UNITED NATIONS UNIVERSITY
UNU-WIDER

WIDER Working Paper 2019/83

Firm-level employment growth in South Africa

The role of innovation and exports

Karmen Naidoo*

November 2019

United Nations University World Institute for Development Economics Research
wider.unu.edu

Abstract: This paper investigates the effect of innovation on employment growth at the firm level in South Africa. Innovation is typically associated with better export performance at the firm level due to productivity enhancements and new products. However, the link between innovation and employment is more ambiguous. R&D targeted towards product innovation has been typically associated with employment growth. Process innovations may have a positive effect, but also have the potential to reduce the demand for labour. This paper aims to isolate the impact of innovation on export performance to understand the direct and indirect channels through which innovation can influence employment growth. The analysis makes use of a novel administrative dataset of all registered firms in South Africa for the 2010–16 period. The study finds that, overall, direct innovation is positively associated with employment growth; however, the indirect innovation channel is negative and points to the idea that the productivity enhancements necessary for South African exporters to compete internationally might promote labour-saving innovations.

Keywords: employment, exports, firm growth, R&D

JEL classification: O3, F16, J23, L25

Acknowledgements: The author would like to acknowledge the support of UNU-WIDER for this project through the SA-TIED programme. Data access was made possible through support from the South African National Treasury and the South African Revenue Service, where special thanks goes to the Treasury staff members who were helpful in answering pertinent questions about the data. The author is thankful for valuable feedback and comments on the paper from participants at the SA-TIED Work-in-Progress Meeting and the National Treasury Seminar Series.

---

*PhD candidate, Department of Economics, University of Massachusetts Amherst, MA.. Corresponding author: knaidoo@umass.edu

This study has been prepared within the UNU-WIDER project Southern Africa – Towards Inclusive Economic Development (SA-TIED)

Information and requests: publications@wider.unu.edu

ISSN 1798-7237 ISBN 978-92-9256-717-0

https://doi.org/10.35188/UNU-WIDER/2019/717-0

Typescript prepared by Gary Smith.

The United Nations University World Institute for Development Economics Research provides economic analysis and policy advice with the aim of promoting sustainable and equitable development. The Institute began operations in 1985 in Helsinki, Finland, as the first research and training centre of the United Nations University. Today it is a unique blend of think tank, research institute, and UN agency—providing a range of services from policy advice to governments as well as freely available original research.

The Institute is funded through income from an endowment fund with additional contributions to its work programme from Finland, Sweden, and the United Kingdom as well as earmarked contributions for specific projects from a variety of donors.

Katajanokanlaituri 6 B, 00160 Helsinki, Finland

1 Introduction

The literature on economic catch-up and industrial dynamics acknowledges the important role of national- and firm-level technological capabilities in closing the economic gap between the developed and the less developed world. In the early theory of economic catch-up by Gerschenkron (1962), the technological gap between lesser developed and more developed countries was seen to create an opportunity for lesser developed countries to make developmental leaps through leveraging technological advancements made in the developed world. Instead of seeing technological transfer as an automatic process, evolutionary perspectives such as those of Nelson (2008), Lall (1992, 1993), and Lee (2013) emphasize the effort required to master new technologies, whether it be to adapt them to new settings, to improve the technologies to varying degrees, or to create new technologies altogether, and therefore sees firm-level technological change as a 'continuous process to absorb or create technical knowledge, determined partly by external inputs and partly by past accumulation of skills and knowledge' (Lall 1992: 166). More generally, the idea that economic development is a process of learning and upgrading of the economic structure through increased diversity and complexity of production has become prominent (Rodrik 2006; Stiglitz 2011).

The role of indigenous technological capability in developing countries has received little attention due to these countries' small share in the world's investment in innovative activities and an understanding of technology as major breakthroughs; however, the assimilation and adaptation of existing technologies still represent important forms of innovation in the context of economic catch-up, and would require formal R&D to achieve (Lall 1993). In addition, policies that facilitate the development of technological capabilities, along with those that promote higher education, have been found to be more important for generating long-term growth for middle-income countries compared to lower-income countries, with the successful cases of South Korea and Taiwan often used as examples (Lee and Kim 2009; Lee and Lim 2001). In the context of increased globalization, middle-income countries are required to shift towards the production of higher value added goods to sustain growth and development, and most importantly for South Africa, employment. This paper is mostly concerned with local firm efforts to improve technological capabilities in a broad sense through the analysis of trade and investment in R&D, and how they impact firm productivity and growth in South Africa.

There are both demand- and supply-side factors influencing the pace and nature of technological upgrading in developing countries. International competition and trade have the potential to spur technological upgrading, but when industries are too quickly exposed to these forces, it may stifle their growth (Lall 1992). On the supply side, a firm's ability to innovate depends on the size of the firm, the availability of skilled labour and managerial know-how, and broader institutional support within a national system of capability building (Lall 1992). While it is widely acknowledged that exports can be a driver of growth, the contemporary literature on trade and growth has highlighted the interdependence of exports and R&D (Esteve-Pérez and Rodríguez 2013; Neves et al. 2016). But the type of innovation matters. R&D targeted towards product innovation has been typically associated with employment growth, whereas process innovations may have a positive effect but also have the potential to reduce the demand for labour in the firm through labour-saving, productivity-enhancing changes in the method of production (Bogliacino and Vivarelli 2012; Dachs and Peters 2014; Harrison et al. 2014). Most of these studies are conducted on high-income countries, and therefore this study represents an important contribution to the literature on firm dynamics in developing countries. This represents an interesting case, since the technological innovations would be intermediate, or of a catch-up nature to countries at the technological frontier.

The main research questions this study investigates are:

1. What is the relationship between firm-level innovation and employment growth?

2. What is the effect of innovation on employment, while accounting for the innovation–export linkages? A sub-question that is initially explored here is about the relationship between firm-level innovation and export performance.

This research addresses critical policy questions for South Africa about the primary constraints to employment creation. It seeks to explore the employment-creating potential of innovation investments, while taking into account the complementary relationship between exports and innovation. It also discusses the institutional policy support for R&D investment in South Africa.

The rest of the paper is structured as follows. Section 2 provides an overview of the data and describes the nature and pattern of employment and employment growth over the period. Section 3 explores the relationship between innovation and employment at the firm level, without yet taking into account the innovation–export linkages. Section 4 investigates the linkages between innovation and export behaviour at the firm level, through applying a theoretically informed econometric model. Section 5 applies a three-stage model to estimate the impact of innovation intensity and export intensity on firm-level employment growth. Section 6 concludes.

2 Data and descriptive statistics

2.1 An overview of the data

The SARS-NT (South African Revenue Service–National Treasury) Firm Panel dataset is the largest firm-level dataset made available in South Africa, which allows for a more nuanced understanding of employment dynamics at the firm level than has been available to researchers until now. The SARS-NT Firm Panel has complete data for 2010–16, which is the main period of analysis here.

The dataset used in this paper was constructed from the main SARS-NT Firm Panel through the following main steps:

1. Firms with missing data were dropped from the dataset. A firm was dropped if (a) it has zero or missing sales, capital stock, or employment for every year present in the data; or (b) it has zero sales, capital stock, and employment for a particular year.

2. Some imputation was necessary to assign each firm to an industry for each year. The International Standard Industrial Classification (ISIC) was used to assign industry codes to firms. If a firm had an industry code in any of the years but not all years (some missing observations), this code was assigned to the firm for all years.

3. Transaction-level customs data (exports and imports) were aggregated at the firm–tax year level and merged into the SARS-NT Firm Panel.

4. All relevant variables were deflated using industry-level deflators. A few industries did not have the industry-level deflators and so the national-level consumer price index (CPI), value added deflator, or capital formation deflator was used as appropriate.

5. The following subsectors were dropped: public administration, utilities, and representatives of foreign governments. Labour-broking firms (offering temporary employment services) were also dropped. These subsectors were dropped because the paper's focus is on formal private-sector employment, and these subsectors are primarily related to public-sector activities. Labour-broking firms are primarily involved in contracting out workers to other firms, and the dataset does not

allow us to classify these workers according to the firm and industry they are actually working in, as they are only connected with the labour-broking firm.

In addition, most of the analysis makes use of a balanced panel of firms—that is, the subset of firms that are present in each year of the data. The reasons are that this removes the effect of new firms that enter, or vulnerable firms that exit, the market, which may be distinctly different from established firms. In addition, some of the firm entry and exit may be because of measurement error. The balanced sample of firms has a similar distribution of firms by industry as the full firm dataset. Robustness checks using all firms have also been conducted and will be discussed in the following sections.

The limitations of this study are that informal firms are excluded, along with workers employed via temporary employment agencies; therefore, the employment dynamics that are analysed in this paper relate to formal, direct employment. According to aggregate data, this still represents the majority share of employment in South Africa. In addition, some of the aspects explored in this paper, such as innovation, have a longer-term time horizon which may not be fully captured by this panel, which only covers the 2010–16 period. Therefore, the analysis can be seen to explain short- to medium-term dynamics. The balanced sample is presented in Table 1.

Table 1: Number of firms in the balanced sample

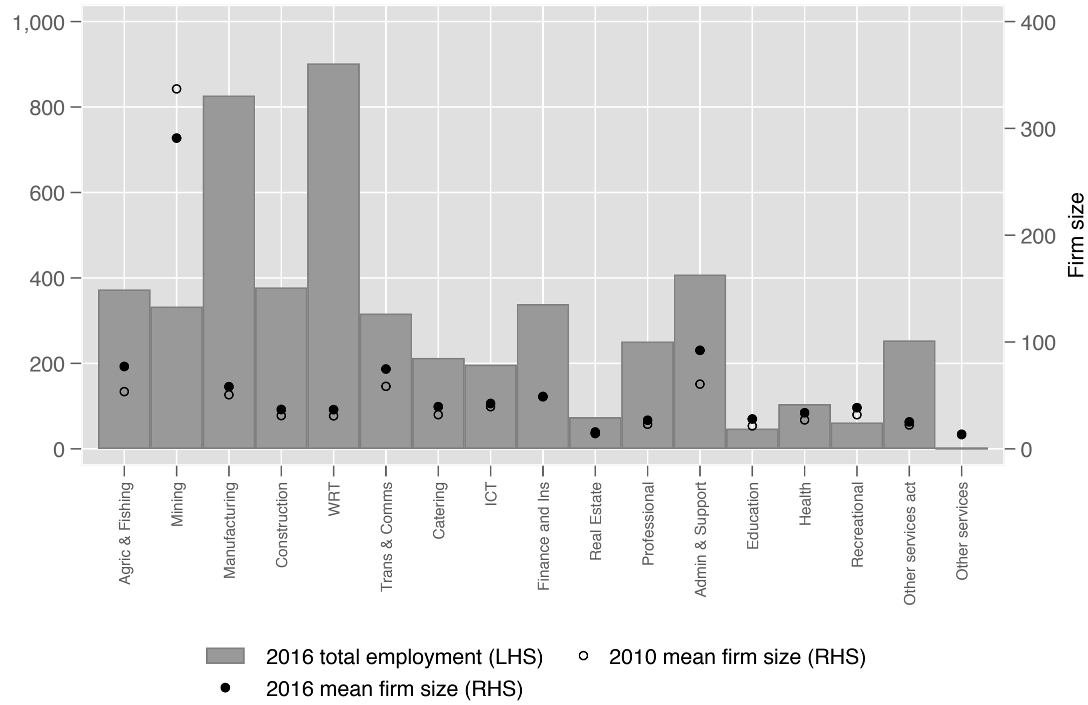
	Number	Percentage
Agriculture, forestry, and fishing	4,053	4.24
Mining and quarrying	945	0.99
Manufacturing	13,490	14.11
Construction	8,593	8.99
Wholsesale and retail	20,708	21.66
Transport, storage, and communication	3,640	3.81
Catering and accommodation	4,403	4.6
Information and communication	3,794	3.97
Financing and insurance	6,286	6.57
Real estate activities	3,843	4.02
Professional, scientific, and technical activities	7,867	8.23
Administrative and support service activities	3,659	3.83
Educational services	1,368	1.43
Human health and social work	2,678	2.8
Recreational and cultural services	1,321	1.38
Other service activities	8,815	9.22
Other services	155	0.16
Total	95,618	100

Source: author's calculations based on SARS-NT CIT Firm Panel.

2.2 Structure of employment and employment growth

As shown in Table 1 and Figure 1, the large majority of South African firms are operating within the tertiary sector and, concomitantly, the majority of South African workers are employed in the same sector. While there has been growth in overall manufacturing employment over this period, the wholesale and retail trade sector has become the largest sector employer, as shown in Figure 1. Regarding firm size, the mining sector has the highest average firm size by a considerable margin, which had decreased to an average of 300 workers per firm by 2016. Administrative and support services, transport, storage and communications, and agriculture then follow as the sectors with the largest average firm size measured by number of employees, which have all increased since 2010.

Figure 1: Total employment and average firm size by sector



Notes: total employment is in thousands and refers to the last year, 2016.

Source: author's calculations based on SARS-NT CIT Firm Panel.

The distribution of firms across size categories is shown in Table 2 and reveals that the overwhelming majority of South African firms, 72 per cent, are classified as very small (1–20 employees).[1] Sectors such as real estate activities, financing and insurance, and health and social work are almost entirely made up of very small businesses, with 1–2.5 per cent of firms in these sectors classified as large. The two primary sectors (mining and agriculture, forestry and fishing) have the highest proportion of medium and large firms at 28 and 24 per cent, respectively, followed by manufacturing (20 per cent). This insight is of particular interest given the debates around firm size and innovation, with a Schumpeterian perspective proposing that larger firms can better exploit the benefits of innovation and will therefore grow faster.

In terms of firm-level growth, Figure 2 presents both annual average employment and sales growth for the entire period by sector. Some of the fastest growing sectors by sales are in services, mining, and resource-based manufacturing, with two of those—mining of coal and manufacturing of coke and refined petroleum products—having correspondingly high employment growth rates. Many of the low-tech and medium- to high-tech sectors fall just above the 45-degree line from the origin, suggesting that these sectors have a simple output–employment elasticity of close to 1 and are not indicative of sectors that cannot absorb labour but instead do show low output growth rates. The graph also serves to emphasize that the structure of the South African economy, and the sectors driving growth, are still reliant on natural resources (such as resource-based manufacturing) and the rest of the manufacturing sector is lagging behind..

[1] The size classifications used in this paper are from the South African National Small Business Amendment Bill, 2003. The only point of departure is that the bill classifies agricultural firms differently (very small = 1–10; small = 11–50; medium = 51–100; large = 100+); however, this paper maintains the same size categories for all firms for ease of comparability.

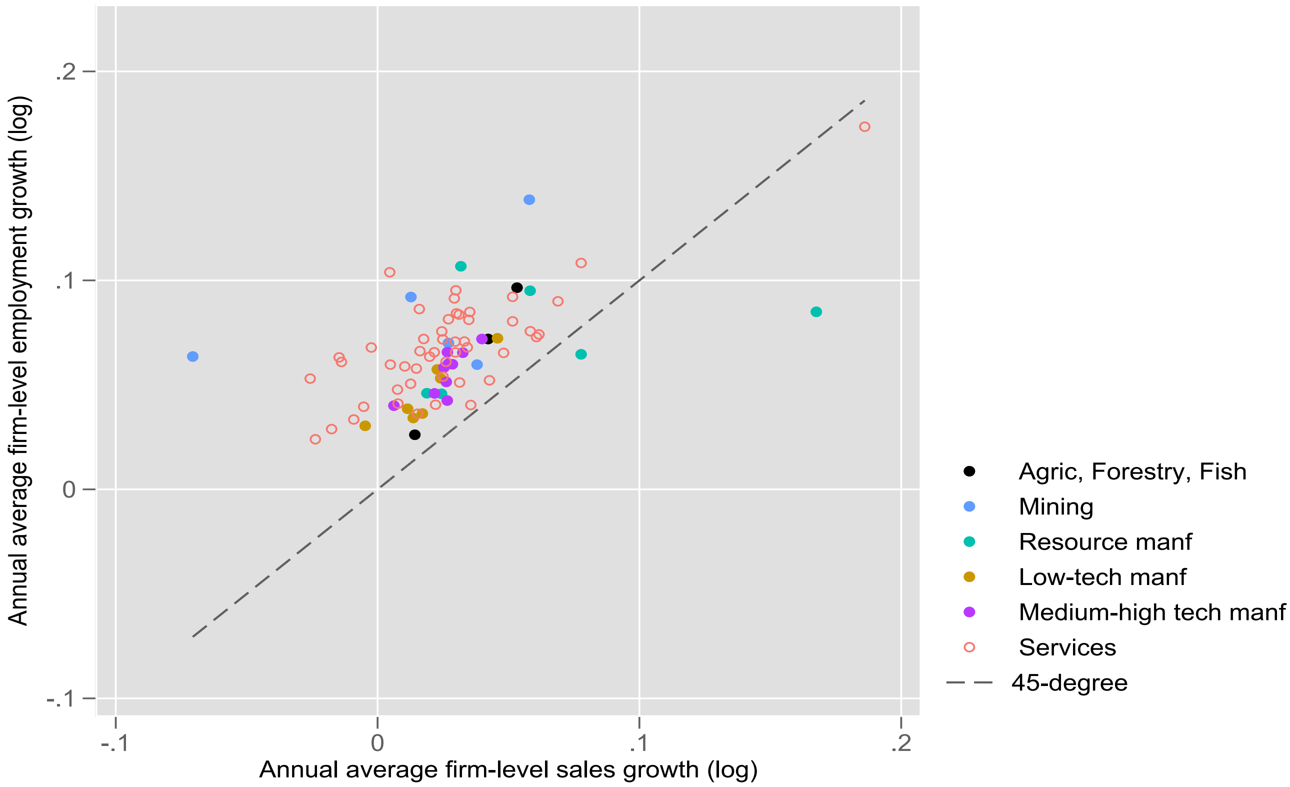
Table 2: Distribution of firms by size category within each sector (percentage)

	Very small	Small	Medium	Large
Agriculture, forestry and fishing	54.35	21.33	17.31	7.01
Mining and quarrying	54.14	17.99	15.99	11.87
Manufacturing	57.36	23.01	15.05	4.59
Construction	68.43	18.21	10.53	2.83
Wholesale and retail	72.41	17.55	8.41	1.62
Transport, storage, and communication	66.86	17.08	11.84	4.21
Catering and accommodation	63.25	23.57	10.74	2.44
Information and communication	77.38	12.90	7.24	2.48
Financing and insurance	83.51	8.99	5.26	2.23
Real estate activities	88.33	7.56	3.38	0.73
Professional, scientific, and technical activities	82.77	10.94	4.82	1.46
Administrative and support service activities	74.27	11.54	9.02	5.17
Educational services	76.53	16.79	5.04	1.64
Human health and social work	84.64	9.14	4.37	1.85
Recreational and cultural services	76.80	12.85	6.86	3.48
Other service activities	79.68	12.88	5.81	1.63
Other services	85.44	9.67	3.93	0.96
Total	72.03	16.12	9.05	2.80

Notes: firm size measured by the number of employees. Very small = 1–10; small = 11–50; medium = 51–100; large = 100+.

Source: author's calculations based on SARS-NT CIT Firm Panel.

Figure 2: Annual average employment growth and sales growth by sector



Source: author's calculations based on SARS-NT CIT Firm Panel.

2.3 Firm-level innovation and export activities

The proportion of innovating firms in South Africa remains very low, ranging from 0.5 to 1.3 per cent over the 2010–16 period, shown in Table A1 in the Appendix. A concerning trend is the decline in the proportion of firms that report R&D expenditures over this five-year period. Table 3 shows that manufacturing has the highest proportion of innovating firms, followed by mining and agriculture. Looking at the total expenditure on R&D, the manufacturing sector contributes the large proportion of total R&D in South Africa (Figure 3), suggesting that R&D activities are spread over a wider range of firms, thus leading to a lower innovation intensity within each firm. Within services, ICT (information and communication technologies) and recreational and cultural services have the highest proportion of innovators. Within the group of firms that innovate, column 2 of Table 3 presents the R&D intensity (ratio of R&D to sales). Service sectors like FIRE (finance, insurance, and real estate) have the highest R&D intensity, along with education services and professional and scientific services, which is expected. The manufacturing sector has a lower average R&D intensity at 1.83 per cent of sales.

Table 3: Summary of innovative and export activities

	Innovators (percentage of firms)	R&D intensity (percentage of sales)	Exporters (percentage of firms)	Export intensity (percentage of sales)
Agriculture, forestry, and fishing	1.50	5.59	12.16	17.36
Mining and quarrying	2.40	5.26	20.71	17.93
Manufacturing	2.70	1.81	34.91	8.44
Construction	0.20	4.63	5.56	9.14
Wholsesale and retail	0.40	2.38	18.17	8.10
Transport, storage, and communication	0.20	5.41	13.64	16.22
Catering and accommodation	0.30	2.54	2.86	8.46
Information and communication	1.30	5.01	10.11	5.85
Financing and insurance	0.40	21.43	2.51	14.94
Real estate activities	0.10	21.90	1.03	20.23
Professional, scientific, and technical activities	1.00	10.73	7.41	9.49
Administrative and support service activities	0.50	8.87	5.47	10.77
Educational services	0.70	15.11	2.17	7.23
Human health and social work	0.60	7.12	5.47	5.44
Recreational and cultural services	0.80	1.96	8.01	11.14
Other service activities	0.40	5.05	9.87	9.89
Other services	0.30	1.00	13.89	4.40
Total	0.80	4.71	13.06	9.36

Notes: each column represents the cross-year average. Column 2 presents the average ratio of R&D expenditure to sales for firms that report positive R&D. Column 4 presents the average ratio of exports to sales for firms that have positive exports.

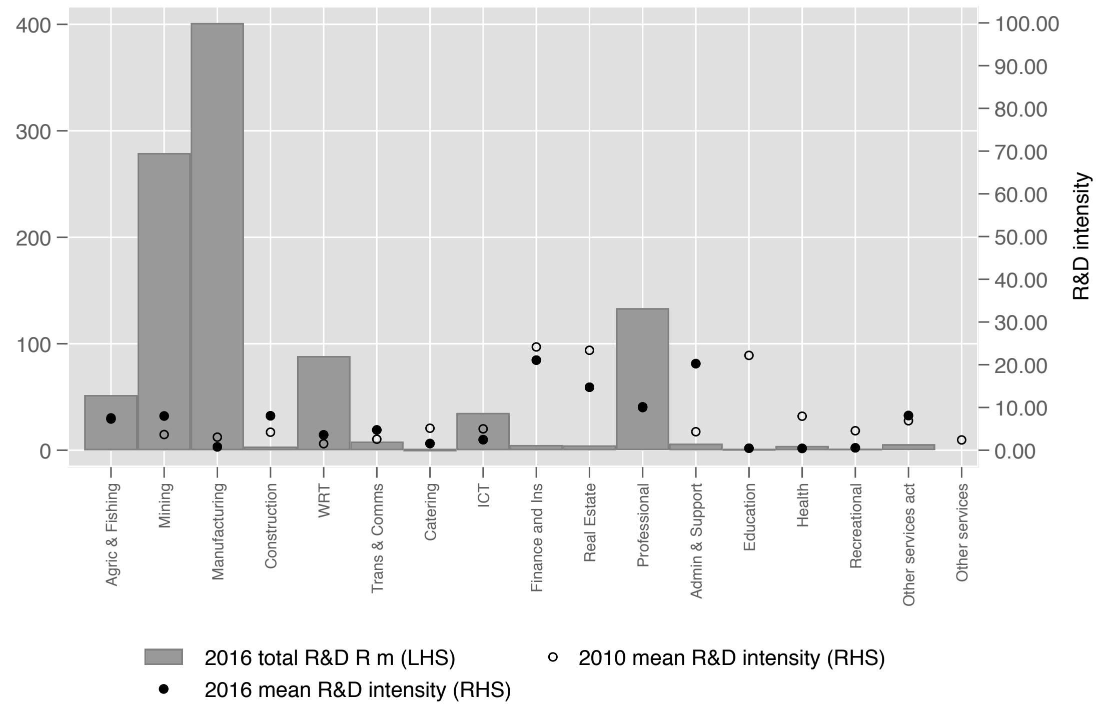
Source: author's calculations based on SARS-NT CIT Firm Panel.

In terms of export activities, the share of all firms that export rose from about 13 per cent to 15 per cent over this five-year period (Table A2). The manufacturing industry has, on average, the highest proportion of firms that export (37 per cent), followed by the mining sector. Figure 4 shows that although mining and manufacturing make up the majority of South African exports, the propensity towards increasing export intensity at the firm level is driven by tradable services, such as transport and communications and the FIRE sectors. Most studies focus on the manufacturing sector as the export-generating sector; however, in the South African context it is clear that many services industries are also involved in export activities. Of the firms that export, exports as a proportion of sales (export intensity) is on average merely 9 per cent. The primary sectors each have an average firm-level export intensity of about 17–18 per cent, whereas this figure is much lower at 8 per cent for manufacturing firms.

To understand what makes innovating firms different from non-innovating firms, Table A3 presents a simple unconditional difference of means between innovating firms and non-innovating firms, and separately for exporting and non-exporting firms, for a variety of firm characteristics. Innovating firms are on average older and substantially larger (measured by the number of employees) than non-innovating firms. Innovating firms have, on average, significantly higher employment growth, labour productivity, and lower profit margins than non-innovating firms. A significantly larger proportion of innovating firms are foreign-owned (or are foreign-connected through a parent company), and innovating firms have a higher export propensity than non-innovating firms. In addition, innovating firms have a higher share of high-tech products in total exports and are more integrated into global markets through having more export partners both within Africa and among OECD (Organisation for Economic Co-operation and Development) countries.

Many of these differences hold true when comparing exporting firms and non-exporting firms. Exporting firms are significantly older and larger, and have higher average employment growth and labour productivity than non-exporting firms. Similarly to innovating firms, exporting firms have, on average, lower profit margins than non-innovators and are also more likely to be foreign-owned.

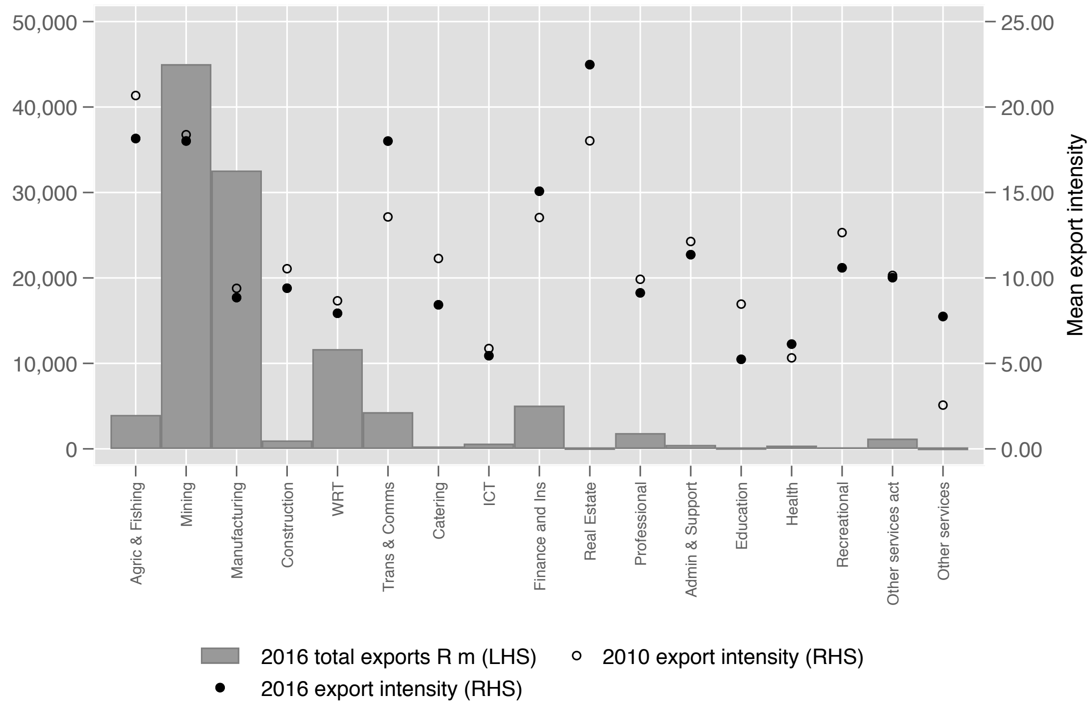
Figure 3: R&D expenditure and mean firm R&D intensity (2010–16)



Notes: the total R&D expenditure refers to the 2016 total expenditure by sector, in million rand.

Source: author's calculations based on SARS-NT CIT Firm Panel.

Figure 4: Export value and mean firm export intensity (2010–16)



Source: author's calculations based on SARS-NT CIT Firm Panel.

3 Innovation and employment

Before considering the direct and indirect (through exports) effects of innovation on employment, through a three-stage model, this section aims to estimate a simpler augmented labour demand model that provides the overall associations between innovation and employment growth at the firm level. Beginning from a simple firm CES (constant elasticity of substitution) production function with two inputs of capital and labour, a competitive firm maximizing profits leads to the following labour demand function in log form (Hamermesh 1993):

$$\ln L = \alpha' - \sigma \ln w + \ln Y, \tag{1}$$

where L represents log employment, w is the real wage, Y is output, and σ is the elasticity of substitution between capital and labour. From this theoretical grounding, seminal work by Van Reenen (1997) augmented this labour demand equation to include innovation and estimated in a dynamic form with a lagged dependent variable. There have been several applications and refinements of this model in the literature, which we follow in this paper (Bogliacino and Vivarelli 2012; Lachenmaier and Rottmann 2011). The following econometric equation is estimated in this paper:

$$l_{ijt} = \beta_0 + \alpha l_{ijt-1} + \beta_1 w_{ijt} + \beta_2 k_{ijt} + \beta_3 innovation_{ijt} + \beta_4 y_{jt} + \lambda_i + \alpha_t + \omega_{ijt}. \tag{2}$$

All variables are in log form, where l is firm employment, w is the average real wage per employee, k is the capital stock, *innovation* is R&D expenditure, and y is the two-digit industry-level sales and acts as a control for demand. In addition, there are firm fixed effects and year controls.

Our estimation approach acknowledges that dynamic specifications have the problem that the lagged dependent variable is by construction correlated with the individual fixed effect, therefore deeming OLS (ordinary least squares) to be biased and inconsistent. A fixed effect approach would improve upon this issue; however, the lagged dependent variable (in changes) is still correlated with the error term and in the case of the firm-level labour demand model may have endogenous right-hand side variables. Therefore, as is commonly practiced in this literature, we rely on an instrumental variable technique, generalized method of moments (GMM) (Arellano and Bond 1991; Arellano and Bover 1995), with system GMM being preferred over difference GMM in this case due to the short time dimension of the panel, which renders the former more efficient.

In the literature on R&D expenditure at the firm level, many studies point out the idea that R&D is often underreported by small- and medium-sized firms, and therefore is an imperfect proxy of their innovative efforts. In order to account for this, we run an additional specification that adds firm expenditure on licensed technologies to R&D expenditure, to arrive at a 'total innovation' measure.

The results for all firms are presented in Table 4, which shows the results for the OLS, fixed effects, difference GMM, and system GMM. The fourth specification is the preferred one as per the discussion above, with an adjustment coefficient on employment of 0.810, lying between the lower bound of the FE (biased downwards) regression and the upper bound of the OLS (biased upwards). As theory would predict, the coefficient on wages is negative and that on capital is positive. Our variable of interest is innovation, and the results confirm that innovation is positively associated with employment growth, controlling for initial size, wages, capital, and demand. To account for other types of innovation that may not be reported in R&D, we re-run the model using the 'total innovation' measure discussed above. The results are presented in Table A4 and are consistent with this set of results.

Table 4: Augmented labour demand model: all firms

Dep. var.: Employment$_t$	(1) Pooled OLS	(2) FE	(3) GMM diff.	(4) GMM sys.
Employment$_{t-1}$	0.862***	0.230***	0.653***	0.810***
	(0.013)	(0.042)	(0.126)	(0.044)
Wage$_t$	–0.079***	–0.241***	–0.423*	0.005
	(0.010)	(0.041)	(0.238)	(0.025)
Capital$_t$	0.062***	0.066***	0.136	0.117***
	(0.008)	(0.010)	(0.100)	(0.024)
Demand$_t$	0.002	–0.025*	0.164	–0.001
	(0.005)	(0.014)	(0.130)	(0.009)
Innovation$_t$	0.018***	0.012***	–0.012	0.035**
	(0.003)	(0.005)	(0.040)	(0.018)
Constant	0.377**	5.419***		
	(0.174)	(0.687)		
Observations	4,956	4,956	1,779	4,731
R^2	0.9480471	0.3219376		
AR(1) *p*-value			0.0045171	.01765
AR(2) *p*-value			0.4297958	0.4323227
Hansen *p*-value			0.4342968	0.1941493

Notes: robust standard errors are reported for OLS and FE. Two-step GMM, with corrected standard errors. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel..

Table 5 presents the results for manufacturing firms. The first four columns are for all manufacturing firms (different estimation approaches), the fifth is for manufacturing firms that export in every year of the data (continuous exporters), and columns six to eight represent manufacturing firms by technological classification. For all manufacturing firms, the results show that innovation is on average positively and significantly associated with employment growth, and the innovation coefficient is slightly larger than the average for all firms of all sectors. The coefficient of interest is slightly larger for established exporters (those that continuously export) and highest for firms in the high-tech category. Investment in innovation does not have a significant association with employment for firms in sectors classified as resourced-based manufacturing or low-tech sectors.

Table 5: Augmented labour demand model: manufacturing firms

Dep. var.:	All manufacturing				Cont. exporters	Resource-based	Low-tech	Medium-high-tech
Employment$_t$	Pooled OLS	FE	GMM diff.	GMM sys.	GMM sys.	GMM sys.	GMM sys.	GMM sys.
Employment$_{t-1}$	0.825***	0.177***	0.608***	0.749***	0.655***	0.657***	0.831***	0.664***
	(0.022)	(0.059)	(0.174)	(0.062)	(0.09)	(0.147)	(0.036)	(0.096)
Wage$_t$	–0.096***	–0.230***	–0.137	–0.017	–0.092**	–0.077	–0.060**	–0.044
	(0.017)	(0.071)	(0.142)	(0.034)	(0.043)	(0.067)	(0.027)	(0.045)
Capital$_t$	0.086***	0.085***	0.115	0.137***	0.167***	0.123*	0.091***	0.163***
	(0.013)	(0.017)	(0.097)	(0.033)	(0.048)	(0.069)	(0.024)	(0.049)
Demand$_t$	–0.013	–0.009	0.03	–0.023	–0.029	–0.009	–0.024	–0.001
	(0.009)	(0.032)	(0.191)	(0.015)	(0.019)	(0.043)	(0.019)	(0.03)
Innovation$_t$	0.014***	0.013**	–0.037	0.038*	0.041**	0.062	0.024	0.068**
	(0.003)	(0.006)	(0.026)	(0.021)	(0.017)	(0.042)	(0.022)	(0.031)
Observations	2,176	2,176	881	2,115	1,308	266	620	1,016
R^2	0.947	0.297						
AR(1) *p*-value			0.038	0.079	0.166	0.050	0.000	0.084
AR(2) *p*-value			0.245	0.263	0.214	0.165	0.971	0.256
Hansen *p*-value			0.110	0.098	0.454	0.499	0.289	0.583

Notes: Constant not shown. Robust standard errors are reported for OLS and FE. Two-step GMM, with corrected standard errors. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

4 The innovation–export nexus in South Africa

4.1 Descriptive evidence of linkages between innovation and exports

The previous section confirmed that innovators are more likely to be exporters than non-innovators, and that exporters are more likely to innovate than non-exporters. This section aims to identify the overlap between the two through classifying firms into mutually exclusive groups of export–innovation status, and the next section will formally test the linkages between innovation and exports. Section 4.2 provides a more formal estimation model of the relationship between innovation and exports at the firm level.

As shown in Table 6, the large majority of South African firms, 85 per cent, do not simultaneously invest in R&D activities and participate in exporting. Less than 1 per cent engage in both activities simultaneously. The proportion of firms spending on R&D and participating in exports is higher in the manufacturing sector at 2 per cent, followed by the mining sector at 1.6 per cent of firms.

A closer look at the manufacturing sector in Table A5 shows that there is a higher propensity to engage in R&D investment across a range of subsectors even among domestic-oriented firms, relative to the economy-wide average shown in Table 6. Sectors with the highest share of firms that both invest in R&D and export are computer, electronics and optical products, pharmaceuticals, and other electrical equipment. These are medium- and high-tech sectors that would be expected to have higher levels of innovation. The commodity-based manufactures also seem to have a higher than average (for the manufacturing sector) share of firms that engage in both activities.

Table 6: Proportion of firms by innovation and export status (percentage)

	No R&D, no exports	Only R&D	Only exports	R&D and exports
Agriculture, forestry, and fishing	87.00	0.90	11.50	0.70
Mining and quarrying	78.50	0.80	19.20	1.60
Manufacturing	64.30	0.60	33.00	2.00
Construction	94.20	0.20	5.50	0.10
Wholsesale and retail	81.60	0.20	17.90	0.30
Transport, storage, and communication	86.20	0.10	13.60	0.10
Catering and accommodation	96.90	0.20	2.80	0.10
Information and communication	88.90	0.90	9.80	0.40
Financing and insurance	97.10	0.30	2.50	0.10
Real estate activities	98.80	0.10	1.00	0.00
Professional, scientific, and technical activities	92.00	0.60	7.00	0.40
Administrative and support service activities	94.10	0.30	5.40	0.10
Educational services	97.20	0.60	2.10	0.10
Human health and social work	94.20	0.30	5.30	0.20
Recreational and cultural services	91.40	0.50	7.80	0.30
Other service activities	89.90	0.20	9.80	0.20
Other services	85.40	0.30	14.30	0.00
Total	86.50	0.40	12.60	0.50

Notes: each column represents the cross-year average.

Source: author's calculations based on SARS-NT CIT Firm Panel.

The transition matrix shown in Table 7 provides the average transition probability across all years for all firms in the top panel, and for manufacturing firms in the bottom panel. The results suggest that almost all firms that have no R&D expenditures nor exports remain in the same status category each year. There is also a strong persistence in exporting activities: there is about an 84 per cent chance that firms with only exports (no R&D) continue to remain in this category, with a 1 per cent chance of moving to the category of having both R&D and export activities. For firms that pursue both activities, there is a 59 per cent probability that these firms will remain in this category; however, almost all of these firms remain exporters over time. Therefore, the probability of remaining an exporter seems higher in firms with initial spending on R&D. For the manufacturing sector, there is higher persistence in both R&D and export activities over time. In addition, there is greater mobility into these activities; for example, of the firms with only R&D investment, there is a 6 per cent probability of obtaining R&D and export status, compared to 3 per cent for the entire economy. Similarly, for firms with participation in neither of these activities, there is a greater probability of moving into any of the other categories than for the overall firm average.

Table 7: Transition matrix: R&D–innovation status

All firms

		No R&D, no exports t	Only R&D t	Only exports t	Both t
No R&D, no exports	$t-1$	98.06	0.16	1.77	0.01
Only R&D	$t-1$	55.55	38.33	2.76	3.36
Only exports	$t-1$	15.13	0.07	83.83	0.97
Both	$t-1$	2.84	2.51	35.72	58.93

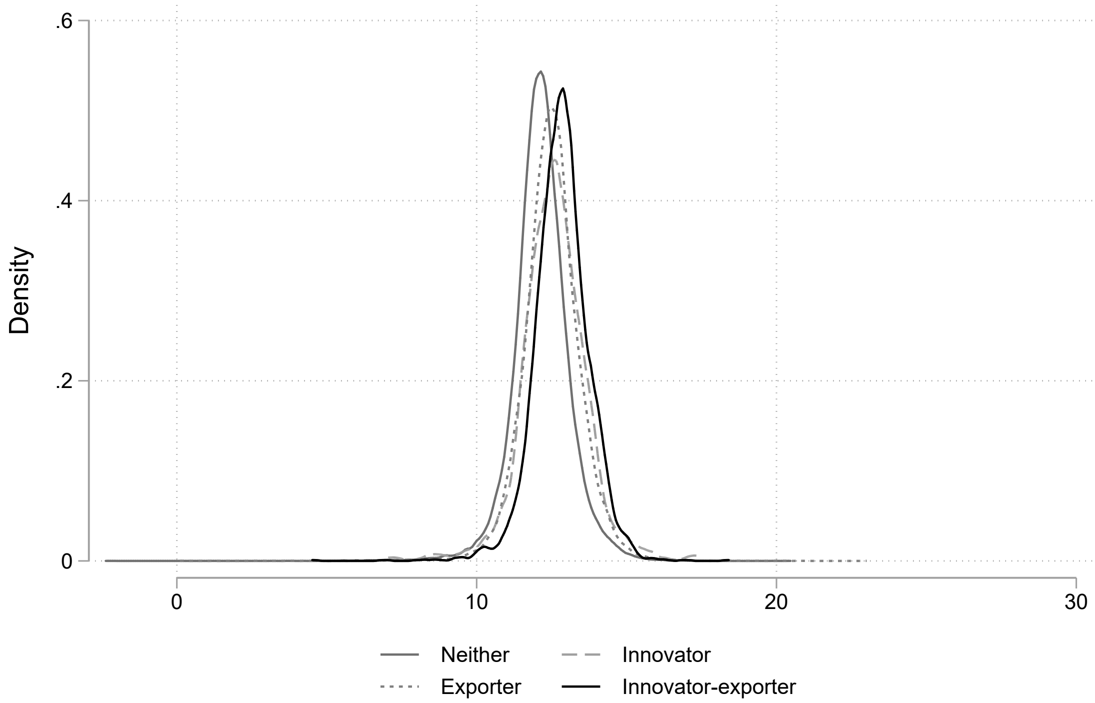
Manufacturing firms

		No R&D, no exports t	Only R&D t	Only exports t	Both t
No R&D, no exports	$t-1$	94.21	0.34	5.40	0.05
Only R&D	$t-1$	44.20	46.26	3.66	5.88
Only exports	$t-1$	11.99	0.07	86.34	1.61
Both	$t-1$	1.61	1.61	32.90	63.87

Source: author's calculations based on SARS-NT CIT Firm Panel.

This section has shown that South African firms have a low propensity to spend on R&D, and this spending is variable over time. The manufacturing sector has the highest proportion of firms engaging in R&D, but at a lower intensity relative to firms in agriculture, mining, and several services subsectors. Exporters, however, tend to persist in export markets over time. In addition, the manufacturing sector has a lower export intensity relative to the primary sectors. There are important linkages between R&D investment and exporting, in that firms that initially engage in R&D have a higher probability of participating in export markets and vice versa. In addition, exporting firms that also engage in R&D export on average a larger share of output, are less reliant on imports, and have a greater number of trading partners. Therefore, R&D investments may be part of the explanation of the differences in productivity between non-exporters and exporters. As Figure 5 illustrates, firms that engage in innovation and export participation are more productive than firms that only export, and in turn more productive than firms that do neither activity.

Figure 5: Labour productivity by innovation–export status



Notes: labour productivity is measured as (log) value added per worker.

Source: author's calculations based on SARS-NT CIT Firm Panel.

4.2 Estimating the linkages between innovation and exporting

The research questions asked in this section are about the linkages between the firm decisions to invest in R&D and to participate in exports. The empirical estimation builds on the theoretical work of Aw et al. (2008). The theoretical model is motivated by the findings that larger and more productive firms enter into export markets; however, the feedback from export activity to productivity has not been thoroughly investigated. In addition, there is little evidence on how innovation, which potentially impacts productivity, impacts export behaviour at the firm level.

In this model, R&D investment and investment in physical capital can be seen as channels to improve future productivity for the firm, and could therefore increase the potential returns from exporting. In return, export participation raises the returns to investment in R&D and could therefore encourage investments in it as a result of export participation. In addition, if the assumption is that there are sunk costs associated with both exporting and R&D, then the decision to engage in these activities will depend on prior status.[2] The decision equations can be summarized as follows:

$$\begin{aligned} \mathrm{X}_t &= \mathrm{f}(\theta_{it}, \mathrm{k}_t, \mathrm{RD}_{t-1}, \mathrm{X}_{t-1}) \\ \mathrm{RD}_t &= \mathrm{f}(\theta_{it}, \mathrm{k}_t, \mathrm{RD}_{t-1}, \mathrm{X}_{t-1}) \\ \mathrm{LP}_t &= \mathrm{f}(\theta_{it}, \mathrm{k}_t, \mathrm{RD}_{t-1}, \mathrm{X}_{t-1}), \end{aligned}$$

where θ represents profitability, k is the capital stock, X represents export participation or intensity, RD represents R&D investment or intensity, and LP represents labour productivity (real value added per worker). All variables are described in Table A6. The log of R&D intensity and export intensity are calculated according to the inverse hyperbolic sine transformation so that the log of the variable is also defined at zero and otherwise can be interpreted similarly to a standard log transformation of the variable.

A dynamic panel model has the issues of both individual-level unobserved heterogeneity and correlation between the lagged dependent variable and the disturbance term. To deal with these issues, the Arellano–Bond estimator is typically used, which is based on a GMM framework that specifies the model as a system of equations, one per time period. This approach is suitable when there are few time periods and many individual units, as is the case here. We employ a slight improvement on the original Arellano–Bond difference GMM—the system GMM estimator. The manufacturing sector is of particular interest in this analysis, but the model was also estimated on the entire sample, which is presented in Table A7.

The results for the manufacturing sector in Table 8 suggest that firms with prior R&D investments are 8.5 per cent more likely to export in the future. On the intensive margin, firms with a higher R&D intensity are associated with higher export intensity—a 1 per cent increase in R&D intensity is associated with a 0.77 per cent increase in export intensity. This confirms a positive and significant relationship that implies R&D investments improve firm export performance. In addition, the magnitude of the relationship between prior innovation and exporting is stronger than for all firms, suggesting that investments in innovation are particularly important for manufacturing firms' export performance. These results that suggest a positive effect of innovation on export participation are in line with the findings of Aw et al. (2008) and Caldera (2010).

When assessing the direction of the relationship from exporting to investments in innovation, the evidence is weaker. The results suggest that the likelihood of investing in innovation is only marginally increased by the firm's prior export status. Regarding the intensive margin, the results do not show a significant impact of higher prior export intensity on innovation intensity. It would seem that the returns to innovation are not perceived to increase once firms have entered export markets, therefore firms do not respond with higher rates of innovation. Finally, the results show that prior innovation activity and export participation are drivers of labour productivity growth.[3]

[2] Or, if R&D creates a stock of knowledge, then the prior stock, which is often proxied by R&D expenditure itself, would also enter the R&D and export decision.

[3] The Hansen test suggests the problem of weak instruments for both of the labour productivity regressions, which suggests caution is required in the interpretation of these results

Table 8: Innovation, exports and productivity: manufacturing firms

	(1) Export dummy	(2) Export intensity	(3) RD dummy	(4) RD intensity	(5) L Prod	(6) L Prod
R&D dummy$_{t-1}$	0.085**		0.427***		0.117**	
	(0.037)		(0.028)		(0.055)	
Exporter dummy$_{t-1}$	0.942***		0.017***		0.097**	
	(0.293)		(0.003)		(0.043)	
R&D intensity$_{t-1}$		0.768**		0.756***		–0.029
		(0.335)		(0.164)		(0.047)
Export intensity$_{t-1}$		0.313***		0.002		0.033***
		(0.094)		(0.002)		(0.013)
Labour productivity$_{t-1}$					0.539***	0.572***
					(0.166)	(0.160)
Observations (firm-year)	1,890	1,882	25,105	25,057	13,978	13,978
AR(1) *p*-value	0.0064561	3.88e-15	1.79e-45	.0000267	4.66e-07	1.16e-07
AR(2) *p*-value	0.1908425	0.8810052	0.1711853	0.8232171	0.2324932	0.1546228
Hansen *p*-value	0.4712448	0.008018	0.0792025	0.2897604	0.08349	0.068395

Notes: all specifications include profit margin and capital stock as controls. Constant also not shown here. Two-step system GMM with corrected standard errors. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

5 The direct and indirect effects of innovation on employment

This section explores the research question relating to the impact of R&D and exports on firm-level employment growth, when accounting for the relationship between R&D and exports. The analysis in the previous section pointed to a significantly positive relationship between investing in R&D and exporting at the firm level, which motivates the use of the three-stage model in the South African context. An important benefit of the three-stage model is that we can separate out the direct effects of innovation and the indirect effect of innovation on firm growth.

5.1 Econometric model

The research design makes use of the panel dimension of the data of heterogeneous firms so that the effect can be identified through controlling for unobserved time-invariant firm effects. The fixed effect estimator is a 'within estimator', and therefore is able to estimate how the changes in R&D investment intensity and export intensity impacts annual employment growth for each firm over time. Other factors that would impact employment growth at the firm level are controlled for (time-varying firm- and sector-level covariates).

Following the literature on this topic, the impact of exports and R&D on firm-level employment is modelled in three steps, adapting the approaches of Hall et al. (2009) and Di Cintio et al. (2017). The first step deals with any potential selection problem and estimates the R&D intensity decision for each firm that has positive R&D expenditures, which results in a predicted R&D intensity variable that is the unobserved latent variable representing the firm's innovation effort. Before doing this, it is acknowledged that firms may self-select into R&D activities and/or export activities, given their initial characteristics. This may lead us to overestimate the effect of R&D investment or exports on employment growth. In order to deal with this problem, prior to step 1, a two-stage Heckman selection model will be estimated to assess the potential of self-selection.

The second step models export intensity that is due to R&D investment, where some firms may export without having any R&D expenditures. Given that there may be a simultaneity problem as firms make a joint decision to invest in R&D and participate in exports, using the predicted R&D intensity variable in this second stage acts as an instrument. In the final stage, the core regression examines the impact of R&D intensity through a direct channel and an indirect channel through exports on employment growth at the firm level.

Given that the model is estimated sequentially and in the second and third stage there are predicted values from the previous stage that are generated with error, the standard errors in these stages will be underestimated and thus there will be an overstatement of significance (Pagan 1984). In addition, the panel feature of the data makes it susceptible to error heteroscedasticity and/or error correlation within clusters (e.g. firms or subsectors). Therefore, to improve the accuracy of inference, this approach implements a bootstrap procedure for all stages to correct the standard errors, as is common in the literature (Cameron et al. 2008; MacKinnon 2006). The model is described formally below.

First stage: obtain predicted R&D values

The literature highlights the problem of underreporting of R&D expenditures by small and medium enterprises (which are the large majority of South African firms). To address this problem, the first step of the econometric model assumes that a latent variable of R&D intensity can be observed as a function of a set of independent variables, which is modelled via a Tobit model as follows, for firm *i*, in industry *j*, in time *t*:

$$\widetilde{\ln RD_{ijt}} = \beta_0 + \beta_1 Z_{it} + \beta_2 ind_{jt} + \varepsilon_{ijt}. \tag{3}$$

The dependent variable is the ratio of R&D expenditure to sales, in log form. *Z* represents a vector of firm characteristics: firm size, age, labour intensity, and foreign ownership; *ind* is a vector of industry-related characteristics, such as the competitive nature of the industry and demand. In addition, the equation includes dummy variables at the two-digit industry level to capture industry-specific shocks, year dummies to capture the time trend affecting all firms, as well as a random error term. From this, the latent R&D intensity variable can be related to observed R&D intensity as follows:

$$\ln RD_{ijt} = \begin{cases} \widetilde{\ln RD_{ijt}}, & \text{if } \widetilde{\ln RD_{ijt}} > 0 \\ 0, & \text{if } \widetilde{\ln RD_{ijt}} \leq 0. \end{cases} \tag{4}$$

Second stage: estimate the innovation–export relationship

The predicted values from Equation 3, $\widehat{\ln RD_{it}}$ are used in the regression that estimates the export–innovation relationship. The dependent variable is the log ratio of exports to sales for firm *i*, in industry *j*, at time *t*. The remaining explanatory variables are the same as the previous step, including the industry- and year-level dummies. This Tobit model is specified as follows:

$$\ln XRatio_{ijt} = \gamma_0 + \gamma_1 \widehat{\ln RD_{it}} + \gamma_2 Z_{it} + \gamma_3 ind_{jt} + \mu_{ijt}. \tag{5}$$

Third stage: estimate the impact of innovation and exports on employment growth

The predicted values from Equation 5 ($\ln \widehat{XRatio_{it}}$) represent the portion of exports that are explained by R&D and the other controls–the indirect R&D effect. The final stage is the core regression estimating the impact of the direct R&D effect and the indirect R&D effect on firm-level employment growth, using firm and year fixed effects:

$$\ln empg_{ijt} = \eta_0 + \eta_1 \widehat{\ln RD_{it}} + \eta_2 \ln \widehat{XRatio_{it}} + \eta_3 Z_{it} + \eta_4 ind_{jt} + \lambda_i + \alpha_t + \omega_{it}. \tag{6}$$

The dependent variable is expressed as the annual log change in employment for each firm.

5.2 Results

The results discussed here focus on the manufacturing sector. In order to identify any potential selection problems relating to firms selecting into R&D investment, we run a richly specified Heckman two-stage selection model that would explain differences in R&D intensity (Table 9). From the first stage (column (1)), the inverse Mills ratio is included in the second stage (column (2)) regression of R&D intensity where it is found to be significant. Therefore, we run the Tobit model with the selection variable, which is presented in the rightmost of Table 9. The results show that firms that are more labour intensive have a significant and positive association with R&D intensity. The predicted values from this stage are used in the second stage regression to investigate the relationship between export intensity and innovation.

Table 9: Accounting for underreporting of R&D

	(1)	(2)	R&D intensity
Firm size (log)	–0.604***	0.272***	–0.046
	(0.114)	(0.013)	(0.029)
Labour intensity (log)	0.340***	0.067***	0.030*
	(0.087)	(0.024)	(0.017)
HHI	–1.332	0.599	–0.210
	(2.737)	(0.702)	(0.847)
Investment rate	0.000	0.000	–0.000
	(0.000)	(0.000)	(0.000)
LT debt/equity (log)	0.089*	0.002	0.008
	(0.052)	(0.012)	(0.012)
Firm age (log)	0.038	–0.036	–0.014
	(0.109)	(0.026)	(0.030)
Demand (log)	0.307	–0.024	0.019
	(0.279)	(0.055)	(0.049)
Import intensity (log)	0.185	0.024	–0.010
	(0.354)	(0.084)	(0.085)
Foreign competition	–1.978	–0.153	–0.184
	(2.188)	(0.527)	(0.583)
Inverse mills		–2.080***	–1.297***
		(0.491)	(0.142)
Constant	19.065	–3.163	3.042
	(16.946)	(4.052)	(4.455)

Notes: Number of firm-year observations: 19,890. The Heckman first and second stage are shown in columns (1) and (2). The selection equation includes prior innovation status as a selection control. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

A similar Heckman two-stage selection model was estimated for selection into export participation; the inverse Mills ratio from the first stage is not significant in the second stage, suggesting no selection bias among manufacturing firms (Table 10, columns (1) and (2)). We then estimate the export–innovation relationship via a Tobit model, with the dependent variable being export intensity. Importantly, the results show a positive and significant relationship between R&D intensity and export intensity when controlling for a range of firm- and industry-level controls, shown in the rightmost of Table 10. In addition, the results show that larger firms, less labour-intensive firms, and older firms are associated with higher export intensity. The predicted values from this regression are used in the next stage in order to analyse the indirect effects of innovation.

Table 10: Estimating the innovation–export relationship

	(1)	(2)	Export intensity
Direct R&D effect	2.200**	–1.377**	2.461***
	(0.858)	(0.678)	(0.708)
Firm size (log)	–0.025	0.342***	0.229***
	(0.030)	(0.014)	(0.016)
Labour intensity (log)	–0.006	–0.204***	–0.268***
	(0.028)	(0.015)	(0.017)
HHI	–0.919	1.085**	0.837
	(0.960)	(0.536)	(0.740)
Investment rate	–0.000	–0.000	–0.000*
	(0.000)	(0.000)	(0.000)
LT debt/equity	–0.023	0.001	–0.020*
	(0.015)	(0.008)	(0.010)
Firm age (log)	0.201***	0.314***	0.437***
	(0.041)	(0.018)	(0.026)
Demand (log)	–0.014	–0.032	–0.018
	(0.064)	(0.034)	(0.051)
Import intensity (log)	0.117	–0.041	–0.046
	(0.107)	(0.055)	(0.071)
Foreign competition	0.537	0.128	0.413
	(0.650)	(0.339)	(0.528)
Inverse mills		0.109	
		(0.157)	
Constant	–8.657*	–7.607***	–8.795**
	(5.039)	(2.609)	(4.089)

Notes: number of firm-year observations: 19,812. The Heckman first and second stage are shown in columns (1) and (2). The selection equation includes prior export status as a selection control. Bootstrapped standard errors are presented. Tobit regression in the rightmost includes year and industry controls. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

The final stage aims to identify the direct and indirect impact of innovation on employment growth, shown in Table 11, using firm and year fixed effects. We find that the direct effect of R&D on employment growth is significant and positive; however, the indirect effect through exports slightly offsets this (it is significant and negative). Our results suggest that a 1 per cent increase in R&D intensity is associated with a 7.7–11.6 per cent increase in firm growth. The indirect R&D effect, through exports, is negatively associated with employment growth, but is of a considerably smaller magnitude than the direct R&D coefficient, therefore resulting in an overall positive effect. Firm size and firm age are also significant determinants of firm growth, suggesting that larger firms have higher rates of growth, whereas older firms grow more slowly.

5.3 Heterogeneous effects

To understand how these effects may differ by different groups of firms, the same three-stage model was estimated on various subsamples of manufacturing firms. The third-stage results are presented in Table 12. The first column is for firms that are more established exporters in that this set of firms reports positive exports for every year in the sample. The pattern of results is similar to that of all manufacturing firms; however, the direct innovation effect on firm growth is smaller in magnitude. This suggests that while innovation is important for a firm's ability to enter export markets and improve export performance, for continuously exporting firms there is a lesser impact on firm growth.

Table 11: Effect of innovation and exports on employment growth: manufacturing firms

	Employment growth	Employment growth
Direct R&D effect	7.715***	11.639***
	(0.827)	(0.971)
Indirect R&D effect	–0.126***	–0.296**
	(0.035)	(0.128)
Firm size (log)	0.578***	0.560***
	(0.034)	(0.036)
Labour intensity	0.006	–0.038
	(0.017)	(0.027)
HHI	–0.230*	11.638
	(0.128)	(9.024)
Investment rate	0.000	–0.000
	(0.000)	(0.000)
LT debt/equity	–0.005*	–0.009**
	(0.003)	(0.004)
Firm age (log)	–0.382***	–0.338***
	(0.065)	(0.075)
Demand	–0.018**	–0.016
	(0.008)	(0.011)
Import intensity	–0.026**	0.256
	(0.011)	(0.200)
Foreign competition	0.004	–0.154**
	(0.014)	(0.070)
Constant	–1.106***	–1.033
	(0.326)	(0.792)

Notes: number of firm-year observations: 19,812. Bootstrapped standard errors are presented. Column 1 has firm and year fixed effects, column 2 has firm and industry-year interacted fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

Table 12: Effect of R&D and exports on employment growth: manufacturing subsamples

	Cont. exporters	Resource-based	Low-tech	Medium-/high-tech	Small firms	Large firms
Direct R&D effect	8.398***	12.103***	12.923***	8.293***	2.277***	3.148***
	(2.638)	(1.972)	(1.724)	(1.252)	(0.523)	(0.450)
Indirect R&D effect	–0.264***	–0.347***	–0.233*	–0.009	–0.508***	–0.675***
	(0.081)	(0.105)	(0.121)	(0.078)	(0.036)	(0.045)

Notes: bootstrapped standard errors are presented. All regressions have firm and year fixed effects. Constant and controls are not shown. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

Looking at the different technology classes separately, the magnitude of the direct R&D effect on firm growth is highest for resource-based and low-tech manufacturing sectors, relative to medium- and high-tech sectors. This may indicate that the more stringent competition that South African firms face in high-tech sectors, such as firms from advanced countries that are at the technological frontier, dampens firm performance. Finally, the comparison of small and large firms shows that the overall innovation effects on firm growth are predominantly driven by larger firms. In addition, the coefficient on firm size from the previous table also indicates that larger firms exhibit more rapid employment growth, signalling the importance of large firms for employment creation in South Africa.

6 Conclusion

The interrelationships between innovation, exports, and firm growth continue to attract considerable interest among economic scholars. This paper first investigates how firms' investments in innovation affect their subsequent export performance and productivity, and how firms' export activities affect their subsequent innovation efforts and productivity. Second, the paper investigates how firms' investments in innovation and export performance are related to employment growth. While some analysis has been conducted for firms across all sectors, this study focused on the manufacturing sector, which is the main sector of interest within this strand of the literature since it typically accounts for the majority of exports and R&D. The study makes use of the new South African SARS-NT Firm Panel Dataset, which is the largest firm-level dataset available in South Africa. The data cover all registered firms in South Africa over the 2010–16 period.

This study provides extensive descriptive evidence of the pattern of R&D and export activities for firms operating in South Africa. We highlight some important linkages between innovation and export participation. The results show that firms with prior R&D investment are more likely to export, and there is a positive relationship between R&D intensity and export intensity at the firm level. There is weaker evidence to suggest that export participation leads to increased innovation intensity at the firm level. The theory outlined predicts that higher rates of innovation would follow from higher returns due to export participation, but export participation does not seem to raise the returns to innovation among South African firms. Finally, the results show that prior innovation activity and export participation are positively associated with subsequent labour productivity growth.

In estimating the linkages between innovation, export performance, and firm employment growth, the approach controls for self-selection and the results reveal that direct R&D investments are associated with higher firm growth rates. R&D-induced exports, however, are negatively related to firm growth, but the effect is considerably smaller than the direct R&D effect. Overall, the results find a positive link between innovation and employment growth at the firm level. This reflects the idea that innovation can have both labour-absorbing and labour-displacing effects, conditional on whether it is associated with output growth or is related to process innovation. The results suggest that firms that participate in international markets may have a stronger focus on productivity enhancements to improve competitiveness (along with product innovation), given that they face stronger competition. A limitation of this study is the inability to separate R&D into the types of innovation—or better yet, to have measures of innovation outputs—and so this represents an important area for future research. Another promising area of future research in this context is to understand more precisely the types of workers that are affected by increased innovation—for example, the impact on the firm-level skills ratio.

From a policy perspective, these results highlight the importance of R&D-related policies that support and promote investments in innovative products. It is innovating firms that are more productive that will be able to compete in international markets and improve firm performance. One pillar of the government of South Africa's approach to increase the rate of private-sector R&D investment is the R&D tax incentive under section 11D of the Income Tax Act (Act No. 58 of 1962), introduced in 2007. Companies that undertake eligible forms of R&D are qualified for a 150 per cent tax deduction and, in addition, companies are eligible for accelerated depreciation on capital used for R&D purposes.[4] However, the SARS-NT Firm Panel Dataset indicates that, of the firms that spent on R&D over the 2010–16 period, about 80–87 per cent do not receive the tax benefit each year (Table A8), which could indicate that the expenditures did not meet the requirements of the policy, companies may not be aware of the incentive, or there are administrative backlogs in approving the incentive. In addition, of the companies that are receiving the tax debit, more companies claim the incentive on accelerated depreciation on capital rather than on the direct innovation expenditures. Parliamentary reports have also shown that there are long waiting times before companies are notified of their eligibility for the tax benefit. Future research on the effectiveness of the policy is needed to inform a broader national innovation policy.

Finally, it is widely acknowledged that it is important to promote the small and medium enterprise (SME) sector for a more inclusive economy. These results suggest that innovation among SMEs is positively associated with firm growth, but that large firms also have an important role as innovators and employment creators. Finally, the direct and indirect innovation effects on growth are largest in the resource-based and low-tech manufacturing sectors, reflecting South Africa's existing comparative advantage. As indicated at the outset, if the South African economy is to transition towards higher value added sectors, the national innovation policy needs to support these emerging sectors.

[4] See Appendix A4 for an explanation of the policy.

References

Arellano, M., and S. Bond (1991). 'Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations'. *The Review of Economic Studies*, 58(2): 277.

Arellano, M., and O. Bover (1995). 'Another Look at the Instrumental Variable Estimation of Error-Components Models'. *Journal of Econometrics*, 68(1): 29–51.

Aw, B.Y., M.J. Roberts, and D.Y. Xu (2008). 'R&D Investments, Exporting, and the Evolution of Firm Productivity'. *The American Economic Review*, 98(2): 451–56.

Bogliacino, F., and M. Vivarelli (2012). 'The Job Creation Effect of R&D Expenditures'. *Australian Economic Papers*, 51(2): 96–113.

Caldera, A. (2010). 'Innovation and Exporting: Evidence from Spanish Manufacturing Firms'. *Review of World Economics*, 146(4): 657–89.

Cameron, A.C., J.B. Gelbach, and D.L. Miller (2008). 'Bootstrap-Based Improvements for Inference with Clustered Errors'. *The Review of Economics and Statistics*, 90(3): 414–27.

Dachs, B., and B. Peters (2014). 'Innovation, Employment Growth, and Foreign Ownership of Firms'. *Research Policy*, 43(1): 214–32.

Di Cintio, M., S. Ghosh, and E. Grassi (2017). 'Firm Growth, R&D Expenditures and Exports: An Empirical Analysis of Italian SMEs'. *Research Policy*, 46(4):836–52.

Esteve-Pérez, S., and D. Rodríguez (2013). 'The Dynamics of Exports and R&D in SMEs'. *Small Business Economics*, 41(1): 219–40.

Gerschenkron, A. (1962). *Economic Backwardness in Historical Perspective: A Book of Essays*. Cambridge, MA: Belknap Press of Harvard University Press.

Hall, B.H., F. Lotti, and J. Mairesse (2009). 'Innovation and Productivity in SMEs: Empirical Evidence for Italy'. *Small Business Economics*, 33(1): 13–33.

Hamermesh, D. (1993). *Labor Demand*. Princeton, NJ: Princeton University Press.

Harrison, R., J. Jaumandreu, J. Mairesse, and B. Peters (2014). 'Does Innovation Stimulate Employment? A Firm-Level Analysis Using Comparable Micro-Data from Four European Countries'. *International Journal of Industrial Organization*, 35: 29–43.

Lachenmaier, S., and H. Rottmann (2011). 'Effects of Innovation on Employment: A Dynamic Panel Analysis'. *International Journal of Industrial Organization*, 29(2): 210–20.

Lall, S. (1992). 'Technological Capabilities and Industrialization'. *World Development*, 20(2): 165–86.

Lall, S. (1993). 'Promoting Technology Development: The Role of Technology Transfer and Indigenous Effort'. *Third World Quarterly*, 14(1): 95–108.

Lee, K. (2013). *Schumpeterian Analysis of Economic Catch-Up: Knowledge, Path-Creation, and the Middle-Income Country Trap*. Cambridge: Cambridge University Press.

Lee, K., and B.-Y. Kim (2009). 'Both Institutions and Policies Matter but Differently for Different Income Groups of Countries: Determinants of Long-Run Economic Growth Revisited'. *World Development*, 37(3): 533–49.

Lee, K., and C. Lim (2001). 'Technological Regimes, Catching-Up and Leapfrogging: Findings from the Korean Industries'. *Research Policy*, 30: 459–83.

MacKinnon, J.G. (2006). 'Bootstrap Methods in Econometrics'. *Economic Record*, 82(s1): S2–S18.

Nelson, R. R. (2008). 'Economic Development from the Perspective of Evolutionary Economic Theory'. *Oxford Development Studies*, 36(1): 9–21.

Neves, A., A.A.C. Teixeira, and S.T. Silva (2016). 'Exports–R&D Investment Complementarity and Economic Performance of Firms Located in Portugal'. *Investigación Económica*, 75(295): 125–56.

Pagan, A. (1984). 'Econometric Issues in the Analysis of Regressions with Generated Regressors'. *International Economic Review*, 25(1): 221–47.

Rodrik, D. (2006). 'Industrial Development: Stylized Facts and Policies'. In: *Industrial Development for the 21st Century*. New York: United Nations, Department of Economic and Social Affairs.

Stiglitz, J.E. (2011). 'Rethinking Development Economics'. *The World Bank Research Observer*, 26(2): 230–36.

Van Reenen, J. (1997). 'Employment and Technological Innovation: Evidence from U.K. Manufacturing Firms'. *Journal of Labor Economics*, 15(2): 255–84.

Appendix

A1 Innovation and exporting

Table A1: Proportion of innovating firms by year (percentage)

	2010	2011	2012	2013	2014	2015	2016
	Mean / SD	Mean / SD	Mean / SD	Mean / SD	Mean / SD	Mean / SD	Mean / SD
Agriculture, forestry, and fishing	2.00	2.20	2.00	1.20	1.20	1.00	1.10
	0.14	0.15	0.14	0.11	0.11	0.10	0.11
Mining and quarrying	2.90	2.60	2.70	2.10	1.80	2.10	2.50
	0.17	0.16	0.16	0.14	0.13	0.14	0.16
Manufacturing	3.50	3.50	3.20	2.40	2.00	2.00	1.90
	0.18	0.18	0.18	0.15	0.14	0.14	0.14
Construction	0.40	0.40	0.40	0.20	0.10	0.10	0.10
	0.06	0.06	0.06	0.04	0.03	0.04	0.04
Wholesale and retail	0.70	0.60	0.60	0.30	0.30	0.30	0.30
	0.08	0.08	0.08	0.06	0.05	0.06	0.06
Transport, storage, and communication	0.30	0.40	0.30	0.10	0.10	0.10	0.10
	0.06	0.06	0.06	0.03	0.04	0.03	0.04
Catering and accommodation	0.60	0.40	0.40	0.20	0.10	0.10	0.10
	0.08	0.06	0.06	0.05	0.03	0.04	0.03
Information and communication	1.90	2.40	1.70	0.90	0.90	0.80	0.90
	0.14	0.15	0.13	0.09	0.09	0.09	0.10
Financing and insurance	0.60	0.60	0.50	0.20	0.20	0.20	0.20
	0.08	0.08	0.07	0.05	0.04	0.05	0.05
Real estate activities	0.30	0.20	0.20	0.10	0.00	0.10	0.10
	0.06	0.04	0.04	0.03	0.02	0.04	0.03
Professional, scientific, and technical activities	1.50	1.50	1.30	0.70	0.60	0.60	0.70
	0.12	0.12	0.11	0.08	0.08	0.08	0.08
Administrative and support service activities	1.00	0.80	0.70	0.30	0.20	0.20	0.20
	0.10	0.09	0.08	0.05	0.05	0.05	0.05
Educational services	1.30	1.20	1.00	0.60	0.10	0.40	0.40
	0.11	0.11	0.10	0.08	0.04	0.06	0.06
Human health and social work	0.90	1.10	0.80	0.30	0.20	0.40	0.20
	0.10	0.11	0.09	0.06	0.05	0.06	0.05
Recreational and cultural services	2.10	1.30	1.30	0.40	0.30	0.20	0.40
	0.14	0.11	0.11	0.06	0.06	0.05	0.06
Other service activities	0.60	0.60	0.50	0.20	0.20	0.20	0.20
	0.08	0.08	0.07	0.05	0.04	0.05	0.05
Other services	0.60	0.50	0.50	0.00	0.00	0.00	0.00
	0.08	0.07	0.07	0.00	0.00	0.00	0.00
Total	1.20	1.20	1.10	0.70	0.50	0.60	0.60
	0.11	0.11	0.10	0.08	0.07	0.07	0.08

Source: author's calculations based on SARS-NT CIT Firm Panel.

Table A2: Proportion of firms that export (%)

	2010 Mean / SD	2011 Mean / SD	2012 Mean / SD	2013 Mean / SD	2014 Mean / SD	2015 Mean / SD	2016 Mean / SD
Agriculture, forestry, and fishing	13.00	12.30	12.00	12.50	12.80	12.40	10.10
	0.34	0.33	0.33	0.33	0.33	0.33	0.30
Mining and quarrying	21.50	20.60	21.50	21.00	21.20	21.60	17.60
	0.41	0.40	0.41	0.41	0.41	0.41	0.38
Manufacturing	34.30	34.70	35.60	36.20	36.40	37.50	29.70
	0.47	0.48	0.48	0.48	0.48	0.48	0.46
Construction	5.20	5.40	5.70	6.00	6.00	6.50	4.10
	0.22	0.23	0.23	0.24	0.24	0.25	0.20
Wholesale and retail	17.90	18.00	18.90	19.20	18.80	19.40	15.00
	0.38	0.38	0.39	0.39	0.39	0.40	0.36
Transport, storage, and communication	12.60	12.20	13.50	14.80	14.80	15.30	12.30
	0.33	0.33	0.34	0.36	0.36	0.36	0.33
Catering and accommodation	3.00	2.90	2.80	2.90	3.10	3.10	2.20
	0.17	0.17	0.17	0.17	0.17	0.17	0.15
Information and communication	9.90	10.30	10.40	11.00	10.50	10.70	8.00
	0.30	0.30	0.31	0.31	0.31	0.31	0.27
Financing and insurance	2.60	2.60	2.60	2.70	2.60	2.60	1.90
	0.16	0.16	0.16	0.16	0.16	0.16	0.14
Real estate activities	0.90	0.90	1.10	1.10	1.00	1.30	0.90
	0.09	0.09	0.10	0.10	0.10	0.11	0.09
Professional, Scientific, and technical activities	7.40	7.30	7.60	8.10	8.00	8.10	5.40
	0.26	0.26	0.26	0.27	0.27	0.27	0.23
Administrative and support service activities	5.10	5.40	5.80	5.70	5.90	5.90	4.50
	0.22	0.23	0.23	0.23	0.24	0.24	0.21
Educational services	2.10	1.90	1.90	2.40	2.60	2.60	1.70
	0.14	0.14	0.14	0.15	0.16	0.16	0.13
Human health and social work	5.40	5.70	5.70	5.80	5.50	5.90	4.30
	0.23	0.23	0.23	0.23	0.23	0.24	0.20
Recreational and cultural services	8.50	8.10	8.70	8.70	7.80	8.80	5.50
	0.28	0.27	0.28	0.28	0.27	0.28	0.23
Other service activities	9.90	10.00	10.40	10.40	10.20	10.70	7.50
	0.30	0.30	0.30	0.31	0.30	0.31	0.26
Other services	15.70	17.50	17.00	15.50	14.50	9.70	7.30
	0.36	0.38	0.38	0.36	0.35	0.30	0.26
Total	13.10	13.00	13.40	13.70	13.50	14.00	10.70
	0.34	0.34	0.34	0.34	0.34	0.35	0.31

Source: author's calculations based on SARS-NT CIT Firm Panel.

Table A3: Comparison of firm characteristics

	Non-innovator	Innovator	Diff.	Signif.	Non-exporter	Exporter	Diff.	Signif.
Age	13.98	17.24	–3.26	***	13.47	17.67	–4.20	***
Size	36.60	379.30	–342.70	***	26.99	124.78	–97.80	***
Employment growth	4.92	9.02	–4.10	***	4.80	5.92	–1.12	***
Labour productivity	470,748.40	821,987.62	–351,239.22	**	434,569.16	731,232.15	–296,663.00	***
Profit margin	28.50	26.09	2.41	***	29.80	20.10	9.70	***
Investment rate	74.07	78.79	–4.72		76.30	67.67	8.63	***
LT debt/equity (log)	5,396.89	256.08	5,140.82		5,230.12	6,069.60	–839.49	
Foreign owned	0.01	0.07	–0.06	***	0.01	0.05	–0.05	***
Export intensity	1.06	5.85	–4.79	***	—	–	–	–
High-tech export share	12.98	15.88	–2.90	***	–	–	–	–
OECD export dest.	2.80	4.74	–1.95	***	–	–	–	–
African export dest.	2.89	5.37	–2.48	***	–	–	–	–
Import intensity	12.43	9.62	2.80		–	–	–	–

Notes: *** represents significance at the 1 per cent level; ** represents significance at the 5 per cent level.

Source: author's calculations based on SARS-NT CIT Firm Panel.

A2 Innovation and employment

Table A4: Augmented labour demand model: all firms, total innovation measure

Dep. var.: employment$_t$	(1) Pooled OLS	(2) FE	(3) GMM diff.	(4) GMM sys.
Employment$_{t-1}$	0.851***	0.196***	0.643***	0.916***
	(0.005)	(0.015)	(0.067)	(0.024)
Wage$_t$	–0.091***	–0.343***	–0.372**	–0.007
	(0.005)	(0.028)	(0.169)	(0.017)
Capital$_t$	0.047***	0.040***	0.030	0.023**
	(0.002)	(0.004)	(0.052)	(0.009)
Total innovation$_t$	0.033***	0.027***	0.019	0.044**
	(0.002)	(0.003)	(0.038)	(0.019)
Demand$_t$	–0.000	–0.008	0.125	0.004
	(0.002)	(0.010)	(0.106)	(0.003)
Constant	0.642***	6.197***		0.000
	(0.076)	(0.424)		(.)
Observations	27,593	27,593	10,485	20,326
R^2	0.9245772	0.3426128		
AR(1) *p*-value			4.23e-10	4.39e-11
AR(2) *p*-value			0.5653176	0.1981488
Hansen *p*-value			0.6309484	0.5077251

Notes: total innovation is R&D plus expenditure on royalties and technology licences.Robust standard errors are reported for OLS and FE. Two-step GMM, with corrected standard errors. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

A3 Linkages between R&D and exports

Table A5: Proportion of firms by innovation and export status

	No R&D, no exports	R&D only	Exports only	R&D and exports
Manufacturing of food products	65.70	1.00	30.10	3.20
Manufacturing of beverages	51.10	1.50	44.30	3.00
Manufacturing of tobacco products	39.70	0.70	55.90	3.70
Manufacturing of textiles	59.30	0.20	39.20	1.20
Manufacturing of wearing apparel	64.20	0.20	34.80	0.80
Manufacturing of leather and related products	52.00	0.80	46.50	0.70
Manufacturing of wood and wood products	78.40	0.10	21.20	0.40
Manufacturing of paper and paper products	60.20	0.30	38.60	0.90
Printing and reproduction of recorded media	76.30	0.10	23.20	0.40
Manufacture of coke and refined petroleum products	69.00	0.30	26.20	4.50
Manufacture of chemicals and chemical products	50.00	1.30	44.70	4.10
Manufacture of pharmaceuticals and related products	49.80	2.00	42.10	6.20
Manufacture of rubber and plastic products	60.20	0.80	37.40	1.60
Manufacture of other non-metallic mineral products	70.40	0.60	26.90	2.00
Manufacture of basic metals	70.20	0.40	28.50	0.90
Manufacture of fabricated metal products	71.80	0.40	26.70	1.10
Manufacture of computer, electronic, and optical products	56.50	1.60	35.20	6.70
Manufacture of electrical equipment	52.40	1.20	41.60	4.70
Manufacture of machinery and equipment n.e.c.	54.30	0.80	42.60	2.20
Manufacture of motor vehicles	52.30	1.40	43.30	3.00
Manufacture of other transport equipment	46.60	0.80	48.90	3.80
Manufacture of furniture	71.30	0.10	28.00	0.70
Other manufacturing	64.10	0.70	32.70	2.50

Source: author's calculations based on SARS-NT CIT Firm Panel.

Table A6: Variable descriptions

Variable name	Description
Employment growth	Annual change in firm-level employment
Firm size	Number of employees
Firm age	Years since establishment
R&D dummy	= 1 if firm reports positive R&D expenditures; = 0 otherwise
R&D intensity	Ratio of R&D expenditures to sales
Export dummy	= 1 if firm reports positive exports; = 0 otherwise
Export intensity	Ratio of exports to sales
Investment	The change in the capital stock from year $t-1$ to year t, plus depreciation in year t
Investment rate	Investment divided by capital stock in year $t-1$
Labour intensity	Ratio of employment to sales
LT debt/equity	Ratio of long-term debt to equity
HHI	Herfindahl–Hirschman Index (market concentration) at the two-digit industry level
Demand	Annual growth in sales at the two-digit industry level
Import intensity	Ratio of imports to sales at the two-digit industry level
Foreign competition	The share of firms that are foreign-owned or foreign-connected at the two-digit industry level

Source: author's compilation.

Table A7: Innovation, exports, productivity: all firms

	(1) Export dummy	(2) Export intensity	(3) R&D dummy	(4) R&D intensity	(5) L Prod	(6) L Prod
R&D dummy$_{t-1}$	–0.015		0.357***		–0.001	
	(0.043)		(0.017)		(0.008)	
Exporter dummy$_{t-1}$	1.256***		0.017***		–0.024	
	(0.207)		(0.001)		(0.005)	
R&D intensity$_{t-1}$		0.547***		0.561***		0.006
		(0.196)		(0.098)		(0.026)
Export intensity$_{t-1}$		0.342***		0.003***		–0.004
		(0.048)		(0.001)		(0.009)
Labor productivity$_{t-1}$					1.003***	0.999***
					(0.058)	(0.055)
Observations (firm-year)	7,777	7,755	139,069	138,715	71,321	71,321
AR(1) *p*-value	0.0000292	3.67e-51	2.4e-119	1.10e-09	3.06e-65	2.50e-68
AR(2) *p*-value	0.0422704	0.6397735	0.0592366	0.0145781	6.21e-14	5.53e-14
Hansen *p*-value	0.0096781	1.33e-07	6.05e-06	0.189373	1.32e-11	1.11e-11

Notes: all specifications include profit margin and capital stock as controls. Constant also not shown here. Two-step system GMM with corrected standard errors. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: author's calculations based on SARS-NT CIT Firm Panel.

A4 A cursory note on the SARS R&D tax incentive

Through the Department of Science and Technology and the Department of Trade and Industry, the South African government has a series of initiatives to enhance the competitiveness of the private sector and to promote firm capabilities to create new products and processes. One pillar of the government's approach to increase the rate of private-sector R&D investment is the R&D tax incentive under section 11D of the Income Tax Act (Act No. 58 of 1962), introduced in 2007. Companies that undertake R&D are qualified for a 150 per cent tax deduction and, in addition, companies are eligible for accelerated depreciation on capital used for R&D purposes.[5]

There are no restrictions on the types of firms that can claim the tax benefit, as long as they are registered as a company under the South African Companies Income Tax Act, but restrictions are placed on the type of R&D that is eligible under the Act. Firms that fund R&D conducted by a third party in South Africa (such as a research council or university) are also eligible to claim the tax benefit on these expenditures (provided the funded entity does not claim). The broad principles of eligibility for R&D expenses can be summarized from the Act as follows; this applies to salaries of R&D personnel, materials, overheads, and contractors, all of which must be funded in South Africa:

1. The discovery of non-obvious scientific or technical knowledge or creating or developing inventions and designs that are covered by the Patent Act and Design Act respectively. Only in 2015 was the development of a computer program, as defined in the Copyright Act, added to the list of eligible R&D investments.

2. In the absence of new inventions, eligible R&D investments include the significant and innovative improvement to any existing invention, functional design, computer program, or knowledge. The purchase of off-the-shelf technologies, without material improvement, are excluded from this tax incentive.

3. Specific clauses related to the biomedical healthcare sector were introduced in 2012 that deem the creation or development of generic pharmaceutical products as eligible R&D investments as well as expenses relating to human clinical trials.

Activities or expenses that are excluded from this benefit relate to market testing or sales promotion, development of internal business processes or software to automate activities, social science research, natural resource exploration, development of financial instruments, or products and capital purchases not used solely for R&D purposes. In 2012, the process of applying for the tax benefit changed from being a retrospective process to one in which companies need pre-approval for the R&D tax benefit based on planned R&D investments. According to documents from the presentations at Parliament portfolio committees, between October 2012 and May 2017, 1,169 applications were received and 88 per cent had been adjudicated as of 7 June 2017. This suggests that there are long lag times before companies are notified of their eligibility for the tax benefit, made worse by a paper-based system (which was made electronic in 2018).

Of the firms that spend on R&D, about 80–87 per cent do not receive the tax benefit each year (Table A8), which could indicate that the expenditures did not meet the requirements of the policy, companies may not be aware of the incentive, or there are administrative backlogs in approving the incentive. In addition, of the companies that are receiving the tax debit, more companies claim the incentive on accelerated depreciation on capital rather than on the direct innovation expenditures.

[5] Capital assets used in R&D activities can be depreciated over three years at a ratio of 50:30:20.

Table A8: Number of firms by innovating status and tax benefit status

	No tax incentive		Tax incentive on R&D		Tax incentive on capital investment		Tax incentive on both	
	Number	%	Number	%	Number	%	Number	%
				2010				
No R&D	0	0	0	0	261	100	0	0
R&D	1,045	82.28	184	14.49	0	0	41	3.23
Total	1,045	68.26	184	12.02	261	17.05	41	2.68
				2012				
No R&D	0	0	0	0	234	100	0	0
R&D	954	80.44	164	13.83	0	0	68	5.73
Total	954	67.18	164	11.55	234	16.48	68	4.79
				2014				
No R&D	0	0	0	0	133	100	0	0
R&D	532	83.91	55	8.68	0	0	47	7.41
Total	532	69.36	55	7.17	133	17.34	47	6.13
				2016				
No R&D	0	0	0	0	93	100	0	0
R&D	500	87.41	42	7.34	0	0	30	5.24
Total	500	75.19	42	6.32	93	13.98	30	4.51

Source: author's calculations based on SARS-NT CIT Firm Panel.