



Innovation and Jobs: a Micro-and-Macro Perspective

Bart Verspagen

Eindhoven Centre for Innovation Studies, The Netherlands

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Department of Technology Management

Technische Universiteit Eindhoven, The Netherlands

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Eindhoven Centre for Innovation Studies

Eindhoven Centre for Innovation Studies,
Eindhoven University of Technology &
TIK, University of Oslo, Norway

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Address for correspondence:

Bart Verspagen
Eindhoven University of Technology
PO Box 513, DG 1.24
5600 MB Eindhoven
Netherlands
b.verspagen@tm.tue.nl

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1. Introduction

The debate on the employment effects of new technologies is one of the oldest ones in economics. At a practical level, the early Industrial Revolution saw the rise of the 'machine breakers'. Led by the mythical, non-existing figure Ned Ludd, the 'Luddites' raised (violent) complaints against new machinery operated mostly in textiles factories, claiming that it destroyed jobs, and in this way increased poverty and caused social problems. Attacks of machine breaking took place from the early 1800s until into the 1820s.

The general view of the philosophers and economists of their days, was that the Luddites had no eye for the longer-run positive effects of new technology. The ruling opinion was that in the long run, technological change would benefit both capitalists (entrepreneurs) and workers, leading to higher productivity, income and living standards. Support for the Luddite view (although not for their means) came, however, from David Ricardo. In the third version of his *Principles*, he added the following sentence to his chapter on machinery:

"The opinion, entertained by the labouring class, that the employment of machinery is frequently detrimental to their interests, is not founded on prejudice and error, but is conformable to the correct principles of political economy" (as cited by Freeman and Soete 1994, p. 20).

Because it was so obviously against the ruling opinion, and because it touched at the heart of the important social problems of unemployment and poverty, Ricardo's sentence led to an intense debate that still has not been solved completely, and to which this paper returns. Traditionally, the debate revolves around a distinction between direct and indirect effects of technological change on employment.

Thinking about process innovations, it seems obvious that one direct effect of this is to reduce the demand for labour. However, it may be the case that as an indirect consequence of the innovation, output rises. This will offset the initial loss of employment at least to some extent, and if the rise of output is high enough, the net employment effect may even be positive.

For product innovations, the employment effects are usually considered to be more positive, because product innovations are expected to lead to an increase of demand, while they may leave productivity unaffected. But also here, indirect effects may exist, for example when the competitive position of other firms in the industry is affected. Product innovation may lead to an increase in demand for the innovating firm, but this may come at the expense of firms that have not made any innovation. Thus, while both theoretical and empirical work has been aimed at the relationship between innovation and employment, a recent survey concluded the following:

"firm level studies on the innovation-employment link are unable to point out whether the output and job gains of innovating firms are achieved at the expense of competitors, or whether there is a net effect on aggregate industry employment. It is often difficult to generalize beyond the groups of firms investigated" (Pianta, 2004).

One of the two aims of this study is to propose and apply an empirical approach to the innovation-employment relationship that makes full use of firm-level data, but still is able to say something about the employment effects at a more aggregate level (i.e., the sector). A second aim of the study is to address the issue of endogeneity of innovation. Most of the literature on innovation and employment (see Pianta, 2004 for an overview, and below for more references) has estimated an

employment equation in which innovation is simply taken as an exogenous factor. However, it is well-known that innovation efforts are motivated by economic motives. In a study aimed at explaining productivity growth, Crépon, Duguet and Mairesse (1998) introduced an econometric model that explains the simultaneous nature of the innovation - economy relationship. A similar model is applied here to the relationship between innovation and employment.

The study makes use of data from a recent innovation survey performed in the Netherlands. The source of the data is the Community Innovation Survey (CIS), which is also performed in many other (European) countries. Use was made of the firm level dataset that covers innovation and economic activity during the period 1994-1996. The analysis is focused exclusively on the manufacturing sector.

The paper starts with a short theoretical outlook in Section 2. This section will summarize some conclusions from the literature, and formulate several hypotheses regarding the relationship between employment and innovation. A full econometric model, including an equation explaining innovation itself, is presented in Section 3. Section 4 presents some descriptive trends in the data, while Section 5 presents the estimation results. Section 6 summarizes the argument.

2. Theoretical Outlook

Two issues dominate the theoretical debate on the relationship between employment and innovation (see, e.g., Freeman and Soete, 1987 and 1994; Vivarelli, 1995; Vivarelli and Pianta, 2000, for broad overviews of the debate). The first of these addresses the distinction between product and process innovation. As argued already above, the dominant view is that product innovation generally tends to have a positive effect on the firm's employment demand, although the aggregate

effects are more ambiguous. Process innovation, so it is usually argued, has a more ambiguous effect even at the firm level, depending on the balance between direct and indirect employment effects of process innovation.

The main indirect effect of a process innovation is related to product prices. In a competitive setting, the introduction of any cost-saving innovation will lead to a lower price of output, and this may increase demand for the product. How much demand rises depends on the price elasticity of demand, and therefore this is an important factor in determining to what extent the initially negative employment effect of a labour saving innovation can be compensated.

In a multi-sector, general equilibrium context, some of the indirect effects of process innovation are likely to be found outside the industry in which the innovation takes place. This may be the result of input-output relations between the industries, but also because of endogenous changes in demand patterns due to changes in relative prices (as a result of process innovation).

The direct and indirect employment effects have been the subject of a series of formal models presented in Katsoulacos (1986). With regard to product innovation, these models generally apply a CES-consumption function, in which the number of goods available for consumption is increased as a result of innovation. The elasticity of substitution between the consumption goods turns out to be the determinant of the size of the employment effect of product innovation. The higher this elasticity, the lower the employment effect will be (and vice versa). The intuitive reasoning behind this is that with a higher elasticity of substitution, competition between consumption goods (i.e., between innovations and 'old' goods) becomes stronger. For process innovation, the crucial role for price elasticity is confirmed in the formal analysis

of Katsoulacos (1986). In a general equilibrium context, the analysis there shows that if a process innovation occurs in a sector with comparatively high (low) price elasticity, the overall (aggregate) employment effect will be positive (negative).¹

What is not included in these models are externalities, which exist both in a negative and positive form. The main negative externality related to innovation that is relevant here, is the possibility that a product innovator captures market share from firms that are not introducing any product innovations. This could be termed the 'business stealing effect', and has been identified often as one of the main reasons why empirical results obtained at the firm level cannot be considered representative for the overall employment effects of innovation. But positive external effects may also exist (Van Reenen, 1997). At least two forms of such positive spillovers may be assumed to exist. The first one stems from the traditional idea that fact that knowledge may not be fully appropriated, and hence spills over to other firms in the industry. The second type of externality relates to complementarities between products: increased demand for innovative products may also raise the demand for related, but unchanged products (think, for example, of sales of digital cameras inducing demand for batteries). Following Van Reenen (1997), the external effect of innovation will be captured by including a variable measuring aggregate innovation activity in the sector in the equation for firm level employment growth.

In summary, the theoretical overview leads us to formulate three hypotheses about the relationship between innovation and employment. First, it is expected that product innovation has a positive effect on firm level employment. Second, it is expected that there are external effects at the sectoral level

¹ Note that in the general equilibrium context, there are restrictions on the sum of the price elasticities, including cross-elasticities.

related to (product) innovation, but both positive and negative externalities exist, and hence the determination of the net externality is an empirical issue. Finally, the sign of the effect of process innovation on employment may differ between industries, and price elasticity is an important factor determining this.

3. Econometric model

The data on innovation take the form of dummy variables, of which there are three. The first variable, denoted INPCS, measures whether or not a firm introduced a process innovation in the period 1994-1996. The second variable, INPDT, measures whether or not the firm introduced a product innovation in the same period. Thirdly, INMARK measures whether or not the firm introduced a product innovation that was also new to the market (INPDT includes both innovations new to the market, and new to the firm, so that INMARK measures a subset of INPDT).

A crucial assumption of the econometric model is that innovation (of all three types) is one of the factors explaining employment growth of the firm over 1994-96, but that employment growth does not have an impact on innovation. In other words, the full model is a recursive one. This seems a reasonable assumption, in line with the approach proposed by Crépon, Duguet and Mairesse (1998), because employment growth over the period is an outcome, while innovation is an activity that can be planned at least to some extent.

The econometric approach consists of estimating a two-stage model, of which the first stage is a Probit model aimed at explaining the three types of innovation. The variables that enter the Probit equation as independents are the size of the firm (natural log of the number of employees, LSIZ), whether or not the firm is owned by a foreign firm (FOROW, a dummy variable), the share of labour costs in total sales (LSH),

four dummy variables indicating whether the firm had various forms of non-technological innovation, three dummy variables indicating problems in the innovation process, and, finally, a set of industry dummies.

The four variables covering non-technological innovation indicate the presence of a change in strategic goals (STRAT), the introduction of new marketing concepts or designs (MARDES), whether or not the firm was reorganized (REORG), and whether or not new management techniques were introduced (MANAG). The variables measuring problems in the innovation process were based on a detailed set of questions regarding potential problems, e.g., a lack of qualified personnel, too high economic risks, too high innovation costs, a lack of technological knowledge, etc. For each of these factors, the firm was asked whether during the 1994-96 period any innovation projects were seriously delayed, stopped or not started at all due to this factor. The dummy variables indicate whether any innovation projects were not started (PR_NSTA), stopped (PR_STOP) or seriously delayed (PR_DELA) due to any of the factors listed.

The sector dummies are included to capture any effects related to differences in technological opportunities and growth potential between the industries. In industries with higher growth potential, innovation may be expected to be more frequent. But, at the same time, simply because of the larger growth potential, employment growth may also be higher in these industries, irrespective of innovation as such. This introduces a potential simultaneity bias in the equation for employment growth, if innovation is simply included as one of the independents in such an equation. Many empirical studies on the relationship between innovation and employment (e.g., Brouwer, Kleinknecht and Reijnen, 1993; Simonetti, Taylor and Vivarelli, 2000, Vivarelli, Evangelista and Pianta, 1996) may be vulnerable to this problem.

The second stage of the approach consists of estimating an equation for employment growth of the firm. In this equation, which is estimated by OLS, the predicted values of the innovation variables from the first stage are used to capture the effects of innovation on employment. Because these estimated values can be considered to be exogenous, this procedure solves the potential simultaneity bias that would be present if the equation included the empirical innovation variables, and was estimated by straight OLS.²

Besides the three innovation dummy variables, the employment equation includes the following variables. First, the already mentioned variables LSIZ and FOROW are included to account for factors not related to innovation. Also, the growth of the average wage rate paid by the firm is included to control for labour market factors other than innovation. This variable, WG, is calculated from the total wage bill and the number of employees of the firm in 1994 and 1996.

INPCS*, INPDT* and INMARK* denote the predicted values of the innovation variables in the first stage of the econometric procedure, and these are included in the employment equation as instruments representing the 'true' innovation variables. Finally, in order to account for the external effects of innovation on employment growth, two additional variables are included. The first one of these is the sum of the market shares in the sector in 1994 of all firms that introduced a product innovation (INPDT) in the period 1994-96. This variable, SPDT, represents (domestic) competitive pressure from innovators in the industry. The second variable of this nature is defined in a similar way, but only includes the market share of firms that introduced an innovation new to the market (INMARK). This variable is denoted SINM.

² The pioneering contribution by Crépon, Duguet and Mairesse (1998) used asymptotic least squares. Mairesse and Mohnen (2003) provide an overview of estimation methods applied in studies following in the footsteps of this study.

For process innovations (INPCS*), theory suggests that the sign may be either positive or negative, in line with the discussion above. But no observations are available for the price elasticity of demand in a sector, which was argued to be the main factor influencing the sign on process innovation. INPCS* is therefore interacted with each one of the industry dummies (this implies that the specification allows a separate sign on process innovation for each of the sectors). An alternative to this approach would be to try to include price elasticity and other demand factors explicitly into the model (see, e.g., Jaumandreu, 2003). While this would generate a more satisfactory theoretical model, it also puts high demands on data, especially in terms of linking the innovation databases to other databases. This is why such an approach is not followed here.

For the non-innovation variables in the employment equation, a negative sign is expected for the wage variable WG. Previous empirical work on firm growth suggests that the sign on the size variable LSIZ is negative. Finally, no clear expectation can be given for FOROW, but this variable may point to important differences between domestic firms and foreign subsidiaries.

4. Data and descriptive trends

The data for the firm level estimations were taken from the Community Innovation Survey, version 2 (CIS-2), as performed in the Netherlands. This survey has been carried out by Statistics Netherlands, according to a questionnaire that has been standardized for the EU countries. The survey contains a great deal of variables on innovation activities by firms. Firms with more than 10 employees have been included in the sample. Participation in the survey is, in principle, obliged, which is why no attempt will be made to correct for any

election bias. Although the total sample includes a number of firms from the primary (mining, agriculture) and services sectors, the analysis here will focus on manufacturing.

Figure 1 shows the distribution of firms over classes of innovators, per sector. The percentage of firms that does not have any innovations ranges from 12% (other chemicals) to 53% (textiles). In all cases, the largest fraction of innovating firms has both process innovation(s) and product innovation(s). Firms that exclusively have process innovations are the smallest minority, and are in some cases even absent. Electrical machinery, machinery and other chemicals stand out as sectors with a relatively high share of firms that have exclusively product innovation. These results indicate that it might be problematic to disentangle the effects of process innovation and product innovation, since so many firms have both types of innovation.

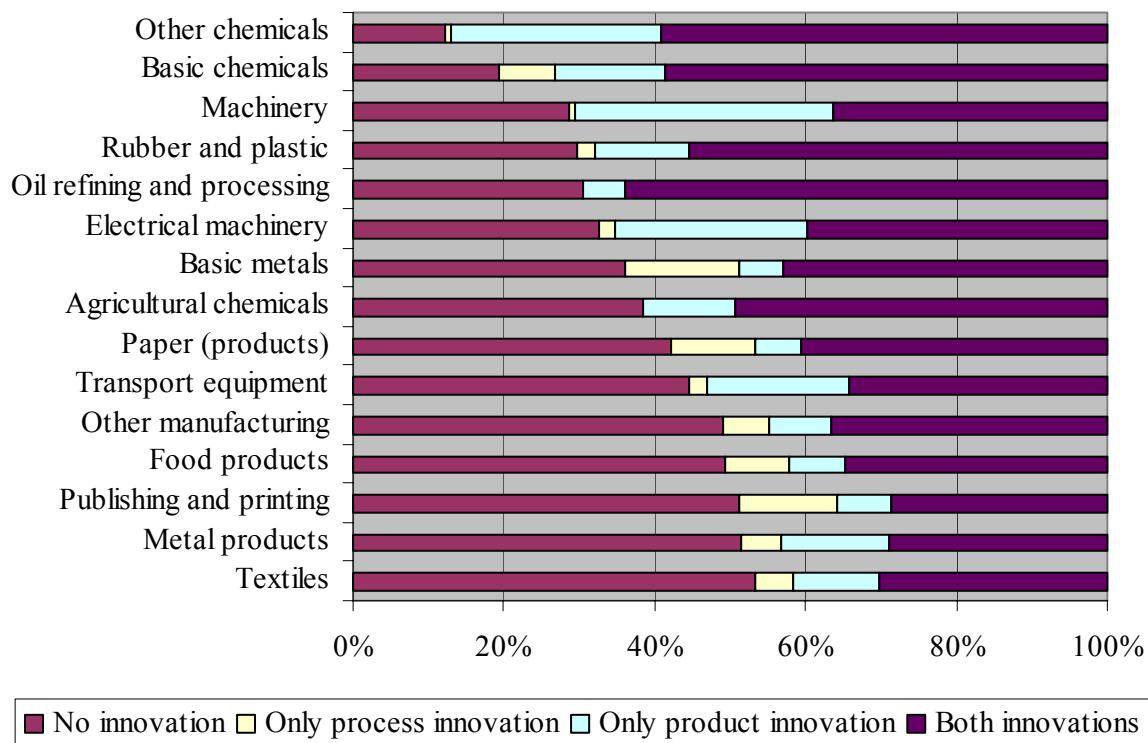


Figure 1. Distribution of firms over classes of innovators, per sector

5. Results

The estimation results for the first stage (equations explaining the occurrence of innovations) are documented in Table 1. Overall, the explanatory power of the equations is rather satisfactory (70-75% of all cases predicted correctly). Firm size is seen to have a positive and significant influence on all three types of innovations. Foreign ownership is never significant. The non-technological innovation variables are usually significant, and always positively related to innovation, but their specific effects differ between the different types of innovations. Surprisingly, the problems encountered in the innovation process are positively related to innovation. This probably indicates a reverse causality (firms that innovate are more likely to run into problems), but since the main aim of the equations in Table 1 is to provide a good set of instruments to be used in the second stage, these variables are simply left in. Finally, the share of labour costs in sales has a significant negative impact on innovation. From a point of view of 'induced innovation', this is a counter-intuitive finding, at least for the case of process innovation. The result may be interpreted to mean that labour-intensive technologies provide less opportunity for innovation. Note that industry dummies were also included, but these are not documented.

Table 1. Estimation results for Probit models explaining innovation

Independent variables	Dependent variable		
	INPCS	INPDT	INMARK
LSIZ	0.181 (0.000)	0.163 (0.000)	0.169 (0.000)
FOROW	0.081 (0.262)	0.020 (0.808)	0.015 (0.837)
STRAT	0.447 (0.000)	0.418 (0.000)	0.368 (0.000)
MARDES	0.052 (0.379)	0.220 (0.001)	0.284 (0.000)

REORG	0.117 (0.042)	0.208 (0.001)	0.089 (0.135)
MANAG	0.277 (0.000)	0.205 (0.013)	0.090 (0.212)
PR_NSTA	0.044 (0.597)	0.284 (0.006)	0.065 (0.422)
PR_STOP	0.358 (0.000)	0.684 (0.000)	0.280 (0.000)
PR_DELA	0.561 (0.000)	0.821 (0.000)	0.469 (0.000)
LSH	-0.415 (0.001)	-0.380 (0.002)	-0.214 (0.095)
% correct predictions	70.1	75.3	74.6
n / n positive	3039 / 1475	3039 / 1756	3039 / 911
R ²	0.21	0.31	0.21

Notes: industry intercept dummies are included in all equations, but not documented; numbers between brackets are *p*-values based on a 2-sided *t*-test.

The dependent variable in all regressions in the second stage is the growth rate of employment in the firm over the period 1994 - 1996. This period is a high-growth period in the Dutch economy, leading to a relatively tight labour market. Unemployment was comparatively low during this period. Table 2 presents the estimation results. Results for OLS estimations with the empirically observed innovation variables are not documented, but these did show important differences as compared with the results in the table, indicating that correcting for simultaneity is indeed important.

Table 2. Estimation results for second stage (employment equation)

	(1)	(2)	(3)	(4)
LSIZ	-0.048 (0.000)	-0.049 (0.000)	-0.048 (0.000)	-0.049 (0.000)
GW	-0.331 (0.000)	-0.344 (0.000)	-0.331 (0.000)	-0.343 (0.000)
FOROW	0.023 (0.108)	0.032 (0.028)	0.022 (0.123)	0.032 (0.026)
INPCS*	0.027 (0.118)	0.019 (0.222)		
INPDT*	0.022	0.026	0.016	0.024

	(0.138)	(0.060)	(0.251)	(0.084)
INMARK*	0.029	0.027	0.037	0.032
	(0.085)	(0.091)	(0.040)	(0.066)
SPDT	0.361		0.341	
	(0.000)		(0.000)	
SINM		0.418		0.395
		(0.000)		(0.000)
Dummy structure	Only intercept	Only intercept	Intercept, and slope on INPCS*	Intercept, and slope on INPCS*
R² (adjusted)	0.08	0.12	0.08	0.12
N	3020	2610	3020	2610

Notes: estimated coefficients for dummies are not documented; numbers between brackets are *p*-values based on a 2-sided *t*-test.

The first two equations include a single process innovation variable (INPCS*), while in the third and fourth equation this variable is interacted with industry dummies. Individual sectoral results are not documented in this case (both negative and positive signs are obtained). Theoretically, the version with slope dummies (equations 3 & 4) is to be preferred, but equations 1 & 2 are given for reference.

In all equations, firm size (LSIZ) is significantly negative, indicating that small firms tend to experience more rapid employment growth. Similarly, the observed wage rate (GW) is always significantly negative, as expected. Foreign ownership is only significant in the second and fourth equation. According to these estimates, foreign owned firms have approximately 3%-points higher employment growth than domestic firms (*ceteris paribus*).

All documented innovation variables show a positive sign, but the level of significance varies between equations. In general, the innovation variables referring to the sectoral level (SPDT and SINM) are more robustly significant than the firm level innovation variables. When process innovation is entered in the equation without sectoral slope dummies, it is

never significant, although positive. At the 10% level (2-sided t -test), INPDT* is only significant when SINM is included as the sectoral innovation variable. INMARK* is significant in equations 2 - 4.

Thus, the results indicate that 'radical' product innovation ('new to the market' as opposed to 'new to the firm') has a robust impact on firm employment growth, while this is less obvious for the variable that also includes 'incremental' ('new to the firm') product innovation. Firms with radical product innovation show some 3½ %-points higher employment growth, compared to firms with an incremental product innovation, and some 5½ %-points extra employment growth as compared to firms without product innovation. The positive sign on the sectoral innovation variables indicate that positive spillovers dominated over negative spillovers (the 'business stealing effect') over the period of the estimation. Hence the overall conclusion is that the positive relationship between innovation and employment growth at the firm level seems to hold also at a more aggregate level.

6. Preliminary conclusions and outlook on future work

This paper has estimated the relationship between innovation and employment growth in a sample of Dutch manufacturing firms over the period 1994-96. In line with theoretical expectations, the impact of product innovation on employment growth was found to be significant at the firm level. Especially more radical product innovations were shown to be a robust source of employment growth.

The empirical method contained two relative novelties. First, account was taken of the endogenous nature of innovation. In

this way, a simultaneity bias, due to the fact that innovation may 'react to' sectoral differences in opportunities, was avoided. Second, a sectoral innovation variable was taken into account, in order to take account of potential externalities (both negative and positive) in the employment - innovation relationship.

Interestingly, product innovation was positively related to employment growth not only at the firm level, but also in the form of the externality. This indicates that for the period and sample under consideration, worries that product innovation may lead to a 'business stealing effect' (innovative firms taking market share from non-innovators) were not warranted. This indicates that product innovation has a positive impact on employment growth, even at the aggregate level.

The period under consideration was a period of economic boom and employment growth in the Dutch economy, which was also performing relatively well compared to the rest of the EU. Since then, unemployment has been on the rise in the Netherlands, as in most other countries. Whether these results are specific for the Dutch economy in the second half of the 1990s, or extend also to different countries and time period, can only be determined by repeating the analysis with more recent data.

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