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# Industrial Innovation, Labour Productivity, Sales and Employment

Geert Woltjer, Michiel van Galen and Katja Logatcheva

Wageningen Economic Research, The Hague, The Netherlands

**ABSTRACT**

This article examines the relationship between firm-level innovation and employment growth for industrial firms in the Netherlands. The empirical analysis uses four waves of the CIS survey for the period 2002-2010. It extends the literature by making an explicit split between the expansion effect of innovation and the labour productivity effect. The results show that both product and process innovation increase labour productivity and therefore induce direct reductions in employment. However, these negative employment effects are more than compensated by increases in sales, implying that both process and product innovations increase employment. In this article for the first time the relationship between both product and process innovations and employment is decomposed in a systematic manner based on explicit econometric equations on the relationship between innovation and labour productivity respectively sales. It is argued that the effects for sales and labour productivity are probably underestimated in all research that uses CIS survey data because these do not show the price effects of increased productivity, but that this effect cancels out in the estimated employment equation.

**KEYWORDS**

Employment; innovation; labour productivity; community innovation survey; industry; Netherlands

**JEL CLASSIFICATION**

O31; D22; J24

## 1. Introduction

Whether technological change increases or reduces employment is an important question from a policy perspective. Different assumptions on the relationship between innovation and employment may significantly alter the results of policy analyses. The analysis of this relation requires investigations on both micro and macro level (Calvino and Virgillito 2018). In this paper we focus on the micro level. An extensive literature exists on this relationship, but most of it assesses simple correlations or estimate reduced form equations (Harrison et al. 2014). It is exceptional that an explicit difference is made between the productivity and sales effect of innovations as well as between product and process innovation (Harrison et al. 2014), and we do not know of any research that estimates all equations econometrically.

**CONTACT** Geert Woltjer Geert.woltjer@wur.nl

One of the few studies that differentiates explicitly between effects on sales and productivity with a theoretical production function based approach is Harrison et al. (2014), while Dachs et al. (2017), Dachs and Peters (2014), Hall, Lotti, and Mairesse (2008) and Peters (2008) use the same approach. Harrison et al. (2014) use individual company CIS data to estimate an equation that explains employment by sales, product innovation and process innovation. Using this equation and differences of average sales between *innovators* and *non-innovators* they also derive conclusions for the effects of innovation on employment through expansion of sales.

We extend the analysis in the literature described above. First, we argue that the econometrically estimated employment equation is basically a labour productivity equation that therefore should be interpreted in the context of the more extensive literature on innovation and labour productivity (Baum et al. 2016; Baumann and Kritikos 2016; Carvalho and Macedo de Avellar 2017; Colombelli, Haned, and Le Bas 2013; Criscuolo 2009; Hall and Sena 2017; Hall 2011; Mohnen and Hall 2013; Raymond et al. 2015). Second, we argue that the use of statistical averages to explain sales in Harrison et al. (2014) is unsatisfactory, and therefore we estimate an explicit sales equation that combined with the labour productivity equation can be written in its reduced form as an employment equation. In order to see the difference in results of using econometric estimates and comparison of averages, we use both methods for both labour productivity and sales.

The paper is organised as follows. After a short review of relevant literature in Section 2, we describe in Section 3 the data and compare our data sample with national statistics. Our analysis starts in Section 4 with the use of unweighted firm-level averages per type of company to analyse the relation between innovation on the one hand and sales and labour productivity on the other hand. This illuminates the difference in results between econometric analysis compared with using averages as used by Harrison et al. (2014) as the only method to explain sales and econometric analysis that is used by Harrison et al. (2014) to explain changes in employment conditional on sales. In Section 5 we explain our model and estimation approach. Section 6 discusses the results for the estimated equations on labour productivity, sales, and employment. Conclusions are presented in Section 7.

## 2. Literature review

The role of innovation in stimulating employment growth as well as potential negative effects on employment have been the subject of many studies. They are important to understand the processes that drive the success of individual firms, industries and national economies. Most of the literature on the effect of innovation on firm performance can be traced back to Schumpeter (1934 [1911]) who introduced the idea of creative destruction as well as the role of entrepreneurial activities as source of innovation and later (Schumpeter 1942) also the role of large firms with capital to invest in R&D. From Schumpeter, so-called Schumpeterian or evolutionary growth theories have evolved. In contrast, the original neo-classical Solow-Swan model of economic growth treats technological change as exogenous (see e.g.Verspagen 1992).

Schumpeter Mark I industries are characterised as dynamic with low entry barriers. Start-ups and fast-growing smaller firms are common in these industries. Schumpeter

Mark II industries are more stable and innovation is commonly the domain of larger firms (Fontana et al. 2012; Malerba 2009). Both hypotheses have been tested and found true for different industries, largely depending on the technological regime of the industry (Malerba and Orsenigo 1996).

Schumpeterian growth theory has operationalised Schumpeter's idea of creative destruction and focusses on the role of market structure, firm size, competition, and firm dynamics in the relationship between innovation and growth (Aghion, Akcigit, and Howitt 2015; Aghion and Howitt 1992). The size of the firm has been a major point of attention in this type of models. Despite the Schumpeterian conclusion that larger firms are generating a major part of growth because they can muster the resources necessary to innovate, Cohen and Klepper (1996) list a number of studies that show that although larger firms are more often involved in R&D and spend more on R&D, they are not generating disproportionate amounts of R&D and actually produce less innovations per dollar spend on R&D (Hashi and Stojcic 2013). Fassio (2015) shows that the R&D intensity can actually be inversely related to firm size in a comparative study of German, Spanish and Italian firms, and he explains that 'firms in national sectors that are close to the technological frontier will rely more on R&D-based innovative strategies, with respect to firms in countries far from the frontier'. Acemoglu et al. (2018) study the role of entry and exit in innovation and economic growth. Aghion, Akcigit, and Howitt (2015) note that existing firms' innovation strategies are more focussed on improving current technologies, while new entrants produce more radical innovations (e.g. Freeman and Soete 1997; Scherer 1986). In a recent study by Barbieri et al. (2019) the role of public funding in the innovation decision and more specifically the type of innovation strategy followed has been investigated for the Italian manufacturing sector. Using Community Innovation Survey (CIS) data and accounting information, they distinguish between inhouse innovation strategies (make), outsourced innovative activities (buy) and mixed strategies that combine both. Such mixed strategies are associated with enhanced innovation success. They show that public funding influences both the decision to innovate and the strategy how to innovate. Firms receiving public funding more often have a mixed innovation strategy. The rationale for public funding to stimulate private innovation activities is that market failures exist in the form of spill-overs from research and innovation, information problems, and uncertainty causing capital market imperfections, which lower R&D and innovation efforts (Aghion and Howitt 1992; Perez-Sebastian 2015). Stiebale and Wö$\beta$ner (2019) find that innovative firms are more often targets for mergers and acquisitions, which may be a way for capital constrained smaller firms to overcome market imperfections and exploit investment opportunities.

Cohen and Klepper (1996) show that cost-spreading can explain why large firms spend more on R&D than smaller firms, even if their R&D productivity is lower. Larger firms have a larger output basis over which the (fixed) costs and (variable) benefits of innovation can be divided. Two conditions are postulated to impact this relationship: the extent to which innovations can be sold in disembodied form, and the expectations of the firm to grow rapidly after the innovation. In industries that exhibit a higher degree of licencing of innovations or a higher degree of extraordinary firm growth, the relationship between firm size and innovation input was found to be less pronounced or even absent. Schmookler (1966) also found that the anticipated size of the market for a product will affect the amount of R&D expenditure, and this was confirmed by Hashi and Stojcic (2013).

The relationship between firm size and innovation activities or R&D tends not to be a linear one. Often U-shaped relationships are found, with smaller firms and very large firms being more innovative. Kleinknecht (2000) and Kleinknecht and Mohnen (2002) demonstrate that the propensity to innovate is positively but not linearly related to firm size, and that smaller innovating firms have higher shares in sales of new products.

Klette and Griliches (2000) explain firm growth as a function of the price and quality of its products vis-a-vis its competitors. Innovation can improve the quality of products, and R&D spending is largely determined by the firm's profit instead of its size. The demand for high quality products and the availability of innovative opportunities are also affecting R&D in their model. Industry specific characteristics may include the degree of competition and the existence of entry-barriers (Acs and Audretsch 1987; Aghion, Akcigit, and Howitt 2015), and the share of low-skilled and high-skilled labour (Hall and Kramakz 1998).

The above mentioned literature shows that firm size, and other firm and industry characteristics may influence the amount of innovation effort and innovation output at the firm level. However, our focus is on the relationship between innovation output and employment. This relationship may be split in two parts, i.e. a relation between innovation and labour productivity growth and a relation between innovation and sales growth, where the difference between the two explains the relation between innovation and employment. The growth in employment equals by definition the difference in growth of sales and labour productivity. However, the literature on innovation and employment is to a large extent separate from the literature on innovation and labour productivity respectively innovation and sales. The three relatively separate brands of literature are briefly discussed below.

### 2.1. Effects on labour productivity

Innovation affects labour productivity in several ways. Product innovations create new demand and higher value for consumers or create scale efficiencies, whereas process innovations are expected to increase efficiency of production. (Crepon, Duguet, and Mairessec 1998; Van Leeuwen and Klomp 2006; Roper, Du, and Love 2008; Mairesse and Jaumandreu 2005; Spiezia and Vivarelli 2002; Freeman and Soete 1987). Differences between high-tech and low-tech industries (Frick, Jantke, and Sauer 2019), and differences between fast-growing, stable, and declining firms, and the age of the firm (Coad, Segarra, and Teruel 2016) have been studied.

In 1998, Crépon, Duguet & Mairesse (CDM) published a paper that incorporates many aspects of the earlier models and distinguishes the various stages of the innovation process. The multi-stage approach models the firm's decision to innovate (the selection equation), the innovation investment equation, the innovation output equation, and the effects on firm performance: the productivity equation (Crepon, Duguet, and Mairessec 1998; Hashi and Stojcic 2013; Lööf and Heshmati 2003; Lööf and Heshmati 2006). The CDM model has been applied to at least 40 countries in dozens of studies (Lööf, Mairesse, and Mohnen 2017). Our focus is on the relation between innovation output and firm performance, i.e. the productivity equation.

For product innovation, CDM studies typically find a positive relationship between product innovation (measured as sales of new products and services per employee, or as a dummy variable for product innovation) and firm productivity (measured as log of sales, turnover, or value added per employee). Hall (2011) and its update Mohnen and Hall (2013) report for the majority of studies in their review that product innovations generate significant increases in labour productivity, while in only one study a negative effect on labour productivity is found. However, results are very difficult to compare due to differences in definitions and differences in representativeness of firms in the used data sets (Vokoun 2017). Hall (2011) also points to the fact that using dummy variables for product and process innovation may be a problem if the measure is related to the size of the firms: larger firms generally have a larger probability of being engaged in innovation just because they are larger and have more diversified products, and therefore the dummy may not be a proper indication of innovativeness. Because one may expect that product innovations normally imply also the use of newer technologies, and they are generally meant to increase the overall profitability of the firm, the generally found positive relation between product innovation and labour productivity effect seems plausible.

The findings of Harrison et al. (2014) and (Dachs and Peters 2014) are, however, not consistent with the results from the reviews by Hall (2011) and Mohnen and Hall (2013). Although Harrison et al. (2014) describe their estimated equation as an employment growth equation, sales growth is exogenous and we show in Section 5.1 that their equation can therefore be rewritten as a labour productivity equation. Their equation of employment growth distinguishes between labour demand from sales of old products and sales of new products between the start and end of the three year period from the CIS survey. Harrison et al. (2014) estimate both OLS and IV equations of process innovations and sales of new products on labour requirement and find that for product innovations the IV estimates find no significant effect of sales from new products on labour productivity; i.e. the new products are found to be produced at the same efficiency as the old products.[1]

With respect to the effect of process innovations the literature reviews by Mohnen and Hall (2013) show that these have significant positive labour productivity effects in many studies, although some studies (Lööf and Heshmati 2006; Van Leeuwen and Klomp 2006) show negative labour productivity effects. Harrison et al. (2014) find for three of the four countries investigated that process innovation increase labour productivity. However, only for Germany the estimated parameter is significant. Because most process innovations are meant to improve efficiency, a positive labour productivity effect is to be expected. Therefore, based on a priori reasoning and the literature we formulate the following hypothesis:

H1. Both product and process innovations will increase labour productivity.

### 2.2. Effects on sales

Because employment growth is the difference between sales growth and labour productivity growth, it is essential to answer the question whether sales grow as a consequence of innovation. It is exceptional that this question is answered in this context: the relation between innovation and employment is in most studies analysed directly, or the sales are not estimated econometrically (Harrison et al. 2014).

Although sales are an indispensable part of labour productivity, the literature on the effects of innovation on firm sales is much less extensive (Audretsch, Coad, and Segarra 2014). Product innovations may bring about additional sales because product innovations are meant to supply better products or even new products, which generate extra demand. At the same time these product innovations may cannibalise on the old products. In order to create a positive effect on employment, the compensation effect of additional sales (and hence employment) of product innovations needs to outweigh the cannibalisation effect (Dachs et al. 2017). The effect may also include a negative externality on other firms, the business stealing effect.

Mansfield (1962) found that firms are not growing or declining at random (as proposed by Gibrat's Law), but noted that innovating firms grow faster than non-innovating firms and that the effect of innovation is larger for smaller firms. He did also find that the effect depends on the industry. This has been a basis for the evolutionary growth theory of Nelson and Winter (1982). In most empirical studies on innovation and firm sales, innovation increase sales (Geroski and Machin 1992; Klomp and Van Leeuwen 2001; Bloom and Van Reenen 2002; Kemp et al. 2003; Colombelli, Haned, and Le Bas 2013; Audretsch, Coad, and Segarra 2014).

Klomp and Van Leeuwen (2001) use the second CIS database for the Netherlands to estimate a simultaneous equations model of the innovation process, but unlike the CDM models they do not use a production function framework and focus on the effect of innovation on sales and employment without considering issues of labour productivity and without integrating the linear relation that should exist been sales and employment in case labour productivity remains the same. Their results show a significant positive effect of sales of innovative products on total turnover growth, but the increase in sales is less than the increase in labour productivity, and therefore the effect of product innovation on employment growth is found to be negative (although just significant at a 10% level).

Kemp et al. (2003) also found a positive relationship between innovation output (measured by the share of sales from new products in total turnover) and the growth of turnover, but in their estimates the effect on employment was also positive. Adamou and Sasidharan (2007) show also positive effects and furthermore show that size and age have a negative effect on the firm's sales growth. Colombelli, Haned, and Le Bas (2013) show that both product and process innovations have positive effects on firm sales. Furthermore, the effects seem more pronounced for firms that have higher employment growth rates, i.e. fast growing and generally smaller firms. This finding has been confirmed in a number of other studies (Coad and Rao 2008; Freel 2000).

Harrison et al. (2014) argue that both product and process innovations should increase sales. Process innovations are meant to increase efficiency and therefore will reduce prices where this price decrease will increase sales. Product innovations are meant to create new markets and therefore will increase sales, where part of the sales of new products will be at the cost of the sales of old products (cannibalisation effect).

Some effects may take more time to materialise than others, and the effects on firm performance are generally found to be temporary only (Hashi and Stojcic 2013). Ernst (2001) shows that sales increase after a lag of two to three years following patent application.

Based on both the theoretical and empirical studies we formulate the following hypotheses on the effects of innovation on firm sales:

H2: both product and process innovations increase sales.

H3: the increase in sales for a product innovator is smaller than the sales of the new product due to the cannibalisation effect.

### 2.3. Effects on employment

Based on the above discussion of the effects on productivity and sales, it is clear that the relationship between innovation and employment is ambiguous.

Process innovations may in first instance directly reduce employment because it normally means that products can be produced with less labour (productivity effect). However, process innovations normally reduce cost price, creating the opportunity to decrease prices which generates extra demand and sales (price effect). If this effect is large enough this will lead to higher employment. Other compensating mechanisms may also increase employment (Vivarelli 2014; Calvino and Virgillito 2018). Therefore, the net effect of process innovation on employment is theoretically undetermined. The total effect of process innovation on firm employment depends on the magnitude of sales and productivity effects, which have opposite signs.

A number of studies is looking at the effects of R&D (intensity) on employment, and results are mixed as well. Positive effects are found by Bogliacino, Piva, and Vivarelli (2012) and Coad, Segarra, and Teruel (2016), while no significant effects of R&D intensity were reported by Capasso, Treibich, and Verspagen (2015) and Stare and Damijan (2015)Stare and Damijan (2015); Capasso, Treibich, and Verspagen (2015). Fast growing firms seem to have a higher effect of R&D on employment growth (Van Roy, Vertesy, and Vivarelli 2015; Coad and Rao 2011; Coad, Segarra, and Teruel 2016).

Product innovations are generally found to increase employment (Benavente and Lauterbach 2008; Crespi and Tacsir 2013; Evangelista and Vezzani 2012; Harrison et al. 2014; Peters et al. 2014), where Klomp and Van Leeuwen (2001) are exceptional in finding a negative effect of innovative sales on employment, which may have to do with the formulation of their system of equations.

The literature on the effect of process innovations on employment is more mixed, because process innovations have a direct employment reducing effect through labour productivity increases that may or may not be compensated by an increase in sales through lower prices (Calvino and Virgillito 2018; Peters et al. 2014). However, it seems plausible that the price elasticity of demand is normally higher than 1 for individual firms implying a positive employment effect. This is in general consistent with the empirical literature. Benavente and Lauterbach (2008) and Crespi and Tacsir (2013) find no significant effects, while Evangelista and Vezzani (2012), Harrison et al. (2014), Lachenmaier and Rottmann (2011), Triguero, Córcoles, and Cuerva (2014) and Zimmermann (2009) find a positive relationship. Triguero, Córcoles, and Cuerva (2014) show that the effect of process innovation is stronger in the years after the process innovation than in the year of process innovation itself. Zimmermann (2009) shows that the positive effect of process innovation is stronger in fast growing SMEs than in slower growing or declining SMEs.

In explaining employment Harrison et al. (2014) and Dachs et al. (2017) differentiate between displacement effects, compensations effects, cannibalisation effects and (at industry level) business stealing effects. They show also that the mechanisms may be different during different parts of the business cycle. However, in their estimation employment growth is replaced by a measure of productivity rather than true employment growth. Calvino and Virgillito (2018) explore the different pass-through mechanisms and summarise them as four neo-classical mechanisms and two Keynesian-Schumpeterian mechanisms: (i) new machines with a negative effect on labour demand in the mechanising industry but a positive effect on the machine producing industries; (ii) decrease in prices as a result of process innovation which has a positive effect on employment for the innovating firms; (iii) decrease in wages which reinforces the decrease in prices and counterbalances the initial decrease in labour demand in the industry; (iv) new investments by the innovating firms that temporary make a profit with a positive effect on output and employment; and (v) increased income through higher wages if innovation leads to higher productivity and wages (of the people still employed in the industry) are responsive. These higher wages can lead to higher demand and counterbalance the initial decrease in labour demand; and finally (vi) new products can stimulate consumption or cannibalise on the old products. Market expansion may increase employment while business stealing might decrease employment in other non-innovative firms. On the latter point we note that markets are generally not separated from foreign markets. The notion that the business stealing effect is neutral at the level of the national industry is not true if one allows for competition with other countries. Moreover, market expansion of one firm or industry may be business stealing from the point of view of another firm or industry.

On the level of firms, we may assume that the price elasticity of demand is more than one as long as the market is more or less competitive, and therefore we expect that also the effect of process innovations on employment is positive. Based on the literature and the logic that the effect of process innovations on employment depends on the size of the effect of sales compared with the effect on labour productivity, we may formulate the following hypotheses:

H4: Product innovations will normally have a positive effect on employment.

H5: Process innovation generates increases in labour productivity that are more than compensated by increases in sales, and therefore also have a positive effect on employment.

## 3. Description of the data and economic context

### *3.1 Data: community innovation survey*

The empirical analysis uses four waves of the Dutch Community Innovation Survey (CIS). The CIS is a more or less harmonised questionnaire performed in European countries and based on the Oslo Manual (OECD/Eurostat 2018). Each questionnaire tackles innovation over three years and asks about turnover and employment for the first and last year. The waves of the questionnaires used in this paper are 2002–2004, 2004–2006, 2006–2008 and 2008–2010. The data were compiled by and accessed through Statistics Netherlands. The model results in our study are based on own calculations of the others, using non-public microdata from Statistics Netherlands.[2]

The key questions on innovation used in this study are (using the 2008–2010 wave as example):

- During the three years 2008 to 2010, did your enterprise introduce new or significantly improved methods of manufacturing or producing goods or services, indicating process innovation?
- During the three years 2008 to 2010, did your enterprise introduce new or significantly improved goods? (exclude the simple resale of new goods and changes of a solely aesthetic nature)
- What is the percentage of your total turnover in 2010 from new or significantly improved products introduced during the three years 2008 to 2010?

The key questions to measure turnover and employment are:

- What was your enterprise's total turnover for 2008 and 2010? Turnover is defined as the market sales of goods and services. (exclude all taxes except VAT)
- What was your enterprise's average number of employees in 2008 and 2010?

The formulations of the questions show that the measure of innovations is based on innovations introduced in a three-year period, while turnover and employment are measured at the start and the end of the three-year period. This implies that only firms that exist over the whole measurement period are included, which makes it impossible to analyse entry and exit of firms.

The focus of the analysis is on the Dutch manufacturing industry as a whole, defined as sectors 10–32 in the SBI 2008 (based on NACE Rev. 2 classification), where firms of the older waves are reclassified according to this classification. The CIS consists of a sample of firms with 10 or more employees. Large firms (250 or more employees) are overrepresented in the Dutch CIS because these companies are obliged to fill in the questionnaire whereas smaller firms participate on a voluntary basis. Consistent with Harrison et al. (2014) we exclude firms with incomplete data or where employment or sales growth is more than 300% or less than -60%. The total number of observations in our sample equals 8210. Data on average annual manufacturer price changes per 2-digit NACE Rev. 2 branch of industry was obtained from Statistics Netherlands.

### *3.2. Economic context: Sales and employment in the Dutch manufacturing industry*

The period of analysis is 2002-2010. During this period the year 2003 was a mild recession year for the manufacturing industry in the Netherlands, as was the year 2008.


**Figure 1.** Percentage change in Dutch industrial employment, production and labour productivity 2002–2010. Source: Statistics Netherlands.

However, 2008 was followed by a deep recession in 2009 and only a partial recovery in 2010. Because the data apply to periods of three years, it is relevant to know the aggregate background of the micro-data. For the period 2002–2004 we see slow growth where the recession is only in the first year. In the periods 2004–2006 and 2006–2008 growth is fast, where we have to be aware that the recession already started in 2008. The period 2008-2010 shows a deep recession, with some recovery in 2010. Figure 1 shows the yearly percentage changes in Dutch industrial employment, production and labour productivity over the years. By definition the percentage change in employment equals the percentage change in production minus the change in labour productivity.

The correlation (based on industry statistics from Statistics Netherlands) of employment and lagged production (t-1 year) is about 0.65, while it is only 0.2 with current production, which is consistent with the hypothesis that production changes drive employment changes and indicates a dynamic relationship. Although we do not have the opportunity to do a full dynamic analysis without losing a large part of the sample, this is something we should have in the back of our minds when analysing results. The correlations do however also indicate that at least a large part of the effect takes place within the three year period of observation.

If we compare the aggregated data from our sample from CIS with the sector data from Statistics Netherlands (CBS), for most periods, the direction of growth is the same for all indicators although some notable differences emerge (Table 1). First, employment growth in the sample is less negative or higher than in the sector statistics. Second, real sales growth is higher in the sample in the first period and the last period, but in the periods in between it is the other way around. In the whole period sales growth is higher in the sample, which is consistent with the employment growth differences. Labour productivity growth in the sample is smaller than in the statistics of Statistics Netherlands except for 2002-2004. Labour productivity growth in the CIS

**Table 1.** Comparison of CIS sample aggregate growth with sector statistics for manufacturing industry in the Netherlands.

| | 2002–2004 | 2004–2006 | 2006–2008 | 2008–2010 | All |
|---|---|---|---|---|---|
| Number of firms in CIS | 2052 | 1780 | 2475 | 1903 | 8210 |
| Employment Growth CIS | −2.51 | −2.42 | 4.67 | −4.31 | −4.72 |
| Employment growth CBS | −6.57 | −2.89 | 0.13 | −5.55 | −14.19 |
| Real sales growth CIS | 9.89 | 4.20 | 3.42 | −2.62 | 15.32 |
| Production growth CBS | 2.77 | 5.83 | 4.39 | −2.25 | 10.99 |
| Labour productivity growth CIS | 12.40 | 6.62 | −1.26 | 1.70 | 20.04 |
| Labour productivity growth CBS | 9.34 | 8.72 | 4.26 | 3.30 | 25.17 |

*Source:* Statistics Netherlands (CBS), CIS, own calculations.

sample is negative for 2006–2008, suggesting labour hoarding, while this is not found in the sector statistics.

Factors that could explain these differences are (1) CIS excludes firms with less than 10 employees; (2) our CIS sample results are unweighted while large firms are overrepresented in the sample; (3) a response bias may exist towards firms that have higher sales growth, lower employment decreases and a higher productivity growth; (4) the CIS only surveys firms that were active during the whole 3-year period covered by the surveys, which means that entry and exit in the industry during the survey period are excluded; (5) firms with more than 300% or less than -60% growth are excluded which may cause truncation.

Aggregating firm-level results to industry totals would be valuable, particularly from a policy perspective. However, the dynamics of employment within and between industries is only partly captured by the CIS data. As shown from the differences between industry statistics and the sample aggregates (including companies that are excluded from the estimations in this article), the sample of CIS has some limitations that make aggregation towards industry totals not very meaningful. Especially the fact that companies that cease activities or may be suffering from economic crises would not be represented in the CIS make that the CIS estimates for employment and turnover growth may be incorrect.

## 4. Statistical analysis based on unweighted averages

Table 2 describes the data as unweighted averages of percentage changes over the years, inspired by Harrison et al. (2014). If we compare the change in productivity of *process-innovators only* with *non-innovators*, we see that *process-innovators only* on average have a higher labour productivity increase than *non-innovators*, although in 2002–2004 it is the other way round (*process-innovators only* experienced slightly higher sales growth than *non-innovators*, *non-innovators* did so with far less employment) and in 2008–2010 the difference is almost zero.

*Product-innovators only* have a slightly higher productivity growth than *non-innovators*, but less than *process innovators only*. Companies with both process and product innovations have more or less the same labour productivity growth as *process innovators only*.

While Harrison et al. (2014) do their analysis for labour productivity completely with an econometric equation (discussed in the next section), they analyse sales in the same manner as we did for labour productivity. With respect to sales we see that *process-innovators only* have a higher increase in both real sales than *non-innovators*,

**Table 2.** Overview of the data (unweighted firm-level averages), average three-year period growth rates.

| | 2002–2004 | 2004–2006 | 2006–2008 | 2008–2010 | All |
|---|---|---|---|---|---|
| Number of firms | 2052 | 1780 | 2475 | 1903 | 8210 |
| Non-innovators (%) | 55.7 | 56.0 | 54.8 | 44.8 | 53.0 |
| Process-innovators only (%) | 10.6 | 8.1 | 9.5 | 9.1 | 9.4 |
| Product-innovators only (%) | 13.9 | 16.3 | 16.9 | 21.1 | 17.0 |
| Product- and process-innovators (%) | 19.8 | 19.6 | 18.7 | 25.0 | 20.6 |
| Sales new products as % of total sales product innovators | 17.3 | 16.6 | 18.7 | 20.8 | 18.5 |
| Employment growth (%) | | | | | |
| All firms | −3.1 | 1.5 | 4.5 | -−3.9 | 0.0 |
| Non-innovators | −4.1 | 1.3 | 4.4 | −4.0 | −0.2 |
| Process-innovators only | −1.0 | 2.3 | 6.6 | −2.7 | 1.6 |
| Product-innovators only | −2.5 | 2.5 | 3.9 | −3.3 | 0.2 |
| Product- and process-innovators | −1.6 | 1.0 | 4.5 | −4.6 | −0.2 |
| Product-innovators total | −2.0 | 1.7 | 4.2 | −4.0 | 0.0 |
| Deflated sales growth (%) | | | | | |
| All firms | 4.4 | 6.0 | 5.7 | −6.5 | 2.6 |
| Non-innovators | 3.2 | 4.8 | 4.9 | −9.5 | 1.6 |
| Process-innovators only | 6.4 | 11.1 | 11.6 | −7.7 | 5.7 |
| Product-innovators only | 5.8 | 6.5 | 5.0 | −4.9 | 2.7 |
| Old products | −14.8 | −11.1 | −17.2 | −34.7 | −20.4 |
| New products | 17.8 | 15.8 | 18.5 | 20.3 | 18.3 |
| Product- and process-innovators | 5.8 | 7.1 | 5.8 | −2.1 | 3.8 |
| Old products | −20.1 | −15.6 | −20.9 | −34.0 | −23.3 |
| New products | 20.3 | 19.4 | 22.0 | 21.9 | 21.0 |
| Product-innovators total | 5.8 | 6.8 | 5.4 | −3.4 | 3.3 |
| Old products | −17.9 | −13.6 | −19.2 | −34.3 | −22.0 |
| New products | 19.3 | 17.8 | 20.4 | 21.2 | 19.8 |
| Deflated labour productivity growth (%) | | | | | |
| All firms | 7.5 | 4.5 | 1.2 | −2.6 | 2.6 |
| Non-innovators | 7.4 | 3.5 | 0.5 | −5.5 | 1.8 |
| Process-innovators only | 7.4 | 8.7 | 5.0 | −5.1 | 4.1 |
| Product-innovators only | 8.3 | 4.0 | 1.1 | −1.6 | 2.4 |
| Product- and process-innovators | 7.4 | 6.1 | 1.2 | 2.5 | 4.1 |
| Product-innovators total | 7.8 | 5.1 | 1.2 | 0.6 | 3.3 |
| Price growth (%) | | | | | |
| All firms | 1.8 | 5.5 | 7.4 | −0.9 | 3.7 |
| Non-innovators | 1.6 | 5.0 | 7.4 | −1.1 | 3.7 |
| Process-innovators only | 1.5 | 4.8 | 7.7 | −1.3 | 3.4 |
| Product-innovators only | 2.1 | 6.6 | 6.7 | −0.5 | 3.7 |
| Product- and process-innovators | 2.5 | 6.2 | 7.7 | −0.9 | 3.7 |

*Source:* CBS CIS surveys, CBS industrial price statistics; own calculations.

especially for the periods 2004-2006 and 2006-2008 and that this compensates for changes in labour productivity consistently generating increases in employment. So, process innovations seem to be good for employment. Even more, *process-innovators only* outperform *product-innovators only* with respect to employment growth.

The dynamics behind this is that process innovations lead to cost reductions which lead to price reductions (in competitive markets), increasing demand. Harrison et al. (2014) provide a rough estimate of the price elasticity of sales for *process-innovators only*. If we follow their approach, over the whole period 2002–2010, real sales growth of *process-innovators only* is (from Table 2) 5.7–1.6% = 4.1% higher than of *non-innovators* as a consequence of a (maximum) price reduction of 4.1–1.8% = 2.3% (equal to the additional deflated labour productivity increase of process-innovators), generating a price elasticity of demand of 4.1%/2.3% = 1.8 (ranging from 1.1 to 3.2 for individual periods). This is only a little bit higher than the 1.4–1.5 which Harrison et al. (2014) found for Germany, France and the UK.

The deflated sales growth for process innovators as calculated above is based on average price changes for the industry, instead of price changes for process innovators only. Therefore, an extra price decrease for *process-innovators* would also imply that the increase in sales for *process-innovators* is higher than the estimate based on average price corrections. Therefore, if the extra price reduction is 2.3%, then the increase in real sales equals 4.1% + 2.3% = 6.4%. That would imply a price elasticity of demand of 6.4%/2.3% = 2.8% (ranging from 2.2% to 5.5% for individual periods). This does not seem implausible for individual firms where a large number of firms is relatively small in size. Firm-level price elasticities are higher than aggregated industry elasticities.

Also *product-innovators* show consistently higher sales than non-innovators. However, in contrast with process innovators, the averages of product-innovators seem not to give a better performance on employment than non-innovators. This seems counter-intuitive, and the econometric estimations in Section 5 show that if other differences between product-innovators and non-innovators have been taken care of, product-innovation generates extra employment.

## 5. Model and estimation strategy

The calculations in Section 4 are based on firm averages, and do not take into account that effects of innovation on sales or employment may in fact be related to sector composition or firm size, while it is also not possible to explain sales and employment by the use of a continuous variable in the CIS questionnaire on the share of newly developed products in total sales. For this reason Harrison et al. (2014) estimated an employment equation in order to disentangle the effect of innovation on employment in an effect of innovation on employment per unit of sales (the inverse of labour productivity) and an effect on sales, which combined explains employment. We follow this strategy by first estimating an equation that explains labour productivity by innovation and then an equation that estimates sales by innovation. Then we estimate an employment equation of which the estimated parameters could also have been calculated from the labour productivity and sales equation, in this way relating the analysis with the literature on innovation and employment.

For the estimation we used Ordinary Least Squares (OLS) estimation with combined year and sector dummies and three other control variables. Because the explanatory variables are already in first differences fixed effect estimation is not necessary. Furthermore, because the dataset has many firms for which information is only available in part of the years, using fixed effects would result in a significant loss of information. As a check we did perform fixed effects estimations on the dataset, losing 70% of the observations, where as expected no major differences in estimated coefficients were found, but the level of significance was much lower.

While Harrison et al. (2014) use instrumental variables for estimation of their employment equation, the reason why their explanatory variable was correlated with the error term has been avoided by rewriting the equation as a labour productivity equation. It does not seem plausible that in the estimated equations the correlation between explanatory variables and error terms is important. For this reason, estimation by OLS is sufficient and optimal.

### 5.1. Labour productivity

Because Harrison et al. (2014) is one of the most well-known studies on innovation and employment (Calvino and Virgillito 2018) and more or less the only study that explains employment by a direct innovation effect and an effect through sales, we start from their approach. We show in this section that they estimate in practice a unit labour requirement equation, the inverse of a labour productivity equation, and therefore that the econometric part of their study must be seen in the perspective of the literature on innovation and labour productivity.

Harrison et al. (2014) derive their model from explicit production functions. Their model uses a two period framework (time $t=1,2$) during which process innovations generate efficiency improvements while product innovations create turnover from new products. Process innovations may increase sales through price reductions, while product innovations may create new markets and/or cannibalise on existing product sales.

The labour demand function is used to analyse the consequences of innovation for employment per unit of output (unit labour requirement or the reciprocal of labour productivity). First, we define the variables from the CIS that we use for the equation[3]. We define $Y_1$ as the sales in the first year of the three year period, and $Y_2$ as the sales in the last year of the three year period[4]. The share of new products $s_n$ is defined as the share of products that were not available at the start of the period in total sales at the end of the period. This share may be used to split $Y_2$ between sales of old products $Y_{2o} = (1-s_n)Y_2$, i.e. sales at the end of the period of products that were already introduced at the start of the period, and sales of new products $Y_{2n} = s_n Y_2$, the sales of products at the end of the period that were not produced at the start of the period. For employment Harrison et al. (2014) do not differentiate explicitly between new and old products, so we have employment at the start of the period, $L_1$, and employment at the end of the period, $L_2$. Finally, we define a dummy variable d that is 1 if there is a process innovation without a product innovation, and 0 otherwise.

Using these definitions and following Harrison et al. (2014), we define an equation that explains employment growth of firm i (index i for simplicity left out of the equation):

$$\left(\frac{L_2-L_1}{L_1}\right)-\left(\frac{Y_{2o}-Y_1}{Y_1}\right)=\alpha_0+\alpha_1 d+\alpha_2\left(\frac{Y_{2n}}{Y_1}\right)$$

Harrison et al. (2014) use this equation[5] to differentiate between employment change as a consequence of changes in sales of old and new products, and efficiency effects of process innovations, where the sales in period 2 are deflated by average sector prices to represent changes in constant prices.

Starting from this equation used by Harrison et al. (2014), we go to an explicit labour productivity equation by using the definitions $Y_{2o}=(1-s_n)Y_2$ and $Y_{2n}=s_nY_2$ :

$$\left(\frac{L_2-L_1}{L_1}\right)-\left(\frac{(1-s_n)Y_2-Y_1}{Y_1}\right)=\alpha_0+\alpha_1 d+\alpha_2\left(\frac{s_n Y_2}{Y_1}\right)$$

Subtracting from both sides $\frac{s_n Y_2}{Y_1}$ and bringing $s_n$ out of brackets:

$$\left(\frac{L_2-L_1}{L_1}\right)-\left(\frac{Y_2-Y_1}{Y_1}\right)=\alpha_0+\alpha_1 d+(\alpha_2-1)\left(\frac{Y_2}{Y_1}\right)s_n$$

Now we have the percentage change in labour intensity at the left hand side of the equation, and the innovation variables at the right hand side of the equation and may rewrite it as a labour productivity equation (adding the index for firm i again):

$$y_i-l_i=\overline{\alpha_0}+\overline{\alpha_1}d_i+\overline{\alpha_2}s_{ni}+u_i,$$

Where

$$l_i=\frac{L_{2i}-L_{1i}}{L_{1i}}$$
$$y_i=\frac{Y_{2i}-Y_{1i}}{Y_{1i}}$$
$$\overline{\alpha_0}=-\alpha_0$$
$$\overline{\alpha_1}=-\alpha_1$$
$$\overline{\alpha_2}=(\alpha_2-1)\left(\frac{Y_{2i}}{Y_{1i}}\right)$$

$u_i$= random error term[6]

The interpretation of this equation is straightforward. The percentage change of unit labour productivity without innovation equals $\overline{\alpha_0}$. The parameter $\overline{\alpha_1}$ is the effect of process innovation only on labour productivity, while $\overline{\alpha_2}$ equals the percentage difference in labour productivity of new products compared with old products.

Based on the equation derived above one may generalise the equation by adding also dummies for firms that have both process and product innovations and firms that have only product innovations. Also the parameter for the effect of the share of new products in total sales can potentially be different between product innovators that also have process innovations and firms that only have product innovations.

Additional to the terms discussed above, we include other variables as control variables explaining unit labour requirement, i.e. firm size, unit labour requirement at the start of the period, the international focus of the company, and sector-and year dummies. As far as sector inflation is not taken into account correctly, it is taken up by the parameter $\overline{\alpha_0}$.

### 5.2. Sales

The same reason why Harrison et al. (2014) may use an equation to estimate differences in labour productivity as a consequence of innovation, holds also for sales. For this reason, we develop an equation to explain sales in the same manner as labour productivity. In the end, the change in employment is the combination of the change in labour productivity and the change in sales.

The structure of the sales equation is exactly the same as the labour productivity equation, except that instead of labour productivity sales is at the left hand side of the equation:

$$y_i = \beta_0 + \beta_1 d_i + \beta_2 s_n + u_i.$$

So, the percentage change in sales is explained by a term $\beta_0$, that represents average sales growth without innovation, and then the two innovation variables that tackle the effect of process innovation and product innovation. The parameter $\beta_2$ is the fraction of the sales of new products that is translated into expansion of total sales of the new innovating company instead of being at the cost of the sales of old products. We include the same control variables as in the labour productivity equation.

## 5.3. Employment

Based on the estimations above, we may calculate the total effect of innovation on employment by combining the labour productivity equation with the sales equation.

$$l_i = (l_i - y_i) + y_i = (\overline{\alpha_0} + \beta_0) + (\overline{\alpha_1} + \beta_1)d_i + (\overline{\alpha_2} + \beta_2)s_n + u_i.$$

The other possibility is to estimate the employment equation directly, and compare this with the calculations above. The advantage of having a direct employment equation is that there are no intervening price effects. However, the disadvantage is that only net effects are estimated, reducing significance levels, and that the equation doesn't explain the causes of the employment changes. So, as a check on significance of the effects the employment will be estimated also directly, while the interpretation of the causes of the changes in employment needs both the labour productivity and the sales equation.

## 5.4. Labour productivity and sales may be underestimated

Because y is only corrected for sector inflation, there will still be a correlation between price and process innovation, as in the equation of Harrison et al. (2014). This problem cannot be solved according to Harrison et al. (2014). However, we may try a simple exercise to get an idea of the boundaries of the effect, especially with respect to process innovations.

If we define $q_i$ as the volume of sales and $p_i$ as the difference in price change of the firm relative to the sector, i.e. $y_i = q_i + p_i$, i.e. corrected for differences in price development of the output of the firm with the sector average price developments, then we may assume that the percentage price change equals $p_i = -\lambda\ (l_i - q_i)$. If we restrict ourselves only to the labour productivity change as a consequence of process innovations, i.e. $p_i = \lambda\ \hat{a}_1 d_i$, where $\hat{a}_1$ is the parameter for $\alpha_1$ when q instead of y would be at the left hand of the equation, we get:

$$l_i - (q_i + p_i) = \alpha_0 + \alpha_1 d_i + \alpha_2 s_n + u_i$$
$$l_i - (q_i + \lambda \hat{a}_1 d_i) = \alpha_0 + \alpha_1 d_i + \alpha_2 s_n + u_i$$
$$l_i - q_i = \alpha_0 + (\alpha_1 + \lambda \hat{a}_1)d_i + \alpha_2 s_n + u_i$$

**Table 3.** Labour productivity (percentage change).

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Process innovation only | 2.20 (0.88)** | 2.56 (0.89)** | 2.39 (0.90)** |
| Process innovation with product innovation | | 2.29 (0.89)** | 2.37 (0.71)** |
| Product innovation without process innovation | | | 0.74 (0.74) |
| Share of new products in total sales | 6.85 (1.86)** | | |
| Share of new products in total sales for process-innovators | | 1.54 (2.95) | |
| Share of new products in total sales for product-innovators only | | 8.60 (2.72)** | |

*Note:* Year-sector dummies, log of original employment, log of original labour productivity and firm operating on an international market included as control variables; standard errors between brackets.
**Significant difference from 0 at the 5% level.

Substituting recursively:

$$l_i - q_i = \alpha_0 + \alpha_1(1 + \lambda + \lambda^2 + \lambda^3 + \cdots)d_i + \alpha_2 s_n + u_i$$

and solving this we get:

$$l_i - q_i = \alpha_0 + \alpha_1\Big(1/(1-\lambda)\Big)d_i + \alpha s_n + u_i$$

This implies that if half of labour productivity increases would be translated into price reductions, then the parameter $\alpha_1$ would be double the estimated value.

Also with respect to the sales equation there is a problem of endogenous prices. Especially with respect to process innovation, cost price will decline and therefore price will decrease and sales will increase according to the price elasticity of demand at firm level, implying an underestimation of the sales effect. Based on the price definition introduced in the analysis of labour productivity, the correction for the parameter of $d_i$ can be derived as follows:

$$y_i = \beta_0 + \beta_1 d_i + \beta_2 s_n + u_i.$$
$$q_i + p_i = \beta_0 + \beta_1 d_i + \beta_2 s_n + u_i.$$
$$q_i + \lambda\hat{a}_1 d_i = \beta_0 + \beta_1 d_i + \beta_2 s_n + u_i.$$
$$q_i = \beta_0 + (\beta_{1\text{-}}\,\lambda\hat{a}_1)d_i + \beta_2 s_n + u_i.$$

In summary, especially for process innovations the estimated parameters may be too low, both for its effect on sales and its effect on labour productivity. In the employment equation both errors cancel out, but this is relevant for the decomposition of the employment effect in sales and labour productivity component.

## 6. Effect of innovation on labour productivity, sales and employment

### *6.1. Labour productivity*

Table 3 presents three variants of the labour productivity equation. Model 1 explains it directly by process innovation and the share of new products in sales. Both coefficients are significant. It means that being a process innovator increases labour productivity by more than 2%, while products that have been introduced in the last three years have a labour productivity that is a little bit less than 7% higher. Model 2 splits the product innovation in three components: one dummy for product innovators that

**Table 4.** Real turnover (percentage change).

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Process innovation only | 4.62 (0.93)** | 5.19 (0.95)** | 5.26 (0.96)** |
| Process innovation with product innovation | | 3.65 (0.94)** | 4.87 (0.75)** |
| Product innovation without process innovation | | | 2.70 (0.79)** |
| Share of new products in total sales | 13.42 (1.97)** | | |
| Share of new products in total sales for process-innovators | | 5.93 (3.13)* | |
| Share of new products in total for product-innovators only | | 14.76 (2.89)** | |

*Note:* Including year-sector dummies, log of original employment, log of original labour productivity, and international market orientation; standard errors between brackets.
*Significance at the 10% level.
**Significance at the 5% level.

also have process innovations, and an opportunity to have different labour productivity effects for product innovators that are also process innovators and product innovators only. This shows that process innovators that are also product innovators do not have a significantly different effect from process innovators only. However, for product innovators that have also process innovations the parameter of the share of new products in sales is significantly lower and not significant. Model 3 shows the estimated equation with only dummies, where the dummy for product innovators without process innovation is not significant at all.[7] The estimations in the third equation are roughly consistent with the statistics in Table 2. The estimation results are roughly consistent with the literature discussed in Section 2.1, and corroborate hypotheses 1 formulated in that section.

In summary, our estimates for the four waves of the CIS in the Netherlands show significant effects of both product and process innovation on labour productivity. Product innovators who don't report process innovations have a direct effect through the share of sales of the new products. This is roughly consistent with the literature on innovation and labour productivity.

## 6.2. Sales

The next step is to explain sales as a consequence of innovation. Table 4 shows that process innovation increases real turnover with about 5%, while the sales of new products increase total sales with 13.5% of the sales value of the new products. This implies that 86.5% of the sales of new products is at the cost of sales of old products. Results for model 2 show that when a firm has both process and product innovations, that the explanation of the increase in sales is only partly related with the share of new products, and that the rest is taken by the dummy as a general increase in sales as a consequence of the combination of process and product innovation. Model 3 shows that when all increases in sales increases because of product and process innovation are forced into dummies, that firms that have both product and process innovation have about the same increase in sales as process innovators only, while process innovators only tend to have a smaller increase in sales. These econometric results in model 3 are all larger than the effects derived from statistical analysis in table 2, where the difference is significant at a 5% level for product innovation only and product innovation combined with process innovation.

**Table 5.** Employment (percentage change).

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Process innovation only | 2.42 (0.67)** | 2.63 (0.68)** | 2.88 (0.69)** |
| Process innovation with product innovation | | 1.36 (0.68)** | 2.51 (0.54)** |
| Product innovation without process innovation | | | 1.96 (0.57)** |
| Share of new products in total sales | 6.57 (1.43)** | | |
| Share of new products in total sales for process-innovators | | 4.39 (2.26)* | |
| Share of new products in total for product-innovators only | | 6.16 (2.09)** | |

*Note:* Including year-sector dummies, log of original employment, log of original labour productivity, and international market orientation; standard errors between brackets.
*Significance at the 10% level..
**Significance at the 5% level.

In summary, process innovations generate an increase in turnover in the order of magnitude of 5%. About 15% of the turnover of new products as a consequence of product innovations without process innovations is an expansion of real turnover by the firms, while 85% of the sales of the new products are at the cost of turnover of old products. This corroborates both Hypotheses 2 and 3 discussed in Section 2.2.

### *6.3. Employment*

The target of this study is to decompose the effect of innovation on employment in a labour productivity and sales component. The employment effect can be calculated directly from these two equations. However, it is interesting to investigate also the significance of the results for employment, and therefore also an employment equation has been estimated directly. This employment equation provides also on opportunity to put the results in the context of the literature on innovation and employment, because this literature tends to estimate reduced form equations for employment.

Because labour productivity growth has an opposite effect on employment to turnover growth, employment growth is the net effect of these two. Because the uncertainty of price changes is not in the employment equation, estimates can be more robust and therefore the standard errors in this equation are smaller than in the other two equations. However, because the parameters of the employment equation are the difference between the parameters of the other two equations, the size of the parameters is also smaller than for the other equations.

Table 5 shows that the estimates are significant for the three models, although the share of sales of new products for process innovators that are also product innovators is only barely significant at a 5% level. A process innovation generates an increase in employment of about 2.5%, while an increase in the share of new products in total sales of 10 percentage points increases employment with 0.7%. Process innovation without product innovation shows a larger effect than with a product innovation, because part of the effect is included in the share of new sales. When both are combined the effect of process innovations only is more or less the same as that for innovators who combine product and process innovations.

The results of model 3 for employment are much higher compared with the statistical analysis of Table 2. For firms that have only process innovations the statistical analysis shows an increase in employment of 1.8% while the econometric evidence is an increase of 2.9, which is indicative although the difference is not significant. For product innovators only and product and process innovators the statistical analysis suggests no effect at all, while the econometric analysis shows very significant estimated parameters.

When we combine all results of the estimations, we see that when a firm has only process innovations labour productivity increases with about 2.4%, while sales increase with about 5.2%, with as a consequence an increase in employment of about 2.8%. When a process innovator also has product innovations the increase in labour productivity is more or less the same as for process innovators only, but the effect on labour productivity is split into a general component and a component that is related with the share of new products in total sales. Because endogenous prices may result in an underestimation of the labour productivity and sales effect of innovation, both estimated parameters may be an underestimation of the effect of innovation (see Section 5.4). However, the two errors cancel out in the employment equation, making this equation unbiased.

Our results show a significant beneficial effect on employment growth of both process and product innovations. This becomes only visible in complete econometric estimations because with simple statistical analysis the positive effect of process innovation on sales would not have been found. Both hypotheses 4 and 5 of Section 2.3 are corroborated.

In summary, we see for the Netherlands clear positive effects of both process and product innovation on employment, where we have shown how this effect can be decomposed in a negative employment effect because of labour productivity increases and a positive employment effect because of increases in sales.

## 7. Conclusion

We have analysed the relationship between innovation and employment on a firm level by decomposing it in a relation between innovation and labour productivity and a relation between innovation and sales. For both sales and labour productivity we did the analysis both by comparison of statistical averages and econometrics, and showed that the use of averages per group to explain sales, as in Dachs and Peters (2014), Harrison et al. (2014) and Peters et al. (2014), gives a poor indication of causality compared with econometric analysis. The difference in results in our dataset is small for the relationship between innovation and labour productivity, but even then the econometric analysis provides an opportunity for more refined analysis.

Process innovations increase employment with about 2.7%. The direct employment effect through increased labour productivity is -2.5%, but this is compensated by an increase in real turnover of 5.2%. This positive effect of process innovation on real turnover is not visible in statistical averages as used for example by Peters et al. (2014). Furthermore, this result is consistent with the theoretical plausibility that for individual firms the price elasticity of demand is much more than 1 (see Sections 4 and 5.2).

Product innovations increase employment. This is clearly found in our estimates and is consistent with the literature. If the share of sales of new products increases with 1 percentage point, employment increases with 0.063 percent, i.e. if all products would be replaced by new products employment would increase with 6.3% for product innovators. This is composed of a negative effect on employment because of a labour productivity increase of 6.8% and a positive effect on employment through an increase in sales of 14%.

In interpreting these results one must be aware that the effect of process innovation on sales is probably underestimated as is the effect of process innovations on labour productivity, where it easily could be that the effects are double the estimated size (see Section 5.4). This issue is not discussed in the literature, although the problem is mentioned in for example Harrison et al. (2014). Both effects cancel out in the employment equation.

In this article for the first time the relationship between both product and process innovations and employment is decomposed in a systematic manner based on explicit econometric equations on the relationship between innovation and labour productivity respectively sales. It is argued that the estimated parameters for the sales and labour productivity equations are too low because no measure on real sales is available in the CIS data sets used in many analyses. It would be valuable to search for opportunities to improve those datasets with respect to this aspect.

## Notes

1. For OLS they find that new products have even a lower productivity than old products, but this may be explained by the negative correlation between the independent and dependent variable because both depend on the same measured variable, i.e. share of new products in total sales.
2. Under certain conditions, these microdata are accessible for statistical and scientific research. For further information: microdata@cbs.nl.
3. We use a little bit different notation than Harrison et al. (2014) and Peters et al. (2014) to simplify reading.
4. Where sales in period 2 are deflated with the percentage change in price of the sector between period 2 and period 1, based on data from Statistics Netherlands, in that manner correcting for inflation and price developments in the sector.
5. With a small difference; they approximate $\left(\frac{Y_{2o}-Y_1}{Y_1}\right)$ as $\ln(Y_{2o}\text{-}\ln Y_1)$ in order to be able to derive the formula; we substituted it back at the end of the procedure.
6. It is obvious that the existence of $\left(\frac{Y_{2i}}{Y_{1i}}\right)$ in $\overline{\alpha_2}$ is a disturbance to the estimation of the parameters. However, the effect of this disturbance is small, while rewriting the equation in this manner solves the problem of endogeneity biases in the equation of Harrison et al. (2014) and makes interpretation of the results more intuitive.
7. When an additional dummy for product innovators only is added to model 2, the effect is also not significant at all, while the other estimated parameters remain roughly the same.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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