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The effect of R&D on performance of high- tech industries: new evidence from Iran

Somayeh Azami[1]

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Abstract

The main objective of this paper is to evaluate the effect of R&D on profitability of high -tech industries with new evidence from the Iranian industries carrying four- digit codes. The Structure- Conduct- Performance (SCP) paradigm, which is relatively well known in industrial economics and in organization management, provides the theoretical construct that guides our empirical model formulation and execution. The data is compiled from observations made at the plantlevel covering all industrial plants employing ten or more persons and carrying four- digit codes within the time span of 1994-2007. The model used essentially consists of a simultaneous equation system framework grounded into a panel data approach and estimated by Two-Stage Least Squares (2SLS). Our findings indicate a positive and significant effect of R&D expenditures, measured in intensive form, on profitability of high-tech industries as evidenced by the Iranian case. Our more notablefinding is the positive effect of lagged profits on R&Dexpenditureintensity, revealing alikely mutually enforcing

1. Assistant Professor of Economics, Department of Economics, Faculty of Social Sciences, Razi University, Kermanshah, Iran.sazami_econ@yahoo.com.

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relationship between profitability and R&D intensityin high tech industries.

Key words: R&D expenditures, High -Tech industries, Profitability, Simultaneous equation systems

JEL Classification: O_{32},O_{14},L_{10},C_{30}

1.Introduction

The main objective of this paper is to evaluate the effect of R&D on profitability of high -tech industries with new evidence from the Iranian industries carrying four- digit codes. The Structure- Conduct- Performance (SCP) paradigm, which is relatively well known in industrial economics and in organization management, provides the theoretical construct that guides our empirical model formulation. The model used essentially consists of a simultaneous equation system framework grounded into a panel data approach and estimated by Two-Stage Least Squares (2SLS).

In an attempt to characterize the nature of technological progress, Mayer (1985) has reminded us that technological progress results in: (1) creation of new products or improvements made in existing products, (2) introduction of new production methods or improvements made in exiting production methods that economize on input use for a given level of output and (3) development and use of new means to fulfill human needs.Ayers(1985) views technological changes as products of R&D induced inventions and innovation(introduction of new products and new production methods) and improvements made in products and production methods. The idea that firms can increase their technological capabilities through investments in R&D has relatively wide spread support among scholars in organizational dynamics and management. As Schumpeter(1950) has noted, the pre-requisite of firms' growth in a capitalist economy is creativity and competition. High -tech industries as intensive consumers of R&D services are considered as engines of growth. They enhance competiveness in global markets and at this junction R&D plays a crucial role. Lawrence (1998)reminds us that high- tech industries' performance is crucialin determining the level of economic and social development of nations and their competitive capability in the global markets.

High -tech industries as identified by OECD in 1994 are industries with high R&D expenditures per sale units. These are: space sciences, office machinery and computers, communication and electronic equipment and pharmaceutical sciences.

In the realm of empirical research, Mansfield (1968) showed that investments in research had a positive andmeaningful effect on value added created in the industrial sector. Grabowski and Muller (1978), undertaking a cross section estimate, found a positive and significant increase in industry profitability that was due to increases in R&D investment expenditures. Erikson and Jacobson (1992) believe that investments in research and development and in advertisement will lead to increases in a firm's value, because under intensive R&D and advertisement expenditures a firm adopts a different strategy than its competitors, hence providing it with a competitive edge. Lev and Sougiannis(1996) view expenditures on R&D and advertisement as non-physical assets, maintainingthat these as well as physical assets have a determinant role in determiningfirm's profitability.Gisser (1999) testing for Granger causality among concentration, profitability, advertisement, price and technology concludes that R&D expenditures are a causal factor in determining concentration and profitability. Chan (2001) divided his data into two groups: one group that included firms with high intensity R&D expenditures consisting of electronic and pharmaceutical firms and the other that included firms with low R&D expenditureintensities, in order to study the differences in firms' stock returns that are likely to arise from differences in firm'sR&D expenditureintensitiesand asked himselfif firmswithhigher intensity R&D expenditures would grow faster than firms with lower intensity R&D expenditures. His findings indicated that the average annual return on stocks of all firms were %19.65 percent, but the same figure for firms with highest intensity R&D expenditures was %19.52, which pointed to the fact firms with higher intensity R&D expenditures did not necessarily grow faster than firms with lowerintensity R&D expenditures . In a follow up study, Rzakhanov(2004) posed a question asking if markets have a correct estimation of the value of intangible assets in industries with high intensity R&D expenditures, such as biotechnology. His findings indicated that markets did take into account the value of intangible assets when determining the value of Firms. His study was carried out in biotechnological industries in the 1980-2000 periodwith the number of

Firms' patent rights taken as a measure of successful innovations. Rzakhanov found a positive and meaningful relationship between the numbers of patent rights that firms acquired and firms market values indicating that biotechnological firms more successful in their R&D attempts were valued higher than those that were not. Kuen-Hung and Jiann-Chyuan(2004) used a Cobb-Douglas type model to estimate the effect of R&D on performance of the electronic industries in Taiwan based on the 1994-2000 period data. A one percent increase in R&D expenditures, according to their estimate, leads to a 0.19 percent increase in industrial production. In a similar vein, Laixin andHuangfeng(2005) studied the relationship between R&D and profitability and found that the correlation between R&D expenditures of the high- tech firms and firm'sperformance was positive and significant.Liu and Buck (2006), using a panel data methodology, carried out an investigation ofempirical interest in innovation performance and international technological spillovers in the context of China, The study shows that knowledge spillover effect of exports and imports has promoted innovation in high- tech industries, and additionally, international technological spillovers as well as domestic efforts have been among the most important and effective factors in improving performance in the Chinese high-tech industries. Shah(2008) studied 1974 firms with positive R&D expenditures and found out that pharmaceutical, electronic and electric industries were the most intensive consumers of R&D services. These altogether had appropriated %50 of R&D expenditures consumed by all the

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firms studied. In his more focused analysis of these two sectors, Shah found that the relationship between the market value of firms and their R&D expenditures was positive. Chen(2011), studying Chinese high tech industries, shows that there is a positive and bi-directional relationship between firms' profitability firms' R&D expenditures.

This paper draws on the Structure –Conduct –Performance paradigm and studies performance in the context of high- tech industries in Iran. Performance according to our model construction is postulated to followmarket organization and also market behavior, whilestructure (concentration) and conduct (R&D expenditures) are viewed as endogenous variables. Accordingly, we construct a simultaneous equation system comprising of three formulations: a performance formulation with performance postulated to follow structure and conduct, a structure formulation with structure postulated to follow conduct and performance and finally a conduct formulation with conduct postulated to follow structure and performance. The system is estimated using the econometric procedure known as Two- Stage Least Squares (2SLS).

The rest of the paper is organized into three sections: model specification and data use is detailed further in section 2 that comes after the introductory section (1). Section 3 proceeds to model estimates and their discussion. The final section (4) summarizes and concludes the paper.

2.Model specification and data Use

Structure, conduct, and performance are three elements of a market. The conventionalview of SCP holds that market organization, meaning structure or in measurable terms, seller's concentration, determines performance. The other structure related measures are: the degree of product differentiation, entrybarriers, buyers' concentration, fixed costs and exit barriers. Market conduct on the other hand, is measured by firms' policy related variables such as the product price, and other variables that influence market different market agents, namely: buyers, competitors and suppliers. There is also market performance that is measured by variables such as profitability, efficiency and technical progress. The conventional perspective of the SCP paradigm sees a causal link from market organization and conduct to market performance, but reality sometimes is not so revealing.

2.1. model specification

There are fundamentally three econometrics approaches to modeling the SCP paradigm: the single equation models used in caseswhere performance is modeled as a function of conduct and structure, the dynamic single equation models where performance is modeled as a function of its own past values and also of conduct and structure, the simultaneous equation models where performance is modeled as a function of conduct and structure, conduct as a function of performance and structure and structure as a function of conduct and performance.

Our modeling strategy follows Kambhampati (1996) whose model formulation depends on lagged variables suchthat lagged conductand performance variables determinestructure variables[S_t= F (C_{t-1}, P_{t-1})], Lagged profit rates determine current conduct variables[C_t=F(S_t, P_{t-1}) with the profit rate determined by

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performance variables[P_t= F (St, Ct)]where S_t represents structure in time t, C_{t-1} and P_{t-1} represent conduct and performance variables lagged one time, respectively. Thus we present our system as follows:

$$\begin{aligned}\mathrm{Profit}_{it} &= \alpha_0 + \alpha_1 \mathrm{HHI}_{it} + \alpha_2 \mathrm{RD}_{it} + \alpha_3 \mathrm{Growth}_{i,t-1} + \varepsilon_{it}\\ \mathrm{HHI}_{it} &= \beta_0 + \beta_1 \mathrm{HHI}_{i,t-1} + \beta_2 \mathrm{RD}_{i,t-1} + \beta_3 \mathrm{Profit}_{i,t-1} + \mu_{it}\\ \mathrm{RD}_{it} &= \gamma_0 + \gamma_1 \mathrm{HHI}_{it} + \gamma_2 \mathrm{Profit}_{i,t-1} + \gamma_3 \mathrm{Growth}_{it} + e_{it}\end{aligned} \quad (1)$$

where Profits, HHI, RD represent profits, degree of concentration, R&D expenditures with subscripts i and t representing industry and time, respectively and $\mathrm{Growth}_{i,t} = \mathrm{Sales}_{i,t}/\mathrm{Sales}_{i,t-1}$,$\mathrm{Growth}_{i,t-1} = \mathrm{Sales}_{i,t-1}/\mathrm{Sales}_{i,t-2}$. In each formulation a stochastic variable ($\varepsilon_{it}, \mu_{it}, e_{it}$) is added to measure the error term.

In this simultaneous equation modeling system, the first formulation represents the performance function where performance (profit) is modeled as a function of concentration (HHI), R&D (RD), and growth (Growth). All variables except the Growth variable are current period (t); Growth is measured as lagged one period (t-1). The second formulation represents the structure function where concentration is modeled as function of structure, performance and conduct, with these latter measured with a one period lagged. The third formulation represents the conduct model where R&D is modeled as a function of profits lagged one period and also current timeconcentration and growth. The reason why R&D expenditures are a function of expected profits as opposed to current profits, according to Lichtenberg (2001), is the usual assumption by economists that capital markets are perfect and that firm's managers try to maximize profits of the shareholders, which make R&D expenditures follow future profits not current.

The simultaneous equation system thus specified for the purpose of this paper is estimated using a2SLS method with endogenous variables consisting of profits, concentration, and R&D expenditures and exogenous variables of growth,lagged growth, profits, concentration and R&D expenditures with these latter variables also lagged one period.

2.2. Data use

The data consists of observations on industrial plants employing ten or more people and carrying four digit codes within the high-tech industrial sectors of Iran (Table 1). The time span covers the 1994-2007 period. We use profit rate, i.e. after tax profit per unit of sales as a measure of performance or profitability, R&D expenditures per sale units(R&D expenditure intensity) as a measure of market conduct and degree of concentration resulting fromHerfindahl-Hirschman Index as a measure of structure.

Table 1. High –Tech Industries of Iran

Industry	Code Number
Chemical products except fertilizers and nitrogen compounds	2411
Pharmaceutical and chemical products used in medicine	2423
Office calculating and computer equipment	3000
Bulbs, electric tube bulbs and other electric equipment	3210
TV and radio transmitters and telegraph and communications equipment	3220
Radio and Television receivers	3230
Medical, surgical and orthopedic instruments	3311
Measurement, experimentation and control equipment and instruments	3312
Optical and photography equipment	3320
Motor vehicle production	3410
Air and space craft's production	3530

Source: Compiled from the raw data provides by the Iranian Statistical Center.

It is interesting to note how the average of each of the concentration index, R&D and profitability rate variables vary across the 11 industries used in this study. The

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profitability rate has the largest variation as measured by the standard deviation of 0.53, compared to 0.3 and 0.36 for the R&D and concentration index respectively (Table 2).

Table 2. A cursory examinations of the data.

Variable	Average	Standard Deviation	Minimum	Maximum
Concentration Index	0.36	0.34	0	1
R&D	0.07	0.3	0	2.48
Profit Rate	0.7	0.53	-3.8	1
Concentration Index Lagged	0.37	0.34	0	1
R&D lagged	0.07	0.31	0	2.48
Profit rate lagged	0.69	0.55	-3.8	1
Sales Growth Lagged	1.99	6.42	0	70

3. Model estimation and discussion

Since there are endogenous variables on the right hand side of all the three formulations in the system (1) an OLS estimate would yield inconsistent results. To avoid the inconsistency problem, we estimated the system using a 2SLS procedure within a panel data methodology framework. The consistency problem is resolved by use of endogenous variables of lagged profit rate, lagged concentration index, lagged R&D expenditure intensity, growth and lagged growth as instrumental variables. The variables are entered into the model in logarithmic forms.

To do some experimentation, we first estimated the system (1) excludingthe growthvariable in the profit and R&D formulations (Table 3), then, we estimated the system (1) including thegrowth variable in these formulations. (Table 4) and finally we estimated the system (1) using the lagged form of the R&D variable in the profit formulation (Table 5).

Comparing tables (3), (5) and (4) from the perspective of coefficient signsand probability, there does not seem to be any significant difference in the tables and thus we arbitrarily choose table (4) for discussion purposes.

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Table3. Parameter estimates of system(1) using 2SLS,excluding the Growth variable from the profit and R&D formulations.

Equations and Statistics		Coefficient Value	P-value
$\text{logProfit}_{it} = \alpha_0 + \alpha_1\text{logHHI}_{it} + \alpha_2\text{logRD}_{it} + \varepsilon_{it}$	α_0	-0.07	0.26
	α_1	-0.09	0.04
N=111 , R^2=0.08	α_2	0.04	0.07
$\text{logHHI}_{it} = \beta_0 + \beta_1\text{logHHI}_{i,t-1} + \beta_2\text{logRD}_{i,t-1} + \beta_3\text{logProfit}_{i,t-1} + \mu_{it}$	β_0	-0.22	0.01
	β_1	0.73	0.00
	β_2	-0.02	0.39
N=111 , R^2=0.56	β_3	0.03	0.85
$\text{logRD}_{it} = \gamma_0 + \gamma_1\text{logHHI}_{it} + \gamma_2\text{logProfit}_{i,t-1} + e_{it}$	γ_0	-2.2	0.00
	γ_1	-0.18	0.5
N=111 , R^2=0.03	γ_2	0.9	0.08

Table 4. Parameter estimates of system (1) using 2SLS, including the Growth variable in the profit and R&D formulations

Equations and Statistics		Coefficient Value	P-value
$\text{logProfit}_{it} = \alpha_0 + \alpha_1\text{logHHI}_{it} + \alpha_2\text{logRD}_{it} + \alpha_3\text{logGrowth}_{i,t-1} + \varepsilon_{it}$	α_0	-0.12	0.06
	α_1	-0.11	0.02
	α_2	0.03	0.002
N=102 , R^2=0.09	α_3	0.006	0.79
$\text{logHHI}_{it} = \beta_0 + \beta_1\text{logHHI}_{i,t-1} + \beta_2\text{logRD}_{i,t-1} + \beta_3\text{logProfit}_{i,t-1} + \mu_{it}$	β_0	-0.16	0.06
	β_1	0.78	0.00
	β_2	-0.01	0.59
N=102 , R^2=0.62	β_3	0.097	0.54
$\text{logRD}_{it} = \gamma_0 + \gamma_1\text{logHHI}_{it} + \gamma_2\text{logProfit}_{i,t-1} + \gamma_3\text{logGrowth}_{it} + e_{it}$	γ_0	-2.08	0.00
	γ_1	0.05	0.84
	γ_2	1.007	0.06
N=102 , R^2=0.04	γ_3	-0.06	0.538

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Table5. Parameter estimates of system (1) using 2SLS with lagged R&D included the profit formulation.

Equations and Statistics		Coefficient Value	P-value
$\text{logProfit}_{it} = \alpha_0 + \alpha_1\text{logHHI}_{it} + \alpha_2\text{logRD}_{i,t-1} + \alpha_3\text{logGrowth}_{i,t-1} + \varepsilon_{it}$	α_0	-0.12	0.04
	α_1	-0.107	0.03
	α_2	0.03	0.06
N=102 , R^2=0.08	α_3	0.006	0.6
$\text{logHHI}_{it} = \beta_0 + \beta_1\text{logHHI}_{i,t-1} + \beta_2\text{logRD}_{i,t-1} + \beta_3\text{logProfit}_{i,t-1} + \mu_{it}$	β_0	-0.13	0.14
	β_1	0.78	0.00
	β_2	-0.004	0.9
N=102 , R^2=0.62	β_3	0.08	0.6
$\text{logRD}_{it} = \gamma_0 + \gamma_1\text{logHHI}_{it} + \gamma_2\text{logProfit}_{i,t-1} + \gamma_3\text{logGrowth}_{it} + e_{it}$	γ_0	-2.08	0.00
	γ_1	0.05	0.8
	γ_2	1	0.06
N=102 , R^2=0.04	γ_3	-0.06	0.3

Our parameter estimates (table 4) indicate that the concentration index coefficient in the formulation related to performance is negative and meaningful and that the profit rate is positively related to R&D expenditures. In other words a one percent increase in R&D expenditures leads to .03 percent increase in the profit rate. The coefficient of sales growth variable in the profit rate formulation is also positive, but without any statistical significance.

Thus profitability in high-tech industries is positively and meaningfully related to the variable reflecting market conduct and increases in market structure do not increase profitability in accordance with the SCP paradigm. In fact increases in market structure show negative and meaningful effects on profitability. The negative relationship between concentration and profitability not only is true at the industry level, but according to Kwoka and Ravenscraft(1986) also at the firm level as resulted from their statistical test of competitor firms. The explanation is that increases in the share of superior firms reduce shares of other firms. The superior firms do not remain binding to joint agreements and cause a break in the merger industry.

The coefficient of lagged profit rate in the formulation related to market structure is positive, but insignificant and that of lagged R&D is negative but insignificant. The lagged concentration index coefficient is positive and significant meaning that the concentration index is driven by its own past values and that the profit rate and R&D expenditures do not have any effect on the concentration index in high tech-industries.

The coefficient of lagged profit rate according to the estimates related to the conduct formulation is positive and meaningful such that aone percent increase in the profit rates of the preceding year leads to about one percent increase in R&D expenditures. The coefficient of the growth variable is negative and meaningless. The effect of market concentration on R&D expenditures is positive but meaningless too. Hence in high-tech industries, profitability is the only major variable influencing R& D expenditures.

The overall conclusion reached by estimating the three formulations related to the SCP paradigm within a simultaneous equation system framework, drawing on observations made of high-tech industries in Iran, points to the direction that conduct and performance are bidirectional related, meaning that performance is under the influence of conduct, though much less than conduct is under the influence of performance. On the other hand there is no uni-directional or bi-directional meaningful relationship between market structure and conduct. The effect of performance on structure is meaningless while structure has a negative and meaningful effect on performance

4.Summary, Conclusion

The thrust of the paper, materialized

in our modeling and estimating the SCP system components with observations drawn from the Iranian high-tech industries, is that performance seems to follow conduct. In more specific terms, in high –tech industries, increases in R&D expenditures are likely to lead to increases on profitability in these industries. Concentration has a negative and meaningful effect on profitability of high-tech industries. Similarly, the market power hypothesis that says market power determines profitability cannot be accepted in our estimates of the market concentration formulation. Market concentration, according to our estimates, is driven by its own past. R&D expenditures, on the other hand, are driven by lagged profitability such that a one percent increase in lagged profitability leads to a one percent increase in R&D expenditures. No meaningful significant two- way relationship between structure and conduct in high-tech industries is detected. That brings us to the final word as advice to the policy makers that policies for enhancing R&D activates in high-tech industries has a strong bearing on future performance of these industries.

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ارزیابی تأثیر مخارج تحقیق و توسعه بر عملکرد صنایع با فناوری بالای ایران

سمیه اعظمی[۱]

تاریخ دریافت: ۹۱/۹/۲۰ تاریخ پذیرش: ۹۲/۱۱/۷

هدف اصلی این مقاله بررسی تاثیر مخارج تحقیق و توسعه بر سودآوری صنایع با فناوری بالا با کد چهار رقمی ایران می باشد. این مطالعه با استفاده از داده های مربوط به کارگاه‌های صنعتی ۱۰ نفر کارکن و بیشتر با کد چهار رقمی، طی سال های ۸٦ – ۱۳۷۳ با تمرکز بر پارادایم ساختار ـ رفتار- عملکرد و استفاده از روش معادلات همزمان به بررسی اثر مخارج تحقیق و توسعه بر عملکرد صنایع با فناوری بالای ایران می پردازد. مدل اقتصادسنجی این مطالعه با استفاده از داده های پانل و به کار گرفتن روش حداقل مربعات دو مرحله ای (2SLS) برآورد شده است. نتایج این مطالعه حاکی از تاثیر مثبت مخارج تحقیق و توسعه بر سودآوری صنایع با فناوری بالای ایران می باشد، همچنین تأثیر مثبت سود با وقفه بر مخارج تحقیق و توسعه صنایع با فناوری بالای ایران تایید می شود. بنابراین مخارج تحقیق و توسعه و سود در صنایع با فناوری بالا متقابلاً همدیگر را تقویت می کنند.

واژه‌گان کلیدی: مخارج تحقیق و توسعه، صنایع با فناوری بالا، سیستم معادلات همزمان، سودآوری.

طبقه بندی JEL: $O_{32},O_{14},L_{10},C_{30}$.

۱. استادیار دانشگاه رازی، دانشکده علوم اجتماعی، گروه اقتصاد.

با تشکر ویژه از دکتر ابراهیم حسینی نسب برای همکاری مؤثر خود در این مقاله.

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