

Coad, Alexander; Vezzani, Antonio

Working Paper

Manufacturing the future: is the manufacturing sector a driver of R&D, exports and productivity growth?

JRC Working Papers on Corporate R&D and Innovation, No. 06/2017

Provided in Cooperation with:

Joint Research Centre (JRC), European Commission

Suggested Citation: Coad, Alexander; Vezzani, Antonio (2017) : Manufacturing the future: is the manufacturing sector a driver of R&D, exports and productivity growth?, JRC Working Papers on Corporate R&D and Innovation, No. 06/2017, European Commission, Joint Research Centre (JRC), Seville

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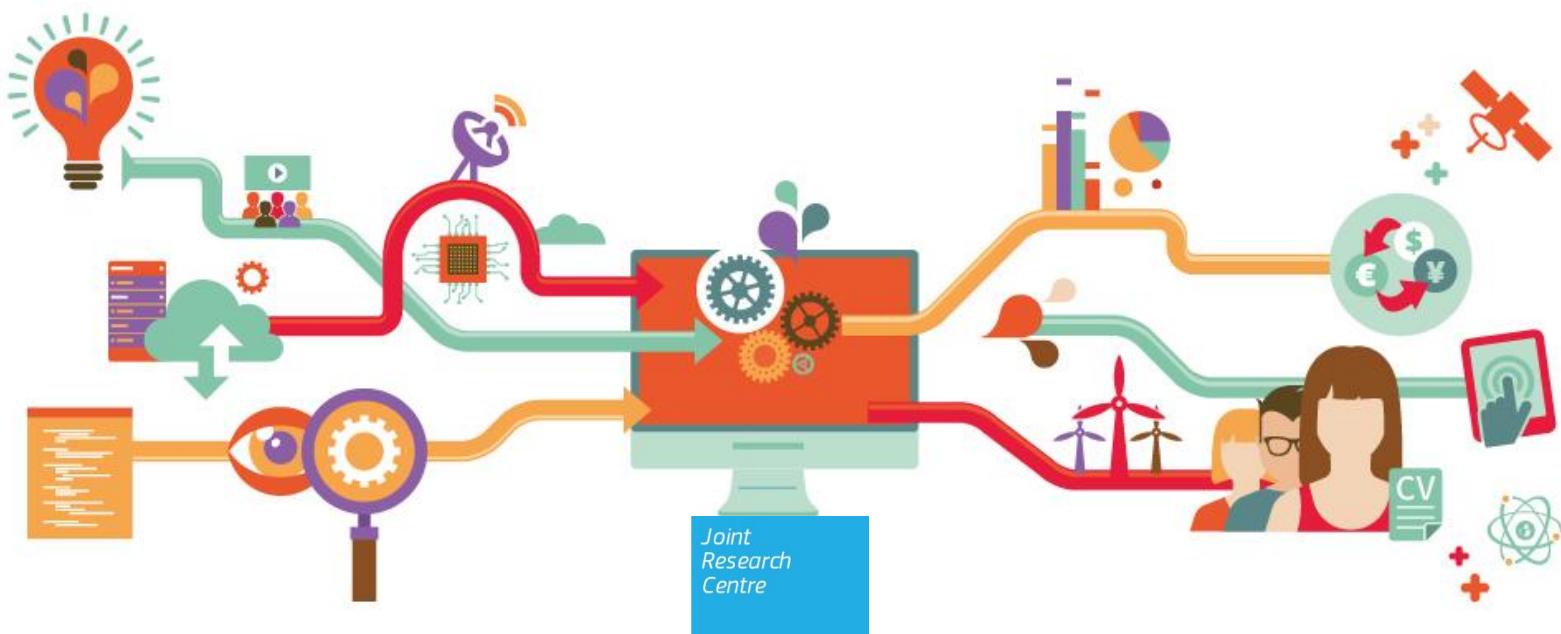
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JRC TECHNICAL REPORTS

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*JRC Working Papers on Corporate
R&D and Innovation No 06/2017*

Alex Coad, Antonio Vezzani
2017



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Contact information

Antonio Vezzani

Address: *Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)*

E-mail: <mailto:jrc-b3-secretariat@ec.europa.eu>

Tel.: +34 954488463

Fax: +34 954488316

JRC Science Hub

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JRC107579

ISSN 1831-9408 (online)

Seville, Spain: European Commission, 2017

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How to cite: Coad A., Vezzani A. (2017). Manufacturing the future: is the manufacturing sector a driver of R&D, exports and productivity growth?. JRC Working Papers on Corporate R&D and Innovation, No 06/2017, Joint Research Centre.

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The **JRC Working Papers on Corporate R&D and Innovation** are published under the editorial supervision of Antonio Vezzani in collaboration with Andries Brandsma, Fernando Hervás, Koen Jonkers, Pietro Moncada-Paternò-Castello, Alexander Tübke and Daniel Vertesy at the European Commission – Joint Research Centre; Michele Cincera (Solvay Brussels School of Economics and Management, Université Libre de Bruxelles); Alex Coad (Pontificia Universidad Católica del Perú, Lima); Enrico Santarelli (University of Bologna); Marco Vivarelli (Università Cattolica del Sacro Cuore, Milan).

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Manufacturing the future: is the manufacturing sector a driver of R&D, exports and productivity growth?

Alex Coad

CENTRUM-Catolica Graduate Business School, Pontificia Universidad Catolica del Peru, Lima, Peru.

Antonio Vezzani

European Commission, Joint Research Centre, Seville, Spain

Abstract¹

Many industrialized countries in Europe and North America have experienced a steady decline in the manufacturing sector over the last few decades. Amid growing concerns that outsourcing and offshoring have destabilized European economies, policymakers have suggested that a large manufacturing sector can: i) boost R&D, ii) encourage exporting, and iii) raise productivity. We examine these claims. Non-parametric plots and regressions show a robust positive association between the manufacturing sector and Business R&D expenditures (BERD), while the relationship between manufacturing and exports or productivity is more elusive. Finally, we explore whether a manufacturing sector target of 20% of value-added will help reach a BERD target of 3% of GDP.

Keywords: Manufacturing sector, R&D, exporting, productivity, industrial policy, industrial renaissance.

JEL Classification: O3, O14, O47.

¹ We are grateful to Giovanni Dosi, Gary Pisano, and seminar participants at the OECD (Paris) and the European Commission (JRC, Seville) for many helpful comments, the usual caveat applies. The views expressed are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission.

1. Introduction

A large number of developed countries have experienced a decline in the relative share of their manufacturing sectors in recent years (see e.g. Pierce and Schott 2016 for the USA, Bernard et al 2016 for Denmark, and Stollinger (2016, Figure 1) for European countries), which has occurred alongside a longer-term shift towards the service sectors (Schettkat and Yocarini, 2006; OECD, 2016). This rapid decline in manufacturing has been interpreted by many as a cause for concern.

There are a number of reasons why the decline of manufacturing may have gone too far. There are fears that excessive outsourcing and offshoring, in the context of global value chains (GVC), has threatened the economic security of countries because of the loss of strategic capabilities (Pisano and Shih, 2009, 2012a and 2012b; Berger, 2013). Pisano and Shih (2009, 2012a, 2012b) introduced the notion of ‘industrial commons’ to refer to the complex web of collective R&D, engineering and manufacturing capabilities that are needed to sustain innovation. The availability of local suppliers and technical skills is seen as a positive externality that facilitates rapid innovative solutions to manufacturing challenges, thus spurring on further innovation, in manufacturing sectors that may be characterized by strong knowledge cumulativeness (Dosi, 1988). Deindustrialization is not as simple as a relocation of low-skill jobs abroad, because of the iterations between manufacturing processes, on the one hand, and innovation and design functions, on the other. If multinational firms can only afford to have one large manufacturing facility (Fuchs, 2014), then the establishment of manufacturing facilities in low-wage countries will lead to the offshoring of higher-skill tasks (related to innovation, design and engineering) in addition to lower-skill manufacturing tasks. Repeated iterations between manufacturing processes and engineers facilitate productivity improvements and process innovations (Pisano and Shih, 2012b). The complexity of manufacturing capabilities, in turn, is a striking predictor of how well an economy can be expected to perform in the coming years (Hidalgo and Hausman, 2009; Cristelli et al., 2013). Furthermore, Moretti (2010) shows that high-tech manufacturing jobs in the tradable sectors generate a multiplier effect on local job creation in service industries.

Policy documents have recently suggested that there are three main advantages of a large manufacturing sector: it is a source of productivity growth; an engine for R&D and innovation; and that it stimulates trade and internationalization (EPSC 2015, page 2). European policy makers, who are pursuing the Lisbon target of 3% of an economy’s GDP invested in R&D, have suggested that deindustrialization should be halted, and that manufacturing activity should be stimulated, as a way of increasing R&D investments. More specifically, EU policymakers have put forward the target of 20% of value added coming from a country’s manufacturing sector by 2020 (European Commission, 2014).

Previous research has investigated the effects of the manufacturing sector on productivity and economic development. Baumol (1967) argues that de-industrialization is due to faster productivity growth in manufacturing, such that the

manufacturing sector has decreasing labour requirements, while labour-intensive services have little scope for mechanization, scale economies, capital accumulation, or productivity growth. The Baumol disease – as this phenomenon has become known – therefore predicts that a decreasing share of the manufacturing sector, and an increasing share of the services sector, is associated with dwindling productivity growth and economic stagnation. Cornwall (1977) argued that the manufacturing sector is an engine of growth because of its role as the locus of technological progress – in particular regarding embodied and disembodied technological progress – whereby technological advance originating in the manufacturing sector diffuses throughout the economy via intersectoral linkages. Some early empirical studies observed a robust correlation between the degree of industrialization and per capita income in developing countries (Szirmai, 2012). An early contribution by Chenery (1960), for example, found a positive relationship between manufacturing intensity and income per capita in several US manufacturing industries. More generally, looking back across the 20th century, all the Asian growth miracles have been stories of industrialization (Szirmai, 2012).

More recent studies have investigated the role of manufacturing for economic growth using panel data for a range of countries, and using either summary statistics (Szirmai, 2012), shift-share analysis (Timmer and de Vries, 2009), standard regressions (Fagerberg and Verspagen, 2002), panel regressions (Szirmai and Verspagen, 2015) or dynamic panel data GMM regressions (Cantore et al., 2017). These studies have often focused on industrialization as a catch-up strategy for developing countries. Recent studies have generally concluded that although the manufacturing sector may have played an important role for economic development, especially for catch-up strategies used by developing countries, nevertheless the size of the manufacturing sector has become a more difficult route for economic growth in recent decades, since the early 1970s onwards (Fagerberg and Verspagen, 2002; Szirmai, 2012; see also Szirmai and Verspagen, 2015). This could be because the growing share of services in household consumption baskets has encouraged service-led growth at higher levels of development (Szirmai, 2012). The concomitant and unexpected productivity improvements in services (Timmer and de Vries, 2009) could be due to the emergence of high-tech service industries such as ICT, logistics, and financial services.

There is a gap in the literature, however regarding the relationship between manufacturing and innovation. Theoretical discussions of the dangers of deindustrialization are discussed in Pisano and Shih (2009, 2012a, 2012b) and Fuchs (2014). Fuchs and Kirchain (2010) present a case study of how the offshoring of manufacturing affects technological competitiveness in the optoelectronics industry. Several investigations of the effects of deindustrialization have occurred within individual countries (e.g. Pierce and Schott 2016 for the USA or Bernard et al., 2016 for Denmark). Stollinger (2016) investigates how GVC participation accelerates deindustrialization in some EU countries. Interestingly, the author also observes heterogeneity in countries' experiences, with some peripheral European countries experiencing deindustrialization, while a central European manufacturing core has strengthened its manufacturing share. However, there seems to be a gap in the

literature regarding cross-country comparisons of the decline of the manufacturing sector and countries' performance in terms of the 'holy trinity' of innovation, productivity growth and exporting, in particular regarding innovation. This is unfortunate, considering that the importance of innovation for economic growth has increased in recent decades (Fagerberg and Verspagen, 2002).

We contribute to this gap in the literature by (to our knowledge) being the first to present cross-country longitudinal evidence on the role of the manufacturing sector for investment in innovation (i.e. BERD), and also for exporting. While previous empirical work regarding the economic importance of the manufacturing sector has focused on individual countries (Pierce and Schott, 2016; Bernard et al., 2016; see also Chakravarty and Mitra 2009 on Indian data) or on case studies (Fuchs and Kirchain, 2010), it seems worthwhile to present cross-country panel evidence in order to provide the wider context of global changes in manufacturing. Indeed, given the policy interest in the manufacturing sector, as highlighted by the European target of a 20% manufacturing share, we consider that our research question merits investigation. Although our research contains a number of caveats, such as the reporting of associations rather than causal effects, and the difficulties in defining what is truly manufacturing activity in each country,² nevertheless – amid the current vacuum of evidence – our results provide a useful background.

In our empirical exercise, we observe that the size of the manufacturing sector is positively associated with growth of R&D investment, whether control variables are included or not. As argued in previous studies (Pisano and Shih, 2009, 2012a, 2012b), our results suggest that a large manufacturing sector coevolves with innovation capabilities and innovation opportunities. Nevertheless, we observe no robust relationship between manufacturing share and either productivity growth or exporting activity.

Section 2 presents our database, constructed from various data sources. Section 3 contains our non-parametric and parametric analysis, and includes a simple counterfactual exercise to see if countries seeking a 3% R&D intensity target should pursue a 20% manufacturing target. Section 4 concludes.

2. Data & descriptive statistics

2.1 Data description

For the empirical application, we build a country level panel dataset combining three different data sources. Indeed, no official data source can alone provide the indicators we are interested in. Our main variable of interest, the manufacturing value added as a

² Some authors (e.g. De Backer et al., 2015) emphasize the fact services "show growing and complex interactions with other sectors including manufacturing" and that manufacturing industries sell increasingly share of services bundle to their products. As a consequence, current statistical classifications may not be able to properly describe the industrial phenomenon and an effective targeting of manufacturing has become increasingly difficult.

share of GDP (*Man_va*) is taken from World Bank indicators (<http://data.worldbank.org/indicator>), as well as the share of merchandise exports at purchasing power parity relative to GDP, PPP (*Export*). The manufacturing sector refers to industries belonging to the International Standard Industrial Classification (ISIC) divisions 15-37, value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. Business R&D expenditures as a share of GDP (*Berd*) are taken from the Main Science and Technology Indicators of the OECD (<http://stats.oecd.org/>). From the OECD statistics we also take the GDP in PPP to which we derive the logarithm (*Gdp_ln*), and the total population, used to calculate per capita figures (*Gdp_cap_ln*). Finally, to measure productivity we consider total factor productivity (TFP) as reported in the Penn World tables – PWT - [version 8.0](#) (Feenstra et al., 2015) and computed using output-side real GDP at constant prices, capital stock, labour input data and the share of labour income of employees and self-employed workers in GDP. In the PWT, total factor productivity is available normalized in order to have value equal to 1 for the United States (CTFP) or to have value equal to 1 for all countries for the year 2011 (RTFP). The first measure is more suitable to compare productivity across countries at a point in time, while the latter is better suited to investigate changes in productivity across years. In our opinion, the RTFP measure is more appropriate in a panel regression framework, and therefore it is our preferred indicator. From the same tables we also take the human capital index (*Hc*). See appendix A1 for the descriptive statistics of the variables used in the empirical analysis and the complete list of countries).

Our primary focus is to analyse the relationship between R&D investments and manufacturing at the country level, which is also the stronger relationship among those discussed in the EPSC note. However, following closely the EPSC (2015) policy recommendations, we will consider three main dimensions of analysis regarding the relative dependent variables: ① R&D ② Productivity growth ③ Trade and internationalization.

2.2 Descriptive statistics

Before moving to the regression analysis, it is worth exploring the main relationships by looking at some descriptive and non-parametric statistics.

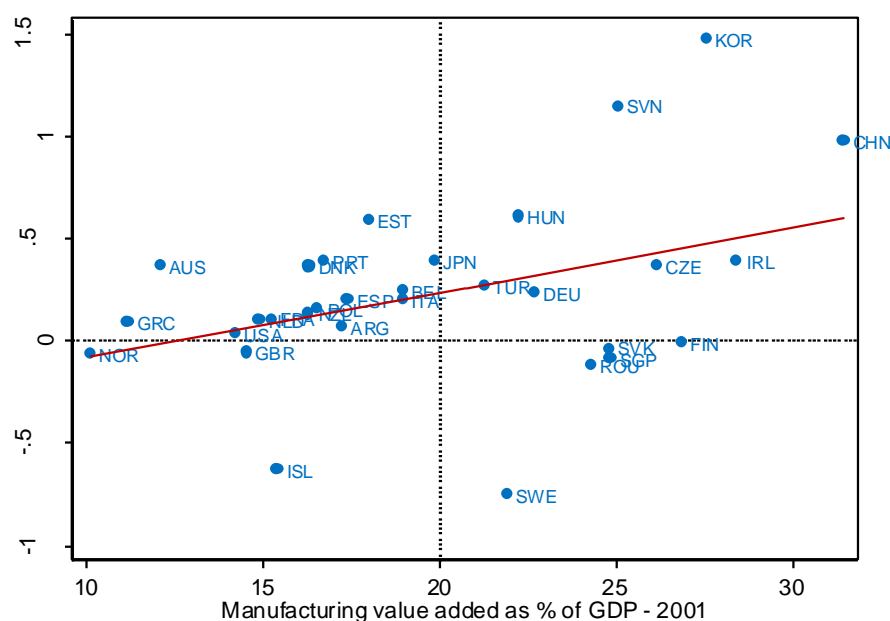
2.2.1 Scatterplots

We begin our visual exploration by showing scatterplots of the relationship between the size of the manufacturing sector and the economic outcomes considered in this paper (R&D, productivity and exporting). In particular, figures 1, 2 and 3 plot the differences of *Berd*, *Tfp*, and *Export* between 2013 and 2001 against the share of manufacturing value added for the year 2001.

Figure 1 shows a positive correlation between the share of manufacturing value added at the beginning of the period and the change of *Berd* share during the period considered. Korea and China exhibit a large manufacturing sector with a large increase

in *Berd*. Sweden and Iceland have experienced the strongest decrease in *Berd* of the sample. Countries above the red line have experienced a relatively high increase in *Berd* given their manufacturing specialization. Overall, there is a positive association between the initial importance of the manufacturing sector in the economy and subsequent changes in *Berd*, although there is a lot of variation around the line of best fit (R-squared = 0.16).

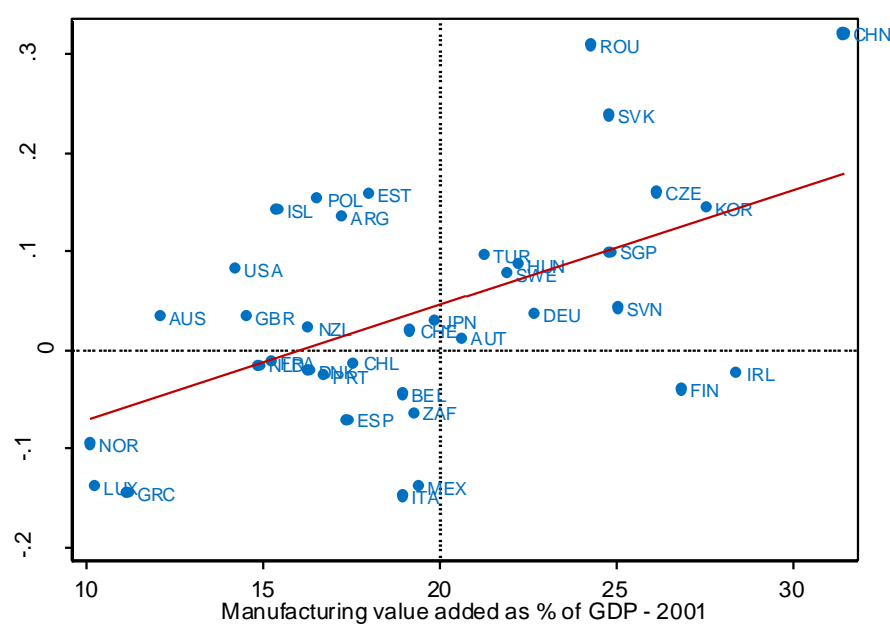
Figure 1: BERD change from 2001 to 2013 versus size of manufacturing sector in 2001



Note: $y = -0.393 \text{ (s.e. 0.279)} + 0.032x \text{ (s.e. 0.014)}$

A positive association is also observed between the share of manufacturing value added in 2001 on GDP and subsequent growth of total factor productivity 2001-2013. This is visible in Figure 2, where the slope of the fitting line is positive and statistically significant. China, Romania and Slovakia, in particular, have large manufacturing sectors in 2001 and also enjoyed large subsequent growth in productivity. This figure offers some early hints that the manufacturing sector and productivity growth are positively correlated, although further work is needed to test whether the positive association may be driven by other potentially confounding variables such as GDP per capita (this will be investigated in section 3 using multivariate regressions that include control variables).

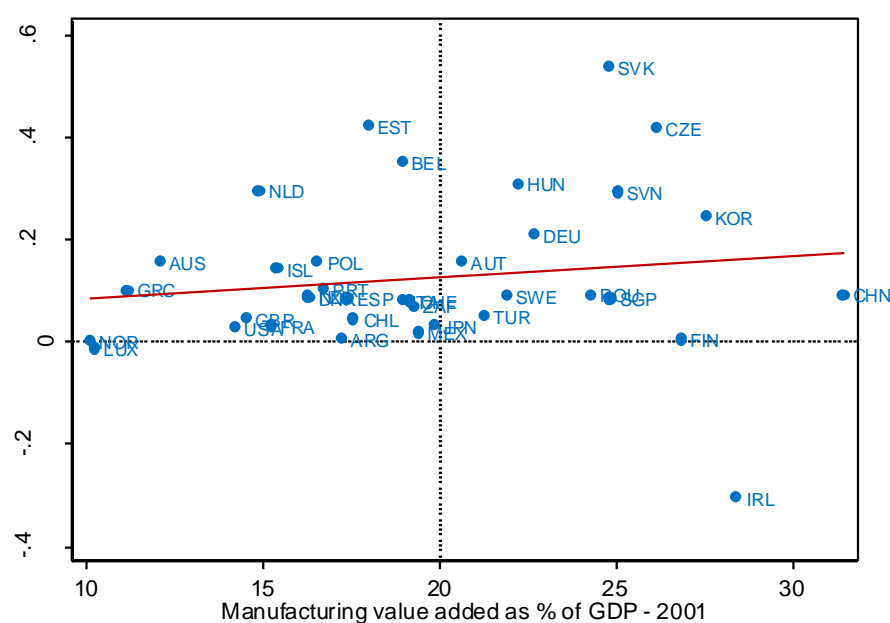
Figure 2: TFP change from 2001 to 2013 versus size of manufacturing sector in 2001



Note: $y = -0.186$ (s.e. 0.064) + 0.012x (s.e. 0.003)

Figure 3 shows the relationship between the size of the manufacturing sector in 2001 and subsequent changes in export intensity. Unlike for the two previous scatterplots, there does not appear to be any significant relationship between manufacturing share and exporting dynamics.

Figure 3: Export change from 2001 to 2013 versus size of manufacturing sector in 2001



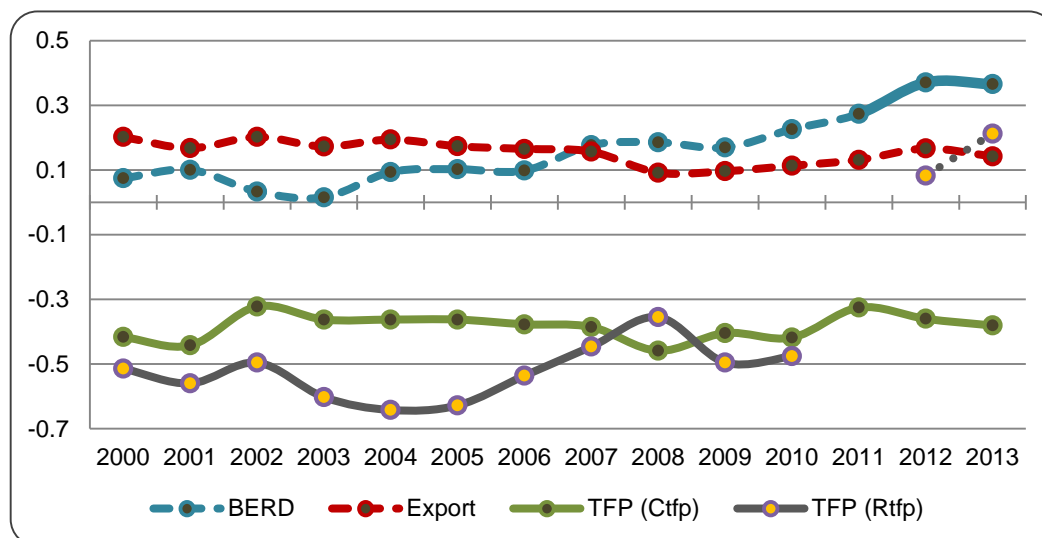
Note: $y = -0.004$ (s.e. 0.005) + 0.044x (s.e. 0.045)

Most countries had a modest change in exports, where few countries experienced large increases (mainly east European countries) or declines (Ireland). Among these countries, Ireland, Slovakia and the Czech Republic couple particularly large manufacturing sectors in 2001 with heterogeneous subsequent export dynamics. The changes in exporting of China and Korea were relatively modest, despite their large manufacturing sectors. This can seem at odds with the spectacular increase in Chinese exports largely discussed in the literature. However, it should be considered that we are talking in relative terms: the increase in exports has been proportional to the increase in Chinese GDP.

2.2.2 Evolution of the correlation coefficients

We pursue our data description by observing the evolution of the correlations between the size of the manufacturing sector and *Berd*, *Tfp*, and *Export*. Over most of the range, the correlations with *Berd* were not significant, but – interestingly – the correlations have become larger in magnitude and also statistically significant in recent years, especially since the onset of the great recession in late 2008. This might explain the growing interest in recent years concerning the role of a possible renaissance of the manufacturing sector for innovation and economic development. For the correlation between the size of the manufacturing sector and *Tfp*, we look both at CTFP and RTFP, because although RTFP is our preferred indicator in our subsequent panel regressions, use of RTFP is problematic for computing the correlation coefficient for 2011 (RTFP is equal to 1 for all countries in the sample). The correlation coefficients for both measures are negative and statistically significant over the period considered (with the exception of RTFP in 2012 and 2013, when the coefficients are not statistically significant), which may appear curious at first, although some explanations can be mentioned. First, productivity growth is observed alongside a decrease of the manufacturing sector in the USA (Pierce and Schott, 2016, their Figure 3), which suggests that manufacturing sectors that are smaller are more efficient or productive. Second, this can be due to the fact that, in the calculation of *Tfp*, expenditures other than physical capital investments (the so-called intangible investments) are not taken into account, thus penalizing manufacturing-intensive countries with lower shares of service industries.

Figure 4: Correlations between manufacturing share and our 3 dependent variables (in levels)



Note: dashed line indicates that the correlation coefficients are not statistically significant at the 10% level.

The correlations for *Export* turn out to be not statistical significant over the period considered; as with the scatterplot in Figure 4, the relationship between *Export* and the size of the manufacturing sector appears rather weak.

The appendices 2 and 3 show line plots for how the size of the manufacturing sector, and R&D, have evolved for individual countries (building on e.g. Stollinger, 2016, Figure 1). For most countries the two data series are relatively flat, although there are some interesting exceptions.

3. Empirical application

3.1 Regression strategy

This paper focuses on three dependent variables: Business expenditures on R&D, productivity growth, and exporting activity. In our econometric analysis, we test the following equations:

$$Berd_{it} = Berd_{it-1} + Man_{va_{it-1}} + Gdp_{ln_{it-1}} + Gdp_{cap_{ln_{it-1}}} + Export_{it-1} + Hc_{it-1} + Tfp_{it-1} + u_{it}$$

$$Tfp_{it} = Tfp_{it-1} + Man_{va_{it-1}} + Gdp_{ln_{it-1}} + Gdp_{cap_{ln_{it-1}}} + Export_{it-1} + Hc_{it-1} + Berd_{it-1} + u_{it}$$

$$Export_{it} = Export_{it-1} + Man_{va_{it-1}} + Gdp_{ln_{it-1}} + Gdp_{cap_{ln_{it-1}}} + Berd_{it-1} + Hc_{it-1} + Tfp_{it-1} + u_{it}$$

Where i identifies the 37 countries included in the empirical application and $t = 2001, \dots, 2013$ stands for the year-observations included in the panel.

We begin with pooled ordinary least squares (OLS) estimates, for the reasons that OLS regressions are relatively straightforward, transparent and well-known. OLS standard errors are clustered at the country-level as a rudimentary way of addressing the longitudinal nature of the data. A drawback of pooled OLS, however, is that there may be country-specific time-invariant components that are associated with the outcome variables, such that the error terms are not independent and identically distributed across years for the same country (thus violating one of the assumptions of OLS regression). To take into account the likely possibility of time-invariant country-specific effects, we perform fixed effects regressions (also known as ‘within’ regressions) that include a dummy variable for each country. We also present between effects panel regressions that emphasize the cross-sectional information in our panel data, as reflected in the changes between subjects (i.e. the effect of x , when x changes between countries).

A drawback of applying fixed effects regressions in dynamic panel contexts (i.e. for regression specifications which include a lagged dependent variable among the regressors) is that the inclusion of the lagged dependent variable becomes a source of bias (known as ‘Nickell-bias’ after Nickell, 1981). The problem is that the fixed effect is included in the error term at time t , as well as being reintroduced via the lagged dependent variable (at time $t-1$). One way of removing this bias is to perform Least Squares Dummy-variable-corrected (“LSDVC”) regressions, where the double-counting of the fixed effect is mitigated (Bruno, 2005). Another way of addressing Nickell-bias is by using an instrumental variables approach via a dynamic panel data GMM estimator such as ‘System GMM’ (Arellano and Bover, 1995; Blundell and Bond 1998). System GMM can be an effective estimator (Cantore et al., 2017), as long as the instrumental variables are valid. GMM estimators are not without problems, however. GMM estimators can have large standard errors, there may be considerable finite sample bias due to weak instrument problems, and GMM estimates may be unstable over alternative instrument sets (De Vos et al., 2015). We inspect the diagnostic statistics to verify whether our instruments are valid, and also report GMM estimates using alternative instrument sets to verify the robustness of our GMM estimates across specifications (Roodman, 2009).

3.2 Regression results

Our first set of regression results, in Table 1, shows the conditional association between the size of the manufacturing sector and subsequent BERD. Manufacturing and BERD show a strong correlation which is positive and significant in most specifications (OLS, between effects - but not fixed effects - and the various GMM specifications),

Our preferred specifications are the dynamic panel data GMM estimates, which control for Nickell-bias and endogeneity. Diagnostic statistics (i.e. the Sargan and Hansen statistics for overidentifying restrictions, as well as the test for second order autocorrelated residuals) support the validity of the instruments. Our GMM estimates

confirm the positive association found earlier in the scatterplot in Figure 1. Overall, therefore, our finding of a positive relationship between manufacturing share and BERD is consistent with the EU strategy of boosting its manufacturing sector in order to hit the 3% R&D intensity target.

Regarding the control variables, Table 1 shows that the coefficient on lagged *Berd* is very high, close to unity. Wald tests confirm that the coefficient on lagged BERD is not statistically significantly different from 1.00.³ The coefficient on lagged BERD is consistent with the suggestion that BERD evolves over time as a random walk process. Table 1 also shows that some other variables – GDP per capita, human capital, and total factor productivity – are positively associated with BERD. These three variables are not included together in the same specification, however, because they are highly correlated among themselves.

Our regression results for the relationship between manufacturing share and other outcome variables are more humbling. Tables 2 and 3 generally show that the only consistently significant coefficient estimate is the lagged dependent variable. Tables 2 and 3 do not find evidence of any positive relationship between manufacturing, on the one hand, and productivity growth or exporting, on the other. The coefficients are generally statistically insignificant and not consistent across regression specifications. The p-values for the second order autocorrelation tests are not satisfactory, suggesting that the GMM estimates are not reliable (even though we tried a large number of specifications). Furthermore, introducing a further lag for the instruments and testing for third order autocorrelation in the residuals also proved unsatisfactory. In further analysis, featuring a specification where we dropped the lagged dependent variable, the coefficient for manufacturing sector was also insignificant.

How can our results in Table 3 be reconciled with the scatterplot in Figure 3? These two results are different in terms of time period considered for the outcome variable (the scatterplot focuses on changes 2001-2013 while the regression focuses on annual changes), and also with regard to the inclusion of control variables. In further analysis, we find that the positive relationship between manufacturing share and TFP change disappears (i.e. it turns from significant to insignificant) when we start to control for GDP per capita, which suggests that the relationship between manufacturing and productivity growth in Figure 3 is a spurious relationship that is being driven by underlying changes in GDP per capita.

³ The coefficient is statistically different from 1 at a 5% level in only one of the GMM specifications.

Table 1: BERD regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	FE	BE	LSDVC	GMM	GMM	GMM	GMM
BERD/GDP (t-1)	0.994*** (0.011)	0.885*** (0.061)	1.009*** (0.012)	0.885*** (0.072)	1.003*** (0.009)	0.926*** (0.044)	0.866*** (0.071)	0.868*** (0.062)
Manuf/GDP (t-1)	0.004*** (0.001)	0.006 (0.006)	0.003** (0.001)	0.007 (0.007)	0.004*** (0.001)	0.013*** (0.004)	0.014*** (0.004)	0.010*** (0.003)
Log GDP (t-1)	0.002 (0.004)	-0.161 (0.230)	-0.002 (0.004)	-0.185 (0.351)		0.012 (0.009)	0.023* (0.012)	0.018* (0.010)
Log GDP/capita (t-1)	0.008 (0.010)	0.274 (0.253)	-0.017 (0.018)	0.301 (0.374)		0.113** (0.049)	0.123** (0.050)	
Govt share (t-1)	-0.046 (0.099)	0.233 (0.273)	-0.122 (0.147)	0.170 (0.508)			-0.002 (0.343)	-0.073 (0.253)
Human capital. (t-1)							0.036 (0.061)	0.130** (0.061)
TFP (t-1)								0.368** (0.166)
Constant	-0.086 (0.070)	1.199 (2.231)	0.056 (0.119)		-0.047** (0.018)	-0.672** (0.274)	-0.906*** (0.319)	-1.018*** (0.339)
Observations	441	441	441	441	441	441	441	441
R-squared	0.985	0.796	0.998					
Number of countries		37	37	37	37	37	37	37
Wald chi2(2)					0.00	0.00	0.00	0.00
Arellano-Bond for (p-val AR2)					0.53	0.56	0.56	0.58
Sargan overid. (p-val)					0.81	0.95	0.92	0.90
Hansen t overid. (p-val)					0.58	0.75	0.62	0.70
Number of instruments					29	29	29	29

*Note: Clustered standard errors for the OLS; Robust standard errors for the FE - *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. GDP used as GMM instrument type (t-2), while total population, human capital (t-1), consumption and tfp (t-1) enter as standard IV instrument type.*

Table 2: Productivity growth regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	FE	BE	LSDVC	GMM	GMM	GMM	GMM
TFP (t-1)	0.859*** (0.022)	0.895*** (0.035)	0.840*** (0.021)	0.952*** (0.063)	0.737*** (0.043)	0.738*** (0.059)	0.719*** (0.080)	0.696*** (0.066)
Manuf/GDP (t-1)	-0.000 (0.000)	0.001 (0.001)	-0.000 (0.000)	0.001 (0.002)	-0.000 (0.001)	0.000 (0.002)	-0.002 (0.003)	0.001 (0.001)
Log GDP (t-1)	-0.001** (0.001)	0.024 (0.040)	-0.001 (0.001)	0.055 (0.134)		-0.004 (0.004)	-0.003 (0.005)	-0.002 (0.005)
Log GDP/capita (t-1)	-0.009*** (0.003)	-0.050 (0.044)	-0.006** (0.003)	-0.090 (0.141)		-0.005 (0.025)	-0.040 (0.043)	
BERD/GDP (t-1)	0.003** (0.001)	0.005 (0.007)	0.002 (0.002)	0.006 (0.023)		0.005 (0.018)	0.018 (0.024)	-0.002 (0.015)
Govt share (t-1)							0.059 (0.046)	0.013 (0.046)
Human capital (t-1)								0.001 (0.016)
Constant	0.186*** (0.022)	-0.067 (0.414)	0.193*** (0.026)		0.268*** (0.048)	0.315*** (0.107)	0.436*** (0.139)	0.310*** (0.093)
Observations	460	460	460	460	498	460	460	460
R-squared	0.888	0.809	0.988					
Number of countries		39	39	39	39	39	39	39
Wald chi2(2)					0.00	0.00	0.00	0.00
Arellano-Bond for (p-val AR2)					0.00	0.01	0.01	0.01
Sargan overid. (p-val)					0.00	0.00	0.00	0.00
Hansen t overid. (p-val)					0.05	0.05	0.04	0.04
Number of instruments					27	27	27	27

*Note: Clustered standard errors for the OLS; Robust standard errors for the FE - *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. GDP used as GMM instrument type (t-2), while total population, human capital (t-1), consumption and tfp (t-1) enter as standard IV instrument type.*

Table 3: Exporting regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	FE	BE	LSDVC	GMM	GMM	GMM	GMM
Export share (t-1)	0.986*** (0.014)	0.702*** (0.094)	1.012*** (0.010)	0.702*** (0.065)	1.031*** (0.016)	1.200*** (0.126)	0.859*** (0.079)	1.006*** (0.029)
Manuf/GDP (t-1)	0.000 (0.001)	-0.001 (0.001)	0.000 (0.001)	-0.001 (0.034)	-0.001 (0.001)	-0.009** (0.004)	0.003* (0.002)	0.000 (0.001)
Log GDP (t-1)	-0.005*** (0.001)	-0.168 (0.105)	-0.002 (0.002)	-0.139 (2.348)		0.011 (0.013)	-0.020** (0.009)	-0.003 (0.003)
Log GDP/capita (t-1)	-0.005 (0.011)	0.196 (0.123)	-0.010 (0.008)	0.165 (2.415)		-0.098** (0.044)		
BERD/GDP (t-1)	0.001 (0.005)	0.006 (0.020)	0.001 (0.005)	0.005 (0.423)		0.039 (0.027)	0.024 (0.027)	0.011 (0.009)
Human capital (t-1)							0.016 (0.024)	-0.003 (0.010)
TFP (t-1)							0.188 (0.122)	0.051 (0.047)
Constant	0.090** (0.036)	1.714* (1.008)	0.060* (0.035)		0.006 (0.014)	0.213 (0.147)	0.018 (0.169)	-0.011 (0.065)
Observations	460	460	460	460	498	460	460	460
R-squared	0.974	0.616	0.999					
Number of countries		39	39	39	39	39	39	39
Wald chi2(2)					0.00	0.00	0.00	0.00
Arellano-Bond for (p-val AR2)					0.04	0.06	0.04	0.05
Sargan overid. (p-val)					0.96	1.00	0.93	1.00
Hansen t overid. (p-val)					0.35	0.19	0.07	0.35
Number of instruments					28	28	28	39

*Note: Clustered standard errors for the OLS; Robust standard errors for the FE - *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. GDP used as GMM instrument type (t-2), while total population, human capital (t-1), consumption and tfp (t-1) enter as standard IV instrument type.*

To summarize, our three regression tables set out to investigate the hypothesized effects of the manufacturing sector on the ‘holy trinity’ of R&D investment, productivity growth, and exporting activity (EPSC, 2015). Only in the case of manufacturing and BERD could we detect a positive and significant relationship. This is consistent with suggestions that a large manufacturing sector provides support to R&D investments. Manufacturing and R&D investment targets appear to be compatible. The implied elasticity of BERD with respect to manufacturing share is 16%, while the elasticity with respect to human capital is higher (39%) and similar to that of TFP (35%).⁴ However, the suggested relationship between manufacturing and exporting activity, in particular, seems to be something of a ‘holy ghost’.

3.3 Discussion on the EU’s R&D and manufacturing targets

In the previous section, we saw that the two targets of 3% R&D intensity and 20% value added in manufacturing seem to be compatible. In this section we extrapolate from our regression results - column (8) of Table 1 - to see the extent to which these targets are also feasible. In particular, we respond to the question: *ceteris paribus*, which would be the manufacturing share that guarantees the attainment of the 3% R&D intensity target?

For each country in the estimation sample we first compute the gap between the actual *Gerd* (Gross R&D expenditures as a share of GDP) and the 3% target. Then, we calculate how much the manufacturing sector share would have to grow in order to close this gap. For this calculation we use the implied elasticity of BERD with respect to manufacturing share (16%) and perform a simple linear extrapolation from the actual data.

Of course, in this simple exercise we implicitly assume that the gap would be closed only with an increase in R&D investments from the business sector. Although the assumption could be considered very restrictive, it seems not completely implausible. Indeed, there are increasing concerns that the reductions of public knowledge investments in higher education and research and innovation (due to short-term perspectives) are curtailing the long-term EU growth and welfare potential (OECD, 2016; Archibugi and Filippetti, 2017). Moreover, the 3% R&D intensity target explicitly foresees that 2/3 should come from the private sector (van Pottelsberghe de la Potterie, 2008) although nowadays most of the policy discussion focuses on how to foster private R&D investments.

In table 4 we report the results of our back-of-the-envelope calculations. Countries are ordered according to their actual GERD figures. For a number of countries, the manufacturing value added as a share of GDP associated with a 3% R&D intensity is much higher than the 20% foreseen by policy documents. This is particularly true for those countries with low R&D intensity, where the increase in manufacturing would

⁴ From the regression results, table 1, column (8), the implied elasticity of *Berd* with respect to a regressor *x* can be computed as: $\varepsilon_{bx} = \frac{\partial(Berd, x)}{\partial x} \frac{\bar{x}}{Berd}$.

need to be above 10 percentage points. Overall, the share of manufacturing corresponding to a 3% R&D target varies greatly across countries, from 13% in the case of Denmark to the 39% of Romania.

Table 4: Calculating the manufacturing share that would guarantee the 3% R&D intensity target

Country	GERD (%)	GAP to 3%	Manufacturing (%)	Change in manufacturing to reach 3% R&D target	Hypothetical manufacturing share
Romania	0.39	2.61	23.0	+15.86	<u>39</u>
Chile	0.39	2.61	11.9	+15.83	<u>28</u>
Argentina	0.61	2.39	15.9	+14.49	<u>30</u>
Greece	0.81	2.19	9.6	+13.27	<u>23</u>
Slovak Republic	0.83	2.17	20.3	+13.18	<u>33</u>
Poland	0.87	2.13	17.9	+12.92	<u>31</u>
Turkey	0.94	2.06	17.3	+12.47	<u>30</u>
Russian Federation	1.13	1.87	7.0	+11.33	18
Spain	1.26	1.74	13.1	+10.55	<u>24</u>
Luxembourg	1.30	1.70	5.1	+10.31	15
Italy	1.31	1.69	15.4	+10.27	<u>26</u>
Portugal	1.33	1.67	13.1	+10.16	<u>23</u>
Hungary	1.40	1.60	22.6	+9.73	<u>32</u>
Ireland	1.54	1.46	20.4	+8.88	<u>29</u>
Norway	1.65	1.35	7.4	+8.18	16
United Kingdom	1.66	1.34	10.8	+8.11	19
Canada	1.69	1.31	11.1*	+7.95	19
Estonia	1.71	1.29	15.6	+7.80	<u>23</u>
Czech Republic	1.91	1.09	24.9	+6.62	<u>32</u>
Netherlands	1.96	1.04	11.8	+6.32	18
Singapore	2.00	1.00	18.8	+6.07	<u>25</u>
China	2.01	0.99	30.1	+5.98	<u>36</u>
France	2.24	0.76	11.3	+4.59	16
Belgium	2.43	0.57	14.0	+3.45	17
Slovenia	2.60	0.40	22.5	+2.40	<u>25</u>
United States	2.74	0.26	12.4	+1.56	14
Germany	2.83	0.17	22.6	+1.05	<u>24</u>
Austria	2.96	0.04	18.5	+0.22	19
Denmark	3.06	<u>-0.06</u>	13.5	<u>-0.35</u>	13
Finland	3.29	<u>-0.29</u>	16.9	<u>-1.74</u>	15
Sweden	3.31	<u>-0.31</u>	16.8	<u>-1.86</u>	15
Japan	3.48	<u>-0.48</u>	18.6	<u>-2.92</u>	16
Korea	4.15	<u>-1.15</u>	31.0	<u>-6.97</u>	<u>24</u>

Note: Computed from the implied elasticity of BERD with respect to manufacturing based on the estimate in Table 1 Column 8. GERD and manufacturing, 2013 (*2012).

The R&D intensity seems to be not independent from the industrial structure of an economy. Indeed, there is a body of evidence showing that EU differences in R&D intensity with respect to other advanced economic areas (e.g. USA and Japan) are largely of a structural nature (Reinstaller and Unterlass, 2012; Cincera and Veugelers, 2013; Moncada-Paternò-Castello, 2016) and that accounting for the industrial structure leads to substantial differences in the traditional R&D intensity country rankings (Mathieu & van Pottelsberghe de la Potterie, 2010). These suggest that high levels of aggregate R&D intensity may be due to a large share of R&D-intensive industries in the economy rather than a macroeconomic environment particularly favourable to R&D.

4. Conclusions

In reaction to the prolonged decline of the manufacturing sector in many developed countries in recent decades, there is currently growing interest among economists and policymakers regarding the revival of the manufacturing sector. European policy makers, in particular, have put forward a 20% manufacturing share target as a means to improve Europe's economic performance with regard to a number of outcomes, in particular R&D investment, productivity growth and exporting (EPSC, 2015).

However, the evidence base underpinning this 20% manufacturing target is scarce. Besides theoretical discussions, case studies, and investigations focusing on individual countries, there is a lack of longitudinal evidence on the performance outcomes of countries with different-sized manufacturing sectors, especially when performance is measured in terms of innovative activity. Our analysis is not without limitations, however. First, we report associations rather than causal effects, although causal interpretations are promoted due to some features of our analysis (e.g. the long-difference setup that compares manufacturing share in 2001 with outcome variables 2001-2013 in the scatterplots; or the use of panel data GMM estimators that can address endogeneity concerns). Second, it is possible that our calculations of the share of the manufacturing sector on the basis of industry classification codes is subject to measurement error (see e.g. Bernard et al 2016 who create an elaborate indicator of manufacturing activity at the level of firms). Nevertheless, given the lack of evidence, and the policy interest surrounding the topic, we believe that these simple cross-country estimates can contribute a useful background to discussions surrounding the importance of the manufacturing sector.

Our results suggest that a manufacturing target is compatible with efforts to boost R&D investment. Scatterplots and regressions report a positive relationship between manufacturing share and BERD. However, we found no robust relationship between manufacturing, on the one hand, and productivity growth and exporting, on the other. This is in agreement with previous work which found that the importance of manufacturing for economic growth has decreased in recent decades (Fagerberg and Verspagen, 2002; Szirmai, 2012). Finally, our counterfactual simulation analysis

shows that the share of manufacturing corresponding to a 3% R&D target varies across countries, suggesting that the industrial structure matters in the country R&D-manufacturing relationship.

Overall, therefore, we find some evidence that a large manufacturing sector has a role to play for innovation-led growth in developed economies. However, our evidence suggests also that this role seems to be sensitive to the specific industrial structure of a country.

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Appendix 1: Descriptive statistics and list of countries considered

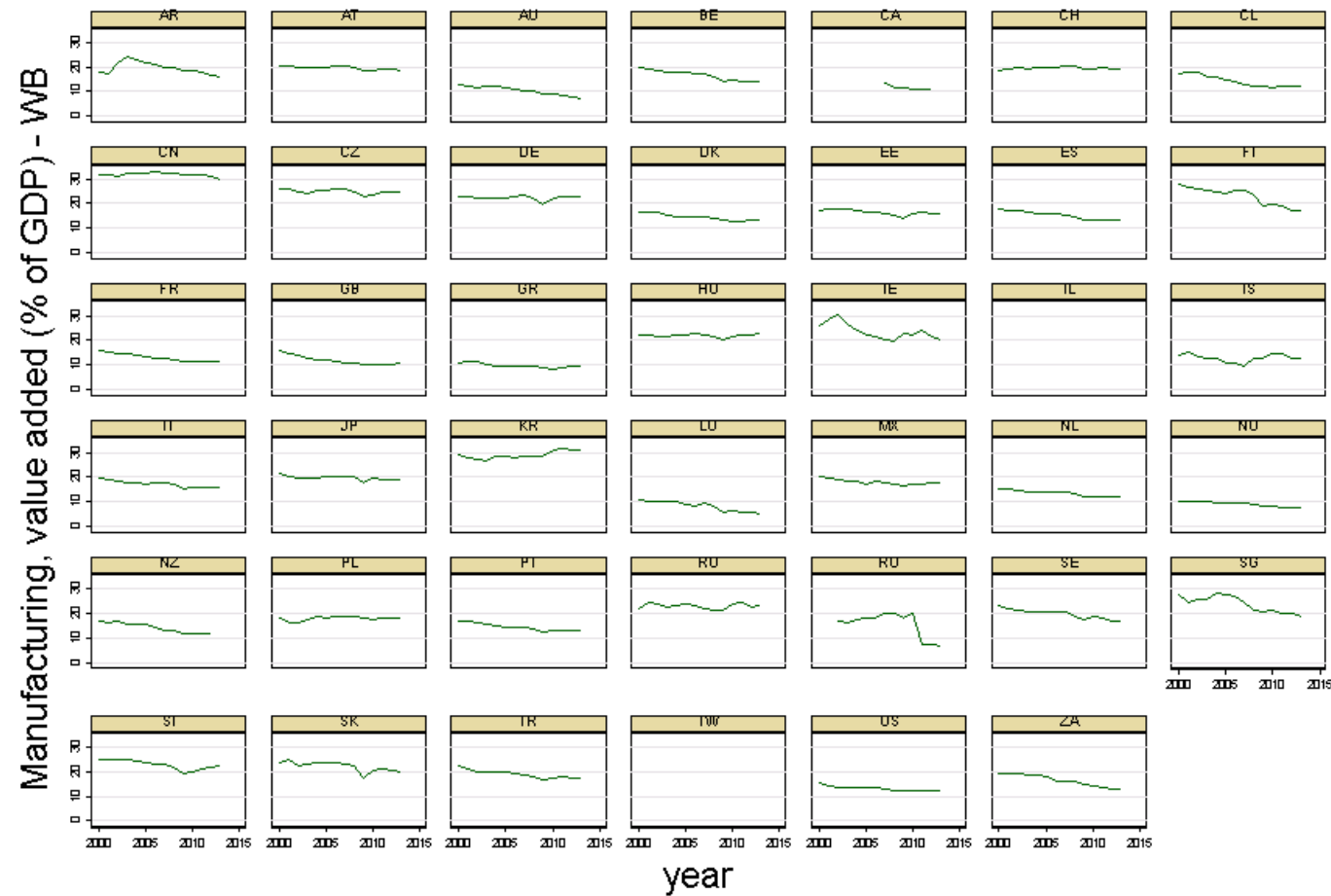
Table A1.1: Descriptive statistics

Variable	mean	sd	p50	skewness	kurtosis	min	max
Manuf/GDP	17.75	5.68	17.71	0.32	2.81	5.06	32.72
BERD/GDP	1.11	0.80	0.95	0.85	3.23	0.08	3.70
Export share	0.45	0.31	0.37	1.70	6.96	0.07	1.84
TFP (rtfpna)	0.99	0.07	1.00	-0.93	5.95	0.69	1.21
TFP (ctfp)	0.81	0.22	0.80	0.60	4.07	0.30	1.62
Log GDP	13.00	1.48	12.85	-0.08	3.26	9.03	16.63
Log GDP/capita	3.27	0.55	3.38	-0.82	3.99	1.07	4.56
Govt share	0.18	0.05	0.18	0.15	2.51	0.07	0.31
Human capital	3.13	0.40	3.20	-0.77	2.99	2.00	3.73

Table A1.2: Countries included in the empirical application

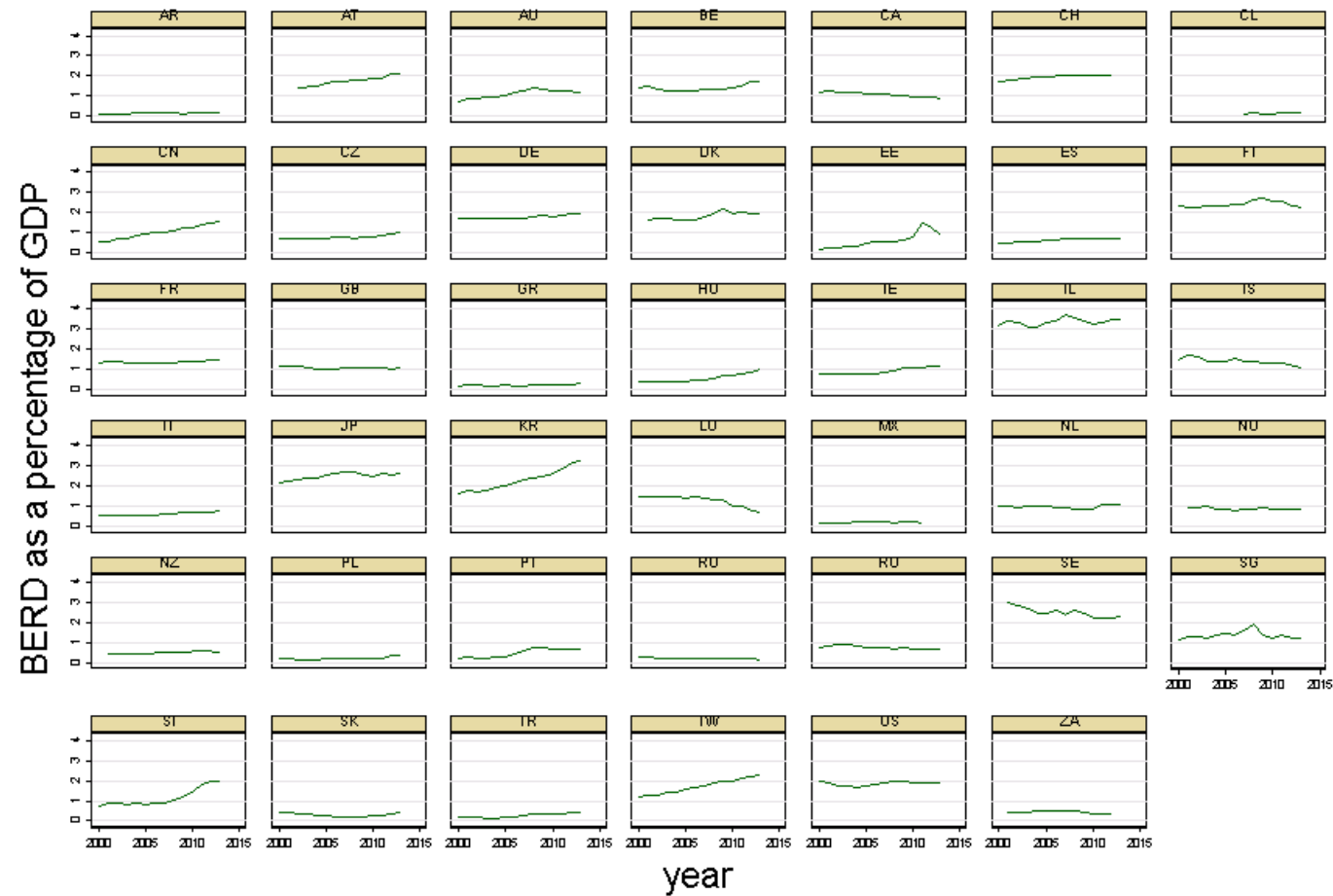
Argentina	Finland	Luxembourg	Slovenia
Australia	France	Mexico	South Africa
Austria	Germany	Netherlands	Spain
Belgium	Greece	Norway	Sweden
Canada	Hungary	Poland	Turkey
Chile	Iceland	Portugal	United Kingdom
China	Ireland	Romania	United States
Czech Republic	Italy	Russian Federation	
Denmark	Japan	Singapore	
Estonia	Korea	Slovak Republic	

Appendix 2: panel line plots of the size of the manufacturing sector across countries



Graphs by iso_code

Appendix 3: panel line plots of the evolution of BERD across countries



Graphs by iso_code



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