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The influence of innovation on firm size

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1 Introduction

Average firm size varies substantially across industries. In this note we try to sort out empirically to which extent we can explain this variation by differences in innovation across industries.

This note is motivated by two reasons. *First*, to give an explanation of the observed broad spectrum of average firm sizes is interesting in itself. Why is it that in one industry firms use – on average - considerably more employees than in another? *Second*, average firm size is often used as a determinant for explaining various economic performance measures of industries, such as profitability, employment growth, R&D intensity, and export intensity. Hence, explaining average firm size gives also further insight in the explanation of these latter economic variables.

This note on the influence of innovation on firm size can be seen as a first step in explaining variation in average firm size across industries. We cannot make strong conclusions in this stage because (i) our data set has limitations, (ii) we encounter a reversed causality problem, and (iii) the empirical model we use is still insufficiently justified by theory. Nevertheless, we think that our empirical results give some first interesting insights.

We continue in the next section 2 by briefly describing existing theories that relate to firm size. These include classic production theories, minimum efficient scale (MES) theory, firm size distribution, life cycle theory, and theories focusing at the inverse of average firm size, i.e. the so-called entrepreneurship rate. Section 3 gives a description of the model used in the underlying study, while section 4 shows the empirical results. Section 5 concludes.

2 Theory

As regards explaining firm size distributions and average firm size, many approaches can be found in economic literature. The brief assessment below makes clear that measures of innovation can – overall – be considered as important determinants of firm size.

Classic micro economic production theory and minimum efficient scale

Using classic micro economic assumptions, the optimal number of firms in the industry is the largest number of firms that can break even. The basic idea is that the supply curve (cost function) determines the level of output for an individual firm. A larger number of firms implies a flatter supply curve and this leads to a lower equilibrium (market) price. The minimum efficient scale (MES) level of output is defined as the minimum size level where average cost is at a minimum. Economic theory predicts entry based on market-structure characteristics and the opportunity for profitable operations. The number of firms in the market is uniquely determined by the market size divided by this minimum efficient scale.

Transaction costs theory

The transaction costs theory initiated by Coase (1937) examines whether transactions of goods or information should take place within the firm (vertical integration) or outside the firm, i.e., in the market. A higher degree of market transactions leads to smaller firm sizes, while the opposite is true for a high degree of vertical integration. Whether a particular transaction is allocated to the market or to an organization is a matter of cost minimisation. Within the framework of transaction costs, firm size is dependent on human characteristics behaviour (Williamson, 1975) and transaction characteristics. These characteristics will continuously change due to economic or institutional developments. A development towards higher levels of knowledge and innovation, for example, would lead to lower levels bounded rationality.

Stochastic models of firm size distributions

Gibrat's Law (Gibrat, 1931) states that it is expected for firms to increase their size proportional to their current size, i.e.,growth would be independent of firm size. Considering the conducted empirical studies to test Gibrat's law of independent growth, its validity may depend on scale economies and on sectoral characteristics. Sutton (1997) gives a useful survey on the outcomes of many empirical studies in this field. Gibrat's law is based on a simple assumption and leads to a particular firm size distributions. Extensions have amongst others been proposed by Ijiri and Simon (1977). These extensions also alter the resulting characteristics of the firm size distributions. De Wit (2003) gives an overview of various firm size distributions, with their underlying assumptions on entry and exit.

Life cycle theories

The evolution of an industry can be divided into four stages: an innovation stage, an imitation stage, a technological competition stage and finally a standardisation stage. Utterback and Suarez (1993) describe the relationship between innovation, competition and industry structure. They also composed the dominant design theory, which states that an emerging market is characterised by many small entrants who are all innovating. It is important distinguish between process- innovations and product-innovations. In the beginning of a new life cycle the emphasis will be on product innovations while in later phases process innovations will play a more important role, in order to improve efficiency. Klepper (1996) states firm size as an important factor for big firms to survive: "large getting larger". Due to increasing returns in R&D large gets larger, especially in process-innovations. Product innovations provide room for smallness. Klepper also proposes a more continuous decline in the number of firms, contrary to the foregoing theories, where a stable end population is assumed.

Entrepreneurship rate: an inverse measure of firm size

Where classic micro economic theories take the (cost) structure of the market as a point of departure - and as such the *demand* for firms, there is also growing interest to take the opposite as a point of departure, i.e. the *supply* of entrepreneurs relative to labour force. This is expressed in the so-called entrepreneurship rate, which can be seen as an inverse measure of firm size. The entrepreneurship rate is seen to differ over countries; a U-shaped relation with capita per income is observed (see Carree et al., 2002). The entrepreneurship rate is dependent on many features from economic, social and cultural perspectives. An eclectic framework in this respect is provided by Audretsch et al. (2003). While the assessment of the entrepreneurship rate is quite developed at the macro level (see Van Stel, 2003), the industry level is at present difficult to explore. This is especially due to the limited availability of harmonized data at the industry level. An exception is formed by Van Stel and Carree (2003). Distinguishing two sectors (manufacturies and services), they present harmonized entrepreneurship rates for 21 OECD countries over the period 1970-1998.

Product and process innovation as determinants of firm size

Linking the above - different - theoretical points of view towards firm size, we see that the degree of innovation seems to be an important feature in most of them. Rather than trying to find a complete set of determinants, we will therefore focus on the degree of innovation as a market characteristic explaining firm size in our empirical model. In this, making a distinction between process innovation and product innovation seems to be necessary.

It could be argued that product innovation would mostly require some minimal firm size, whereas process innovation would also be feasible for small-sized organisations. Process innovations may, especially in services sectors (for example, new techniques related to ICT) be produced by small companies to be used by larger companies. However, the distinction between process and product innovation is particularly in the services sectors rather difficult to make.

Cohen and Klepper (1996) argue that returns of an innovation are positively related with the size of the firm and that this relationship is stronger for process innovations than for product innovations. For process innovation, they assume that it cannot be sold in disembodied form; the return of a process innovation that improves the price-cost margin is positively related to the internal applications (that depend on the firm's output). Higher volumes of production imply higher gross benefits of an innovation. Hence, larger firms are able to benefit more from a certain innovation than smaller firms because larger firms can spread the benefits over a greater volume.

We hypothesize that innovative activities lead to larger firm size. The positive association between innovation and firm size is also known as the "Schumpeterian view". Furthermore, we expect that process innovation will be associated more with large firms than product innovation (following Cohen and Klepper). The relationship will be investigated using a simple model without acknowledging the two-way effects between innovation and firm size as set out in the next section. We do, however, explicitly regard innovative activities in the period *before* the year that relates to firm size (as the dependent variable).

3 Model and data

Model

The model we use to estimate the effect of innovation on firm size is a simple linear regression model:

$$FS_{98} = \beta_0 + \sum_{i=1}^{I} \beta_i x_i + \varepsilon_i$$

where FS_{98} denotes the logarithm of average firm size in 1998 and x_i denotes determinant i. We take logarithms to retrieve relative effects: a certain percentage change in the independent variable leads – independent of levels - to a certain percentage change of the dependent variable.

Reversed causality

In the above model it is assumed that innovation measures have an influence on average firm size. However, the reverse might also be true: firm size might also influence innovation. Recognising this problem of a complex relationship between innovation and firm size, some authors have used instrumental variables for concentration in the context of single equation models, while others have applied simultaneous equation system with innovation and industry structure entering as endogenous variables. Considering the dataset that is available, we abstain from such modelling techniques and simply consider the one-way effect of innovation on average firm size.

Data

For exploring the firm size distributions in the Netherlands an EIM dataset has been used, containing average firm size for 66 industries in 1993 and 1998. These 66 industries together encompass the whole Dutch business sector. Average firm sizes in 1993 and 1998 were seen to be rather robust, i.e. significant changes in average firm sizes were not observed for a large majority of the investigated sectors. The data on innovation were collected by the Dutch Central Bureau of Statistics, based on questionnaires among firms within most of the sectors covered by the firm size dataset described above. The dataset includes various measures related to innovation. The information refers to 1994-1996, which suits the one-way relationship suggested by the model used, as our dependent variable relates to average firm size in 1998.
The two key variables are the share of firms in the industry that undertakes process innovation and the share of firms in the industry that undertakes product innovation. Additionally to these two measures, it is known what share of the innovating firms have developed their own innovations. Other determinants will be used as control variables. Data characteristics are shown in the Appendix. Especially the high correlation between process innovation and product innovation deserves some special attention in the empirical analysis. This is described in the next section.

4 Empirical results

Applying the model to our dataset while using OLS, we arrive at the results displayed in table 1. Each column represents a different model specification. In the first column, the complete set of determinants is included. Considering the highly significant correlation between product innovation and process innovation the presence of multicollinearity is highly probable. Hence, the process innovation and the product innovation variables should not be included within the same model. Process innovation and product innovation are therefore separately investigated in models II and III. Both types of innovation are to some extent associated with higher levels of firm size. This finding is according to "Schumpeter's hypothesis" and can partly be explained by the fact that for many activities, to be able to do innovations, there must be some minimum level of firm size. For these activities, however, the causal effect can be ambiguous. The positive association found between innovation and firm size should than be interpreted as a correlation rather than a causal effect. The model including process innovation results in a better overall-fit of the regression model.

Models IV and V exclude investment shares in machinery and computers respectively. These were seen to be non-significant in models I – III. We observe that the exclusion of both variables leads to an increase of the effects of process innovation.

table 1 Empirical results. Dependent variable is average firm size.

	I	II	III	IV	V
constant	-0.56	0.60	-0.17	0.55	0.78
Share of firms that use **process** innovation	1.02	2.81 *		2.82 **	3.90 **
Share of **process** innovating firms that use their own innovations	-5.12 **	-1.45		-1.43 *	-1.67 **
Share of firms that use **product** innovation	0.94		3.17 *		
Share of **product** innovating firms that use their own innovations	4.85 **		0.45		
Investment share in machinery	0.81	0.03	-0.28		
Investment share in computers	-1.94	-0.93	0.22	-0.92	
Uncertainty about competition level	0.12 **	0.10 **	0.09 **	0.10 **	0.10 **
Share of subsidized innovation in total innovation	5.10 **	3.00 **	4.05 **	3.03 **	2.16 **
Share of patented innovation in total innovation	-5.04 **	-3.95 *	-4.07 *	-3.95 *	-3.27 *
F Statistic	13.26	13.57	12.35	16.13	17.93
Adjusted R^2	0.65	0.60	0.57	0.60	0.57

In model V it appears that the more firms use their own process innovations (rather than those of other firms), the lower the average firm size. This suggests that the effect of process innovation that is created *outside the own firm* is more associated with large firms. This is not in line with the proposed mechanism of Cohen and Klepper (1996). However, Cohen and Klepper investigate the impact of firm size on R&D expenditure while the present study focuses at the reverse effect.

Perceived uncertainty (measured by the proportion of companies that cannot estimate the degree of competition very well) enhances average firm size. Apparently, uncertainty in the market requires a larger firm size that enables more to cope with the uncertainty. The positive effect found for subsidized innovation may be related to larger firms being more aware of the possibilities to apply for subsidies. The share of patented innovation is associated with smaller average firm size.

5 Conclusion

This study puts forward the relevance of investigating the relation between innovation and firm size, acknowledging differences between process innovation and product innovation. From different strands in economic literature, the relevance of innovation in explaining average firm size has been put forward. The efforts made so far in this particular research area, are still limited. Future empirical studies in this area would ideally require a two-way causation model and appropriate datasets. Our empirical results suggest a positive impact of innovation on average firm size. Furthermore, larger shares of process innovation performed by the company itself are associated with smaller average firm size.

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Annex I Innovation Data characteristics

	mean	st. dev.	correlations							
			1	2	3	4	5	6	7	8
1. Share of firms that use process innovation (%)	6.66	9.83	-							
2. Share of process innovating firms that use their own innovations (%)	0.40	0.12	-.40**	-						
3. Share of firms that use product innovation (%)	7.27	10.31	.97**	-.41**	-					
4. Share of product innovating firms that use their own innovations (%)	0.33	0.16	-.54**	.83**	-.59**	-				
5. Investment share in machinery (%)	0.41	0.22	.59**	-.52**	.69**	-.67**	-			
6. Investment share in computers (%)	0.06	0.06	.61**	-.16	.64**	-.55**	.53**	-		
7. Uncertainty about competition level, share (%)	0.21	0.03	.37**	.06	.38**	-.19	.14	.44**	-	
8. Share of subsidized innovation (%)	0.20	0.17	.71**	-.56**	.78**	-.81**	.84**	.70**	.25*	-
9. Share of patented innovation (%)	0.10	0.09	.67**	-.40**	.67**	-.48**	.40**	.56**	.50**	.60**

Number of sectors: 66

** significant at 5% level

* significant at 10% level