Does innovation stimulate employment? A firm-level analysis using comparable micro data on four European countries

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Does innovation stimulate employment? A firm-level analysis using comparable micro data from four European countries*

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Abstract

This paper studies the impact of process and product innovations introduced by firms on their employment growth. A model that relates employment growth to process innovations and to the growth of sales due to innovative and unchanged products is derived and estimated using a unique source of comparable firm-level data from France, Germany, Spain and the UK. Results for manufacturing show that, although process innovation tends to displace employment, compensation effects are prevalent, and product innovation is associated with employment growth. In the service sector there is less evidence of displacement effects, and growth in sales of new products accounts for a non-negligible proportion of employment growth. Overall the results are similar across countries, with some interesting exceptions.

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1. Introduction

Innovation is widely considered to be a primary source of economic growth, and policies to encourage firm-level innovation are high on the agenda in most countries. The consequences of innovation for employment are of particular interest, but the relationship between innovation and employment is complex. On the one hand, the long-run *macro*-economic impact of innovation on employment is clearly not negative; many decades, and even centuries, of innovation in advanced economies have not been accompanied by ever-decreasing levels of employment. Yet, at the same time, the impact of innovation on employment at the firm level remains unclear. Individual innovations may destroy jobs, but innovation can also stimulate demand, and evidence suggests that on average innovative firms are more likely to survive and grow than firms that do not innovate. The firm-level relationship between innovation and employment is an important topic of research for several reasons. For example, the effects of innovation on employment at the firm level are likely to influence the extent to which different agents within the firm resist or encourage innovation. In addition, the incentives of managers and workers will determine the types of innovations that are introduced and their subsequent effects on prices, output and employment. Understanding these incentives and welfare effects at the micro level is essential for the effective design of innovation policy, and for predicting how other interventions, such as labour market regulations, might affect the rate of innovation.

This paper investigates empirically the firm-level employment effects of innovation, and makes three main contributions to the literature. First it uses a unique comparable firm-level dataset across four large European countries: France, Germany, Spain and the UK. Firms in these countries operate in different economic and institutional environments, and our results identify several robust common effects as well as interesting cross-country differences in the firm-level relationship between innovation and employment. Secondly the structure of the data allows us to apply a simple model of innovation and employment that disentangles many of the different effects at work. In particular we observe the mix of each firm's output growth between existing and newly introduced products, enabling us to quantify the employment effects of product innovation. Finally, we present evidence from roughly 19,000 firms, of which more than 6,000 are in the service sector. Almost all previous studies have focused exclusively on manufacturing, yet much of the employment creation in these four economies in recent years has been within the service sector.

We estimate equations relating firms' employment growth to the introduction of process innovations and to those parts of sales growth accounted for by unchanged and newly introduced products respectively. In doing so we attempt to control for potential sources of correlation between the included variables and the residual using suitable econometric methods. The results suggest that, while process innovations tend to displace employment, compensation effects are prevalent and product innovations are an important source of firm-level employment growth. In particular we find no evidence of employment displacement effects associated with product innovation. These effects are measured at the firm level, but we discuss how they should be aggregated up to the industry level by taking into account rivalry between competitors and the effects of entry and exit. Due to data limitations, the paper does not contribute to the literature on skill-biased technical change, focusing solely on the level of employment without distinguishing between different types of worker.

The data used in this paper come from the Third Community Innovation Survey (CIS3). These data are available for a number of European Union countries in a similar format. Basic CIS3 variables (set out in the core questionnaire) include, for each firm in the sample, employment and sales in the years 1998 and 2000, and information about whether the firm has introduced process and product innovations during the period. Particularly useful for our purposes, the data includes the share of sales in 2000 stemming from new or significantly improved products introduced since 1998.[1] In addition, the Survey gathers information on R&D and innovation investments, firms' sources of information and innovation aims, and co-operation and patenting activities. The paper uses data on four European countries: France, Germany, Spain and the UK. The micro-data have been accessed at the national level under strict rules to preserve confidentiality, but the model and its implementation have been discussed and coordinated among the researchers from the four countries. The results of such cross-country work are stimulating: consistent regularities appear across the countries, while the empirical framework highlights interesting cross-country variation.

The rest of this paper is organised as follows. Section 2 discusses the potential firm-level employment effects of innovation and relates our contribution to the literature. Section 3 develops the model and discusses what effects can be identified using the data. Section 4 briefly comments on the data and the evidence provided by simple descriptive statistics on

[1] Definitions are unified according to the Oslo Manual (see OCDE and Eurostat, 1997).

employment and innovation outcomes in the four countries. Section 5 presents the main econometric estimates and checks their robustness. Section 6 comments on the results and presents a decomposition of firms' employment growth in the four countries, and Section 7 concludes. A Data Appendix contains details on the sample and variables used in the empirical analysis.

2. Employment effects of innovation at the firm level

In this section we summarise the ways in which innovation might be expected to affect employment at the firm level, and how this relates to changes in aggregate employment. We then briefly survey previous findings on the firm-level relationship between innovation and employment.

2.1 Process and product innovations

The potential firm-level employment effects of innovation are summarised in Table 1.[2] It is convenient to distinguish between the effects of process innovations, which are directed at improving the production process and hence have a direct impact on factor productivity and unit costs, and the effects of product innovations, which are mainly undertaken to reinforce demand for the firm's products. In practice, of course, the distinction between the two types of innovation is not always so clear, since process innovations often accompany product innovations and vice versa. As indicated in Table 1, both types of innovation can be interpreted as the (partly random) result of the firm's investment in R&D and other innovative activities.[3]

Pure process innovations are likely to reduce the quantities of (most) factors required to obtain a unit of output, including the required labour input. Thus process innovations tend to displace labour for a given output, although the size of this displacement effect will depend on the extent to which the process improvement is labour or capital augmenting. The effects of a single identifiable process innovation will be additional to those of any incremental improvements in efficiency, usually attributed to factors like learning and spillovers, that

[2] In this section we draw on theoretical discussions in several papers, including Nickell and Kong (1989), Van Reenen (1997), Garcia, Jaumandreu and Rodriguez (2002) and the more theoretical works quoted therein; see also the survey by Chennells and Van Reenen (2002).

[3] For a recent analysis of simultaneous R&D investment decisions and innovation results using the same kind of firm-level data, see Griffith, Huergo, Mairesse and Peters (2004).

reduce input requirements over time.[4]

Any increase in productivity resulting from a process innovation implies a reduction in unit costs. Depending on the competitive conditions facing the firm, this is likely to result in a lower price, which will stimulate demand, and hence produced output and employment, with the size of the effect determined by the elasticity of demand for the firm's products. The size of this compensation effect is also likely to depend on the behaviour of the agents inside the firm and the nature of market competition. For example, unions may attempt to transform any gains from innovation into higher wages, while managers may seek to use market power to increase profits.[5] Both behaviours can dampen or override the compensation effect.

Product innovations may also have productivity effects, even if they are not associated with simultaneous process innovations. The new or improved product may imply a change in production methods and input mix, which could either reduce or increase labour requirements. The extent and direction of the effect must be determined empirically. However, the most important effects of product innovations are likely to be positive compensation effects resulting from increases in demand for the firm's products. The importance of any increases in demand resulting from product innovation will depend on the nature of competition and the delay with which rivals react to the introduction of new products. In addition, sales of new or improved products may cannibalise some proportion of the firm's existing sales, reducing the positive compensation effect of product innovation.

The service sector has become the largest part of most developed economies, and contrary to traditional wisdom many areas of the service sector have demonstrated high levels of innovation and productivity growth.[6] However, innovation in services is often concerned with changes in organisation, delivery and variety, possibly linked to the adoption of Information and Communication Technologies (ICT).[7] As a result it is more difficult than in manufacturing to clearly identify new products (Triplett and Bosworth, 2004) and to distinguish product

[4]Estimates of production functions frequently account for ongoing improvements in productivity using time trends or time dummies, when estimating in levels, or constants when estimating in first differences. See, for example, Hall and Mairesse (1995). Indicators of specific innovative investments or outcomes typically leave a large amount of unexplained additional productivity growth. See Huergo and Jaumandreu (2004) for an illustration of this point with detailed panel data.

[5]See Nickell (1999) for a discussion.

[6]See for example Evangelista (2000), or the recent study of the US service sector by Triplett and Bosworth (2004).

[7]Examples include Internet Banking and the introduction of scanners and computers in Retailing.

innovations from process innovations. Moreover, statistical concepts and measurement in services are currently in a period of change and refinement. As a result of these considerations, while we think it is important to include the service sector in the analysis, it is important to bear in mind that the same variables may be less precisely measured or have different interpretations than in manufacturing.

2.2 Innovation and employment at the aggregate level

The focus of this paper is the firm-level relationship between innovation and employment in a sample of firms. An interesting question is thus how the employment effects of innovation that we observe at the firm level relate to aggregate changes in employment. There are two main reasons why the aggregate effect of innovation on employment cannot be directly inferred by multiplying the average firm-level effect by the number of firms.

First, the firm-level compensation effects that we observe do not distinguish between a pure market expansion component and a business-stealing component.[8] If innovation by firms results in business-stealing rather than market expansion then the aggregate effect of innovation on employment will in general be smaller (either less positive or more negative) than the firm-level effect. We should note, however, that the average firm-level employment outcomes that we observe already embody the effects of business-stealing by firms' rivals, even if we do not know the rivals' identity or observe them in the sample. Secondly, and related, we do not observe entering or exiting firms in our sample of continuing firms. Firm entry, which may be the result of innovation, is an important source of employment growth, while exit may be induced by successful innovation and business-stealing by rival firms. A full industry-level analysis would have to explicitly incorporate entry, exit and competition between rival firms. Evidence on the rivalrous effects of innovation could possibly be obtained through similar techniques to those used in the measurement of R&D spillovers, while data on entering and exiting firms would be needed to assess the role of entry and exit.

While our analysis does not relate directly to aggregate employment effects, it does provide essential information on the micro-mechanisms that underly aggregate employment growth. As discussed in the introduction, this micro-level relationship between innovation and employment is an important topic of research in itself.

[8] See, however, the use of rival's data in Garcia, Jaumandreu and Rodriguez (2002) to separate these effects.

2.3 Previous literature on innovation and employment

A number of previous papers have provided evidence on the relationship between innovation and employment at the firm level. The survey by Chennels and Van Reenen (2002), although focused on a related but different question, provides a useful overview.[9] Existing papers differ widely in terms of both methodology and data employed. Given the relationships summarised in the previous discussion, it is not surprising to find a broad range of modelling strategies, ranging from the assessment of correlations or estimation of reduced forms to more structural models. At the same time, different data provide various measures of innovation, some output oriented, such as innovation counts, and others input oriented, such as R&D intensity. Finally, papers differ widely in the extent to which they address issues of heterogeneity and endogeneity.

On the whole, product innovation emerges as clearly associated with employment growth, although the balance between displacement and compensation effects remains unclear (see, for example, Entorf and Pohlmeier, 1991; König, Licht and Buscher, 1995; Van Reenen, 1997; Greenan and Guellec, 2000; Smolny, 1998 and 2002; Garcia, Jaumandreu and Rodriguez, 2002; Peters, 2004). R&D is often found to be positively associated with employment growth (see, for example, Blechinger, Kleinknecht, Licht and Pfeiffer, 1998, and Regev, 1998), although not always (see Brouwer, Kleinknecht and Reijnen, 1993, and Klette and Forre, 1998). Process innovations and the introduction of new technologies show effects which range from negative to positive according to the specification (see, for example, Ross and Zimmerman, 1993, for a negative process innovation effect; Doms, Dunne and Roberts, 1995 or Blanchflower and Burguess, 1999 for positive technology impacts, and the various effects obtained for process innovations from many of the above papers).

The focus of our paper is the derivation and estimation of a simple theoretical model of employment and innovation that is applicable to the comparable cross-country data at hand. In particular, our data allow us to observe firms' sales of new or significantly improved products as well as sales of unchanged products. Using a production function framework, we derive various restrictions on the data that allow us to separately identify some of the displacement

[9] The survey is focused on the impact of technological change on the skill and pay structure of labour. This is an important related literature of which an early example is Berman, Bound and Griliches (1994). On the relationship between innovation and employment, see also the survey contained in Spiezia and Vivarelli (2002).

and compensation effects of innovation on employment. We use appropriate econometric techniques to control for potential sources of correlation between the included variables and the residual. Overall our findings support the robustness of the product innovation effect on employment. In particular we find no evidence for employment displacement effects associated with product innovation. Our findings also throw some light on the reasons why the estimated effects of other technological measures vary across studies. In addition we present evidence from the service sector as well as from manufacturing, whereas almost all of the existing literature has focused exclusively on manufacturing.

3. Theoretical framework and estimation strategy

3.1 A simple production function

A firm can produce two types of products: old or only marginally modified products ("old products") and new or significantly improved products ("new products"). Outputs of old and new products at time t are denoted Y_{1t} and Y_{2t} respectively. We observe firms at two points in time, at the beginning and end of the period. At the beginning of the period all products are old products by definition, so Y_{21} is always equal to zero. If the firm does not introduce any new products during the period then Y_{22} is also equal to zero. We assume that each type of product is produced with an identical separable production technology, with constant returns to scale in capital, labour and intermediate inputs. Each production technology has an associated efficiency parameter that can change over time. New products can be produced with higher or lower efficiency than old products, and the firm can influence the efficiency of production of either product through investments in process innovation. The production technology for product i at time t can be written as follows

$$Y_{it} = \theta_{it} F(K_{it}, L_{it}, M_{it}) \qquad i = 1, 2; t = 1, 2$$

where θ represents efficiency and K, L and M stand for capital, labour and materials. The firm's cost function at time t can then be written

$$C(w_{1t}, w_{2t}, Y_{1t}, Y_{2t}, \theta_{1t}, \theta_{2t}) = c(w_{1t})\frac{Y_{1t}}{\theta_{1t}} + c(w_{2t})\frac{Y_{2t}}{\theta_{2t}} + F$$

where $c(w)$ is marginal cost (a function of input prices w) and F stands for some arbitrary fixed costs. According to Shephard's Lemma, we have

$$L_{it} = c_L(w_{it}) \frac{Y_{it}}{\theta_{it}}$$

where $c_L(w_{it})$ represents the derivative of marginal cost with respect to the wage.

3.2 An employment equation

The growth of employment over the period can be decomposed into the growth of employment due to production of the old product, and the growth of employment due to production of the new product as follows (recall that $L_{21} = 0$).

$$\frac{\Delta L}{L} = \frac{L_{12} - L_{11}}{L_{11}} + \frac{L_{22}}{L_{11}}$$

We assume that the derivative of marginal cost with respect to the wage does not change over the period, so that $c_L(w_{11}) = c_L(w_{12}) = c_L(w_1)$. This will be the case, for example, if relative prices are constant over the period.[10] Using the results of the previous section we can then write an approximate employment growth decomposition as follows

$$\frac{\Delta L}{L} \simeq -\left(\frac{\theta_{12} - \theta_{11}}{\theta_{11}}\right) + \left(\frac{Y_{12} - Y_{11}}{Y_{11}}\right) + \frac{c_L(w_2)}{c_L(w_1)} \frac{\theta_{11}}{\theta_{22}} \frac{Y_{22}}{Y_{11}} \quad (1)$$

where we use a linear approximation to obtain the two first terms.

This expression says that employment growth is the result of the change in efficiency in the production process for the old products, the rate of change of the production for these products, and the expansion in production attributable to the new products. The increase in efficiency of the old production process ($\frac{\theta_{12}-\theta_{11}}{\theta_{11}}$) is expected to be larger for firms which introduce process innovations relating to the old product, although the efficiency of all firms may grow over time. If we assume that the derivative of marginal cost with respect to the wage is equal for old and new products, i.e. $c_L(w_1) = c_L(w_2)$,[11] the effect of product innovation on employment growth depends on the difference in efficiency between the production processes for the old and the new products (the ratio $\frac{\theta_{11}}{\theta_{22}}$). If new products are produced more efficiently

[10] Notice that $c(.)$ is homogeneous of degree one and hence $c_L(.)$ is homogeneous of degree zero.

[11] Again this will be the case, for example, if relative input prices are the same for the two products. In fact, it seems quite likely that input prices would be the same for both products

than old products then this ratio is less than unity and employment does not grow one-for-one with the growth in output accounted for by new products.[12]

Equation (1) suggests the following population relationship

$$l = \alpha + y_1 + \beta y_2 + u \tag{2}$$

where l stands for employment growth over the period, variables y_1 and y_2 stand for the rates of output growth $\frac{Y_{12}-Y_{11}}{Y_{11}}$ and $\frac{Y_{22}}{Y_{11}}$ respectively (output growth accounted for by the old and new products), and u for a random disturbance which is expected to have zero mean conditional on a suitable set of instruments, i.e. $E(u|z) = 0$. The parameter α represents (minus) the average efficiency growth in production of the old product, while β captures the relative efficiency of the production of old and new products.

In principle we could extend equation (2) to allow process innovation to affect changes in the efficiency of production of old and new products as follows

$$l = (\alpha_0 + \alpha_1 d_1) + y_1 + (\beta_0 + \beta_1 d_2) y_2 + u \tag{3}$$

where d_1 and d_2 are dummy variables equal to one if the firm introduced any process innovations over the period relating to the production of old or new products respectively. In practice we do not know whether the process innovations of firms that introduce new products relate to their old or their new products, but we can experiment with various alternatives, for example we can assume that all such process innovations relate to old products, or all to new products.

3.3 Interpretation

We should comment briefly on the significance and limitations of equation (2), as well as the likely properties of u. On the one hand, equation (2) can identify two important effects. Firstly, under the assumption that the growth of output due to the introduction of new products is observed, equation (2) clearly identifies the gross effect of product innovation on employment. Secondly, observation of the introduction of process improvements in the production of the old products allows us to identify the productivity or "displacement" effect

[12] If the derivative of marginal cost with respect to the wage is higher for new products (i.e. $c_L(w_1) < c_L(w_2)$), then the estimated ratio will be biased upwards, in other words the efficiency increase associated with new products will be underestimated.

of process innovation.[13] On the other hand, the variable y_1 embodies three different effects which cannot be separated without additional (demand) data: the "autonomous" increase in firm demand for the old products, for example due to cyclical or industry effects; the "compensation" effect induced by any price variation following a process innovation; and the demand "substitution effect" resulting from the introduction of new products. As these components cannot be disentangled, y_1 will be in practice simply substracted from l , thereby imposing the unitary coefficient.

To compare (2) or (3) with other specifications, notice that it can be transformed into a productivity growth equation by simply rearranging terms as follows (for simplicity we assume that all process innovations refer to the production of old products, i.e. $d_2 = 0$)

$$y_1 + y_2 - l = -\alpha_0 - \alpha_1 d + (1 - \beta) y_2 - u$$

This transformation shows that growth in output per worker will depend positively on process innovation and that the expected sign for product innovation depends on the value of the relative efficiency of the old and new processes. If β is equal to one, efficiency is the same across production processes and new products do not affect output per worker. If β is less than one, new products are produced more efficiently, and thus output growth due to new products increases output per worker.

Finally, the need for a suitable set of instruments results from the possibility that the key variables d and y_2 may be simultaneously determined and thus correlated with the error term u, although this is not necessarily the case. Notice that equations (2) and (3) involves rates of growth of the variables. We must clearly allow for the possibility that the error term contains unobserved shocks to productivity growth correlated with the introduction of process or product innovations (for example investments, bursts in capacity utilization, labour and organizational problems). However, we exclude *a priori* the presence of long run determinants of productivity growth differences in the error term that are correlated with product or process innovations. These would imply rather surprising long run differences in growth rates, and we would be unlikely to find suitable instruments in our data. Nevertheless, we should bear in mind that a positive correlation between the introduction of innovations and unobserved favourable productivity shocks would induce a downward bias in our estimates

[13] However, see below for a discussion of the problem that arises when the data refer to sales that are not properly deflated.

of both α_1 and β. In other words we would estimate employment displacement effects of process innovation and the introduction of new products that are too large.[14]

3.4 Estimation strategy

To estimate equation (2), however, we must substitute nominal sales, which are the magnitudes that we observe, for real production. The problem that prices are unobserved is common in productivity analysis, but it is particularly relevant in this case since we are attempting to separately identify the productivity effects of old and new products, which may be sold at different prices. Let g_1 be the nominal rate of growth of sales due to the old products ($\frac{P_{12}Y_{12}-P_{11}Y_{11}}{P_{11}Y_{11}}$). If π_1 is the rate of increase in the prices of these products over the period ($\frac{P_{12}-P_{11}}{P_{11}}$), we can write the approximate relation $g_1 = y_1 + \pi_1$. Let g_2 be the nominal growth in sales that is due to new products ($\frac{P_{22}Y_{22}}{P_{11}Y_{11}}$), and define π_2 as the proportional difference of the prices of new products with respect to the prices of the old products ($\frac{P_{22}-P_{11}}{P_{11}}$), so that we have $g_2 = y_2(1+\pi_2) = y_2 + \pi_2 y_2$. We assume that π_2 is mean-independent of y_2 with a mean of zero, i.e. $E(\pi_2|y_2) = 0$.[15] Then $E(\pi_2 y_2) = 0$ and $\pi_2 y_2$ is uncorrelated with y_2 (although $\pi_2 y_2$ is likely to be correlated with π_2). Substituting g_1 and g_2 for y_1 and y_2 respectively in equation (2), and reordering the expression, we obtain

$$l - g_1 = \alpha + \beta g_2 + v \tag{4}$$

where the new unobserved disturbance is now $v = -\pi_1 - \beta\pi_2 y_2 + u$. In case of a non-zero mean of π_1 the model will include $-E(\pi_1)$ in the intercept and $-(\pi_1 - E(\pi_1))$ in the disturbance. The equivalent estimated version of equation (3), assuming again that all process innovations relate to old products, will be

$$l - g_1 = \alpha_0 + \alpha_1 d + \beta g_2 + v \tag{5}$$

To estimate the parameters of (4) or (5) consistently, we have to take into account three

[14] To see this notice that a favourable unobserved productivity shock is a negative realization of u in the "productivity" equation, where u enters with minus sign. This would be trasmitted to d and y_2 through their dependence on productivity and, hence, their "reduced" forms would contain a positive shock, negatively correlated with the realization of u in equation (2).

[15] New product sales will depend, among other things, negatively on the new product price according to the price elasticity of demand for the new product, and positively on the price of the old product (if they are substitutes) according to the cross elasticity of demand. Equilibrium price level relationships are likely to vary widely across firms even for similar y_2 values.

main problems.[16] First, g_2 is an endogenous variable, in the sense that it is correlated with the composite error term. The problem originates in our inability to measure the ratio y_2 directly (a variant of the classical errors in variables problem), and we can try to solve it by instrumenting g_2 with variables correlated with the real ratio and uncorrelated with the price differences. We discuss potential instruments below.

Secondly, the composite error term includes π_1, the change in the prices of the old products, as long as we cannot control for them. This creates an identification problem. Any increase in proportional efficiency decreases marginal cost by the same proportion. If, for example, firms are pricing by setting some unspecified markup on marginal cost, then price variations are likely to be roughly proportional (with the opposite sign) to the increases in efficiency. In addition, firms endowed with some market power might pass on this cost decrease by different amounts. Suppose that price variations follow marginal cost variations c according to $\pi_1 = \pi_0 + \gamma c$, where γ is the pass on parameter. Marginal cost changes are then related to innovation efficiency gains, ceteris paribus, according to $c = \alpha_1 d$. Hence $\pi_1 = \pi_0 + \gamma\alpha_1 d$, and in equation (4) we will only be able to estimate an effect $(1-\gamma)\alpha_1$. That is, we only identify an effect of productivity changes on employment net of any compensating price movements.

In our econometric estimates we use a system of price indices $\widetilde{\pi}_1$ computed at a detailed industry disaggregation as a proxy for π_1.[17] Thus we use $l - (g_1 - \widetilde{\pi}_1)$ as the dependent variable, which will leave in the error the term $-(\pi_1 - \widetilde{\pi}_1)$. With this arrangement, we are likely to identify the average real productivity effect, but an identification problem will remain to the extent that firms deviate from average price behaviour. That is, if individual differences in price behaviour $(\pi_1 - \widetilde{\pi}_1)$ are, as is likely, related to individual efficiency growth differences, then the identification problem is only partially addressed.

Finally, we must take into account the possible endogeneity of d and g_2 for employment growth as discussed above. The instruments that we use for the errors in variable problem

[16] We should also note that growth rates g_1 and g_2 are not observed directly, but are constructed from observations of the share of new products in total sales at the end of the period, s, and the growth rate of total sales, g. The relevant rates are hence constructed as $g_2 = s(1+g)$ and $g_1 = g - s(1+g)$ (see the Data Appendix). One may then wonder about the effect of having on both sides of the estimating equation a variable that is likely to be measured with error. Suppose $s = s^* + \varepsilon$, where s^* is the true share. Standard error-in-variables substitutions show that g_2 will be correlated with an error component $(1-\beta)\varepsilon(1+g)$. Potential bias is hence small and likely to fade away with the instrumentation of g_2.

[17] However, due to data limitations the level of disaggregation is much higher in manufacturing than in services. See the Data Appendix for more details.

embodied in g_2 may help to address this problem, but we also test for the endogeneity of d given the available instruments. We discuss these issues further in the results section below.

4. Innovation and employment across four countries

In this section we present descriptive statistics and discuss the results of initial exploration of the data. Table 2 presents descriptive statistics for manufacturing from the four countries. For each variable the sample in each country is split into three sub-samples according to whether the firm reports that it has not introduced any innovations, has introduced only process innovations, or has introduced product innovations. For ease of presentation we do not distinguish firms that have introduced both product and process innovations from those that only introduce product innovations, since the data cannot distinguish if the two types of innovations introduced by one firm are related and to what extent. The table shows that innovators represent between about 40% (UK) and 60% (Germany) of firms in the samples. Innovators that only introduce process innovations generally constitute up to one in four of all innovators.

The sizes of the national samples differ, but all samples are broadly representative by strata. Representativeness, however, diverges somewhat across countries, and therefore direct comparisons must be interpreted carefully. Details on the samples and variable definitions can be found in the Data Appendix.

Employment growth of innovators is consistently higher than the employment growth of non-innovators across the four countries, with the employment growth of product innovators slightly higher than firms that only introduce process innovations. Productivity gains tend also to be higher in the innovating firms (with the exception of Spain, where there is little difference in average productivity growth between innovators and non-innovators). Notice that the increase in employment of innovative firms is higher despite their larger labour productivity gains. This suggests that compensation effects resulting from the growth of output dominate displacement effects of innovation at the firm level.

The average increase in sales over the period 1998-2000 is high in all countries, reflecting both an expansionary phase of the industrial cycle and the fact that these are samples of continuing firms. Average sales growth is particularly high for Spain, even when deflated with the corresponding highest rate of price increase, but the Spanish economy was at the time experiencing high overall growth. Average industry price increases are negligible at that time in the UK and very low in Germany.

Sales growth is consistently higher for innovators than non-innovators, with no systematic difference between firms that only introduce process innovations and those that introduce product innovations. For product innovators, sales of new products are a very important component of total sales growth: sales in 2000 of new or significantly improved products introduced during the 1998-2000 period amount to more than one third of sales of the old products in 1998 for the German, Spanish and UK firms, and nearly 20% for the French firms. Sales of new products appear to partly cannibalise sales of old products, although the extent of cannibalisation varies across countries, and is markedly lower in France than in the other countries.[18] The proportion of sales of new products that are accounted for by products that are new to the market (as opposed to simply new to the firm) is almost one half for France, about one third for Germany and Spain, and only one quarter for the UK.

Table 3 reports the same information for firms in the service sector.[19] The proportion of innovators is lower in all countries than in manufacturing, but relatively high in Germany and particularly low in the United Kingdom and Spain. The proportion of innovators that only introduce process innovations is slightly higher than in manufacturing for all the countries.

In all countries employment growth is somewhat higher for innovators, and is higher for product innovators than for firms that only introduce process innovations. This suggests that demand increases associated with new products play an important role in employment creation in service sectors.

The growth of nominal sales during the period is very high, but notice that average price increases are now also significant for all countries. As with employment growth, sales growth is higher for product innovators, but not particularly for firms that only introduce process innovations. The productivity growth of innovators is, however, sometimes higher (France, Spain) and sometimes equal or lower (Germany, UK) than productivity growth of non-innovators.

For product innovators, sales of new products are as large a part of total sales growth as in manufacturing, although there appears to be slightly less cannibalisation of old products by new products. As in manufacturing, the proportion of sales of new products that are

[18] We should note that the fact that average growth in sales of unchanged products is negative for product innovators does not necessarily imply cannibalisation of old products by new products. For example, it is possible that firms whose traditional markets are declining are more likely to introduce product innovations.

[19] See the Data Appendix for a description of the industry composition of the service sector samples.

accounted for by products that are new to the market (as opposed to simply new to the firm) is higher in Germany and Spain than in France and the UK.

4.1 Exploratory OLS regression results

Before estimating our empirical model in the next section, we briefly discuss an initial exploration of the conditional correlations observed in the data. Table 4 presents OLS regressions for the manufacturing and services samples in each country. In each case, employment growth is regressed on deflated total sales growth, dummies for "process innovation only" and product innovation, and a full set of industry dummies.

The coefficient on real sales growth is fairly stable across samples and is a long way below unity in all cases. On face value this suggests that sales growth is associated with less than one-for-one growth in employment. However, in the presence of the type of errors in variables problem discussed in the previous section this coefficient is likely to be biased downwards.[20] The coefficient on the "process innovation only" dummy is insignificant in all cases apart from Spanish manufacturing, where it is positive, suggesting a negative correlation between process innovation and productivity growth. This Spanish result remains in the results that follow, and may reflect greater pass-through of cost savings in prices, or possibly the fact that process innovation is correlated with negative shocks to productivity growth. The coefficient on the product innovation dummy is positive in all cases and significant about half the time, again suggesting the possibility of important demand enlargement effects of product innovation.

Overall the results are quite uninformative about the relative roles of displacement and compensation effects in the relationship between innovation and employment growth. For this reason, in the next section we impose more structure on the data using our theoretical model and information about the mix of sales between old and new products.

5. Econometric results

5.1 Basic specification: the effects of product innovation on employment

Table 5 presents the results from estimating equation (4) for firms in manufacturing. In all cases the dependent variable is employment growth minus the growth of sales due to the

[20] In this case both the g_1 and g_2 components of g are likely to be affected.

unchanged products. As discussed above, we control for changes in the prices of old products by deducting an industry price growth index from the nominal sales growth of unchanged products. The value of the constant is therefore an estimate (with negative sign) of average real productivity growth (over a two year period) in production of the old products, after any compensating price effects. We include in all regressions a full set of industry dummies, but their coefficients are constrained to add up to zero in order to preserve the interpretation of the constant.[21]

Panel A presents OLS results. The estimated coefficient on sales growth due to new products is an estimate of the relative efficiency of the production process for new products compared with that for old products. The fact that the coefficient is significantly less than one for all countries suggests that new products are produced more efficiently than old products. However, as discussed above, any endogeneity due to unobserved price changes is likely to produce a downwards bias in this coefficient, overstating the efficiency increases associated with new products.

Panel B applies a two stage least squares approach, taking the *sales growth due to new products* variable as endogenous and using a single instrument (i.e. the equation is exactly identified). Ideally any instrument would be related to growth in sales of new products but not to any change in the price of new products compared to old products. In order to preserve comparability across countries, our choice of instruments is restricted to variables that are present in the common questionnaire. The instrument that we use is the degree of impact of innovation on the increase in the range of goods and services produced, as reported by the firm (*Increased range*). The variable is coded as zero if innovation is not relevant for the range of goods and services produced, one if the impact of innovation on the range is low, two if it is medium and three if it is high.[22] Other related questions ask about the impact of innovation on market share or product quality, so the *increased range* variable could be interpreted as a measure of the extent to which the firm's innovation is associated with horizontal as opposed to vertical product differentiation. As a result we expect the instrument to be uncorrelated with changes in the price of new products compared to old products. In addition, while innovation activity itself may not be exogenous with respect to employment growth, it seems

[21] Firm size dummies, when included, turned out to be in general not very significant, and did not materially affect the results.

[22] We have experimented with a more flexible form of this variable, but this step variable appears to fit the data remarkably well, with very little evidence of any non-linear effect in the reduced form equation.

plausible that the *effects* of innovation on the range of products produced might be. The variable is positively and significantly correlated with the endogenous variable,[23] but there remain concerns about the true exogeneity of the instrument. We attempt to investigate this in Panel C by testing the validity of overidentifying restrictions in an overidentified specification.

The IV estimates of β in Panel B are as expected higher than the OLS estimates, consistent with a downwards bias due to unobserved price changes. All of the IV estimates are now extremely close to one, so there is no evidence that new products are produced with higher efficiency than old products. That is, there is now no evidence of employment displacement effects associated with product innovation. From the constant term we get an estimate of average productivity growth (over two years) in production of the old products that varies between about 3.6% in France and 7.4% in Germany.

In Panel C we attempt to test the validity of the instrument using an overidentified specification. The two additional instruments that we use are the extent to which the firm uses clients as a source of information for its innovation activities, and a dummy variable indicating whether the firm is continously engaged in R&D. Neither of these instruments has as much explanatory power in the reduced form as the *increased range* variable, but there seems no obvious reason why they should be correlated with the relative price of new products compared to old products. The important point is that in all countries the results are extremely robust to the inclusion of the new instruments (compare Panel B to Panel C), and the test of overidentifying restrictions does not reject at conventional levels. The test does nevertheless have some power for rejection: different subsets of potential instruments from a broader list, including *improved quality*, *increased market share*, and *R&D* and *Innovation effort* (the ratios of expenses to sales), were invariably rejected as valid instruments in at least one country.

5.2 Introducing process innovation

In Table 6 we extend the basic specification in Panel B of Table 5 by allowing process innovation to affect productivity growth. Panel A considers only the process innovations of

[23] In France, Germany, Spain and the UK the R-squared statistics obtained in the first stage reduced form regressions are 0.39, 0.20, 0.35 and 0.28 respectively. The coefficients on Improved range are equal to 5.3, 10.5, 11.2 and 14.5 respectively, with t-statistics of 30.8, 15.8, 26.9 and 16.0.

firms that do not introduce new products, since in this case we can be sure that the process innovation relates to the old product. In this context a negative coefficient on the *process innovation only* dummy represents an increase in productivity (and thus a displacement of labour) in production of the old product, after allowing for any pass through of productivity improvements in lower prices.[24] The coefficient is negative and significant for Germany and the UK. In both cases the size of the coefficient is similar to that of the constant, suggesting that process innovation is associated with about a doubling in the rate of productivity growth in production of the old product. The coefficient is negative but insignificant for France, and positive but insignificant for Spain. As discussed above, the Spanish result is a little surprising, and could be due to larger pass-through of any productivity improvements in prices, or alternatively to reactive process innovation in response to negative productivity growth shocks.[25]

In Panels B and C we introduce separately the process innovations of firms that also introduce product innovations. Since we do not know whether these process innovations refer to the production of the old or the new products we try both alternatives. In Panel B we assume that all the process innovations of product innovators refer to production of the old product, while in Panel C we assume that they all refer to production of the new product.

The coefficient on *process and product innovation* in Panel B is negative and insignificant for Germany and Spain, but positive and marginally significant for France and the UK, apparently suggesting that the process innovations of product innovators are associated with employment growth in production of the old product (or slower productivity growth) after allowing for any price pass-through. However, in both cases the coefficient on *sales growth due to new products* is reduced from about one to 0.9, suggesting lower employment growth associated with production of the new product.

An alternative hypothesis is that the process innovations of product innovators are in fact associated with production of the new product, and this is tested in Panel C, where we introduce an interaction between the *process and product innovation* dummy and *sales growth*

[24] We tested for the endogeneity of the *process innovation only* variable using the overidentifying restrictions provided by the additional instruments in Panel C of Table 5. We were never able to reject the hypothesis that the variable was exogenous, though this may be partly due to the relatively low explanatory power of the instruments in predicting process innovation.

[25] Larger pass-through of productivity improvements in prices could be related to the higher levels of nominal price growth in Spanish manufacturing during the period than in the other countries.

due to new products.[26] This allows the average relative productivity in production of the old and the new products to be different for firms that also introduce process innovations. The results correspond closely with those in Panel B, with insignificant negative coefficients on the interaction for Germany and Spain, and positive and marginally significant coefficients for France and the UK, suggesting that new products are associated with smaller productivity increases (or larger productivity decreases) for firms that also introduce process innovations. One possible interpretation of this result for France and the UK is that new products that are associated with less productive production technologies tend to induce process innovations in order to reduce the cost of production.

However, given the available data we are not able to distinguish between the alternative hypotheses embodied in Panels B and C, and the truth is probably somewhere in between, with some process innovations being associated with old products and some with new products. For this reason our preferred specification is that in Panel A, where we can be sure that the process innovations of firms that do not introduce new products relate to the old product.

5.3 Service sector results

Tables 7 and 8 present equivalent results for firms in the service sector. As discussed in Section 2.1, several general considerations suggest that the results should be treated with more care than the manufacturing results. In addition, we should note the following specific differences. First, we use only a single price deflator for all services activities in Spain, and the deflators used for France, Germany and the UK are at a higher level of aggregation than those used in the manufacturing results. Secondly the proportion of innovating firms is lower than in manufacturing, particularly in Spain and the UK. Despite these caveats, the results throw up some interesting differences.

Table 7 presents the results of the basic OLS and IV specifications. As with manufacturing the coefficient on *sales growth due to new products* is less than one in the OLS case (particularly in Germany), but rises to become insignificantly different from one for all countries once the variable is instrumented with the *increased range* variable. Thus we cannot reject the hypothesis that new products are produced with the same productivity as old products on

[26] We also introduce as an additional instrument the interaction between the *process and product innovation* dummy and the existing *increased range* instrument.

average, although there is some suggestion that new products are produced with higher productivity in Germany and lower productivity in France. As with manufacturing the results are extremely robust to introducing more instruments, and the overidentifying restrictions are not rejected. Average productivity growth in production of the old product, as revealed by the constant term, is higher than in manufacturing for France, lower in Germany and Spain, and about the same in the UK.

Table 8 introduces the effects of process innovation as before. None of the coefficients on *process innovation only* is significant in Panel A, suggesting no net effect, after any price pass-through, of process innovation on the productivity of production of the old product for firms that do not introduce product innovations. The same is true for both process innovation variables in Panel B. In Panel C we assume that all the process innovations of product innovators relate to the new product. The only significant result is the negative interaction term for Spain, suggesting that new products are associated with larger productivity increases (or smaller productivity decreases) for firms that also introduce process innovations. There is very little evidence in these results of significant employment displacement effects associated with process innovation in services, although it is difficult to draw strong conclusions given the various concerns discussed above.

5.4 Robustness

In Table 9 we present examples for manufacturing firms of various robustness checks and extensions. In three out of the four cases, we take advantage of the availability of a given variable for a single country. These are variables that were not included in the core CIS3 questionnaire, but were added by the relevant statistical agencies in individual countries.

First, in all countries we included as an explanatory variable the ratio of physical investment to the value of the sales at the beginning of the period (in 1998). This is an attempt to control for the role of investment in the subsequent growth of employment, and can also be interpreted as an indirect check on the assumption of only minor changes in relative factor prices. The variable has by far the largest impact in France, and in the first column of Table 9 we present the results for a similar specification to that in Panel A of Table 6. The results suggest that investment is significantly correlated with productivity growth, with a one percentage point increase in investment intensity associated with about a 0.4 percentage point lower growth in employment over the period for a given growth in sales. The coefficients on *process innovation only* and *sales growth due to new products* are not significantly affected.

In the second column we introduce a variable specific to the German data that asks if firms have introduced process innovations associated with rationalisation (cost reduction) to check for possible heterogeneity within process innovations.[27] The results suggest that these types of process innovations are driving the displacement effect found in Panel A of Table 6, with no significant effect of other types of process innovations. One interpretation is that cost-reducing process innovations in Germany are particularly focused on reducing employment requirements. The estimated effect is an 8 percentage point reduction in employment growth over the period for a given growth in sales.

In the third column we test whether the observed growth in employment over the period might be measuring only a fraction of the total effect of innovation, with the remaining effect taking place after the end of the period. To test for this possibility, we include a variable specific to the Spanish data that asks firms what they expect to be the change in their level of employment over the coming two years. The coefficient on *expected employment growth* is negative but insignificant, suggesting that only a tiny fraction of the total change in employment tends to be postponed. One interpretation is that we are not missing important dynamic effects in our preferred specification.

Finally, firms in the UK are asked separately the proportion of their sales in 2000 that are accounted for by "significantly improved" and by "new" products, whereas firms in other countries are only asked the proportion accounted for by "new or significantly improved" products. This allows us to test whether our main specification is missing important productivity effects of new products by grouping them together with products that are merely significantly improved. In the final column of Table 9 we repeat the basic UK specification from Panel A of Table 6, except that we now define g_1 as *sales growth due to existing or significantly improved products* and g_2 as *sales growth due to new products only.* The coefficient on *sales growth due to new products only* now represents the relative efficiency in production of existing or significantly improved products and of new products. The results are almost entirely unchanged from the original specification in Panel A of Table 6, although the coefficient on *sales growth due to new products only* is estimated less precisely than before. As before there is no evidence of significant employment displacement effects associated with

[27] See Peters (2004) for more details.

product innovation.

6. An employment growth decomposition

An interesting way to summarise the evidence obtained with our estimates is to decompose firms' employment growth into several components. Using our preferred specification in Panel A of Table 6 we can write employment growth for each firm in the following way

$$l = \sum_j (\widehat{\alpha}_0 + \widehat{\alpha}_{0j}) ind_j + \widehat{\alpha}_1 d + [1 - 1(g_2 > 0)](g_1 - \widetilde{\pi}_1) + 1(g_2 > 0)(g_1 - \widetilde{\pi}_1 + \widehat{\beta} g_2) + \widehat{u}$$

where ind_j represents the industry dummies, the $\widehat{\alpha}_{0j}$ their estimated coefficients, and d is a dummy variable denoting the introduction of process innovation by firms that do not introduce new products. For a given firm, the first component gives the change in its employment attributable to the (industry specific) *productivity trend in production of old products* ($\sum_j (\widehat{\alpha}_0 + \widehat{\alpha}_{0j}) ind_j$). The second component measures the change in employment associated with the *net effect of process innovation in the production of old products* ($\widehat{\alpha}_1 d$). The third component gives the employment change associated with *output growth of old products* for firms that do not introduce new products ($[1 - 1(g_2 > 0)](g_1 - \widetilde{\pi}_1)$). Finally, the fourth component measures the *net contribution of product innovation,* after allowing for any substitution of new products for old products ($1(g_2 > 0)(g_1 - \widetilde{\pi}_1 + \widehat{\beta} g_2)$). The last term is a residual unexplained component ($\widehat{u}$).

Table 9 reports the application of this decomposition to the whole samples of manufacturing and services firms, using the proportions and averages from Table 2 and Table 3, and the regression results from Table 6 Panel A and Table 8 Panel A. Notice that the average residual component $\widehat{u}$ is equal to zero by construction, and so the productivity trend in production of old products can be obtained by subtracting the other components from average employment growth.

Before discussing the results of the decomposition, let us comment briefly on its interpretation. First, given that many of the estimated coefficients are similar across countries, differences in the results of the decomposition across countries will often be driven by differences in the average values of the variables. Neverthless, the decomposition would not be possible without the estimated coefficients. Secondly, many limitations of the estimation results have been stressed above. In particular, process innovation effects are not separately identified from the effects of associated price changes, and firm-level compensation effects do not distinguish between pure market expansion and business stealing. Thirdly, recall that we are describing the average employment growth of a sample of continuing firms. Entering and exiting firms should be included to obtain a more complete picture of aggregate employment effects. And finally, the results are based on an expansionary period for all four countries, and so may not be representative of average firm-level effects at other stages of the cycle.

Table 10 shows that, in Manufacturing, incremental productivity improvements in the production of existing products are an important source of reductions in employment requirements for a given level of output. The effect is smallest in France (-1.9% over two years) and largest in Germany (-7.5% over two years). However, growth in output of existing products over this expansionary period more than compensates the productivity effect in all countries except Germany.

Individual process innovations account for only a small employment change in all countries, generally resulting in a small net displacement effect. This is partly because we are measuring process innovation effects in net terms after any price pass-through, but also because the number of firms that introduce only process innovations is small. Employment reductions resulting from process innovations may be important for individual firms, but they amount to only a small fraction of overall employment changes.

In contrast, product innovations play an important role in stimulating firm-level employment growth. The decomposition shows that the effect of new product sales, even net of the substitution for old products, is sizeable in all countries. It implies an average firm-level employment increase over the period ranging from 3.9% in the UK to 8.0% in Germany.

Overall, the importance of innovation in stimulating firm-level employment growth becomes clear when the different sources of employment change are compared. In Germany, where the combined effect of growth in existing output and trend productivity increases in production of existing products is slightly negative, product innovation is responsible for more than the whole average firm-level employment increase in the during the period. Even in Spain and the UK, where increases in sales of existing products are responsible for a large proportion of net employment growth, product innovation was on average more important than the net effect of growth in sales of existing products.

The results for service sector firms are somewhat different. Average within-firm employment growth is almost double that in manufacturing during the period, and more than double in the UK. On average, product innovation accounts for a smaller, but still non-negligible, proportion of total employment growth than in manufacturing. In Spain and the UK the main source of firm-level employment growth is growth in production of old products, with a small counterbalancing effect of trend productivity increases only in the UK. In France the contribution of product innovation is roughly the same as the net contribution of growth in sales of existing products. Total employment growth is lower in Germany, and growth in production of new products accounts for a larger share of employment growth than in the other countries.

7. Conclusions

In this paper we have derived and estimated a simple model of employment and innovation using a unique source of comparable and representative micro-data on manufacturing and services firms across four European countries. The results are illuminating about the relative roles of displacement and compensation effects in the firm-level relationship between innovation and employment growth. The results also provide a rare insight into the relationship between innovation and employment growth in service sectors. The firm-level relationship between innovation and employment is an important topic of research for several reasons. For example, the firm-level effects of innovation on employment are likely to determine the extent to which different agents within the firm resist or encourage innovation. At the same time, the incentives of managers and workers will determine the types of innovations that are introduced and their subsequent effects on prices, output and employment. Understanding these incentives and welfare effects at the micro level is essential for the effective design of innovation policy, and for predicting how other interventions, such as labour market regulations, might affect the rate of innovation.

Our results are only a first look at this important topic in many respects. First, the lack of data to model the demand side of firms' activity imposes some obvious limitations when estimating the displacement and compensation effects of innovation. In particular, "business stealing" effects cannot be separately identified from pure market expansion, and compensation effects resulting from price pass-through cannot be fully assessed. Secondly, we have considered only the total level of employment and not its composition in terms of skills or types of worker. For example, our results suggest that workers on average have little to fear from product innovation, but we have not been able to address the possibility that new products are more complementary to skilled than to unskilled workers. Both these topics present important lines of research at the micro level, and suggest high returns to increasing the richness of available data sources.

The main results reveal that, in manufacturing, although process innovation tends to displace employment, compensation effects are prevalent, and product innovation is associated with employment growth. The destruction of jobs through process innovation, as well as being relatively infrequent, appears to be partly counteracted by compensation mechanisms that increase demand through lower prices. At the same time we find no evidence of displacement effects associated with product innovation, and compensation effects resulting from the introduction of new products are significant even when the cannibalization of old products is taken into account. In the service sector there is less evidence of displacement effects from process innovation, and though less important than in manufacturing, growth in sales of new products accounts for a non-negligible proportion of employment growth. Interestingly, our results accord well with scarce existing evidence, and provide explanations for both the strong positive effect of product innovation on employment and the unrobust effects of process innovation that are usually found.

Overall the results are similar across countries, although some interesting differences emerge which might also merit further investigation. For example, we find no evidence for a net displacement effect of process innovation in Spanish manufacturing, possibly due to greater pass-through of productivity improvements in lower prices. Product innovation appears to play a larger role in employment growth in Germany than in the other countries, and possibly a smaller role in the UK, while higher levels of firm-level employment growth over this period in Spain are largely explained by faster growth in output of existing products.

Data Appendix

The Community Innovation Surveys (CIS) are carried out in European countries every 4 years by national statistical offices coordinated by Eurostat. The questionnaire is harmonised, including some common "core" questions as well as others which are optional, and follows the recommendations of the Oslo Manual. CIS3 is the name for the data collected in 2001, referring to the 1998-2000 period. The statistical offices in charge were INSEE and SESSI (as the main institutions) for France, ZEW for Germany, INE for Spain and the DTI for the United Kingdom. Participation is compulsory in France and Spain and volontary in Germany and the UK. Samples are representative, although the level and form of representativeness differ across countries. A complete analysis of the characteristics of CIS3, as well as an analysis of the comparability of the data and its main characteristics can be found in Abramovsky, Jaumandreu, Kremp and Peters (2004).

The samples described in Tables 2 and 3 are the result of homogenising the raw samples available for each country. Manufacturing industries, as well as the service industries selected in order to have a common sample, are listed below. The German sample has been restricted to firms with 10 and more employees to match the Spanish and UK samples. French manufacturing data refer, however, to firms with 20 or more employees. In addition the French sample for the service sector does not include the transport industry (see Table A2). Firms which show significant reductions or increases in turnover as a result of mergers, closures or scisions have been dropped, as well as all firms which show incomplete data or outliers (changes in sales or employment higher than 300%). See Tables A1 and A2 for the industry composition of the country samples and statistics on average firm size by country and industry.

Prices growth: France: computed at the 2.5 digit level using the National Accounts value added deflators, both for manufacturing and the services sector. Germany: computed from producer price indices on a 3-digit level for manufacturing published by the German statistical office. In a few cases no 3-digit level information was available and corresponding 2-digit indices are used. 7 different price indices are used for services (producer price indices or different components from the consumer price index, see Peters (2004) for more details). Spain: computed from 88 industry series for manufacturing, coming from the “Indices de precios industriales,” elaborated by the INE, and from the services component of the Consumer Price Index. UK: computed at the 4-digit level for manufacturing using ONS output deflators, and at the 1.5 digit level for services using OECD output deflators.

Variable Definitions

Clients as sorce of information: Variable which takes the value 0 if the firm reports that clients as a source of information for innovation have been not used, 1 if they have been of low importance, 2 if they have been of medium importance and 3 if they have been of high importance.

Continuous R&D engagement: Dummy variable which takes the value 1 if the firms reports continuous engagement in intramural R&D activities during the period.

Employment growth: Rate of change of the firm's employment for the whole period.

Expected employment growth: Rate of change in employment implied for expected employment by 2002.

Increased market share: Variable which takes the value 0 if the firm reports that the effect of innovation has been irrelevant for market share, 1 of it has had a low impact, 2 if it has had a medium impact, and 3 if it has had a high impact.

Increased range: Variable which takes the value 0 if the firm reports that the effect of innovation has been irrelevant for the range of goods and services, 1 of it has had a low impact, 2 if it has had a medium impact, and 3 if it has had a high impact.

Industry dummies: System of industry dummies according to the above grouping of manufacturing and service sector.

Innovation effort: Ratio of total innovation expenditure to current turnover.

Improved quality: Variable which takes the value 0 if the firm reports that the effect of innovation has been irrelevant for the quality of goods and services, 1 of it has had a low impact, 2 if it has had a medium impact, and 3 if it has had a high impact.

Investment/sales98: Ratio of the value of investment during the period to the value of turnover in 1998.

Process and product innovation: Dummy which takes the value 1 if the firm reports having introduced new or significantly improved products and production processes during the period.

Process innovation: Dummy which takes the value 1 if the firm reports having introduced new or significantly improved production processes during the period.

Process innovation of rationalisation: Dummy which takes the value 1 if the firm reports having introduced some process innovation with rationalisation (cost reduction) purposes during the period.

Process innovation only: Dummy which takes the value 1 if the firm reports having introduced new or significantly improved production processes during the period but no new or significantly improved products.

R&D effort: Ratio of total R&D expenditure to current turnover.

Sales growth: Rate of change of the firm's turnover for the whole period (formally equal to $g = \frac{P_{22}Y_{22}+P_{12}Y_{12}-P_{11}Y_{11}}{P_{11}Y_{11}}$).

Sales growth due to new products: Computed as the product of the fraction of turnover due to new or significantly improved products and one plus the rate of change of the firm's turnover for the whole period (notice that, denoting s as the proportion of sales in 2000 accounted for by new products, we have $\frac{P_{22}Y_{22}}{P_{22}Y_{22}+P_{12}Y_{12}} = s$ and hence $g_2 = \frac{P_{22}Y_{22}}{P_{11}Y_{11}} = s(1+g)$).

Sales growth due to unchanged products: Sales growth minus sales growth due to new products.

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Table 1. Employmente effects of innovation

			Displacement	Compensation		
R&D innovation expenditures	⟹	Process innovation	Productivity effect: less labour for a given output	Price effect: cost reduction, passed on to price, expands demand	⟸	Depends on firm agents' behaviour ⇑
		Product innovation	Productivity differences of the new product?	Demand enlargement effect	⟸	Depends on competition

Table 2. Manufacturing firms: Process and product innovation, employment and sales, 1998-2000[1,2]

	France	Germany	Spain	UK
N^o of firms	4631	1319	4548	2493
Non-innovators (%)	47.7	41.5	55.4	60.5
Process only (%)	7.1	10.2	12.2	11.0
Product innovators[3] (%)	45.2	48.4	32.4	28.5
[Of which product & process innovators]	[*24.3*]	[*27.4*]	[*20.0*]	[*14.2*]
Employment growth (%)				
All firms	*8.3*	*5.9*	*14.2*	*6.7*
Non-innovators	7.0	2.4	12.6	5.6
Process only	7.5	6.0	16.2	8.0
Product innovators[3]	9.8	8.9	16.2	8.5
Sales growth (%)				
All firms	*13.0*	*15.2*	*23.2*	*12.3*
Non-innovators	11.0	10.8	21.7	10.8
Process only	13.4	21.7	23.6	16.3
Product innovators[3]	15.0	17.5	25.7	13.9
Unchanged products	*−2.3*	*−17.0*	*−13.7*	*−21.5*
New products	*17.3*	*34.5*	*39.4*	*35.4*
[Of which new to the market]	[*8.2*]	[*13.1*]	[*13.8*]	[*9.1*]
Productivity growth (%)				
All firms	*4.7*	*9.3*	*9.0*	*5.6*
Non-innovators	4.0	8.4	9.1	5.2
Process only	5.9	15.7	7.4	8.3
Product innovators[3]	7.5	8.7	9.5	5.4
Prices growth[4] (%)				
Non-innovators	2.5	1.1	4.0	0.1
Process only	3.1	2.4	4.2	−0.2
Product innovators[3]	2.4	1.3	3.7	−0.4

[1]Rates of growth for the whole period 1998-2000.

[2]Population are firms with 10 or more employees. Entrant firms and firms affected by mergers and scissions not considered.

[3]Product innovators only + process and product innovators.

[4]Prices computed for a set of industries and assigned to firms according to their activity.

Table 3. Services firms: Process and product innovation, employment and sales, 1998-2000[1,2]

	France	Germany	Spain	UK
N° of firms	1653	849	1839	1794
Non-innovators (%)	60.2	51.4	69.1	73.2
Process only (%)	8.5	9.3	9.4	7.0
Product innovators[3] (%)	31.3	39.3	21.5	19.8
[Of which product & process innovators]	[*17.2*]	[*21.7*]	[*11.9*]	[*8.1*]
Employment growth (%)				
All firms	*15.5*	*10.2*	*25.9*	*16.1*
Non-innovators	14.2	5.9	24.8	13.8
Process only	9.9	6.1	24.5	18.6
Product innovators[3]	19.4	16.9	30.1	23.7
Sales growth (%)				
All firms	*18.4*	*18.5*	*32.3*	*22.7*
Non-innovators	16.3	14.4	30.9	21.2
Process only	16.1	11.2	30.9	24.1
Product innovators[3]	23.1	25.6	37.8	28.2
Unchanged products	*−3.2*	*−15.9*	*−8.9*	*−14.1*
New products	*26.3*	*41.5*	*46.7*	*42.2*
[Of which, new to the market]	[*9.8*]	[*16.4*]	[*19.2*]	[*11.1*]
Productivity growth (%)				
All firms	*2.9*	*8.3*	*6.4*	*6.7*
Non-innovators	2.1	8.5	6.1	7.4
Process only	6.2	5.1	6.4	5.5
Product innovators[3]	3.7	8.7	7.7	4.5
Prices growth[4] (%)				
Non-innovators	1.8	5.0	7.3	2.3
Process only	1.8	4.7	7.3	1.0
Product innovators[3]	1.8	3.0	7.3	3.0

[1]Rates of growth for the whole period 1998-2000.
[2]Population are firms with 10 or more employees. Entrant firms and firms affected by mergers and scissions not considered.
[3]Product innovators only + process and product innovators.
[4]Prices computed for a set of industries and assigned to firms according to their activity.

Table 4. Manufacturing and Service sector firms
Exploratory OLS regressions: employment growth on (real) sales growth and innovation dummies[1]

Dependent variable: l

Regression (Sector)	A (Manufacturing)				B (Services)			
	France	Germany	Spain	UK	France	Germany	Spain	UK
Explanatory variables								
Constant	2.52	-2.21	6.59	0.25	5.15	2.71	8.44	6.10
	(0.53)	(0.54)	(0.59)	(0.64)	(2.23)	(3.50)	(1.67)	(1.31)
Real sales growth: $(g - \widetilde{\pi}_1)$	0.43	0.43	0.35	0.48	0.45	0.49	0.48	0.46
	(0.02)	(0.04)	(0.02)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)
Process innovation only	-0.54	-0.49	2.98	-0.45	-3.78	-0.12	0.57	3.68
	(1.17)	(1.20)	(1.25)	(1.57)	(2.73)	(1.97)	(2.60)	(3.29)
Product innovation	1.11	3.99	2.0	2.14	3.30	3.94	2.82	5.57
	(0.72)	(1.21)	(0.88)	(1.31)	(2.74)	(1.85)	(2.31)	(2.05)
N^o of firms	4631	1319	4548	2493	1653	849	1839	1794
Standard error	21.64	19.31	26.10	24.38	39.33	23.50	36.09	30.13

[1]Coefficients and standard errors robust to heteroskedasticity. All regressions include industry dummies.

Table 5. Manufacturing firms
The effects of product innovation on employment[1]

Dependent variable: $l - (g_1 - \widetilde{\pi}_1)$

Regression (Method)	A (OLS)				B (IV[2])				C (IV[3])			
	France	GER	Spain	UK	France	GER	Spain	UK	France	GER	Spain	UK
Explanatory variables												
Constant	-1.87	-5.63	-3.58	-3.28	-3.60	-7.43	-5.88	-5.22	-3.51	-6.90	-5.83	-5.20
	(0.57)	(1.23)	(0.67)	(0.81)	(0.58)	(1.71)	(0.84)	(0.85)	(0.74)	(1.55)	(0.83)	(0.85)
Sales growth due to new products	0.77	0.88	0.86	0.80	0.98	1.00	1.02	0.99	0.97	0.97	1.02	0.99
	(0.05)	(0.06)	(0.03)	(0.06)	(0.06)	(0.07)	(0.04)	(0.05)	(0.06)	(0.06)	(0.04)	(0.05)
N^o of firms	4631	1319	4548	2493	4631	1319	4548	2493	4631	1319	4548	2493
Standard error	28.02	27.25	35.97	30.44	28.21	27.34	36.28	30.84	28.19	27.23	36.27	30.83
Test of overident. restrictions	–	–	–	–	–	–	–	–	1.77	3.20	0.45	1.72
(degrees of freedom)									(2)	(2)	(2)	(2)

[1]Coefficients and standard errors robust to heteroskedasticity. All regressions include industry dummies.

[2]Unique instrument used is Increased range.

[3]Instruments used are Increased range, Clients as a source of information, and Continuous R&D engagement.

Table 6. Manufacturing firms
The effects of innovation on employment: adding process innovation[1]

Dependent variable: $l - (g_1 - \widetilde{\pi}_1)$

Regression (Method)	A (IV[2])				B (IV[2])				C (IV[3])			
Explanatory variables	France	GER	Spain	UK	France	GER	Spain	UK	France	GER	Spain	UK
Constant	-3.52	-6.95	-6.11	-4.69	-3.51	-6.96	-6.14	-4.73	-3.50	-6.97	-6.12	-4.62
	(0.78)	(1.86)	(0.9)	(0.88)	(0.78)	(1.88)	(0.91)	(0.88)	(0.78)	(1.86)	(0.90)	(0.88)
Process innovation only	-1.31	-6.19	2.46	-3.85	-1.26	-6.20	2.47	-3.84	-1.32	-6.18	2.47	-3.88
	(1.57)	(2.92)	(1.78)	(1.87)	(1.56)	(2.92)	(1.79)	(1.87)	(1.57)	(2.92)	(1.78)	(1.87)
Process and product innov.					2.59	-1.98	-1.49	5.51				
					(1.43)	(2.80)	(2.64)	(2.55)				
Sales growth d.t. new products	0.98	1.01	1.02	0.98	0.90	1.04	1.05	0.90	0.90	1.03	1.03	0.89
	(0.06)	(0.07)	(0.04)	(0.05)	(0.09)	(0.07)	(0.07)	(0.07)	(0.09)	(0.08)	(0.06)	(0.07)
Sales growth d.t. new products * process innovation									0.14	-0.04	-0.02	0.16
									(0.08)	(0.07)	(0.06)	(0.08)
N^o of firms	4631	1319	4548	2493	4631	1319	4548	2493	4631	1319	4548	2493
Standard error	28.21	27.31	36.25	30.74	28.07	27.46	36.35	30.40	28.20	27.27	36.26	30.47

[1]Coefficients and standard errors robust to heteroskedasticity. All regressions include industry dummies.
[2]Unique instrument used is Increased range.
[3]Instruments are Increased range and Increased range interacted with Process innovation.

Table 7. Service sector firms
The effects of product innovation on employment[1]

Dependent variable: $l - (g_1 - \widetilde{\pi}_1)$

Regression (Method)	A (OLS)				B (IV[2])				C (IV[3])			
	France	GER	Spain	UK	France	GER	Spain	UK	France	GER	Spain	UK
Explanatory variables												
Constant	-2.13	-0.31	-3.04	-3.53	-5.32	-3.29	-4.06	-5.12	-5.08	-3.59	-3.95	-5.05
	(1.95)	(7.09)	(2.01)	(1.48)	(2.42)	(8.99)	(2.21)	(1.53)	(2.36)	(8.76)	(2.20)	(1.53)
Sales growth due to new products	0.85	0.75	0.92	0.89	1.15	0.93	0.99	1.04	1.13	0.94	0.98	1.03
	(0.07)	(0.06)	(0.05)	(0.06)	(0.13)	(0.08)	(0.08)	(0.06)	(0.13)	(0.08)	(0.08)	(0.06)
N^o of firms	1653	849	1839	1794	1653	849	1839	1794	1653	849	1839	1794
Standard error	44.59	33.42	43.32	37.94	45.09	33.68	43.37	38.01	45.02	33.80	43.36	37.99
Test of overident. restrictions	–	–	–	–	–	–	–	–	0.41	1.09	0.35	3.55
(degrees of freedom)									(2)	(2)	(2)	(2)

[1]Coefficients and standard errors robust to heteroskedasticity. All regressions include industry dummies.

[2]Unique instrument used is Increased range.

[3]Instruments used are Increased range, Clients as a source of information, and Continuous R&D engagement.

Table 8. Service sector firms
The effects of innovation on employment: adding process innovation[1]

Dependent variable: $l - (g_1 - \widetilde{\pi}_1)$

Regression (Method)	A (IV[2])				B (IV[2])				C (IV[3])			
	France	GER	Spain	UK	France	GER	Spain	UK	France	GER	Spain	UK
Explanatory variables												
Constant	-5.25	-3.36	-4.04	-5.51	-4.96	-3.39	-3.82	-5.45	-5.24	-3.23	-4.07	-5.61
	(2.48)	(9.28)	(2.25)	(1.61)	(2.44)	(9.22)	(2.20)	(1.62)	(2.48)	(9.29)	(2.24)	(1.62)
Process innovation only	-1.45	1.54	-0.38	3.21	-1.63	1.56	-0.46	3.10	-1.45	1.46	-0.32	3.25
	(3.47)	(3.07)	(3.37)	(3.54)	(3.47)	(3.06)	(3.36)	(3.53)	(3.47)	(3.07)	(3.37)	(3.53)
Process and product innov.					-3.81	1.80	-6.52	-6.26				
					(5.55)	(4.26)	(6.72)	(4.96)				
Sales growth d.t. new products	1.16	0.92	0.99	1.05	1.23	0.90	1.07	1.10	1.18	0.86	1.13	1.10
	(0.13)	(0.08)	(0.08)	(0.06)	(0.18)	(0.11)	(0.14)	(0.09)	(0.17)	(0.11)	(0.12)	(0.10)
Sales growth d.t. new products * process innovation									-0.04	0.09	-0.23	-0.10
									(0.20)	(0.10)	(0.12)	(0.11)
N^o of firms	1653	849	1839	1794	1653	849	1839	1794	1653	849	1839	1794
Standard error	45.11	33.66	43.37	38.02	45.36	33.53	43.51	38.19	45.11	33.76	43.25	38.07

[1]Coefficients and standard errors robust to heteroskedasticity. All regressions include industry dummies.

[2]Unique instrument used is Increased range.

[3]Instruments are Increased range and Increased range interacted with Process innovation.

Table 9. Manufacturing firms
Some robustness checks[1]

Dependent variable: $l - (g_1 - \widetilde{\pi}_1)$
Method: IV[2]

Explanatory variables	France	GER	Spain	UK[3]
Constant	-1.86	-6.55	-5.87	-4.70
	(0.73)	(1.72)	(0.90)	(0.87)
Process innovation only	-0.74		2.60	-3.83
	(1.59)		(1.79)	(1.86)
Sales growth due to new products	1.00	0.99	1.03	
	(0.06)	(0.06)	(0.04)	
Investment/Sales98	-0.39			
	(0.05)			
Process innovation of rationalisation only		-8.02		
		(3.44)		
Other Process innovation only		-3.17		
		(4.97)		
Expected employment growth			-0.09	
			(0.06)	
Sales growth due to new products only				0.96
				(0.10)
N^{o}of firms	4631	1319	4548	2493
Standard error	30.00	27.20	36.26	30.74

[1]Coefficients and standard errors robust to heteroskedasticity. All regressions include industry dummies.
[2]Unique instrument used is Increased range.
[3]Dependent variable defined using "new products" only, as opposed to "new or significantly improved" products, as described in the text.

Table 10
The contribution of innovation to firms' employment growth[1]
Manufacturing and Services, 1998-2000[2]

	France	Germany	Spain	UK
Manufacturing[3] (Average values)				
Firms' *employment growth*	*8.3*	*5.9*	*14.2*	*6.7*
Productivity trend in production of old products[4]	-1.9	-7.5	-5.7	-5.0
Net effect of process innovation in production of old products	-0.1	-0.6	0.3	-0.4
Output growth of old products contribution	4.8	6.0	12.2	8.3
Net contribution of product innovation	5.5	8.0	7.4	3.9
Services[3] (Average values)				
Firms' e*mployment growth*	*15.5*	*10.2*	*25.9*	*16.1*
Productivity trend in production of old products[4]	-2.3	-3.0	1.0	-5.0
Net effect of process innovation in production of old products	-0.1	0.1	-0.0	0.2
Output growth of old products contribution	9.9	5.4	18.5	15.5
Net contribution of product innovation	8.0	7.6	6.5	5.4

[1]Decomposition based on tables 2 and 3 and regressions 6 (A) and 8 (A).
[2]Rates of growth for the whole period.
[3]The sum of decomposition values may differ slightly from employment growth because of rounding.
[4]Productivity trend is the weighted sum of industry dummy values and hence differs from the constant of the regression.

Table A1. Manufacturing:
Number of firms and average firm size, by country and sector.

	Number of firms (%)				Average firm size[1]			
	France	Germany	Spain	UK	France	Germany	Spain	UK
Manufacturing								
All firms	*4631*	*1319*	*4548*	*2493*	*345*	*276*	*132*	*172*
Vehicles	197 (4.3)	53 (4.0)	252 (5.6)	262 (10.5)	1164	340	367	224
Chemicals	381 (8.2)	92 (7.0)	297 (6.5)	82 (3.3)	483	330	213	364
Machinery	425 (9.2)	184 (14.0)	286 (6.3)	202 (8.1)	302	291	150	178
Electrical	460 (9.9)	214 (16.2)	370 (8.1)	398 (15.9)	540	482	157	197
Food	893 (19.3)	113 (8.6)	502 (11.0)	179 (7.2)	282	149	150	303
Textile	571 (12.3)	77 (5.8)	668 (14.7)	143 (5.7)	124	219	78	148
Wood	420 (9.1)	112 (8.5)	629 (13.8)	355 (14.2)	234	358	87	144
Plastic/rubber	279 (6.0)	116 (8.8)	199 (4.4)	130 (5.2)	396	148	105	131
Non-metallic	163 (3.5)	78 (5.9)	332 (7.3)	52 (2.1)	415	247	141	260
Basic metall	617 (13.3)	227 (17.2)	610 (13.4)	358 (14.4)	258	153	110	67
NEC	225 (4.9)	53 (4.0)	403 (8.9)	332 (13.3)	217	253	66	132

[1] Average firm size is measured by the average number of employees in year 2000.

Table A2. Services:
Number of firms and average firm size, by country and sector.

	Number of firms (%)				Average firm size[1]			
	France	Germany	Spain	UK	France	Germany	Spain	UK
Services								
All firms	*1653*	*849*	*1839*	*1794*	*233*	*531*	*268*	215
Wholesale	743 (44.9)	204 (24.0)	406 (22.1)	743 (41.4)	62	410	146	124
Transport		204 (24.0)	341 (18.5)	464 (25.9)		1272	373	291
Post/telecomm.	31 (1.9)	26 (3.1)	76 (4.1)	64 (3.6)	102	220	191	586
Financial int.	251 (15.2)	97 (11.4)	128 (7.0)	328 (13.3)	1044	808	527	282
Computers	211 (12.8)	80 (9.4)	180 (9.8)	79 (4.4)	81	95	151	238
R&D	64 (3.9)	75 (8.8)	72 (3.9)	34 (1.9)	168	91	68	337
Technical serv.	353 (21.4)	163 (19.2)	636 (34.6)	172 (9.6)	129	56	301	135

[1]Average firm size is measured by the average number of employees in year 2000.