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

Rupert Harrison[†] IFS and UCL

Jordi Jaumandreu[‡] UC3M

Jacques Mairesse[§] CREST

Bettina Peters[¶] ZEW

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Abstract

This paper studies the impact of process and product innovations introduced by firms on their employment. A model which relates employment growth to process innovations and to the growth of sales due to innovative and unchanged products is derived and estimated with comparable firm-level data from France, Germany, Spain and the UK. Results for manufacturing firms 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 from process innovation, and some indication of employment displacement resulting from product innovation. Nevertheless, growth in sales of new products accounts for a non-negligible proportion of employment growth in services. Overall the results are similar across countries, with some interesting exceptions.

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[†]Institute for Fiscal Studies, and University College London. E-mail: rupert.harrison@ifs.org.uk

[‡]Universidad Carlos III de Madrid. E-mail: jordij@eco.uc3m.es

[§]CREST. E-mail: jacques.mairesse@ensae.fr

[¶]Centre for European Economic Research. E-mail: b.peters@zew.de

1.Introduction.

Innovation is widely considered to be a primary source of economic growth, and policies to stimulate firm-level innovation are high on the agenda in most countries. But what are the employment consequences of innovation? Low levels of employment growth are currently a key concern in many European countries, yet the links between innovation and employment remain unclear. This paper uses a unique comparable dataset across four large European countries to investigate empirically the firm-level employment effects of innovation. Although evidence at the firm-level cannot take account of important general equilibrium effects, it is an essential ingredient for the effective design of innovation policy.

The data used in this paper comes 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. Most usefully 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 the R&D and innovation investments of firms and their financing, firms' sources of information and innovation aims, and cooperation and patenting activities.

Firm-level employment effects of innovation are complex[2]. Both process and product innovation are expected to affect employment through different channels. Some effects imply the reduction of labour for given tasks ("displacement effects") while others imply the creation of new labour needs ("compensation" effects). One remarkable feature of CIS data is that, using a simple theoretical framework which implies only mild assumptions, some of these effects can in principle be neatly disentangled. We observe, as reported by firms, the implicit changes in production (derived from the change in sales) that underly changes in employment. In particular, we observe the output resulting from product innovation as well as the evolution of output corresponding to unchanged products. We also have information on the changes applied by the firm to the productive process. We show that this is enough

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

[2] See García, Jaumandreu and Rodriguez (2002) and the references therein for the microeconomic firm-level modelling of the effects of innovation.

to identify some effects of theoretical and policy interest.

The paper uses data on four European countries - France, Germany, Spain and the United Kingdom - to estimate the model. The employed sample consists of a total of more than 20,000 firms, roughly 12,000 of which are in Manufacturing and 8,000 in the Services sector. 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 employed framework can account for many differing country-level details.

The rest of this paper is organised as follows. Section 2 discusses the potential firm-level employment effects of innovation. 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 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 employment growth in the four countries, and Section 7 concludes. A Data Appendix contains details on the sample and variables employed.

2. Employment effects of innovation.

The potential firm-level employment effects of innovation are summarised in Table 1. 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 is not so clear since process innovations often accompany product innovations and vice versa. Both types of innovations may be envisaged 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. Any continuous increase

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

in labour productivity, even in the absence of particular intramural innovations, can be understood as the result of improvements in labour and other factors (mainly capital) as well as incremental process improvements. More drastic process innovations inside the firm are likely to result in discrete changes to this increase, tending to displace labour for a given output.

At the same time any productivity increase implies a reduction in unit costs. Depending on competitive conditions facing the firm this is likely to result in a lower price, which will stimulate demand, and hence produced output and employment, according to the value of the elasticity of demand. This is the main compensation effect that we can expect from process innovations. But the degree to which such a compensation effect is likely to operate depends on the behaviour of the agents inside the firm and the nature of market competition. Unions may attempt to transform any gains from innovation into higher wages and hence unit costs, while managers may seek to increase market power[4]. Both behaviours can dampen or override the compensation effect.

Product innovations may have productivity effects even if they are not linked to simultaneous process innovations. The new product may imply a shift in production methods and input mix, and so could either have labour displacement effects or increase labour requirements. The extent and direction of any 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. The importance and endurance of any increases in demand resulting from product innovation will depend on the state of competition and the delay with which rivals react to the introduction of new products. In addition, sales of new products may cannibalise some proportion of the firm's existing sales, reducing the positive compensation effect of product innovation.

Finally, any firm-level compensation effect arising from a product innovation is likely to be composed of a pure market expansion effect as well as a business-stealing effect. The effect of one firm's innovation on the sales, and thus employment, of other firms is beyond the scope of this paper. Such effects are likely to be important when considering the effects of innovation on employment at the level of the economy.

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

3. The model.

We assume that firms can produce a range of different products, and focus on the firm's decision to begin to produce and sell new (or significantly improved) products during the period of reference. We group the unchanged or only marginally modified products into an "old products" aggregate output at the beginning of the period, Y_1, which changes during the period by ΔY_1, and group the new or significantly improved products into a "new products" aggregate output at the end of the period Y_2. By definition no new or significantly improved products are produced at the beginning of the period. To produce different outputs, firms must replicate (scale) conventional inputs, and there is knowledge capital which constitutes a non-rival input and drives the specific efficiencies for each process and its evolution over time. We assume that production processes show constant returns to scale in the conventional inputs, and that product-specific knowledge proportionally increases the marginal productivity of all conventional inputs of a given process. In addition we assume that production processes for different products are separable, so that there are no economies of scope. Thus we can write

$$Y_i = \theta_i F(C_i, L_i, M_i) \qquad\qquad i = 1, 2$$

where θ represents efficiency (a function of knowledge capital) and C, L and M stand for capital, labour and materials. The cost function can be written

$$C(w, Y, \theta) = c(w)\frac{Y_1}{\theta_1} + c(w)\frac{Y_2}{\theta_2} + F$$

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, $L_i = c_L(w)\frac{Y_i}{\theta_i}$, where $c_L(w)$ represents the derivative of marginal cost with respect to the wage. Using this expression, and assuming w is unchanged, we can write employment at the beginning of the period as $L_1 = c_L\frac{Y_1}{\theta_1}$, end-of period employment used to produce the old products as $L_1 + \Delta L_1 = c_L\frac{Y_1+\Delta Y_1}{\theta_1+\Delta\theta_1}$, and end-of-period employment used to produce the new products as $L_2 = c_L\frac{Y_2}{\theta_2}$. Hence, we can write an approximate employment growth decomposition as

$$\frac{\Delta L}{L_1} = \frac{\Delta L_1 + L_2}{L_1} \simeq -\frac{\Delta\theta_1}{\theta_1} + \frac{\Delta Y_1}{Y_1} + \frac{\theta_1}{\theta_2}\frac{Y_2}{Y_1} \qquad (1)$$

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

This expression says that, with input prices unchanged, employment growth is the result of the increase in efficiency in the productive 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 process $-\frac{\Delta\theta_1}{\theta_1}$ is expected to be different for firms which introduce process innovations relating to the old process, although the efficiency of all firms is expected to grow over time. The effect of product innovation on employment growth depends on the efficiency difference between the old and the new processes (the ratio $\frac{\theta_1}{\theta_2}$). If new products are produced more efficiently that 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.

Equation (1) suggests the population relationship

$$l = \alpha_0 + \alpha_1 d + y_1 + \beta y_2 + u \tag{2}$$

where l stands for employment growth, α_0 for (minus) average efficiency growth for non-process innovators, d is a dummy which takes the value one if the firm has introduced a process innovation (and hence α_1 measures average additional efficiency growth for process innovators), y_1 and y_2 stand for the output rates of growth $\frac{\Delta Y_1}{Y_1}$ and $\frac{Y_2}{Y_1}$ respectively (output growth accounted for by the old and new products), and u for a random disturbance which has zero unconditional mean.

Equation (2) can be transformed into a productivity growth equation

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

by simply rearranging terms. 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.

To estimate equation (2), however, we must substitute nominal sales, which are the magnitudes that we observe, for real production. Let g_1 be the nominal rate of growth of sales due to the old products. If π_1 is the proportional increase in the prices p_1 of these products over the period, we can write the approximate relation $g_1 = y_1 + \pi_1$. Let g_2 be the ratio of sales of new products at the end of the period to total sales (by definition of old products) at the beginning of the period. We define π_2 as the proportional difference of the prices of new products p_2 with respect to the old prices p_1, $\frac{p_2 - p_1}{p_1}$, so that we have $g_2 = y_2 + \pi_2 y_2$. We assume that π_2 is mean-independent of y_2 with a mean of zero (or close to zero), i.e. $E(\pi_2|y_2) = 0$[5]. 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, and reordering the expression, we obtain

$$l - g_1 = \alpha_0 + \alpha_1 d + \beta g_2 + v \tag{3}$$

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.

To estimate the parameters of (3) consistently, we have to take into account two main problems. 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 variable 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. The fact that prices are unobserved is a common problem in productivity measurement, but the difficulty is especially relevant in the current context because we are attempting to isolate the productivity effects of new products from those of old products.

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 induces 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

[5] New product real sales will depend negatively on the new product price according to the price elasticity of the idyosincratic firm demand for the new product, and positively on the price of the old product (substitutes case) according to the cross elasticity of the idyosincratic old product demand. Equilibrium price level relationships are likely to vary widely across firms even for similar y_2 values.

in efficiency. In addition, firms endowed with some market power, confronted with different competitive environments, might pass on this cost decrease by different amounts. As an example 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 depend on innovation efficiency gains, ceteris paribus, as $c = \alpha_1 d$. Hence $\pi_1 = \pi_0 + \gamma\alpha_1 d$, and we will only be able to estimate an effect $(1-\gamma)\alpha_1$. That is, we only identify the net effect of productivity changes on employment once the compensating price effect has been accounted for.

In our econometric estimates we use a system of price indices $\widetilde{\pi}_1$computed at a detailed industry disaggregation for manufacturing as a proxy for π_1. Thus we use $l - (g_1 - \widetilde{\pi}_1)$ as 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 gross real productivity effect, but a problem of identification 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, with price variation only partially controlled for, then the identification problem is only partially addressed.

A final problem to take into consideration is the possible simultaneous determination of innovation. Our model is formulated in differences and hence robust, in principle, to the presence of idyosincratic unobserved firm effects correlated with the levels of the innovation variables. But both the dummy for process innovation d and the sales growth due to new products g_2 might be correlated with unobserved productivity shocks embodied in u. If innovation is assumed to depend positively on these shocks, we should expect a negative bias on the coefficient of process innovation (a too strong employment effect of process innovation) and on the coefficient of sales growth due to new products (a too small employment effect of new sales growth).

4. Innovation and employment across four countries.

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. 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 less than 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. For example, while the Spanish and UK samples present proportions of innovators close to the estimated population proportions (+3.5 and 2 percentage points), the German sample slightly underestimates the population proportion (-4.5 percentage points) and the French sample seem to be over-representing innovators (+12%)[6]. 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. However, apart from in Spain, productivity growth (computed as sales growth minus employment growth) tends to be higher only for firms that only introduce process innovations. This result that product innovators in manufacturing do not generally experience relatively faster productivity growth corresponds closely with the econometric results below. Overall, 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, corresponding to an expansionary phase of the industrial cycle. 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, new product sales are very important: sales of

[6] To check the country population proportions see Abramovsky, Jaumandreu, Kremp and Peters (2004).

new or significantly improved products introduced during the three years 1998-2000 amount to more than one third of the old products sales at the beginning of the period 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. It is convenient to summarize this fact in an elasticity of substitution (of new sales for old sales) computed as the ratio of % of new product sales to the (absolute value of the) % of old product sales reduction. This elasticity is 2.35 for France, 2.03 for Germany, 2.88 for Spain and 1.65 for the United Kingdom. This simply means that for product innovators, on average, a one percent reduction in sales of old products is replaced by a minimum sales increase due to new products of over one and half percent (UK) and a maximum sales increase of nearly 3 percent (Spain). This suggests an important role for product innovations in the compensation effects apparent in the data.

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 about one third for Germany and Spain but only one quarter for the UK. On average products that are new to the market account for about 10% of the increase in sales over the period, before allowing for any cannibalisation effects.

Table 3 reports the same information for firms in the Service sector[7]. The proportion of innovators is lower in all countries, but relatively high in Germany and particularly low in the United Kingdom and Spain. In all countries employment growth is higher for product innovators, but quite similar for non-innovators and firms that only introduce process innovations. This suggests that demand increases due to new products are particularly important for employment creation in service sectors.

The growth of sales during the period is very high, but notice that average price increases are here 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 product innovating firms is, however, sometimes higher (France, Spain) and sometimes equal or lower (Germany, UK) than productivity growth of non-innovators. The elasticity of substitution of new products for old products

[7] The particular service industries included differ slightly across countries. In the UK the sample only includes NACE codes 51, 60-67 and 70-74. Other countries?

shows extremely high values: 2.8 for France, 2.6 for Germany, 6.1 for Spain, 3.3 for the United Kingdom. As in manufacturing, 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 higher in Germany and Spain than in the UK.

To check and disentangle these different effects we now take our theoretical framework and econometric model to the data.

5. Econometric results.

Tables 4 to 6 present econometric results from estimating the employment equation (3) for firms in manufacturing. Panel A of Table 4 shows the results of regressing by OLS the dependent variable (total employment growth minus the growth of sales due to the unchanged products) on a constant, a process innovation dummy and the growth of sales due to the new products. 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 constitutes therefore an estimate (with negative sign) of average real productivity growth (over a two year period) in production of the old products for firms that do not introduce process innovations, after any compensating price effects. The process innovation dummy should pick up any additional productivity growth in production of the old products (again with negative sign) resulting from the introduction of process innovations.

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 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. Auxiliary OLS regressions (not reported) on a subset of firms that do not introduce any products that are new to the market (this is true for most firms) show that the estimate of β tends to increase when market novelties are excluded. Since market novelties are likely to have higher quality and may be associated with market power, this is consistent with a downwards bias in the coefficient due to unobserved π_2, the relative price of new products compared to old products.[8] The fact that the process innovation dummy is insignificant in Germany and the UK, and significantly positive in Spain (indicating lower productivity growth) may also suggest that the estimated coefficients are inconsistent.[9]

5.1 Instrumental variables results.—

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 new products but not to any change in the price of new products compared to old products. However, 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 (*Improved 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.[10] Other related questions ask about the impact of innovation on market share or product quality, so the *improved 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. While innovation activity itself is clearly not exogenous with respect to employment growth, it seems plausible that the *effects* of innovation on the range of products produced could be. The variable is positively and significantly correlated with the endogenous variable[11], but there remain concerns about the true exogeneity of the instrument. We attempt to investigate this later by testing the validity of overidentifying restrictions in an overidentified specification.

The IV estimates of β in Panel B are higher than the OLS estimates, consistent with a downwards bias due to unobserved price changes. None of the IV estimates is significantly

[8] Although these results are also consistent with the efficiency of production of market novelties being very high compared to that of production of non-market-novelties.

[9] It is also possible that some upwards bias on the process innovation dummy could be a result of process innovation in response to low productivity growth.

[10] 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.

[11] In the UK the R-squared in the first stage reduced form regression is 0.28 and the coefficient on improved range is equal to 14.5 with a t-statistic of 16.0. In Germany the equilavent numbers are 0.20, 10.5 and 15.8 respectively.

different from one, so there is no evidence that new products are produced with higher efficiency than old products. These estimates give an estimate of average productivity growth in production of the old products between about 5% in Spain and the UK and just over 7% in Germany (about 2.5% and 3.5% per year respectively). The coefficient on the process innovation dummy is negative in Germany, suggesting additional productivity increases, but insignificant in Spain and the UK.

The dummy for process innovation does not distinguish between process innovations applied to the old or the new product, but the theory suggests that the dummy should correspond to changes in the efficiency of production only of the old product. For this reason Table 5 further explores process innovation effects employing the same IV framework. Panel A splits the process innovation dummy in two: firms with process innovation only and firms which introduce both process and product innovations. Firms that only introduce process innovations must by definition be changing the production process of the old product, while product innovations may often be associated with process innovations in the production of the new product.[12] The results in Panel A suggest this distinction is indeed important. The coefficient on the dummy for *process innovation only* is significantly negative for Germany and the UK, suggesting productivity improvements in the production of the old product. The coefficient is not significant for Spain. The coefficient on the dummy for *process and product innovation* is insignificant for Germany and Spain, but positive and significant for the UK. At the same time the coefficient on *sales growth due to new products* for the UK is reduced from 0.95 to 0.85. This suggest that the *process and product innovation* dummy in the UK may be picking up some of the demand increasing effects of product innovation, resulting in a lower coefficient on *sales growth due to new products*.

Panel B keeps only the *process innovation only* dummy and the resulting estimates are very similar except, as expected, for the UK where the coefficient on *sales growth due to new products* returns to its previous level. This is our preferred specification: the *process innovation only* dummy captures the average effect of process innovations relating to the old products, while *sales growth due to new products* captures the average employment (and thus productivity) effects of new products. For Germany and the UK, firms that introduce

[12] For a given product innovation the data do not allow us to distinguish, unfortunately, between "simultaneous" and "associated" process innovations.

process innovations almost double the average increase in productivity in production of old products, while new products are on average produced with about the same productivity as old products. However, the coefficient on *process innovation only* remains positive and insignificant for Spain. There are several potential explanations for this. Recall that we only identify the net effect of process innovations after firms have passed on part of any resulting productivity improvements in lower prices. Average prices were rising faster over the period in Spain than in the other countries, so it is possible that firms were more likely to reduce prices as a result of productivity improvements. In addition, it is possible that firms introduced process innovations in response to poor productivity growth, resulting in reverse causation from productivity to process innovation. It is not clear why this should be more important in Spain than the other countries, however.

5.2 Robustness.—

Table 6 presents IV estimates carried out using more instruments as a robustness check. Panel A uses a common set of instruments across countries while panel B presents estimates where instruments change sightly across countries. We use as instruments other "effects of innovation" variables, as reported by firms: the degree of impact of innovation on improved quality of the goods (*Improved quality*), the degree of impact on increased market share (*Increased market share*). We also add a typical innovation "input" measure, the firm's innovation expenditure over sales (*Innovation effort*).

Not all instruments are accepted universally as valid. A robust test for overidentifying restrictions is used to examine the validity of the additional instruments. Panel B reports estimates performed with subsets of instruments whose validity is accepted. The quality variable can be accepted in all countries, according to the tests, as an additional instrument. But innovation effort is rejected as instrument by the German data and the market share variable by the Spanish data. Apart from the validity of the instruments, the most important point is that the estimated coefficients are very robust to different instrument sets.

The estimates were subjected to a series of further robustness checks (not reported). Robustness to industry heterogeneity was checked by including in the specification a set of 11 industry dummies. We also included various measures of physical investment in an attempt to control for any productivity effects resulting from variations in capital intensity. There were some indications that investment accounted for some of the productivity increases, but the coefficients were generally not significant, and the other coefficients were not affected.

Finally, a series of robustness checks are possible with some country-specific data. It is possible that the observed employment change is measuring only a fraction of the total effect of innovation, and dynamic effects may be important. To test for this possibility, we included in the regression the expected change in employment for the two years to come using Spanish data (as reported by the firm, *Expected employment growth*). Results show that only a tiny fraction of the change tends to be postponed. A different role for different process innovation strategies was tested with German data. The variable *rationalisation innovation,* which characterises the introduction of process innovations to reduce costs, picks up most of the German process innovation manufacturing productivity effects.

5.3 Service sector results.—

Tables 7 to 9 reproduce the same results for firms in the service sector. Several factors suggest that the results should be treated with more care than the manufacturing results. First we use only a single price deflator for all services activities in Spain. In addition the composition of the sample is more heterogeneous across countries, and the proportion of innovating firms is lower. Neverthless, the results throw up some interesting differences.

First, the average productivity change is not as large as in manufacturing. In fact, only the UK shows a consistent average increase in efficiency independent of innovation, although IV estimates (see Table 7, Panel B) also exhibit a weaker effect for Germany. Secondly, only in Spain do process innovations have a significant effect on productivity growth in production of the old product (see Table 7, panel B). However, even the Spanish result disappears when we include only the *process innovation only* dummy in Table 8, Panel B.

Thirdly, the coefficients on *sales growth due to new products* seem to point to more significant productivity increases linked to the development of the new products than in manufacturing, although this is only consistently true for Germany, and is never the case in the UK. Interestingly the coefficient on the *process and product innovation* dummy in Panel A of Table 8 is negative and significant in the UK. This could suggest that new products are associated with productivity increases but only if also accompanied by process innovations.

6. An employment growth decomposition.

Using the results of estimation, we can decompose employment growth for each firm in the following way

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

For a given firm, we can interpret these components as a "general efficiency increase effect," a "process innovation net contribution," a "general output growth contribution" (only non-zero for non product innovators), a "product innovation net contribution" (taking into account any substitution of new products for old products), and a random effect resulting from other unobserved variables. An average value for this decomposition can be computed using average variable values. Table 10 reports the application of this decomposition to the whole samples of manufacturing and services firms, using the the averages from Table 2 and Table 3, and the regression results from Table 5 Panel B and Table 8 Panel B.

Table 10 shows that in Manufacturing general efficiency increases in existing products, for example due to incremental technical improvements or spillovers, are an important source of reductions in employment requirements for a given output. Roughly 2.3-3.5% of employment may be expected to be reduced in this way each year. However, output increases in existing products over the period more than compensate the efficiency effect in all countries except Germany. We should note that the years 1998-2000 represent an expansionary phase of the cycle. Output effects may not be so large at other stages of the cycle.

Process innovation accounts for only a small employment change in all countries, generally resulting in a small displacement effect. This is partly because we are measuring process innovation effects in net terms, but also because the number of firms that introduce only process innovations is small. Employment reductions resulting from process innovations can be important for individual firms, but they amount to only a small fraction of overall employment changes. Product innovations have, in contrast, an important role in boosting employment. The decomposition shows that the effect of new products sales, even net of the substitution for old product sales, is sizeable in all countries. It implies an employment increase of about a 3.7% a year in Germany and Spain, and 1.8% in UK.

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

The results for service sector firms are somewhat different. Total employment growth is almost double that in manufacturing during the period. In Spain and the UK the main source of employment growth is growth in production of old products, with a small counterbalancing effect of general productivity increases only in the UK. Product innovation accounts for a smaller, but still non-negligible, proportion of total employment growth than in manufacturing. 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.

Using a simple model of employment and innovation applied to comparable data across four European countries, these results are illuminating about the role of innovation in stimulating employment growth. In manufacturing, 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 from process innovation, and some indications of employment displacement associated with product innovation. Nevertheless, growth in sales of new products accounts for a non-negligible proportion of employment growth in services.

Overall the results are similar across countries, although some interesting differences emerge which might merit further investigation. For example, there appears to be no identifiable effect of process innovation in Spanish manufacturing, possibly due to greater pass-through of productivity improvements in prices. Also, product innovation appears to be associated with employment displacement in the German and possibly the Spanish service sectors, but not in the UK.

Data Appendix

The CIS3 survey was conducted in Spain by the Instituto Nacional de Estadística (INE) under the name "Encuesta sobre Innovación Tecnológica en las Empresas 2000" (see INE (2002)). The survey collected data on 11,778 firms, 6094 of which are in Manufacturing (NACE 15-37), 4778 in Services (NACE from 50 to 95), and the rest in Mining and quarrying (NACE 10-14), Electricity, gas and water supply (NACE 40-41) and Building (NACE 45). The population target was firms with 10 or more employees. From the Manufacturing (Services) sample we do not include in the exercise 637 (636) firms established during the period or affected by mergers or scissions, and we drop 855 (753) firms for which we cannot compute employment or turnover growth because of partially incomplete data. We also drop a total of 54 (107) firms for which employment or sales growth turns out to be higher than 300%. This leaves us with the basic number of 4,548 (3,282) firms.

The CIS3 survey was conducted in the UK by the Department for Trade and Industry. The survey collected data on 8172 firms, 3440 of which are in Manufacturing (NACE 15-37), 3605 in Services (NACE from 50 to 74), and the rest in Mining and quarrying (NACE 10-14), Electricity, gas and water supply (NACE 40-41) and Building (NACE 45). From the Manufacturing (Services) sample we do not include in the exercise 548 (720) firms established during the period or affected by mergers or scissions, and we drop 339 (496) firms for which we cannot compute employment or turnover growth because of partially incomplete data. We also drop a total of 41 (63) firms for which employment or sales growth turns out to be higher than 300%. This leaves us with the basic number of 2493 (2325) firms.

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: Dummy variable which takes the value 0 if the firm reports that an 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: Dummy variable which takes the value 0 if the firm reports that an 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 eleven dummies grouping industries in the following way

NACE	Industry name
34-35	Vehicles
23-24	Chemicals
29	Machinery
30-33	Electrical
15-16	Food
17-19	Textile
20-22	Wood
25	Plastic rubber
26	Non-metallic
27-28	Basic metal
36-37	NEC

Sectors Vehicles to Electrical correspond to the High and Medium-high technology intensive sectors of the OECD, sectors Food to Basic metal to the Medium-high and Low.

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

Improved quality: Dummy variable which takes the value 0 if the firm reports that an 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 growth: Rate of change in the firm investment for the whole period (computed as $2(x_t - x_{t-1})/(x_t + x_{t-1})$ to avoid the effect of zeroes for non-investment in the base year).

Market novelties share: Fraction of the turnover due to new or significantly improved products introduced during the period corresponding to new products for the enterprise market.

Marketing expenditures: Fraction of innovative expenditures accounted for by the expenditures on market introduction of the new products.

Prices growth: 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; Germany:

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 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.

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, calling s to the fraction, we have $\frac{S_2}{S_1+\Delta S_1+S_2} = s$ and hence $\frac{S_2}{S_1} = (1 + \frac{\Delta S_1+S_2}{S_1})s$).

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

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Table 1. Employment 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
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]	[12.0]	[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[4,5] (%)				
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 afected 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.

[5]The symbol "–" means non-available data.

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

	France	Germany	Spain	UK
N^o of firms	1653	849	3282	2325
Non-innovators (%)	60.2	51.4	74.7	73.9
Process only (%)	8.5	9.3	8.4	7.7
Product innovators[3] (%)	31.3	39.3	16.9	18.4
Employment growth (%)				
All firms	15.5	10.2	23.3	15.5
Non-innovators	14.2	5.9	22.4	13.4
Process only	9.9	6.1	21.6	15.9
Product innovators[3]	19.4	16.9	28.1	23.8
Sales growth (%)				
All firms	18.4	18.5	30.5	22.5
Non-innovators	16.3	14.4	29.0	21.0
Process only	16.1	11.2	30.5	20.9
Product innovators[3]	23.1	25.6	37.2	28.9
Unchanged products	−3.2	−15.9	−7.3	−12.4
New products	26.3	41.5	44.5	41.3
[Of which, new to the market]	[9.8]	[16.4]	[17.2]	[10.2]
Productivity growth (%)				
All firms	2.9	8.3	7.2	7.0
Non-innovators	2.1	8.5	6.6	7.6
Process only	6.2	5.1	8.9	5.0
Product innovators[3]	3.7	8.7	9.1	5.1
Prices growth[4,5] (%)				
Non-innovators	1.8	5.0	7.3	4.0
Process only	1.8	4.7	7.3	3.5
Product innovators[3]	1.8	3.0	7.3	4.2

[1]Rates of growth for the whole period 1998-2000.
[2]Population are firms with 10 or more employees. Entrant firms and firms afected 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.
[5]The symbol "−" means non-available data.

Table 4. Manufacturing firms
The effects of innovation on employment: Basic OLS and IV specifications[1]

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

Regression (Method)	A (OLS)				B (IV[2])			
	France	Germany	Spain	UK	France	Germany	Spain	UK
Explanatory variables								
Constant	−0.96(0.55)	−5.42(1.09)	−4.14(0.68)	−4.14(0.71)	−1.59(0.63)	−7.27(1.15)	−5.29(0.76)	−5.23(0.76)
Process innovation	2.89(0.92)	−1.34(1.68)	3.41(1.19)	2.79(1.63)	1.59(1.07)	−3.70(2.02)	0.68(1.40)	0.41(1.54)
Process innovation only								
Process & product innov.								
Sales growth due to new products	0.72(0.05)	0.88(0.06)	0.84(0.03)	0.78(0.06)	0.86(0.07)	1.04(0.07)	1.00(0.05)	0.95(0.05)
N^o of firms	4631	1319	4548	2493	4631	1319	4548	2493
Standard error	28.3	27.3	36.0	30.6	28.3	27.8	36.3	30.9
Test of overidentifying restrictions								
(degrees of freedom)					(0)	(0)	(0)	(0)

[1]Coefficients and standard errors robust to heteroskedasticity.

[2]Unique instrument used is Improved range.

Table 5. Manufacturing firms
The effects of innovation on employment: Specifying process innovation effects[1]

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

Regression (Method)	A (IV[2])				B (IV[2])			
	France	Germany	Spain	UK	France	Germany	Spain	UK
Explanatory variables								
Constant	−1.39(0.67	−7.04(1.24)	−5.48(0.84)	−4.59(0.80)	−1.37(0.67)	−7.06(1.25)	−5.47(0.83)	−4.58(0.80)
Process innovation								
Process innovation only	−1.50(1.57)	−6.30(3.00)	2.38(1.78)	−3.90(1.86)	−1.53(1.57)	−6.28(3.00)	2.36(1.77)	−3.92(1.87)
Process & product innov.	3.02(1.41)	−2.34(2.76)	−1.10(2.58)	6.24(2.50)				
Sales growth due to new products	0.81(0.08)	1.02(0.08)	1.03(0.07)	0.85(0.07)	0.91(0.05)	0.98(0.06)	1.01(0.04)	0.94(0.05)
N^o of firms	4631	1319	4548	2493	4631	1319	4548	2493
Standard error	28.3	27.6	36.4	30.5	28.4	27.5	36.2	30.9
Test of overidentifying restrictions								
(degrees of freedom)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

[1]Coefficients and standard errors robust to heteroskedasticity.

[2]Unique instrument used is Improved range.

Table 6. Manufacturing firms
The effects of innovation on employment: Using more instruments[1]

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

Regression (Method)	A (IV[2])				B (IV)			
	France	Germany	Spain	UK	France[3]	Germany[4]	Spain[3]	UK[3]
Explanatory variables								
Constant	−1.38(0.66)	−7.59(1.20)	−4.76(0.78)	−4.58(0.78)	−1.38(0.66)	−6.96(1.15)	−5.09(0.79)	−4.61(0.78)
Process innovation								
Process innovation only	−1.52(1.57)	−5.75(2.99)	1.66(1.75)	−3.91(1.86)	−1.51(1.57)	−6.38(2.92)	1.98(1.75)	−3.89(1.86)
Process & product innov.								
Sales growth due to new products	0.91(0.05)	1.01(0.06)	0.96(0.03)	0.94(0.05)	0.91(0.05)	0.98(0.05)	0.98(0.03)	0.94(0.05)
N° of firms	4631	1319	4548	2493	4631	1319	4548	2493
Standard error	28.4	27.6	36.2	30.9	28.4	27.5	36.2	30.9
Test of overidentifying restrictions	2.7	17.6	8.09	0.69	2.6	1.03	2.15	0.44
(degrees of freedom)	(3)	(3)	(3)	(3)	(2)	(2)	(2)	(2)

[1]Coefficients and standard errors robust to heteroskedasticity.
[2]Instruments are Improved range, Improved quality, Increased market share and Innovation effort
[3]Instruments are Improved range, Improved quality and Innovation effort for France, Spain and the UK.
[4]Instruments are Improved range, Improved quality and Continuous R&D engagement for Germany.

Table 7. Services firms
The effects of innovation on employment: Basic OLS and IV specifications[1]

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

Regression (Method)	A (OLS)				B (IV[2])			
	France	Germany	Spain	UK	France	Germany	Spain	UK
Explanatory variables								
Constant	0.24(1.31)	−1.40(1.52)	1.39(0.80)	−2.42(0.87)	−1.40(1.43)	−2.82(1.65)	1.04(0.83)	−2.96(0.88)
Process innovation	−1.76(2.48)	4.78(2.39)	−2.22(1.96)	−0.50(2.10)	−5.51(3.12)	1.50(2.70)	−4.20(2.25)	−2.72(2.32)
Process innovation only								
Process & product innov.								
Sales growth due to new products	0.89(0.07)	0.75(0.05)	0.87(0.05)	0.94(0.05)	1.20(0.15)	0.90(0.08)	0.97(0.07)	1.05(0.06)
N^o of firms	1653	849	3282	2325	1653	849	3282	2325
Standard error	45.1	34.0	41.3	37.8	45.6	34.4	41.4	37.9
Test of overidentifying restrictions								
(degrees of freedom)					(0)	(0)	(0)	(0)

[1]Coefficients and standard errors robust to heteroskedasticity.

[2]Unique instrument used is Improved range.

Table 8. Services firms
The effects of innovation on employment: Specifying process innovation effects[1]

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

Regression (Method)	A (IV[2])				B (IV[2])			
	France	Germany	Spain	UK	France	Germany	Spain	UK
Explanatory variables								
Constant	−1.54(1.49)	−2.88(1.71)	0.94(0.87)	−3.32(0.90)	−1.46(1.48)	−2.85(1.72)	0.92(0.87)	−3.39(0.90)
Process innovation								
Process innovation only	−2.87(3.47)	2.54(3.04)	−2.61(2.65)	1.84(2.67)	−2.95(3.46)	2.51(3.06)	−2.59(2.65)	1.91(2.67)
Process & product innov.	−7.29(4.79)	0.87(4.03)	−6.80(5.07)	−10.31(4.40)				
Sales growth due to new products	1.24(0.17)	0.90(0.09)	1.00(0.10)	1.13(0.08)	1.08(0.11)	0.91(0.07)	0.92(0.06)	1.04(0.06)
N^o of firms	1653	849	3282	2325	1653	849	3282	2325
Standard error	45.7	34.4	41.4	38.0	45.3	34.4	41.3	37.8
Test of overidentifying restrictions								
(degrees of freedom)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

[1]Coefficients and standard errors robust to heteroskedasticity.
[2]Unique instrument used is Improved range.

Table 9. Services firms
The effects of innovation on employment: Using more instruments[1]

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

Regression (Method)	A (IV[2])				B (IV)			
	France	Germany	Spain	UK	France[3]	Germany[4]	Spain[5]	UK[3]
Explanatory variables								
Constant	−0.92(1.43)	−3.67(1.63)	0.87(0.86)	−3.32(0.90)	−0.64(1.44)	−2.94(1.66)	0.74(0.86)	−3.33(0.90)
Process innovation								
Process innovation only	−3.49(3.45)	3.33(2.97)	−2.54(2.63)	1.84(2.67)	−3.77(3.46)	2.60(2.98)	−2.41(2.63)	1.84(2.67)
Process & product innov.								
Sales growth due to new products	1.02(0.10)	0.96(0.06)	0.92(0.05)	1.03(0.05)	0.98(0.10)	0.92(0.06)	0.94(0.06)	1.03(0.05)
N° of firms	1653	849	3282	2325	1653	849	3282	2325
Standard error	45.2	34.7	41.3	37.8	45.1	34.5	41.4	37.8
Test of overidentifying restrictions	12.6	6.57	6.16	15.67	4.9	1.29	2.05	2.67
(degrees of freedom)	(3)	(3)	(3)	(3)	(2)	(2)	(1)	(2)

[1]Coefficients and standard errors robust to heteroskedasticity.

[2]Instruments are Improved range, Improved quality, Increased market share and Innovation effort

[3]Instruments are Improved range, Improved quality and increased market share for France and the UK.

[4]Instruments are Improved range, Improved quality and Continuos R&D engagement for Germany.

[5]Instruments are Improved range and Improved quality for Spain.

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

	France	Germany	Spain	U K
Manufacturing[3] (Average values)				
Employment growth	8.3	5.9	14.2	6.7
General efficiency effect	-1.4	-7.1	-5.5	-4.6
Process innovation net contribution	-0.1	-0.6	0.3	-0.4
General output contribution	4.8	6.0	12.2	8.3
Product innovation net contribution	5.0	7.5	7.3	3.5
Services[3] (Average values)				
Employment growth	15.5	10.2	23.3	15.5
General efficiency effect	-1.5	-2.9	0.9	-3.4
Process innovation net contribution	-0.3	0.2	-0.2	0.2
General output contribution	9.9	5.4	18.2	13.9
Product innovation net contribution	7.3	7.4	4.5	4.9

[1]Descomposition is based on Table 5 (B) and Table 8 (B).
[2]Rates of growth for the whole period.
[3]The sum of decomposition values may differ slightly from employment growth because of rounding.