Impacts of Firm size on Innovation Based on Quality Data from a Developing Context

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Abstract

The debate over innovativeness of large firms and SMEs, which was bolded by Schumpeter, still continues under mixed empirical evidences. The present study has explored the proportionality of increase of innovation activity versus firm size over 522 Iranian knowledge-based firms categorised in eight industries. Distinctively, a first-time nation-wide, external, and specialised four-stage evaluation including site visits was conducted by industry experts for verification of financial figures and their attribution to innovative products and services.

Innovation activity was defined as R&D expenditure and sales of innovative products and services (two runs), while number of employee stood for firm size. Using log-log regression, significant more-than-proportionate relationships were found for both input and output measures of innovation for all industries, with two industry exceptions that were justified. Yielding similar satisfactory explanatory powers of about 10-50% and a very low standard error, the proportionality coefficient was found to be greater for innovation output measure of sales when compared with R&D expenditure measure, i.e. 1.35-2.04 versus 1.08-1.41 respectively. As result, it is advocated that large firms should not be underestimated in innovation policies in a start-up atmosphere. Networking of SMEs around innovative large firms is reemphasized here to take the power of both and move toward capability building, especially in developing states with a large body of government such as Iran. For generalisation purposes, the relatively small-sized population and the rigorous operationalisation of innovation output measurement should be taken into consideration as the limiting and strength features of the present research, respectively.

Keywords: Innovation activity, Firm size, R&D expenditure, Sales, Log-log regression

1 Introduction

The debate over a more than proportionate positive relationship between firm size and innovation activity, which was first bolded by Schumpeter, still continues under mixed empirical evidences (Noori et al., 2016). Schumpeter (1942) argued that in a concentrated market, technological progress is mainly achieved by the engine of large firms. The importance of such debate goes back to the hypothesised underlying mechanisms, such as economy of scale and centralisation, and the subsequent policy implications, such as policy orientation in support of large firms, justifying industrial policies of support for "large firms" as national champions and saviours of economy, allocation of research and development (R&D) subsidies to large firms, and relaxation of anti-trust laws (Sachs and McArthur, 2002).

Although there have been confirmatory empirical studies, there are also some findings which, at least apparently, contradict the Schumpeter’s hypothesis and favours small- and medium-sized enterprises (SMEs) (Becheikh et al., 2006). One of the issues contributing to this indecisiveness is various measurement proxies of innovation and firm size, which are not necessarily correlated and makes results less comparable (Becheikh et al., 2006). While firm size is mostly measured by number of employees, although number of R&D employees or total sales has been used too, it is the innovation measurement that adds to the complexities and ambivalence of the research designs and interpretation of the findings. On this basis, several classifications have been emerged in the literature for measurement of innovation activity, including direct versus indirect innovation, product versus process innovation, and input versus output measures of innovation (Becheikh et al., 2006; Hansen, 1992).

While output measures of innovation, such as number of patents, number of significant innovations, patented products and sales attributable to innovative products and services indicate the modern approach and are theoretically preferred to the input ones, their operationalisation suffers from a set of obstacles (Archibugi and Sirilli, 2000). One of the obstacles is about the attribution of innovation to products and services, and thus measuring sales, profit or efficiency ascribed to innovation activity. Practically, reaching such attribution of innovation activity to specific products and services requires specialised knowledge and experience about the industry and products, which is not usually at the hand of a researcher. This may in turn cause inclination towards input measures of innovation or less broad investigations.

The present paper is intended to empirically explore and compare the degree of innovativeness of large firms and SMEs, via both an input and output measure of innovation, i.e. sales attributable to innovative products and services, and research and development (R&D) expenditure. For this purpose, Iranian knowledge-based firms were chosen as the population and regression was used as the statistical method. While examining Schumpeter's idea via both input and output measures of innovation is not a new thing, it is the methodological rigor of the attribution of sales to innovative products and services which makes the present study distinctive from previous studies. Thanks to the database of Iranian knowledge-based firms (The Iranian Vice-presidency for Science and Technology, 2015), the four-stage process for evaluation and confirmation of innovative products and services of firms and attribution of sales share and other financial data thereto have formed the core of the distinctive methodological rigor of the present study. For example, experts and specialists are independently assigned for site visit of all firms, which let them access all financial documents to verify the previously self-reported data by firms. Experts would hold a meeting soon after each site-visit to reach a consensus, and the documented opinions and assessment would be sent to the second and third rounds of official verification. Specifically speaking, the results indicate whether financial information are genuine and true, and what extent of them stem from innovation activities, and of what nature, e.x. technological or non-technological, market, etc. Thus, a specific section is devoted to the details of the four-stage evaluation process, and the resulting rigor and quality.

In the forthcoming sections, at first, definition of innovation, its distinction with surrounding concepts and the literature on advantage of large firms or SMEs in doing innovation is discussed, which is accompanied by some empirical evidences. Then, practical issue of innovation measurement would be debated, with a focus on the dichotomy of input versus output measures. The methodology is another section which explains the statistical method applied, the characteristics of the population. After that, the rigor and distinctiveness of the measurement of sales of innovative products and services of the present research is elaborated. The paper would be concluded after discussing the log-log regression findings in the format of two tables, to see if there is any more-than-proportionate relationship between firm size and innovation activity in each industry, using sales and R&D expenditures of more than 500 knowledge-based firms.

2 Literature review

2.1 Background

Regarding innovation sources, Schumpeter (1934) suggested that entrepreneurs and start-ups represent the foremost source of new ideas and technologies. However, in "Capitalism, Socialism, and democracy", Schumpeter (1942) stated that innovation activity increases more than proportionally with firm size. Some important hypothesised reasons which explain increase of innovation more than proportionate with firm size are as below:

1. Since R&D projects typically involve large fixed costs, sufficient large sales are required.

2. Production of innovation involves economy of scale and scope.

3. Large diversified firms are in a better position to exploit unforeseen innovations.

4. The risk of R&D could be better distributed and lowered in large firms through defining simultaneous diverse R&D projects.

5. Large firms have better access to external finance.

6. Firms with greater market power are more relaxed of the competition which let them advance the technology.

7. Having high market power or share let firms utilise returns of their innovations which in turn encourages them for further innovation activity (Sachs and McArthur, 2002).

There have also been some counterarguments. The often quoted argument states that due to loss of managerial control and bureaucratisation of innovation activity, there would be a decrease of returns to scale in the production of innovations. Another argument points to the inertia which may arises out of the absence of strong competitive pressures, i.e. related to market power concept (Symeonidis, 1996). Utilising interactive learning networks as a complementary response to the lack of internal resources, advantage of greater flexibility, being more dynamic and responsive despite minor share of R&D are also argued in favour of SMEs (Doloreux and Melançon, 2008). The former suggested deficit could be marked as internal (intra-organisational) and the latter as external (inter-organisational). Of course, these arguments should be checked by empirical studies, which is the topic of the next section.

To be more exact by innovation activity, at least as it should be understood in the present investigation, innovation is not meant to be confined to R&D activities or the products and services introduced for the first time to the world, but also to cover products and services developed for the first time in a country via reverse-engineering or catch-up, besides mere innovation. In fact, there is a distinction between R&D activity and innovation activity according to Frascati Manual, such that reverse engineering and catch-up are excluded from R&D activities (OECD, 2002), but not from innovation activities as a more inclusive area. In other words, innovative products and services are not necessarily from R&D sources, but could derive from, inter alia, reverse engineering and catch-up. Having such wide definition is necessary for technological advancement of developing countries, as is the case of the present study, and is also compliant with measurements done in previous studies, such as Patel and Pavitt (1992).

2. 2 Empirical investigation of Schumpeter's hypothesis

Scherer (1965a, 1965b), in his two early influential studies, regressed R&D employment intensity (i.e. R&D employment relative to total employment) and number of patents on sales data of 448 firms from the 500 largest US industrial firms. As a result, an inverted U-shape relationship was found between R&D employment intensity and sales for the total sample and also for each industry, except the chemical sector. It was found that the number of patents increased less than proportionately with sales, except for a few very large firms, which in case was interpreted by Scherer as a rejection of the Schumpeterian hypothesis indicating a positive disproportionate effect of firm size on innovation. In another attempt using US data for 500 firms within the years of 1975 and 1976, Soete (1979) reached a mixed result that R&D intensity used to raise with size in a number of industries and to decrease with size in others. Since the effect of industry type was not controlled, the results obtained by Soete for the overall pooled sample may not be very reliable, besides that a mere correlation was investigated and not the proportionality. Controlling the effect of industry for such studies has been emphasised by several scholars, since firm size is likely to be correlated with industry-level variables, such as technological opportunity, which are, in turn, likely to have a positive effect on innovation activity (Cohen and Levin, 1989; Symeonidis, 1996).

Scherer (1986) examined the effect of business unit size on business unit R&D intensity using FTC Line of Business data. Despite the fact that the over-categorisation of industries caused only a few observations per most of the industries investigated, Scherer ran simple regressions of R&D expenditure on sales data for 196 industries. The results showed an increase of R&D intensity with sales in 20.4% of the industries and a decrease with sales in 8.2% of the industries, while the size coefficient was not statistically significant for the rest (it was positive in roughly half of the cases). In running regression over patent counts, Scherer discovered an increase more than proportionately with sales in 11.3% of the industries, less than proportionately in 15.3% of the industries, and no statistically significant departure from proportionality within the remnant. In general, it could be said that his findings were mixed and only supported a little overall effect of size on innovation activity.

The mixed or contrary results of such studies focused on R&D do not necessarily question the results of studies targeting innovation activity in its broader meaning, since innovation activity is more inclusive than just R&D and covers catch-up, reverse-engineering, non-technological innovation, etc. In fact, the assumption that R&D expenditure measures inputs of innovation activities and patents the resulting output, has become increasingly brittle such that today, strong empirical findings and better understanding of innovation concept dictate inclusion of design, testing, production and marketing under innovation concept umbrella (Mansfield et al., 1971; Patel and Pavitt, 1992).

In a later study, Acs and Audretsch (1991) statistically investigated possible relationship between innovation production and firm size for 732 relatively large firms. Of those firms, 426 had not produced any innovation, while 306 had at least one innovation. Counting number of innovations for 14 industrial sectors and also in total, they depicted that innovation increases less than proportionately with firm size. Unfortunately, innovation count suffers from several shortcomings, including favouring radical innovations over incremental ones (Becheikh et al., 2006), product over process innovations (Flor and Oltra, 2004), disregard of unsuccessful innovations and expertise of industry (Archibugi and Planta, 1996).

Investigating the world's 660 largest technologically active manufacturing firms, Patel and Pavitt (1992) examined the relationships between firm size and R&D expenditure, on the one hand, and firm size and number of US patents, on the other, for 16 industries. It should be noted that in their view, patent and R&D expenditure are two indicators of innovation activity. Through the R&D expenditure measurement, they found just 3 sectors having a significant relationship between innovation activity and firm size; When measuring US patent numbers, 11 sectors depicted no statistically significant difference from proportionate, 4 sectors more than proportionate (mining, electrical and electronic products, materials and food) and one sector (pharmaceuticals) a relationship less than proportionate between innovation activity and firm size. With some exceptions, they concluded that innovation activity in general tends to increase proportionally with firm size. It should be noted that their sample although covered a broad spectrum of firm size, was mostly composed of large sized firms. Shefer and Frenkel (2005) also empirically inspected the role of firm size in the share of labour engaged in R&D as well as the rate of investment in R&D in a group of high-tech firms and reached a very close relationship but of a negative nature. Of course, as they stated, their results were inconsistent with the previous researches. Supportably, Raymond and St-Pierre (2010) found a mediating role of process innovation, less studied empirically, between R&D and innovation, which reinforces doubts about using the input measure of R&D expenditure as a true proxy of innovation activity. In a related vein, Lee et al. (2014) have found a negative relationship between firm explorativeness, as the degree of using knowledge new to the organisation in pursuit of innovation, and R&D intensity, which gain could be interpreted in favour of the idea that R&D intensity does not truly capture innovation activity.

In addition to measuring R&D expenditure, patent valuation and counting, and enumerating innovative products which was shown above, some studies have used sales data of innovative products as an innovation activity indicator, such as Hansen (1992), Herrera and Sánchez-González (2012), Kemp et al. (2003), Kleinknecht (2000), and Kleinknecht and Oostendorp (2002). In this regard, Bertschek and Entorf (1996) analyzed the Schumpeterian link between innovation activity and firm size with four data sets referring to the manufacturing industries of three European countries, i.e. Belgium, Germany and France, using share of sales attributable to innovative products as the indicator of innovation activity output. They found a U-shaped link between innovation activity and firm size, saying that small and large firms are more innovative than medium ones.

More recently in a study conducted on the firms of developing countries for the first time, Waheed (2011) studied the impact of size and competition on firm-level innovation activities in 14 Latin American countries using Enterprise Survey data of the World Bank and by taking into account both input and output innovation measures. He found that firm size increases the likelihood of R&D and product innovation and that the influence on R&D expenditures is positive but at less than proportionate rate. Aiello and Castiglione (2013) investigated whether firm size has impact on the probability to carry out R&D efforts and to R&D intensity, taking into account learning and spillover effects. They used a panel of Italian manufacturing firms over the period 2004-2006 and find a strong relationship between firm size and innovation activity. However, they found that results were strongly influenced by the Pavitt sectors so that firms belonging in the supplier dominated and scale intensive sectors have different results from those in the specialised supplier and science based sectors. In another instance, Alsharkas (2014) has investigated the effect of firm size in a 2-year panel study composed of both cross-sectional and longitudinal investigation which revealed that large firms innovate more than smaller ones. He has also stressed the vital role of financial resources in innovation. Moreover, Dooley et al. (2015) recently depicted that large-scale firms are more active than SMEs in leveraging external resources for innovation which logically supports the Schumpeter's hypothesis.

2. 3 Innovation measurement

In empirical studies of the relationship of innovation and firm size, there is an absence of consensual measures of innovation activity (Aiello and Castiglione, 2013; Kemp et al., 2003). Accordingly, one would encounter with different categories of innovation activity measures, i.e. direct versus indirect measures (Becheikh et al., 2006) or traditional (input) versus new (output) measures (Hansen, 1992). In general, there are some disadvantages associated with each measure and those advantages highly depend on the case under study (Becheikh et al., 2006). In addition, it is difficult to capture, measure or assess innovations embedded in products and services (Griliches, 1979). Despite the difficulties, a variety of practical measures has been developed for the measurement of innovation activity which could be broadly classified as measures of either innovation inputs or outputs (Alsharkas, 2014; Becheikh et al., 2006; Hansen, 1992; Waheed, 2011). As seen in previous sections, measures of innovation output, which indicate the modern approach to innovation measurement (Hansen, 1992), include number of patents (Furman and Hayes, 2004), number of patented products (Laforet, 2008), number of significant innovations (Alsharkas, 2014; Furman and Hayes, 2004), and various indices of the market value of innovations such as patent value (Koski et al., 2012) or sales and profit attributable to innovative products and services (Becheikh et al., 2006; Hansen, 1992).

There are some shortcomings associated with each innovation measure. Some R&D activities, or in a broader sense some informal innovations, take place outside a firm's formal R&D operation. Thus the measures being focused on R&D department may derive misleading results, especially for small firms which usually do not have any formal R&D department (Kleinknecht, 1987; Patel and Pavitt, 1992; Schmookler, 1972). On the other side, input measures of innovation hamper from the shortcoming that efficiency and effectiveness of R&D or innovation activity are not taken into the consideration (Hansen, 1992). Regarding measures of innovation output, patent is one of the measures which may be counted or valued. The main problem with patent count is that patents are of different or even diverse economic value (Koski et al., 2012) and that the propensity to patent varies significantly across industries, countries or even regions (Furman and Hayes, 2004). Patent value measures also suffer from a robust and reliable methodology of estimation and quantification (Kamiyama et al., 2006). In fact, such measures assess the dedication of an organisation to allocation of financial or human resources to R&D, but do not determine if the resources and policies in place are yielding sufficient and desired returns. To cover the shortcoming, output measures of innovation activity should be used in addition to input ones, if possible (Hansen, 1992; Kemp et al., 2003).

A distinction should also be made between R&D activities and innovation activities (Mansfield et al., 1971). Innovation activity is not confined with R&D activities or the products and services introduced for the first time to the world, but also covers products and services developed for the first time in a country/ firm via reverse-engineering or catch-up in addition to mere innovation of either technological or non-technological nature. Although Frascati Manual excludes reverse engineering and catch-up from R&D activities (OECD, 2002), it does not relate to innovation activities as a more inclusive area. Therefore, although R&D indicators such as R&D expenditure are used as an innovation activity measure, it does not cover all of innovation activities occurring in a firm, including informal, incremental and insignificant innovations.

3 Research design

For measurement of innovation activity, two definitions were selected based on the available database, R&D expenditure as an input indicator of innovation activity; and sales of innovative products as an output indicator. Not selecting patent measures goes back to the reasons: 1) patenting at foreign or international patent office such as USPTO or PCT is unusual among Iranian residents, and 2) Iranian Patent Office does not incorporate necessary proofing procedures and tools compared with international rivals, and 3) patent counting suffers from previously mentioned shortcomings which makes it an overestimate of innovation activity, and in some cases, underestimate.

Firm size could be measured by various indicators such as the number of employees and firm sales (Becheikh et al., 2006; Laforet, 2008). Of course, these indicators are not necessarily correlated. Number of employee, which is a prevalent measure of firm size (such as, Amara et al., 2008; Cheng and Krumwiede, 2012; Delgado-Verde et al., 2016; White, 1988), has been used in the present study. Usually, firms with less than 20 employees are considered as SME (small), with 20-49 employees as medium-sized, and with 50+ employees as large (Becheikh et al., 2006; Laforet, 2009; Patel and Pavitt, 1992; White, 1988). Since regression has been used as the statistical method of the present study which enables one to continuously monitor the changes of dependent variable, there was no need to piece-wisely demarcate between small, large and medium-sized firms, and such threshold was only used for provision of descriptive statistics regarding size distribution. The population under investigation consisted of 532 firms. The employee numbers (firm size) ranged from 2 to 189, of which 120 firms (over 20%) had more than 20 employees. Thus, although the population has covered a broad spectrum of firm size, the firms could be considered mostly small, especially when compared with an study such as Patel and Pavitt (1992). Since the database itself suffered from an over-categorisation of industries, the authors re-categorised the firms into eight industries. The number of firms in each industry is shown in Table 1 which ranges from 29 firms active in food industry to 129 firms active in ICT industry.

Importantly, in contrary to previous studies, the database of Iranian knowledge-based firms of The Iranian Vice-presidency for Science and Technology (2015) used here has several interesting characteristics, including not being self-reported but rather cross-checked by several independent external evaluators, benefitting from a four-stage evaluation of process, utilisation of experts of each industry and product group, doing a site-visit, and checking and approving financial statements. This gives a reasonable degree of confidence regarding the validity of the sales figures attributed to innovative products and services. Finally, the database is considered a comprehensive one, since it is gathered and organised by the formal authority in a country-wide scope. The details of the evaluation process are provided in the next section.

As a delimiting point, it should be stated the governmental definition of knowledge-based firm in Iran is focused on technological innovation, and thus encompasses both manufacturing and service firms, but not non-technological innovations. Of course, there are several established criteria for determination of technological and non-technological eligibility of firms to be included to the approved list, which have not been made public. In addition, the governmental evaluation, and thus our study, does not encompass process innovation, but just innovative products and services.

Observing the probability distribution diagrams of the R&D expenditure and innovative sales of the firms, a linear relationship was rejected. This led the authors to test logarithmic scale, which its normal probability plots initially seemed satisfactory. Therefore, a log-log regression method was considered appropriate. It should be noted that upon visual checking of the initial overall regression (not separately for each industry), 10 outlier data having non-sense values, such as no sales data or having no employee, were removed which did not change the output of the regression more than 0.1%.

4 Methodological rigor

Although output measures of innovation activity are preferred to the input ones due to better capture of the efficiency, they still suffer from shortcomings. For example, market value of innovations, such as sales associated with innovations, stock market response to patent grants and patent renewals are called imperfect proxies for the actual value of innovations (Symeonidis, 1996). On the other side, the difficulty of attribution of sales share to innovative products and services, and even determination of innovative products and services, made researches inclined toward input measures which are more readily available.

Fortunately, The Iranian Vice-presidency for Science and Technology (2015) has started a nation-wide evaluation and registration of Iranian knowledge-based firms several years ago, which encompasses a four-stage specialised evaluation of innovative products and services of applicant firms by external evaluators and reviewers. The first stage includes a preliminary assessment of financial and technical documents submitted by applicant firms. This assessment would be conducted by approved independent private evaluation agencies to determine eligibility of applicant firms. The second stage includes a site visit of the applicant firm by the same evaluators and reviewers of the first stage, including a professional accountant and a technical expert of considerable experience in that products introduced by an independent evaluation agency, and an auditor introduced by The Iranian Vice-presidency for Science and Technology, the formal authority.

It should be noted that there are also some technical and financial criteria established for evaluation of innovativeness of a product and service and the attribution of financial figures thereto. In the third stage, the professional accountant would check and approve the financial statements and claims of the applicant, after having a site visit. Finally, a committee of about five professionals and government representatives would vote if an applicant is a knowledge-based firm, according to the formal definitions set out by the law and regulations, and also approve/ decline the details of technical and financial results out of the three previous evaluation stages, including sales attributed to innovative products and services and both informal and formal R&D expenditure.

Such an external comprehensive evaluation and determination of innovative products and services and the financial figures associated with, such as sales, expenditures and efficiency, is difficult could be replicated by a researcher, since it requires a lot of cost, specialisation, time and involvement of many professionals and experts in a large scale. But, the rigor out of such comprehensive external specialised evaluation of innovation activity of firms, which was possible just through a previously-ran nation-wide evaluation by formal authority, adds a distinctive value to the findings resulted from careful operationalisation of innovation activity measurement via an output measure, i.e. sales.

5 Findings and discussion

The log-log regression was performed for 10 industries. The two hypothesised relationships were defined as:

Log (innovation activity) = a + b × Log (firm size) (1)

In Table 1, innovation activity is measured via the input proxy of R&D expenditure, while it is the output measure of sales of innovative products and services which determines innovation activity in Table 2. It is worth reminding that intercept of regression (a) is statistically not of importance and just acts as an equation fulfilment.

Table 1 Regression results for relationship of firm size and innovation activity using R & D Expenditures (on a log-log scale)

Industry	Coefficient (b)	Adjusted R square	Standard error	Number of firms
Advanced Industrial Equipment* **	1.017	0.1442	0.6766	93
Advanced Materials	0.449	0.0124	0.6105	43
Biomedicine**	1.409	0.2054	0.6689	42
Electronics*	0.550	0.0501	0.7029	68
Energy***	1.083	0.2903	0.5376	54
Food Industry*	1.077	0.1279	0.6202	29
ICT***	1.124	0.3106	0.6075	129
Pharmaceutical Industry***	1.309	0.4999	0.6164	29
Miscellaneous **	0.960	0.1963	0.6737	35
Total***	0.999	0.2088	0.6386	522

* Significance-level of 5%; ** Significance-level of 1%; *** Significance level of 0.1%.

Table 2 Regression results for relationship of firm size and innovation activity using sales (on a log-log scale)

Industry	Coefficient (b)	Adjusted R square	Standard error	Number of firms
Advanced Industrial Equipment***	1.665	0.1757	0.9913	93
Advanced Materials*	1.547	0.1296	0.9643	43
Biomedicine**	1.920	0.1944	0.9403	42
Electronics*	0.827	0.0807	0.8571	68
Energy***	1.467	0.2226	0.8619	54
Food Industry**	1.685	0.2078	0.7587	29
ICT***	1.349	0.2500	0.8454	129

Pharmaceutical Industry* **	2.035	0.4318	1.0933	29
Miscellaneous	0.977	0.0575	1.1928	35
Total* **	1.394	0.1951	0.9302	522

* Significance-level of 5%; ** Significance-level of 1%; *** Significance level of 0.1%.

Generally speaking, while the adjusted R-square column shows the percentage of the variance of the dependent variable explainable by the independent variable, the coefficient column stands as the most important one to the research objective. Upon the condition of having a significant p-value, coefficients (column 3) notably greater than 1 convey that innovation activity increases more than proportionate with firm size in that industry, while a coefficient near 1 implies no meaningful superiority for larger firms and a value less than unity indicates a less than proportionate relationship in favour of smaller firms.

5. 1 Statistical significance

As it could be seen from both tables, except advanced materials and miscellaneous categories, all industries depicted significant relationships between firm size and R&D expenditure at a significance level of 5%, which indicates a consistency regarding significance of the results in both cases of measurement. Interestingly, the significance level for each industry was the same for both measurement proxies of innovation activity, with an exception of food industry which varied between 5% and 1%. In other words, pharmaceutical industry, energy, ICT and advanced industrial equipment industries all have shown the high significance level of 0.1% in both Tables, while biomedicine industry depicted a significance level of 1% in both measurement proxies. Of course, there was no expectation for significant results regarding the miscellaneous category or even the total run.

5. 2 Explanatory power

Excluding electronics and advanced materials industries, the adjusted R squares (column 3) ranged 12-50% and 12-43% for R&D expenditure (Table 1) and sales (Table 2) data, respectively, which essentially are very close together and consistent with each other. While the lower range of such R square values may indicate insufficient explanatory power for a full model predicting a dependent variable, it seems fine for firm size as an explanatory factor besides many other determinants of innovation activity, such as firm age, ownership, culture, management team, functional assets and strategies, global strategies, structure and control activities (Becheikh et al., 2006). In other words, firm size is not expected to be a good or sole predictor of innovation here, but rather it is just intended to find if there is a relationship more than proportionate between innovation activity and firm size. Accordingly, relatively low R square values are justified here.

Standard error is another statistic, which covers information closely related to R square, but not limited to it. Unlike R square, standard error of regression could be used to assess the precision of predictions. Approximately, 95% of the observations should fall within ±2*standard error of the regression from the regression line, which is also a quick approximation of a 95% prediction interval. Therefore, about 95% of the observations should fall within ±2.1% of the fitted line in both cases, which is a close match for the prediction interval.

5. 3 More-than-proportionate relationship

Looking into the column of Coefficient reveals that except electronics and advanced materials industries, all other industries yielded a significant coefficient (b) greater than unity, which implies a more than proportionate relationship between innovation activity and firm size, in favour of Schumpeter's idea. Mathematically speaking, for example, by the coefficient of 1.124 for ICT industry, a non-linear relationship with a power of 1.124 is meant, i.e. innovation activity equals $10^{a}*(\text{firm size})^{1.24}$.

Besides the similarity of both results regarding confirmation of Schumpeter's hypothesis, by excluding electronics and advanced materials and miscellaneous categories, one could see the general higher range of the coefficients for the case of sales measurement (Table 2), i.e. about 1.35-2.04 when compared with about 1.08-1.41 for R&D expenditure measurement (Table 1). Specifically, the relationship was as disproportionate as a coefficient of 2 (in a log-log scale) for pharmaceutical and biomedicine industries and at least 1.35 times for ICT industry.

The overall pattern is reinforced and bolded when one compares the coefficients industry by industry, which yields an always higher coefficient for sales measurement, no matter which industry investigated. This should be translated to a stronger confirmation of Schumpeter's hypothesis by utilisation of the output measure of innovation activity, i.e. sales of innovative products and services, rather than an input measure of R&D expenditure, if the advantages of the modern approach of output measurement of innovation activity is accepted as emphasised by the literature (). The total regression shows a correlation coefficient very close to unity in Table 1, while a considerable more than proportionate relationship is depicted for the total data in Table 2. Considering the sales data as an output measure of innovation activity, the overall regression revealed a great significant level (0.1%) and a disproportionate relationship of about 1.39 times between innovation sales and size, which confirmed the segregated findings for each industry.

5. 4 Two industries excluded

As it was repeatedly mentioned earlier, the conclusions derived so far were based on the exclusion of two industries of electronics and advanced materials, which depicted inconsistent patterns with the rest of the industries. Accordingly, the authors tried to investigate if there is any justification for such discrepancy, with the aid of open interviews with some of the professional evaluators engaged with and also the experts of those industries.

As a matter of fact, the interviewees all emphasised that electronics industry is characterised by economy of scale, heavy international competition and capital intensiveness. In this industry, manufacturers should focus on international competition and export, and cannot survive on a local or national basis of sales and economy of scale. Therefore, Iranian electronics firms are mostly small and cantered on designing, and not manufacturing, due to obstacles such as high investment needed for purchase of highly expensive equipment, the required economy of scale and exportation. Thus, Iran's electronics industry is mostly composed of small firms (in number of employees) dedicated to solely designing specialised electronic parts, such as specific ICs, and ordering international manufacturers for the production to fulfil domestic market niches. This has caused a special firm size distribution in this industry, which is mostly consisted of small ones. Accordingly, it could be argued that Iranian electronics industry do not possess sufficiently broad distribution of firm size, especially the larger extreme, to make it a fair candidate for investigation of the Schumpeter's hypothesis.

Based on further interviews with the experts of advanced materials industry of Iran, the same conditions and reasoning were found to be applicable to that industry, too. Concerning these two industries, the similarity of the statistical results in both measurement cases (Tables 1 and 2), such as very low explanatory power as depicted by adjusted R square, a less than proportionate relationship in contrast with other industries as depicted by coefficient b, and statistical insignificance or the least significance achieved, reinforced the argument set forth. Accordingly, the different behavior observed for these two industries and their exclusion is justified. Needless to restate that it was not expected to observe a significant relationship for the miscellaneous category, since it is a combination of various other industries, a relatively small number of firms in each, which is in contrary to the stress of the literature on controlling industry effects (Cohen and Levin, 1989).

5. 5 Comparison with prior studies

A substantial body of the literature has focused on the relationship between innovation and firm size, which in general have yielded mixed results. Of course, this does not necessarily mean contradicting results, but many contextual and internal factors affecting type and volume of innovation activity (Becheikh et al., 2006). In this regard, influence of factors such as firm size (Bertschek and Entorf, 1996), firm age (Hansen, 1992), ownership (Bishop and Wiseman, 1999; Shefer and Frenkel, 2005), strategies (Ahuja, 2000; Beneito, 2003; Hitt et al., 1997, 1996), sectoral and industry parameters such as competition and concentration (Alsharkas, 2014; Evangelista et al., 1997; Waheed, 2011), policies (Coombs and Tomlinson, 1998), and finance (Beneito, 2003; Hitt et al., 1997, 1996) have been studied. In addition, the diversity of innovation measures, including input and output indicators of innovation, such as sales of innovative products and services, R&D expenditure, patents, and number of R&D employees exaggerates the mixed results. As a consequence, finding exact counterpart study from all aspects of population, type of innovation, innovation measure, and industries or products involved, if not impossible, is difficult.

The present study found consistent results for both innovation activity measures of sales and R&D expenditure, in favour of the Schumpeter's hypothesis. Regarding relationship between R&D

expenditure and firm size, Patel and Pavitt (1992) found just three industries out of the fourteen studied, including chemicals, mining and motor vehicles, to have a significant more than proportionate relationship between innovation activity and firm size, using R&D expenditure measure. Using patent statistics as measure of innovation activity, they have found significant more than proportionate relationships of innovation activity and firm size for three different industries out of the fourteen studied, i.e. food, non-metallic minerals, electronics and mining. Their study could be characterised as a vast study of large firms from all countries, which in brief, was concluded to support a proportionate relationship between innovation activity and firm size, despite some discrepancies among the industries and also the innovation measures. Their database missed smaller sized firms to some extent, as confirmed by the authors. Accordingly, since the database of Iranian knowledge-based firms is a small sized one, especially when compared with that of Patel and Pavitt (1992), they could be considered complementary to each other by fulfilling different firm size extremes.

Contrarily, Waheed (2011) in a study on 14 developing countries of Latin America found a less than proportionate relationship between R&D expenditure (innovation) and employment (firm size) using Enterprise Survey data of the World Bank. In a recent study, Alsharkas (2014) by citing researches such as Fisher and Temin (1973), Scherer (1965a, 1965b), Shefer and Frenkel (2005), and Tether et al. (1997), pointed to the fact that literature at best gave us a mixed and inconclusive result regarding relationship between R&D expenditure as a measure of innovation activity and employee number as a measure of firm size. This is so while the present study found consistent results for both input and output measures of innovation activities across all industries investigated. Although the consistency may be attributed to the relatively small-sized population, but it seems that the rigor out of external four-stage evaluation of innovative products and services and their financial figures precisely attributed forms the basis of such consistency and homogeneity.

Regarding relationship between sales of innovative products as an output measure of innovation activity and employee number as an indicator of firm size, it should first be mentioned that using sales figures of innovative products and services is not much usual in the literature and is estimated to be about 10% of the empirical studies conducted in this topic (Becheikh et al., 2006). Secondly, using different indicators for measurement of sales, such as value or number of patents out of sales of innovative products, counting the number of significant innovative products and services, or sales figures attributable to innovative products and services, lowers the comparability with scarce studies done so far (Hansen, 1992). Interestingly, the present study is in alignment with the results of Tether (1998), in which larger firms were shown to be more innovative than SMEs, when significance of innovations are taken into consideration by using e.x. sales figures instead of counting innovations. To sum up, the authors could not find any study fully comparable to the present research, taking into account the innovation measurement indicator, firm size definition, and the industries under study. The present results need not to be considered comparable with those studies that counted number of patents or significant innovations, but just patent value or more precisely sales figures.

The advantages associated with sales of innovative products and services, as an innovation output measure, makes it interesting for empirical studies, since it broadly reflects economic performance of innovation process (Herrera and Sánchez-González, 2012). Brouwer and Kleinknecht (1996) found that larger firms generally have a higher probability of selling some innovative products, although this probability increases less than proportionately with firm size. This contrary finding does not negate our results, since just innovation counting was in place which does not inherently corroborate with financial figures of sales, and suffers from the previously mentioned shortcomings. Kleinknecht (2000), and Mohnen and Kleinknecht (2002) also found that among the innovators, smaller firms tend to have higher shares in sales of innovative products. This again introduces another measure, i.e. sales share of innovative products out of the total sales, which is not comparable with the measure of sales of innovative products and services. In addition, it seems that innovation count, patent count, sales share of innovative products and also input measures of innovation activity cannot capture the essence of the concept for empirical examination of Schumpeter's idea. On the other side, if sales figures could appropriately be attributed to innovative products and services through rigorous methodology and evidences, it could best candidate actual innovation activity occurred in its economic sense. Thus, the conclusive part of the present study's findings does not contradict with previous researches, but also provides consistent empirical results in favour of Schumpeter's (1942) idea, utilising a first-time comprehensive rigorous external four-stage evaluation process, which contained site visits. Of course, the findings should only be interpreted within the limitations of the study, i.e. the relatively small-sized and knowledge-based population.

6 Conclusion

The present paper empirically investigates Schumpeter's (1942) idea that innovation activity of larger firms would disproportionately be greater than smaller ones, using log-log regression on sales of innovative products and services (an innovation output measure) and R&D expenditure (an innovation input measure) over Iranian knowledge-based firms. While controlling for the effect of industry type, the results out of both innovation measures were found to be consistent with each other and confirming Schumpeter's hypothesis in favour of large firms, conditional upon the exclusion of two industries of electronics and advanced material equipment. The exclusion of these two industries out of the eight industries studied was ignited by their statistically different behavior, which was then justified upon interviews with the experts emphasising on their special features of capital intensiveness, requirements of economy of scale, and thus typically small firms focusing on mere design, and not manufacturing. These have dictated a biased and insufficient distribution of firm size toward the small extreme, which have arguably caused inconsistent or insignificant statistical findings.

Accordingly, Schumpeter's (1942) idea was confirmed in favour of large firms. The literature pointed several reasons for such hypothesised relationship including coverage of large fixed costs of R&D, distributing and lowering risks of innovation, economy of scale and scope, and access to external finance. Interestingly, size has shown a satisfactory explanatory power and a good significance level of 1 and 0.1% for the industries studied. The explanatory power range of firm size variable was found similar for both measurement cases, i.e. about 10-50%, while the proportionality coefficient was found to be greater for innovation output measure of sales when compared with R&D expenditure measure, i.e. 1.35-2.04 versus 1.08-1.41 respectively. Conclusively, the findings were interpreted to be consistent with or complementary to previous empirical results, noting the advantages of output measures of innovation activity over the input ones, especially when operationalised through our first-time comprehensive rigorous external four-stage evaluation process, including site visits. Comparing the results, it is suggested that innovation output indicators be utilized instead of input ones, and to take their significance into account too, e.x. by sales or profit figures, instead of counting innovations. As an innovation policy advice, it is suggested that start-up atmosphere should not make large firms neglected, as they could leverage innovation more than proportionally with their size, by mechanisms such as economy of scale and scope, diversification, lowering risk of R&D, utilization of larger fixed costs, etc. Networking SMEs with large firms could also be utilized in innovation policies to build upon the advantage of firm size, besides targeting capability building. As it was seen by the two discrepancies and widely ranging coefficients, differences across industries should not be neglected in innovation policy making. Finally, these policy advices in favour of large firms are more relevant in states with a large government body and large quasi-public firms, as it was the case of Iran as an oil country.

Of course, the results should be interpreted within the limits and features of the research. The database was confined to Iranian knowledge-based firms of size 2-189 employees, which was relatively small-sized due to the nature of knowledge-based firms and Iran's economy. The external four-stage evaluation process consisting of site visits by experts forms another distinctive characteristic of the present research, which although makes the attribution of sales figures to innovative products and services much more valid, but lowers replicability and comparability. Investigation of the same relationship over different types of firms, industries and geographical regions of different innovation systems may reveal different patterns or set the basis for a generalisation. In addition, since it was a cross-section analysis, doing a longitudinal analysis may be of value in understanding temporal patterns.

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