Fraunhofer ISI Discussion Papers *Innovation Systems and Policy Analysis* No. 76

Post-growth and the demand-pull hypothesis of innovation: Biting the hand that feeds you?

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Place: Karlsruhe
Date: July 2023

Responsible for content

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Recommended citation

Jasny, J.; Schubert, T. (2023): Post-growth and the demand-pull hypothesis of innovation: Biting the hand that feeds you?, Fraunhofer ISI Discussion Paper, No. 76. Karlsruhe: Fraunhofer ISI.

Published

July 2023

ISSN

1612-1430

Doi

10.24406/publica-868

Contents

Figure and Tables

Abstract

The post-growth discourse emphasizes the role need to limit economic growth as a primary means to stop continuous environmental degradation associated with production induced overexploitation of natural resources. A criticism of the post-growth discourse is, however, that innovation is known to be demand-driven implying that limiting growth may then undermine incentives to innovate. This may reduce the speed with which new environmentally friendly technologies are developed. Empirical analysis of this claim however do not exist. Relying on data from the European Manufacturing Survey 2018 for Germany, we match macroeconomic sector-growth statistics from the German Statistical Office and analyse how firm-level and sector level growth drive firms' innovation activities with a specific focus to environmental innovations. We find that while firm-level growth is strongly associated with all kinds of innovation activities, sector-level growth is not. Our results suggest that limiting overall economic growth may not undermine incentives to innovate as long as growth is still feasible on the level of the firm.

1 Introduction

Post-growth discourses have proposed to limit economic growth in order to face the challenges posed by environmental degradation, climate change and the depletion of natural resources (Kallis et al. 2012; Kerschner et al. 2018; Lietaert 2010). Green growth advocates have criticised this position claiming that principally it is possible to reconcile growth and environmental sustainability through the development of green innovations and technologies (Østergaard et al. 2021; Smulders et al. 2014). Following the demand-pull hypothesis by Schmookler (2013), which states that innovation is highly dependent on aggregate demand and economic growth, post-growth situations may in fact stifle innovation. On an aggregate level, Schmookler's hypotheses has indeed received some support (Aflaki et al. 2014; Geroski et al. 1995; Scherer 1982). On the firm-level this relationship appears to be substantially less clear, also because the demand-pull hypothesis has been interpreted in different ways. One way to look at demand pull is to analyse how aggregate demand affects firm level performance. This route has been taken by Brouwer et al. (1999) and Filippetti et al. (2011). A second way is to consider firm-level (sales) growth instead (Crepon et al. 1998; García-Quevedo et al. 2017; Piva et al. 2007). However, not telling apart the effects of aggregate and firm-level growth makes it difficult to infer to the likely effects of policies aiming at the reduction of macroeconomic growth rates. To do this, we need models that effectively consider the effects of aggregate and firm level growth likewise, while ideally also modelling the interdependencies between them. Delivering such a more comprehensive analysis of the growth effects on firm-level innovation is the first goal of this paper. Discussing the implications for innovation-policy with a background to post-growth scenarios is the second goal.

In order to analyse how aggregate and firm-level growth affect innovation behaviour, we compile a dataset, which links the German contribution of the European Manufacturing Survey 2018 comprising cross-sectional information about the innovation activities of 1,500 firms from the German manufacturing sector to sectoral growth figures obtained from macro-economic accounting statistics. Based on this dataset, we show that, on the firm level, innovation increase by higher firm-level growth, but decrease by higher sector-level aggregate growth. Overall, we find that both effects are roughly equally sized, which means that an equal change in both variables would leave overall innovation levels almost unchanged. Interestingly, we can also show that the mere fact that a sector is growing does not significantly affect innovation levels. Thus, as long as firms can grow individually, a low aggregated growth, as it would also occur in post-growth scenarios, does not have a significant effect on innovation. This pattern remains stable for a wide variety of indicators including the introduction of product innovations, new-to-market product innovations and eco-innovations. It also extends to turnover shares with new products. However, it is important to underline that the relationship between growth and innovations may depend on the underlying type of innovation (Sartorius et al. 2022).

From the policy-side, our results have deep implications for the desirability of post-growth scenarios. Since low sector-level growth does not negatively, and potentially even positively, affect innovation, post-growth is unlikely to be a dreadful scenario for innovation. This conclusion however only holds under the condition that firms can grow at least individually, which is well in-line with the notion that innovation is a competition strategy that intends to

create a competitive advantage allowing firms to grow, thereby promoting industrial change (Dosi 1988; Janger et al. 2017). This insight sheds some light on the somewhat elusive relationship between post-growth and market organization: economic policies aiming at reducing growth should focus on setting growth targets at the aggregated levels, such as the sectoral level, while avoiding to stifle growth as a market-based incentivizer of innovation on the level of the firm.

2 Theoretical background

2.1 Post-growth, green growth and innovation

In the sustainability literature, two partly opposed growth discourses can be identified. These are on the one hand post-growth/degrowth and on the other hand green-growth discourses. Both are in agreement that traditional economic growth-paradigms equating welfare and growth in terms of production value have acted as a major driver of unsustainable production modes and thus have given rise to a socio-economic institutional setting, where natural resources are overused and environmental degradation (including climate change) has become rampant (Alvarado et al. 2017; Jammazi et al. 2015). The discourses differ, however, in that the green-growth perspective argues for changes in the incentive schemes so that economic production is reorganized more sustainably (Hallegatte et al. 2012). As the term green growth already suggests, this approach assumes that at least principally economic growth and sustainability goals can be reconciled within the current socio-economic market based institutional setting. The required changes largely refer to three items of actions. First, there is a need to fix market-based misleading incentives, for example from uncompensated negative externalities. Mechanisms can be taxing and/or restricting unsustainable production methods, most notably by increasing the costs of energy in particular, if coming from non-regenerative resources. Second, in many cases there is a risk for system failures inhibiting the transition towards more sustainable societies. An instance is the change of unsustainable demand and consumption patterns. This is not only a matter of increasing costs of consuming unsustainable products (which would be a market failure adjustment), but also one of changing values and attitudes as well as the formation of new cooperation between producers making novel offerings, which deliver comparable utility, but with less detrimental impact for the environment. With an emphasis also on system failure, the green growth discourse is definitely already an ambitious one. Nonetheless, it does embrace economic growth as a legitimate goal of economic policy, because it is assumed that growth is a source of welfare and prosperity. The rationale for reconciling sustainability and economic objectives within a market-based institutional system is based on the concept of green innovations, i.e. the development of both technological and non-technological innovations, which aim at preserving and further increasing customer utility while keeping the environmental impact low. Examples are digital technologies, which can increase efficiency in energy and transport systems (Lange et al. 2020a; Lange et al. 2020b; Sarc et al. 2019). In that respect, this position puts high hopes on the ability of the market-based economy to provide a sufficient level of green innovativeness that indeed allows combining economic growth with sustainability. The EU Green Deal is a prime policy initiative based on the green-growth hypothesis (Wolf et al. 2021).

Post-growth and degrowth discourses question this optimistic view on the innovation. It is interesting to see that actually some authors in the field have taken a rather positive stance on new green technologies, while others have discarded the innovation-focus as a fetish (Kerschner et al. 2018). Yet, there is an agreement, that green innovation may at best reduce negative consequences of economic growth, however, not to an extent that growth and sustainability could go hand in hand. Thus, from the literature review we conclude that there is no other way than to transform the socio-economic institutional setting such that it limits

economic growth to zero (post-growth), or alternatively below zero (degrowth). It is needless to say that this does not easily work within the current institutional market-based setting, where competition and profit maximization will create strong incentives for growth. Most explicit are degrowth discourses about that aspect. The post-growth/degrowth discourses have accordingly received considerable criticism, not only because they tend to put little emphasis on economic goals, but also because they implicitly or explicitly question the market-based economy.

A further important criticism follows from the green-growth discourse in conjunction with Schmookler's demand-pull hypothesis on innovation. In particular, demand-pull puts forward the notion that innovation is triggered by demand and growth for a variety of reasons, such as higher profit margins and higher availability of financing. Thus, innovation itself may be dependent on growth, which would imply that limiting growth might undermine the potential to develop green innovations in the future. In that respect, post-growth or degrowth scenarios may do more harm than good. We will scrutinize this argument in detail, by analysing the demand-pull hypothesis from two perspectives, at micro-level of firms and the macro-economic level.

2.2 Is innovation dependent on economic growth? Previous literature

The demand-pull hypothesis initially developed by Schmookler (2013) states that an important driver of innovation is demand. Notably, it has been argued that economic upturns provide better conditions to absorb new products. Moreover, because firms have only limited time to profit from their innovations, they are more likely to introduce them into the market, irrespective on when they were produced (Filippetti et al. 2011; Geroski et al. 1995).

Contrary to the demand pull hypothesis, a criticism is that because higher demand is usually associated with higher rents, firms have a larger incentive to delay the market introduction innovation during recessions (Mensch 1979). That is to say, that innovation activities may still be ongoing, while at best its implementation in the market may be retarded. In addition, it is well-known that innovation activities on the level of the firm display a high degree of persistence (Antonelli et al. 2012, 2013; Dosi et al. 2010). This is often a result of the fact that firms' innovation activities are embedded in complex networks including also actors exposed to business cycles to the same degree (e.g. universities), which may shield innovation activities against business cycle influences (Filippetti et al. 2011). Finally, evolutionary economics has highlighted that firms are satisficers rather than optimisers (Dosi et al. 2010; Winter et al. 1982), which implies that during upswings firms may more likely react with reduced innovation activities because satisfactory firm-level outcomes can be achieved c.p. with less innovative effort.

On the empirical side, the results on the demand-pull hypothesis are somewhat mixed, we claim that this is a result not only of complexities of the process, but also of incompatibilities in how the demand-pull hypothesis is understood and tested. For our research question, we consider two strands of the literature, which are particularly relevant. The first, which considers the effects of firm-level growth on innovation, and the second, which looks at the effects of aggregate (e.g. sector-level) growth. We consider both as legitimate and useful conceptu-

alizations of the demand-pull hypothesis. However, at the same time, they reflect quite distinct concepts and it is not a priori clear that the effects can be expected to be identical. We will now shortly review the literature on both strands. It will become apparent that on both levels, even though there may be a slight majority of studies confirming Schmookler's hypothesis, overall the results retain a considerable level of ambiguity. Because, however, none of the studies considered aggregate and firm-level growth simultaneously, the ambiguity may well have to do with differences in the definitions and problems accounting for the two concepts at the same time, which may run a risk of conflating their effects.

Starting with the macroeconomic or sectoral level, the support of the demand-pull is somewhat stronger. Using macroeconomic data from the UK between 1948 and 1982, Geroski et al. (1995) show that cyclical variations in output Granger-cause innovation activities. This result is also confirmed for eco-innovations (Aflaki et al. 2014). Also, on the sectoral level there is evidence that innovation is positively dependent on demand (Bogliacino et al. 2009; Kleinknecht et al. 1990). While the results by Brouwer et al. (1999), who rely on firm-level data matched sector-level aggregate demand statistics, also confirm the demand-pull hypothesis, Filippetti et al. (2011) argue that this relationship depends heavily on the institutional context and may thus differs by country. A further counter result is given by Choi (2018), who shows for the electrical vehicle sector that demand does not precede innovation.

Several studies focusing on firm-level growth have also confirmed the demand-pull by showing that firm-level innovation is positively related to sales (Cainelli et al. 2006; Crepon et al. 1998; Piva et al. 2007). In line with the pivotal role of demand, several authors provide evidence of significant policy-induced demand pull-effects for the creation and uptake of innovations (Dai et al. 2021; Gao et al. 2019; Stojčić et al. 2020), of more complex ones such as environmental innovations in particular (Ghisetti 2017).Yet, studies have also uncovered important contingencies. For example, several results show that the relative importance of the demand-pull might depend on the type of innovation considered, where a distinction may be made between product, process, management or eco-innovations (Crespi et al. 2008; Ma et al. 2018). Relatedly, García-Quevedo et al. (2017) show that lack of demand reduces the R&D propensity but increases R&D spending. There is now also evidence that the sector of origin plays a larger role for the relative importance of demand push (Costantini et al. 2015). On a more conceptual ground it has been argued that not only demand volume but also demand uncertainty (García-Quevedo et al. 2017) should be accounted for. Somewhat in line, there is also evidence that the technical sophistication of the demand makes a difference (Antonelli et al. 2015).

In summary, while Schmookler's demand-pull hypothesis claims a rather stable relationship, we find only ambiguous support. This is irrespective of whether we look at the role of aggregate or firm-level demand. Because of that we abstain from concluding with clear-cut hypotheses. Interestingly, however, none of the reviewed works made an effort to tell apart the effects of the two demand conceptualizations. We posit that this constitutes a major shortcoming, because it runs a risk of conflating the effects of aggregate and firm-level demand, which would be particularly problematic if the effects were to differ. In the next two sections we will therefore present the theoretical and empirical framework and the results of a first empirical exercise trying to disentangle the effects of firm-level and aggregate demand.

3 Data and Identification

3.1 Data

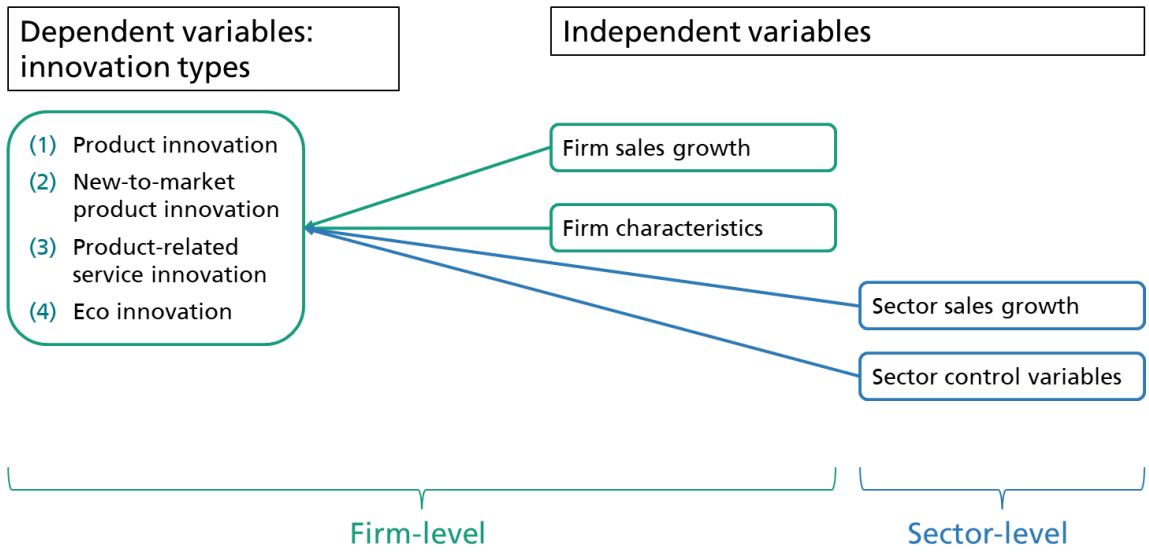
In order to disentangle the transmission mechanisms behind the demand-pull hypothesis it is necessary to analyse the impact of aggregated sectoral growth and firm-level growth on innovations simultaneously. Therefore, we construct a dataset combining two different sources. First, we employ data from the European Manufacturing Survey 2018 (EMS), using the German sample which compiles cross-sectional information about the growth rates and innovation activities of 1,500 firms from the German manufacturing sector. The EMS data also entails a variety of important firm-level information such as the number of employees, and industry affiliation. The industry definitions rely on the two-digit NACE classification. Although the EMS is a cross-sectional dataset some important variables, such as firm's growth rate are included as an average over several years, which allows implementing temporal averages in a cross-section framework. Second, we use publicly available data on sector growth provided by the Federal Statistical Office (DESTATIS) obtained from macro-economic accounting statistics. This data categorizes sectoral growth rates by industry branches, which are also based on the NACE classification. We use the sectoral growth data from DESTATIS and merge it with the firm-level data from EMS, creating a unique dataset. One can think of the sectoral growth from DESTATIS as an exposure variable to the microdata in the EMS based on the corresponding industry category from the NACE classification. The scope of the analysis is aggregated at the firm-level, and since we are also interested in the innovation impact of sector growth, the DESTATIS dataset is a vital component of the database.

3.2 Model and Identification

The objective is to analyse the impact of sectoral and firm-level growth on innovation activity while controlling for firm and sector specific factors. Hence, we require a framework, which models firm-level innovation activity with regard to firm-level growth while also considering sectoral growth. Figure 1**Fehler! Verweisquelle konnte nicht gefunden werden.** illustrates a simple model, where firm's innovation outputs are dependent on firm-level growth, firm characteristics, sectoral growth as well as sectoral control variables. We focus on four types of innovation measures in our model which are drawn from the EMS dataset, namely (1) product innovations, (2) new-to-market product innovations, (3) product-related service innovations, and (4) eco-innovations. Product innovations are products offered by a company for the first time and do not necessarily have to be market innovations. This category may, for example, include products that a company has developed and/or offered for the first time in order to tap into new markets. It may well be that the products already exist on the market and are offered by others. New-to-market product innovations are offered on the market for the first time. By offering these products, the company thus obtains a clear unique selling proposition. Service innovations are complementary or stand-alone services that have not been offered on the market before. We define eco-innovations as products or product enhancements that lead to an improved environmental impact during use or disposal. We model each innovation type separately, each depending on firm-level factors as well as sec-

toral factors while being independent from each other. Among the firm-level factors, company growth is of primary interest, and identifying it requires assumptions. First, according to Mensch (1979), firms can have an incentive to delay the market introduction, so it is reasonable to assume that firm level growth has a delayed effect on firm level innovation because periods with higher revenues relax a firm's budget constraint. A higher capital availability can positively affect a firm's propensity to invest, which may result in higher R&D investments and additional hiring of new employees, potentially in an innovation related department. However, it is likely that this type of investment will not bear fruits immediately, but rather in future periods with temporal delay. For example, investments in manufacturing, production facilities and other tangible assets take several months to become fully operational. The same also applies to human capital, because new employees need time to be trained before they are available to the company at full effectiveness. On the opposite, in periods with stagnant aggregated growth firms are more likely to restrain market introductions of new products and services. Hence, we model the innovation impact as a function of average firm-level growth over a period of three years, i.e. 2015 to 2017. Second, we assume that firm level growth, which occurred *further* in the past, i.e. more than three years ago, has a lesser impact on current innovation activity of a firm. This assumption is in line with common corporate practice, where growth-based investment decisions have short and medium term planning horizons, which range from a few months up to three years. Strategic decisions are planned over a longer period of time (usually five to ten years) and are less dependent on short-term growth (Schweinitz et al. 1965).

Figure 1: A simple model on the influence of firm-level and sectoral growth on firm's innovation activity



Source: Authors

The implementation of sector growth is central to modelling the demand-pull hypothesis. In our framework, we measure the sector growth for each NACE category respectively. Since every industry is different, it also takes a different amount of time for innovation to emerge. Hence, we assume that firms respond differently to industry growth, so that some adapt more quickly to positive (or negative) growth, while others show greater inertia. Sector growth is

obtained from the DESTATIS database and merged to the firm level data via the corresponding NACE category resulting in a novel dataset. Like in the case of firm-level growth, we assume a delayed impact of sector growth on innovation output for similar reasons. Firms might want to evaluate a changing industry environment and adapt their actions to the new circumstances after an observational period. Therefore, we model the impact of sectoral growth on firm-level innovation as an average of the previous three years. A single year of growth in an otherwise downward or stagnant period could be interpreted as a one-time event which might not affect firm's innovation activities. Hence, for a rational firm, it is more reasonable to take decisions based on the medium-term sectoral development, rather than on short-term fluctuations. Hence, we assume that firms make their decisions based on average growth trends over a few years rather than basing one-off years with high growth. Another important factor regarding sectoral growth which has to be taken into account is the difference between positive and negative growth. Since firms might respond differently to positive and negative growth, we use two different specifications for sector growth. The first model uses unrestricted growth, which allows positive as well as negative growth (Table 2), while the second model considers only positive sectoral growth. In addition to the growth variables, we include a number of firm and sector-specific covariates. In order to account for inter-industry differences, we include sector dummies based on the NACE classification as covariates in the model. Another important factor is the size of the firms. According to (Acs et al. 1987) large firms in the USA prove to be more innovative in a number of industries, while the opposite is true in others. We account for firm size by implementing the number of employees as a covariate. Moreover, for innovation output it also matters whether firms are producing domestically, or abroad Yue (2022) studies the impact of firms' foreign direct investments abroad and shows that foreign direct investment helps to improve the innovation performance of Chinese local enterprises. Hence, we include the share of production, which is outside of Germany, as a covariate. Furthermore, the age of a company's core product is another important innovation factor, because mature firms act as pacifiers (Dosi et al. 2010; Winter et al. 1982) which produce successful core products and place more emphasis on making incremental improvements to the existing products rather than pursuing the development of new-to-market product innovations. Since firms' innovation activities are often embedded in complex networks (Filippetti et al. 2011), we also control for the intensity of production cooperation and the share of intermediary products in our estimation.

3.3 Variable Selection and Regression Analysis

The variable selection is based on the considerations in the previous chapters. Table 1 summarizes the required variables for the analysis. The econometric analysis aims at estimating the impact of sector and firm-level sales growth on innovation. The dependent variables, i.e. the four innovation types, are binary variables which take the value of one, in the event that the company produces the corresponding innovation, and zero otherwise. Due to the binary structure of all dependent variables we choose a probit approach, where we estimate the impact of the aforementioned variables on each of the four innovation types separately. Since we also differentiate between unrestricted and restricted (i.e. strictly positive) sector growth, we end up with a total of eight estimations which are split into two tables. Table 2 contains the main results for the model without sector growth limitations, whereas Table 3 illustrates the results for strictly positive economic growth. To ensure comparability among

different types of innovation, we restrain the sample so that 841 observations remain. To ensure that potential non-monotonicity in the relationship does not invalidate our main conclusions, we also reran the models using spline regressions as robustness checks. Splines are semiparametric regressions, which also allow for non-linear effects of the independent on the dependent variables and can avoid estimation problems resulting from non-monotonicity. The spline regression results are illustrated in figure 2 for the unrestricted specification and in figure 3 for the restricted specification. They corroborate the conclusion from the parametric probit regression models.

Table 1: Variable overview and summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Product innovation introduced	841	0.513	0.500	0	1
New-to-market product innovation introduced	841	0.243	0.429	0	1
Product-related services introduced	841	0.150	0.358	0	1
Eco-innovation introduced	841	0.215	0.411	0	1
Firm sales development 2015-2017 in Mil. Euro	841	8.464	33.91	-44.78	728.6
Sector sales growth 2015-2017 in Mil. Euro	841	167.2	47.06	67.50	235.2
Positive sector sales growth 2015-2017	841	0.919	0.273	0	1
Log number of employees	841	4.205	1.100	2.303	10.66
Production cooperation participation	841	0.196	0.397	0	1
Production outside of Germany	841	0.122	0.327	0	1
Product being sold for more than 10 years	841	0.896	0.305	0	1
Share of intermediary products obtained from Germany	841	75.16	24.89	0	100
Location: West Germany	841	0.818	0.385	0	1
NACE 10-19	841	0.195	0.396	0	1
NACE 20-29	841	0.732	0.443	0	1
NACE 30-23	841	0.072	0.259	0	1

Source: Authors

4 Results

4.1 Main regression results

The novel value of this work consists in a simultaneous consideration of the aggregated demand, i.e. sectoral level growth, and firm-level growth effect on firms' innovation, which leads to a deeper understanding of the demand-pull mechanism and yields some interesting insights. Overall, our estimates provide evidence that firm-level growth is conducive to innovation, whereas sectoral growth has either no impact or a negative impact on innovation activity. Hence, the demand pull hypothesis is supported at the firm level, while it is rejected at the sectoral level. In contrast to much of the literature, we find little convincing evidence supporting the demand-pull hypothesis at the aggregated level. In all of the eight specifications the effect of sectoral growth on innovation is either significantly negative, or insignificant. There is no evidence, that positive sectoral growth leads to higher innovation activity at the firm level. This argument is confirmed in both specifications. In the unrestricted model (Table 2) firms' probability for introducing product innovation, service innovations and eco-innovations are reduced by positive sectoral growth. On the contrary, this means that firm-level innovation arises more likely in periods with negative sectoral growth. In the restricted specification (Table 3) there is no significant relationship between higher positive sectoral growth and innovation, with the exception for eco-innovations, which respond negatively to positive sectoral growth. New-to-market product innovations are not affected by sectoral growth at all, which is confirmed in both specifications. Thus, when considering sectoral growth, the results argue against the demand pull hypothesis.

Table 2: Binary regression with unrestricted sector growth for product innovation, new-to-market product innovation, product related service innovations, and eco-innovations

	(1) Product innovations	(2) New-to-market product innovations	(3) Product-related service innovations	(4) Eco-innovations
Sector sales growth 2015-2017	-0.0010*	-0.0006	-0.0009***	-0.0013***
	(-2.52)	(-1.78)	(-3.59)	(-4.04)
Firm sales growth 2015-2017	0.0012*	0.0010*	0.0004	0.0009*
	(1.98)	(2.32)	(1.10)	(2.31)
Log employees	0.1215***	0.0327*	0.0460***	0.0714***
	(5.91)	(2.16)	(4.03)	(5.01)
Production cooperation	-0.0062	-0.0095	0.0419	0.0284
	(-0.14)	(-0.26)	(1.55)	(0.83)

	(1) Product innovations	(2) New-to-market product innovations	(3) Product-related service innovations	(4) Eco-innovations
Production outside Germany	0.0643	0.1244**	0.0618	-0.0243
	(0.99)	(2.74)	(1.82)	(-0.54)
Products older 10 years	0.2056**	0.1071	-0.0289	0.0496
	(3.11)	(1.93)	(-0.77)	(0.97)
Share intermediates from Germany	-0.0026***	-0.0005	0.0001	-0.0014*
	(-3.55)	(-0.82)	(0.12)	(-2.53)
Location: West Germany	0.0425	0.0390	0.0278	-0.0037
	(0.87)	(0.97)	(0.87)	(-0.10)
Sector dummies	Yes	Yes	Yes	Yes
Observations	841	841	841	841

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: Authors

However, it is still too early to reject the demand pull hypothesis because the effects of firm-level growth on innovation are in stark contrast to sectoral growth. With the exception of product related service innovations, the propensity to innovate is increased by higher firm sales growth, and lowered by negative growth. Hence, the introduction of product innovations, new-to-market product innovations and eco-innovations is more likely, when firms exhibit higher sales growth, and less likely with lower sales growth. The enhancing effect of firm-level growth varies depending on the innovation type. The introduction of product innovations benefits most from firm-level growth (the coefficient is at .0012 in both specifications), while the introduction of new-to-market product innovations and eco-innovations is at a slightly lower level (.0010). Product related service innovations do not respond significantly to firm-level sales growth in both specifications. Overall, our results indicate that the effect of sectoral growth and firm-level growth can work in opposite directions. Positive sectoral growth either dampens firms' innovation output, or leaves them unaffected at best, while positive firm-level growth is enhancing most types of firm-level innovation. Hence, whether a demand pull is benefiting firms' propensity to innovate largely depends on which of the two effects predominates. We can illustrate this point using the example of a firm which introduces product innovations in a positive growth environment (i.e. within the restricted specification in Table 3). In this case, the average firm does not respond to sector growth, while it positively responds to firm-level growth. Hence, there is no demand pull at the aggregated level, but at the individual level the propensity to innovate is positively affected by firms' higher sales growth. Therefore, since low sector-level growth does not negatively affect

innovation, it is unlikely that post-growth scenarios will be dreadful for innovation. This conclusion however only holds under the condition that at least individually firms can grow (Dosi 1988; Janger et al. 2017). In order to draw meaningful conclusions about the demand-pull hypothesis, it is urgently necessary to consider sectoral growth and firm-level growth simultaneously because the sum of both effects ultimately determines whether a firm is more (or less) likely to innovate.

Table 3: Binary regression with restricted positive sector growth for product innovation, new-to-market product innovation, product related service innovations, and eco-innovations

	(1) Product innovations	(2) New-to-market product innovations	(3) Product-related service innovations	(4) Eco-innovations
Positive sector sales growth 2015-2017	-0.0375	-0.0671	-0.0630	-0.1088*
	(-0.55)	(-1.22)	(-1.46)	(-2.10)
Firm sales growth 2015-2017	0.0012*	0.0010*	0.0004	0.0010*
	(1.98)	(2.35)	(1.17)	(2.35)
Log employees	0.1227***	0.0343*	0.0481***	0.0741***
	(5.97)	(2.25)	(4.12)	(5.14)
Production cooperation	-0.0042	-0.0091	0.0443	0.0285
	(-0.09)	(-0.25)	(1.62)	(0.83)
Production outside Germany	0.0671	0.1259**	0.0647	-0.0218
	(1.04)	(2.76)	(1.86)	(-0.48)
Products older 10 years	0.2059**	0.1064	-0.0273	0.0501
	(3.14)	(1.93)	(-0.72)	(0.98)
Share intermediates from Germany	-0.0027***	-0.0005	0.0001	-0.0014*
	(-3.67)	(-0.79)	(0.12)	(-2.49)
Location: West Germany	0.0421	0.0375	0.0283	-0.0065
	(0.87)	(0.94)	(0.87)	(-0.17)
Sector dummies	Yes	Yes	Yes	Yes
Observations	841	841	841	841

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: Authors

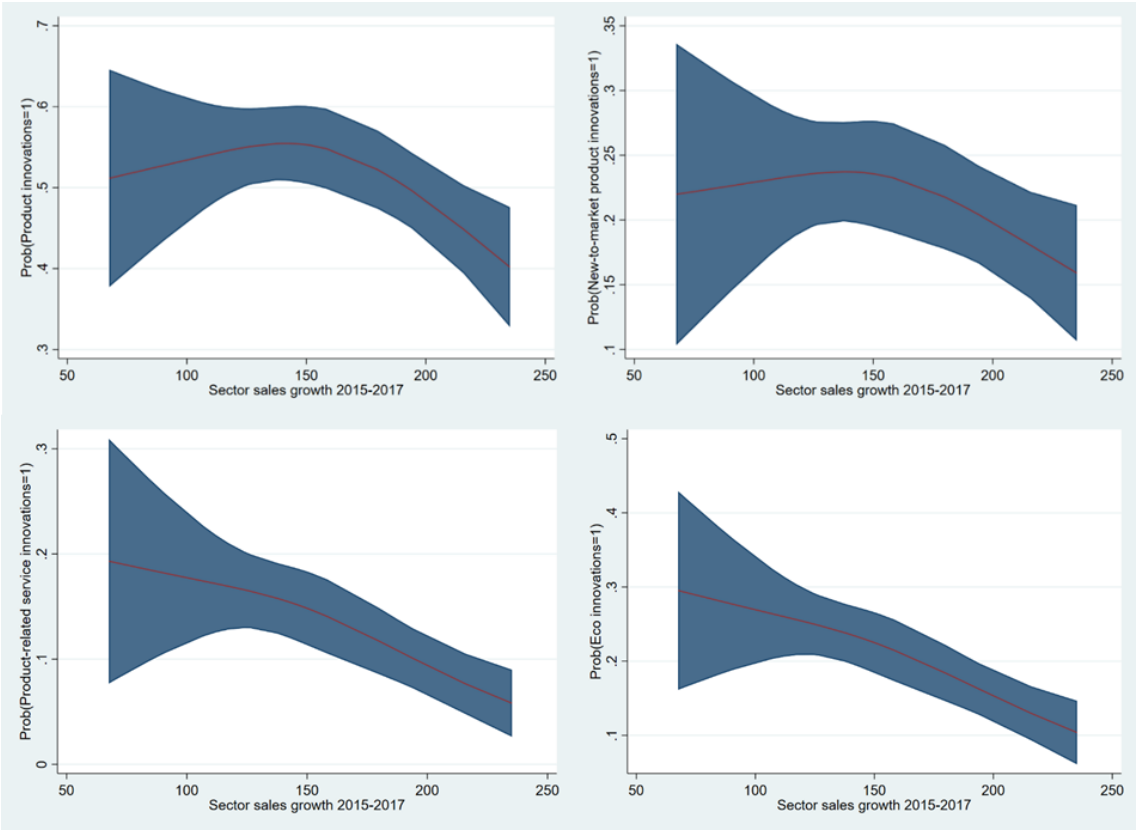
In addition to the main (growth-) variables, the other covariates reveal some interesting insights. Overall, larger companies with larger numbers of employees have a higher propensity

to innovate across all four innovation types and in both specifications. Firms which operate a higher share of production outside of Germany, have a higher probability to release new-to-market innovations. This evidence is in line with Yue (2022) who argues, that a firms with higher FDI can boost domestic innovation activity. Furthermore, we find that mature companies, which have been manufacturing at least one product for more than 10 years, are more likely to release product innovations. This result supports (Dosi et al. 2010; Winter et al. 1982)), who argue that mature firms act as pacifiers which produce successful core products and focus their innovation activity on incremental improvements. Another interesting finding is the negative correlation between the share of intermediary products manufactured in the homeland and the propensity to release product innovations and eco-innovations. It appears that both types of innovation depend on domestic supply chains. This is an interesting result which requires further studying. Overall, our results are also in line with Filippetti et al. (2011), who argue that innovation activity depends heavily on the institutional context and may thus differ by country.

4.2 Robustness checks

In order to ensure the validity of our findings, we conduct several robustness checks. We run a total of eight spline regressions for each innovation type and each specification, i.e. one with restricted and unrestricted sectoral growth. This results in a total of eight spline diagrams which are illustrated in the figures below. Figure 2 shows the spline regression diagrams for the four types of innovation responding to sector sales growth. The top two graphs within the figure illustrate the spline regression for product innovation and new-to-market product innovations, which show a downward sloping, nonlinear and insignificant relationship to sector sales growth. The bottom two graphs present evidence for a significant negative linear relationship between service innovations, eco-innovations and sectoral growth. Although we can observe nonlinearities for product innovations and new-to-market product innovations, it does not strongly affect the results because sector growth remains either a non-significant or negative factor for firm-level growth. Figure 3 shows the spline regression diagrams for four types of innovation responding to firm-level growth. All four figures show clear evidence for a monotonous relationship between the four innovation types and firm-level growth. It can therefore be concluded that non-monotonicity is negligible between firm-level growth and innovations. Thus, the results are robust or not-affected by nonlinearity, which underlines the stability of our results.

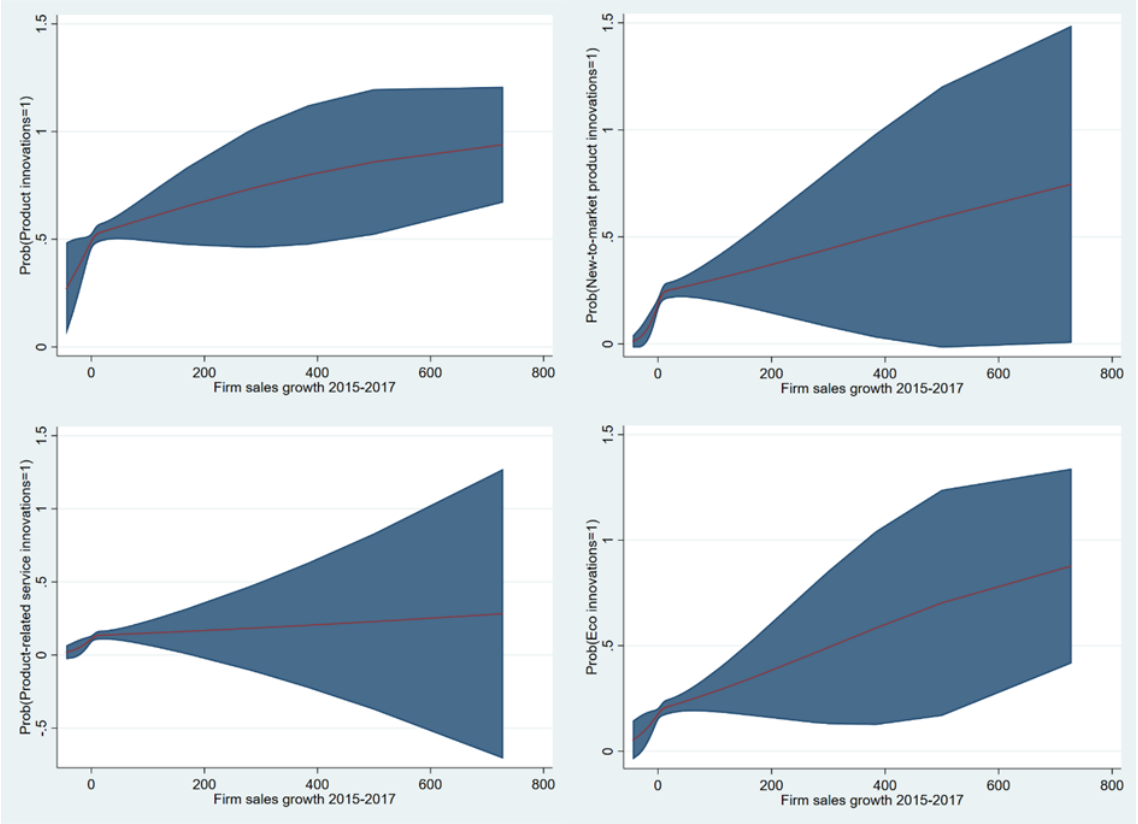
Figure 2: Spline regression for four types of innovation responding to sector sales growth



Source: Authors

To ensure comparability between the different types of innovation, we decided to use binary dependent variables in our main regressions. This is because eco-innovations are exclusively available as a binary variable in our dataset, while the other three innovation types, i.e. product innovations, new-to-market innovations and product-related service innovations are also available as continuous variables measuring their share of turnover. Thus, with the exception of eco-innovations, it is also possible to calculate the specifications from the previous section with continuous dependent variables. Analysing the share of turnover with these types of innovation provides a measure of actual success rather than a pure activity estimator. Therefore, we run tobit regressions for product innovations, new-to-market innovations and product-related service innovations each. Furthermore, we distinguishing between unrestricted sectoral growth and strictly positive sectoral growth for each innovation type as we did in the main regressions. The results from the tobit regressions support and strengthen our main finding. The negative relationship between unrestricted sector growth and product innovation as well as product-related service innovations become in fact more pronounced in terms of statistical significance.

Figure 3: Spline regression for four types of innovation responding to firm sales growth



Source: Authors

For the specifications with restricted sectoral growth the tobit regressions are also in line with the main results from binary regression. The positive relationship between product innovations as well as new-to-market product innovations and firm-level growth has a higher level of statistical significance in the tobit regressions. Hence, these regressions confirm that there is a strong significant positive relationship between firm-level growth and product innovations as well as new-to-market innovations.

5 Conclusion

In this article, we examine the demand-pull hypothesis and shed light on the mechanisms behind it. We view the demand-pull hypothesis as a multilayered mechanism that is essentially composed of two effects, i.e. firm-level growth and sectoral growth, which affect firm level innovations. Our key findings suggest that firm-level growth has a positive impact on innovation output at the firm level (with the exception of product-related service innovations). In contrast, positive sectoral growth has no effect on three out of four types of innovations (with the exception of eco-innovations). Hence, positive sector growth makes little to no contribution to firms' innovation activity. It has neither an innovation-promoting nor an innovation-inhibiting effect with the aforementioned exception of eco-innovations. Interestingly, we find evidence that negative sector growth, i.e. sector decline, can actually have an innovation-enhancing effect on firms. In summary, our findings suggest that growth does offer strong incentives for innovation albeit not through the channel of sectoral growth but rather firm-level growth. Hence, we support Schmookler's demand pull hypothesis *at the firm level* but not *at the sectoral level*. Our results have important implications for innovation policy. A post-growth scenario is well within the realm of possibility as long as firm growth is unrestricted. Innovation-enhancing policies that limit overall growth are conceivable as long as they do not limit growth at the firm level.

There are several ways in which policy measures can be designed against this background. For example, the public sector could promote and commission green technologies and solutions. Xu et al. 2022 argue that environmental regulation is an effective (but not necessarily efficient) way to enhance eco-innovations. Another possibility would be to limit sector growth e.g. with macro-level measures such as taxation schemes or the setting of overall CO2 emission goals. One example for such a policy is presented by Rogge et al. (2010) who argue that the innovation impact of restrictions set by emission trading have a rather limited impact on innovation. These results are in line with our findings which suggest that macro-level growth has little to no impact on firm-level innovation activity. Hence, it is reasonable to conclude, that macro-level policy which restricts growth will also have little to no effect on firm-level innovation. But the obvious advantage of such policy is to set upper limits on growth – at least implicitly the part of it that is associated with increased CO2 emissions – while still allowing growth of individual firms and thereby not weakening competition as a major driving force of innovation. Our results suggest that even if macro-level growth is limited, the targeted promotion of desirable technologies, such as green technologies is still within the realm of possibilities. For example, Song et al. (2020) support that view and argue that setting appropriate financial and regulatory incentives in form of subsidies for green technology development, setting emission goals, taxation and regulation could further propel the diffusion of desirable technologies. Specifically, companies successfully introducing new green technologies would still thrive on greater competitiveness allowing them to grow. Firm-level growth would imply that such technologies would diffuse faster. A policy scenario in line with our finding would be one in which firms' competitive incentivization remains intact, desirable technologies are supported by public policy while keeping that part of growth that is associated with environmental degradation for example in terms of CO2 emissions within bounds.

Our results make an important contribution to understanding the relationship between growth and innovation. In particular, the breakdown of the demand pull into sector and firm-level growth is a key contribution of this work. Nevertheless, there are some limitations in our approach. First, an important factor that could potentially affect our results are the institutional conditions. Our research is based on data exploiting growth cyclical or sectoral variations in growth conditions. These variations are associated with certain expectations about future developments taking the specific institutional market-based framework for granted. While we believe that our results extend to milder changes in to that framework e.g. in terms of an increased use of CO2 or other trading mechanisms, it is not at all guaranteed that they would extend to more radical shifts away from market incentivization as discussed in some parts of the degrowth literature (Akbulut 2021; Schmelzer et al. 2022). If at all, our results would hint at problems associated with that view, because a degrowth understanding moving away from market-based economies would not only result in lower macro-economic growth but would also imply loosing market-based incentivization of the development of green technologies. Finally, another limitation is that our sample consists of firms from just the manufacturing sectors and just Germany. Whether our results apply to the service sector or and how growth affects the servitization in general, can therefore not be answered. Also the degree to which the results extend to other countries, in specific with very different economic and institutional contexts such as China, remains unclear and warrants further research.

6 Literature

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