thermodynamics equations of state have been used in temperature defining

Equation of state	Equation
Vander Waals	$(p+\frac{a}{\bar{v}^2})(\bar{v}-b)=\Re T$
Clausius	$p(\bar{v}-b)=\Re T$
Ideal Gas	$p\bar{v}=\Re T$
Beattie-Bridgeman	$p=\frac{\Re T}{\bar{v}^2}(1-\frac{c}{vT^3})(\bar{v}+B)-\frac{A}{\bar{v}^2},\ where\ \ A=A_0(1-\frac{a}{\bar{v}}), B=B_0(1-\frac{b}{\bar{v}})$
Peng-Robinson	$P=\frac{RT}{(V-b)}-\frac{a\alpha}{V^2+2bV-b^2}$ $where\ \ a=0.457235\frac{R^2T_C^2}{P_C},\ b=0.07796\frac{RT_C}{P_C}, T_r=\frac{T}{T_C}$ $\alpha=(1+k(1-T_r^{0.5}))^2,\ k=0.37464+1.54226\omega-0.26992\omega^2$

R: Gas Constant (278 kJ/kg.K), a, b, c, w: constant

Ref.: Cengel & Boles (2001)

In these equations, parameters related to the air gas obtained from thermodynamic tables. By obtaining temperature foe each component, the amount of entropy (equivalent to value) of the resources and products can be determined. The amount of entropy in one Pascal pressure obtained using the tables and changed in entropy at pressure p using $s=s^o_{\mathrm{Ref}}-R\ln(p/p_o)$ equation. In other words, value of resources and products changes to the value in their price through conversion (steps 3 and 4, Fig. 2). Then, an entropy change in the conversion process is determined by the difference between inputs and outputs:

$$dS=\sum S_{output}-\sum S_{Input}, \qquad (4)$$

By examining the relationship between EVA with dS entropy changes per unit, applicability of value added analysis is investigated and compared to thermodynamic relations (Relativity of EVAeconomic to dS thermodinamics). For this purpose, the correlation of the results of economic added value and absolute entropy between input and output in each equation of state based on Spearman statistics. However, based on the Kolmogorov-Smirnov test, distribution of variables is not normal. Considering the high value of the sample (n>30), Parametric test can be used based on the central limit theorem. In this study, 61 units were selected among 155 active units of Fars

Chemical Industries by stratified random sampling method based on Cochrane equation of at a confidence level of 95% and tolerance of 10%.

Results

With stratified random sampling method, 61 samples in 18 groups were selected among 155 active units whose number is given in the Table 2.

Table 2: Classification of Chemical Industries & statistical population and Sample sizes

Row	Industry Group	Active units	Samples
1	Acids	8	3
2	Ameliorative	4	2
3	Petrochemicals	1	1
4	Plastic, PE, PP, Nylon , and PVC	14	5
5	Chemical powders	2	1
6	Adhesives	4	2
7	Solvents	9	4
8	Resin	7	3
9	Dye	18	6
10	Oil	1	1
11	Toxins	3	1
12	Detergents, cosmetics	30	10
13	Insulator	1	1
14	Formaldehyde and melamine	3	1
15	Chemical fertilizer	12	5
16	Industrial gases	12	5
17	Rubber	1	1
18	Inorganic chemicals	25	9
Total		155	61

Ref.: Research findings

First, Stewart equation was used to calculate economic value added per unit from Eq. 2. Results of EVA computation are shown in Table 3.

Table 3: Results of EVA computation based on Stewart-Stern Method (Thousand US Dollars)

Unit		1	2	3	…	61
Factory Outputs	Product	90000	17500	45500	…	15750
	Waste	2250	438	1138	…	394
Factory Inputs	Material	37500	4375	9625	…	3375
	PM	2250	313	525	…	984
	Energy	2250	438	1138	…	394
	Depreciation	7000	2500	4500	…	1764
	Labor	18368	4592	6888	…	3616
	Capital	40000	10000	35000	…	11025
	Debt	30000	15000	10000	…	6615
NOPAT		24882	5721	23962	…	6010
Capital	Charge	13600	4300	9950	…	3550
EVA		11282	1421	14012	…	2460

Ref.: Research findings

On the other hand, the change in entropy between the input and output of each unit was calculated with equivalent of economic and thermodynamic variables as Fig. 2. In step 2, with 61 samples and 5 EOS, 2,440 equations are solved for temperature determination. For example, some results of entropy change calculation with Peng Robinson EOS are given in Table 4.

Table 4: Entropy of inputs and outputs on each unit, calculated based on the Peng Robinson EOS (J/K.mol)

The entropy of	Unit				
	1	2	3	…	60
Product	-1628	-1411	-1588	…	-1411
Waste	-970	-751	-269	…	-751
Material	-1250	-951	-752	…	-906
Capital	-1351	-1115	-1229	…	-1289
Debt	-1339	-941	-1090	…	-853
Depreciation	-1403	-1186	-1101	…	-1250
Labor	-1403	-1398	-1467	…	-1410
Energy&PM	-751	-378	-577	…	-378
Sum of Inputs entropy	-7496	-5969	-6216	…	-6086
Sum of output entropy	-2598	-2162	-1857	…	-2162
Factory entropy change	4898	3807	4359	…	3924

Finally, entropy change of each factory is calculated that the results are as shown in Table 5.

Table 5: Entropy change of factories with used EOS's

Unit	Van-der-waals	Clausius	Ideal Gas	Beattie-Bridgeman	Peng-Robinson
1	4,898	4,898	4,898	4,898	4,898
2	3,807	3,807	3,807	3,808	3,807
3	4,357	4,357	4,357	4,359	4,359
…	…	…	…	…	…
61	3,927	3,925	3,925	3,926	3,924

Ref.: Research findings

Spearman test was used to investigate the linear relationship between economic value added and entropy changes. Moreover, ANOVA analysis was conducted to confirm the obtained results. The results are given in the Table 6.

Table 6: Correlation coefficients between EVA and entropy changes in evaluating equations of state

Correlation Coefficient EVA with Entropy changes (dS) that dT calculated by:						
Equation of State		Van-der-waals	Clausius	Ideal Gas	Beattie-Bridgeman	Peng-Robinson
Pearson	Coefficient	-0.608	-0.607	-0.607	-0.607	-0.607
	Sigma	0.001	0.001	0.001	0.001	0.001
ANOVA	r2	0.369	0.369	0.369	0.369	0.369
	r2adj	0.359	0.358	0.358	0.358	0.358

Ref.: Research findings

Regarding the close relation between obtaining results, it seems that the results obtained from the entropy changes in the equations of state at a confidence level of 95 % have a significant relationship with economic value added. Among the state equations, it seems that van deer Waals equation has more correlated with the amount of economic value added in calculation of input and output's temperature. Negative correlation means that in each economic unit in the process of transformation of resources into products, economic value added will reduce or increase (or in losing units or with the high cost of capital). Economically, the resources with the lower price and internal value are entered, which results in output of products with higher price and intrinsic value in the production process. Thermodynamically, resources with pressure (equivalent to the price) and temperature (equivalent to internal value) are entered which results in higher pressure and temperature in the output in the process of the transformation. However, the remarkable point is that the pressure increase ration is higher than that of temperature, so the output with lower levels of entropy will be exited:

Input|Ti,Pi,Si →Output|To, Po,So, (5)

$$\left.\begin{array}{l} \frac{dT}{T} \geq 0, \frac{dP}{P} \geq 0 \\ \frac{dP}{T} \geq \frac{dT}{T} \\ dS = c_p \ln(\frac{T_2}{T_1}) - R\ln(\frac{P_2}{P_1}) \\ c_p,\ R: const. \end{array}\right\} \Rightarrow \frac{dS}{S} \leq 0 \quad , \qquad (6)$$

Where cp and R are constant

This is why the correlation coefficient of economic value and the entropy changes are negative. An economic interpretation of this point is that every single unit capable of selling products with higher price and lower changes in the relative changes in the internal value of material has a higher value added. This issue is represented in the operating profit of Stewart equation. On the other hand, the higher price ratio of product compared with the resources (dp/p) with lower transformations (dT/T) leads to higher economic value added in the unit.

Table 7: Value ratios of Chemical Industry groups based on entropy changes

Unit	Sum of input entropy	Sum of output entropy	dS	Value Ratio
Petrochemicals	-1418	-1201	217	-0.15
Rubber	-5900	-2948	2952	-0.50
Formaldehyde and melamine	-3728	-1565	2163	-0.58
Minerals	-56,880	-23,842	33038	-0.58
Insulation	-7751	-3099	4652	-0.60
Toxins	-9687	-3814	5872	-0.61
Resin	-19,457	-7442	12016	-0.62
Detergent & Cosmetics	-89,239	-33,558	55681	-0.62
Plastic, PE, PP, Nylon, and PVC	-31,661	-11,864	19797	-0.63
Ameliorative	-14,270	-5344	8926	-0.63
Solvents	-27,296	-10,221	17075	-0.63
Fertilizers	-33,701	-12,572	21129	-0.63
Chemical powders	-6975	-2561	4414	-0.63
Adhesives	-12,981	-4733	8248	-0.64
Acid	-17,873	-6498	11375	-0.64
Dye	-42,789	-15,483	27305	-0.64
Oil	-8291	-2776	5515	-0.67
Industrial gases	-32,434	-9297	23137	-0.71

Ref.: Research findings

Therefore, the ratio of value added to the input group is used in the comparison of production units (Eq. 7).

$$Value\,Ratio = \frac{dS}{\sum S_{input}}, \quad (7)$$

In this regard, based on what's mentioned about negative ratio of dS/S, the lower ratio of the change in entropy to the input entropy causes further success in the production of value added. Status of different groups of industries in the studied samples is as Shown in Table 7.

Among these studied groups died, petrochemical industries had the best situation followed by rubber (tires) and formaldehyde industries. In fact, these three industries classified as large and medium size industries in the province. Manufacturing industries of oil, industrial gases and dye are at the bottom of Table 7 in which the ratio of manufacturing value added to the input of this group is at a low level as Eq. 8:

$$TP = \frac{\sum S_{output}}{\sum S_{input}},\; LP = \frac{\sum S_{output}}{S_{Labor}},$$
$$KP = \frac{\sum S_{output}}{S_{Capital} + S_{Debt}},\; EP = \frac{\sum S_{output}}{S_{Energy} + S_{PM}}, \quad (8)$$

Where TP is total productivity equivalent to the ratio of output to input entropy, LP is labor productivity equivalent to the ratio of the output entropy to labor costs entropy, KP is productivity of capital equivalent to the ratio of the output entropy to the entropy of capital and debt cost, EP is energy productivity equivalent to the output entropy to entropy of energy and maintenance costs. The results are given in the Table 8.

Table 8. Total and partial Productivities of Chemical industry group based on entropy changes

Unit	TP	LP	KP	EP
Petrochemical	0.847	2.744	10.224	6
Rubber	0.500	2.695	1.869	3
Formaldehyde and Melamine	0.420	2.804	1.336	2
Minerals	0.419	1.780	1.355	4
Insulation	0.400	1.996	1.285	3
Toxins	0.394	1.842	1.086	3
Resin	0.382	1.602	1.263	3
Detergent & Cosmetics	0.376	1.703	1.175	3
Plastic, PE, PP, Nylon, and PVC	0.375	1.717	1.172	3
Ameliorative	0.374	1.810	1.154	3
Solvents	0.374	1.638	1.006	6
Chemical fertilizers	0.373	1.895	1.128	3
Chemical powders	0.367	1.773	1.106	3
Adhesives	0.365	1.704	1.107	3
Acid	0.364	1.511	1.029	6
Industrial and constructional dyes	0.362	1.658	1.087	3
Lubricants	0.335	1.673	0.920	3
Industrial gases	0.287	1.263	0.792	2

Ref.: Research findings

As it can be observed, industries with higher value added have higher total productivity while the higher productivity of labor force and capital have been investigated than other industry groups. Although this is not a definite superiority, its effect is less on added value given the low energy cost compared to the cost of capital and labor. In other words, if the findings of this section to be analyzed by the conventional method of economic value added (Stewart), higher productivity of labor force impacts the operating profit while proper utilization of capital has an impact on capital cost. Therefore, it is not surprising that units with high productivity of capital and labor have a higher added value.

Conclusions

This study is an attempt to use the principles and laws of thermodynamics to investigate the value added of different groups of Fars Chemical Industries. According to various conducted studies, thermodynamic parameters can represent somehow the economic variables. Accordingly, some economic concepts and principles of thermodynamics are expressed. One of these concepts investigated as the subject of this study is economic value added affected by operational variables, benefit of economic unit and variable of capital cost. By considering economic unit and ideal gas system of air, pressure variables and market price as equivalent variables, the temperature, intrinsic value, thermodynamic volume and economic volume calculated based on entropy equations of state. Among the studied equations of state, Van der Waals equation with little difference provided better results in determining the temperature of sources and products per unit based on which entropy changes were calculated. According to the statistical analysis, there is a significant relationship between the entropy change and the economic value added per unit and appears that this law can be used for comparison of different groups. The main advantage of thermodynamic law is to reduce the environmental impact governing the production value system. This is because market prices resulting from the interaction of internal and external factors of an economic unit are considered in calculating economic value added and it can cause deviations in determining the actual and intrinsic value of a single economic unit. Also in thermodynamic approach, the pressure resulting from internal and external factors is equal to the market price and it is used to reduce the external effects of temperature, entropy and value using equations of state. Therefore, it can be argued that entropy can be performed in a better way determine the value added of a single unit. Large and medium chemical industries in the samples are in a better situation in terms of the value added ratio to inputs. This finding is confirmed by the investigations of productivity ratios. The interesting point is that Province's major industries are in a better position due to the high productivity of capital and labor as the two main factors in the production cost. In contrast, gas manufacturing industries have a high finished cost despite the low productivity of capital and labor cost due to not registered small production workshops in the system of the Ministry of Industry, Mine and Trade and too many workshops of filling the liquid gas cylinders in the group. This issue can be interpreted in the high-temperature of resources and lack of the unit capability to raise the temperature of the unit products. Other industries like lubricants and dye industries involve the use of brands. Such units did not find in the sample, and therefore the output of products had low market prices or low thermodynamic pressure.

Suggestions

In addition, according to the requirements of this research, some physical phenomena equations in economics and management identified which could be the basis for further scientific studies in the field of management science and economics performed with physics. According to the findings of this study, it seems possible to analyze the value chain in different industries, in particular the chemical industry, by using the laws of thermodynamics. Other notable studies in this area are analyzing the factors affecting the internal value-added of production units such as capital cost rates, total labor force, notable points in job creation or strengthening of missing links in the value chain using thermodynamic rules and parameters.

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