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PRODUCT-MARKETING INNOVATION, SKILLS, AND FIRM PRODUCTIVITY GROWTH

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The role of product and marketing innovation for productivity growth is addressed using survey and register data for the Danish economy. It is hypothesized that product and marketing innovation are complementary inputs and that innovation activities are skill-intensive. It is established that product and marketing innovation in skill-intensive firms results in significantly faster productivity growth. Moreover, product and marketing innovation have independent roles in productivity growth, which cannot be attributed to organizational changes. Finally, we apply an instrument variable approach for firms, innovation choices to study endogeneity. The results strongly support the idea that product–marketing innovation leads to faster productivity growth in skill-intensive firms.

JEL Codes: J24, M31, O31

Keywords: educational composition, instrumental variables, marketing innovation, non-technological growth drivers, product innovation

1. INTRODUCTION

This paper studies the effects of marketing innovation on productivity growth. It is not claimed that marketing innovation necessarily plays an independent role in productivity growth; instead, it is hypothesized that the *complementarity* between product innovation and marketing innovation is an important growth driver. The abilities to create new and improved products and to commercialize these products into higher demand appear to require the coordination of

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product and marketing innovation activities, which is what informs this hypothesis. Empirical support for the independent role of product and marketing innovations in productivity growth is established. More precisely, the combination of the two innovation activities results in significantly faster productivity growth in skill-intensive firms.

Over the past decade, the importance of non-technological growth drivers has been recognized. One prominent driver is organizational changes. Caroli and Van Reenen (2001) argue that these types of changes have an independent role in productivity growth. Moreover, the authors find that organizational changes are skill-intensive, which implies that the growth effect of these activities is greater in skill-intensive firms than in non-skill-intensive firms. In another line of research, Bloom and Van Reenen (2007) establish that good management practices are important for firm productivity.[1]

Complementarities between non-technological and technological growth drivers are also important for firm performance. Micro studies have demonstrated that the relationship between organizational changes and new technologies is important for productivity.[2] The evidence reveals that a combination of investments in information technology (IT) and organizational changes contributes to firm productivity growth. Crespi *et al.* (2007) examine data from the United Kingdom and find that the interaction between IT investment and organizational innovation produces positive effects on firm performance. Moreover, Bloom *et al.* (2012) find that the IT-related productivity advantage in the U.S. is primarily related to "tougher" human resource management in U.S.-owned multinationals compared with non-U.S.-owned multinationals.

The contribution of the present paper to the literature is identification of another complementarity between non-technological and technological growth drivers; in particular, this study assesses the complementarity between marketing innovation and product innovation. Surprisingly, the empirical importance of this complementarity for productivity growth remains unstudied despite the facts that product innovation is central to the growth literature and that marketing is an important business activity.

Marketing innovations involve the implementation of new marketing practices. Specifically, these innovations include changes in sales and distribution methods and changes in product design and packaging. This concept of marketing innovation follows the definition in the *Oslo Manual* of the OECD (2005). Moreover, this concept is applied in the Community Innovation Survey (CIS), which is the source of the innovation data that are used in this paper.

It is important to understand the distinguishing factors between product and marketing innovations in the course of studying the complementarity between these two innovation activities. The *Oslo Manual* states that "the main distinguishing factor for product and marketing innovations is a significant change in the products functions or uses." For example, product innovation occurs if the functionality or user characteristics of existing products are significantly improved. Marketing innovation occurs if the design of an existing product

[1]For a survey that empirically assesses organizational changes, see Bloom *et al.* (2010).
[2]See, for example, Brynjolfsson and Hitt (2000) for a survey.

changes significantly; however, new designs without significant changes in functionality or user characteristics are not product innovations.[3]

For this paper, we have constructed a new and important database that combines survey data on innovation activities with register data on growth in firm performances and skill intensities at the firm level. More precisely, information on firm-level innovation activities from the CIS is combined with firm information from Danish register data. This database includes comprehensive descriptions of innovation activities, skills, and productivity growth.

The importance of marketing has rarely been studied with respect to firm performance. In the marketing literature, the idea that new and better products, success is related to marketing activities is suggested in theoretical work by Gupta *et al.* (1986); in particular, they argue that the success of research and development (R&D) may potentially be influenced by the integration of R&D and marketing. In an empirical study that examines a cross-section of firms and focuses on the U.S. semiconductor industry, Dutta *et al.* (1999) find that the interaction between marketing and R&D capabilities is correlated with firm performance. Moreover, in a case study, Park (2004) finds that marketing ability partially explains the success of the VHS format at the expense of Betamax in the videocassette recorder market.

In the present study, we formulate and test a joint hypothesis that is based on two separate hypotheses. The first of these separate hypotheses relates to the complementarity between product and marketing innovation. This hypothesis states that product and marketing innovation have a positive effect on productivity growth and that the growth effect is greater than the effect from either product or marketing innovation alone. The motivation for this hypothesis is that product innovation generates new and improved products that potentially shift the firm demand curve outwards. However, to effectively approach existing or new markets with new or improved products, firms will use marketing tools. The second separate hypothesis states that innovation is a skill-intensive activity. Combining the two hypotheses, product innovation and marketing innovation in skill-intensive firms are expected to result in significantly faster productivity growth.

The main result of this paper is empirical support for this joint hypothesis, which implies that product innovation and marketing innovation in skill-intensive firms result in significantly faster productivity growth. In contrast, firms that engage in either product innovation or marketing innovation alone do not demonstrate a positive growth effect from these innovation activities. Moreover, we rediscover the main result for two broadly defined sectors, manufacturing and services, which leads us to conclude that the main result constitutes a general phenomenon.

There are two main concerns with respect to the validity of the main result of this study. The first concern relates to the observation that the majority of firms with product and marketing innovation also demonstrate organizational innovation. Therefore, it is important to exclude the possibility that the effect from product and marketing innovation is spurious and may simply reflect the effects of

[3]For services, "the main distinguishing factor for service innovations and marketing innovations is whether the innovation involves a marketing method or a service (i.e., a product). The distinction may depend on the nature of the firm's business." See OECD (2005).

organizational changes. We are able to eliminate this concern. More precisely, we find that product–marketing innovation and organizational innovation play independent roles in productivity growth.

The second concern relates to the endogeneity of product–marketing innovation. To address this issue, we use an instrumental variable (IV) approach that is based on a form of exogenous variation in innovation costs, which will give us independent variation in the firms, choices for product–marketing innovation. The applied instrument is industry–region variation in the employment share of educated workers within the social sciences. This instrument relies on the notion that coordination is required between the creation of new and improved products and their commercialization; in addition, workers educated within the social sciences are presumed to possess the requisite competences and qualifications to accomplish this type of coordination. Consequently, innovation costs are expected to be lower in industry–region clusters with high concentrations of this type of labor.

It is established that the instrument is not a weak instrument. Moreover, the IV estimation confirms the main result that product–marketing innovation leads to faster productivity growth in skill-intensive firms. Although we are careful not to claim causality, as the instruments used are not applicable at the firm level and, thus, do not explain the full random variation in the variables of interest, the results strongly support the idea that product–marketing innovation leads to faster productivity growth in skill-intensive firms.

In addition to product, marketing, and organizational innovation, firms can also perform process innovation. This type of innovation is excluded from the analysis because it turns out to have no empirical importance in the present study, which is a surprising result but consistent with findings in the literature (Hall, 2011). Process and organizational innovation are very collinear in the data set. Eighty percent of firms that do process innovation also perform organizational innovation. However, process innovation does not contribute to explain value-added growth, even when organizational innovation is disregarded. Our interpretation of this result is not that process innovation is unimportant for firm productivity growth, but rather that the process innovation questions in the CIS questionnaires are not well-measured and do not appropriately capture process innovation investments. A superior approach is to measure process innovation as part of the capital stock (e.g., IT capital stock or investments in IT-based production capital). See, for example, Bartel *et al.* (2007) and Draca *et al.* (2009).

The paper proceeds as follows. The next section briefly presents the simple model and data used in the empirical analysis. Section 3 presents the empirical results. Section 4 presents additional robustness analyses. Section 5 presents the results of a sector-specific analysis, and Section 6 concludes. The applied model, data and definitions are described in detail in an appendix, which also includes a discussion of the relationship between the two approaches that are used in the empirical analysis.

2. Model and Data

The equation to be estimated in the empirical analysis is a standard growth equation of the following form:

$$\Delta \ln Y = \beta_0 + \beta_1 \Delta \ln K + \beta_2 \Delta \ln L + \Delta \ln A + \varepsilon \tag{1}$$

with knowledge creation modeled as follows:

$$\Delta \ln A = \lambda_1 I^P E + \lambda_2 I^M E + \lambda_3 I^P I^M E + \lambda_4 I^O E$$

where Y denotes real value added; K denotes the physical capital stock; L denotes employment; and A denotes the knowledge capital stock. Δln indicates log-changes. I^P, I^M, and I^O denote the intensities of product, marketing, and organizational innovation, respectively. E denotes the education mix, where high values indicate skill-intensive firms. The applied model is motivated and described in detail in Appendix A.

The most important aspect of the model is the complementarity between product and marketing innovation, which is represented by the interaction term $I^P I^M$. We hypothesize that marketing innovation strengthens the growth effect of product innovation (and vice versa). In other words, firms that not only innovate new and improved products but also expend the required effort to bring their products to market via marketing innovation are expected to perform better than firms that simply innovate their products. Another important aspect is that innovation is assumed to be a skill-intensive activity. Product–marketing innovation in skill-intensive firms is thereby expected to lead to significantly faster productivity growth. This expected effect is reflected in a positive value of parameter λ_3 to $I^P I^M E$, which captures the positive growth effect in skill-intensive firms. Our main focus in the empirical analysis will be the point estimate and significance of λ_3.

The most important aspect of the data set is that innovation variables are constructed as binary indicators from the CIS survey data. In addition, Y is measured as the value-added in current prices that have been deflated by narrow industry-specific price series; K is developed using investment data using the Perpetual Inventory Method (PIM), whereas L is measured using full-time equivalent units. For three-year periods, the log differences in these variables are determined in annualized changes. As a measure of the education mix in each single firm, E, we use the share of full-time employees who possess at least 16 years of education. By this measure, higher levels of E indicate more skill-intensive firms. The descriptive statistics of the sampled firms are provided in Appendix Table A1. The data set and definitions are described in Appendix B.

3. Empirical Results

This section presents the study's empirical results. First, we discuss the descriptive statistics. Second, we comment on a number of econometric problems that are addressed in the analysis. Finally, we provide the results of the regression analysis.

3.1. *Descriptive Statistics*

The innovation activities for the firms in our sample are presented in Table 1. In Table 1A, the firms are organized in terms of whether they perform product

TABLE 1A

Firms with Different Types of Innovation

		Product Innovation		
		Yes	No	Total
Marketing Innovation	Yes	164	105	269
	No	363	689	1052
	Total	527	794	1321

TABLE 1B

Firms with Different Types of Innovation

			Product Innovation		
Organization Innovation			Yes	No	Total
	Marketing Innovation	Yes	136	68	204
		No	265	307	572
		Total	401	375	776
			Product Innovation		
No Organization Innovation			Yes	No	Total
	Marketing Innovation	Yes	28	37	65
		No	98	382	480
		Total	126	419	545

and/or marketing innovation. In Table 1B, they are classified in terms of whether they perform product, marketing, and/or organizational innovation.

From Table 1A, it is evident that 527 of the 1321 sampled firms—approximately 40 percent—engage in product innovation. Approximately one-third of these firms accomplish both marketing innovation and product innovation, whereas the remaining two-thirds do not conduct marketing innovation. Moreover, 269 firms participate in marketing innovation. Approximately 60 percent of these firms also perform product innovation.

Most firms that engage in product and marketing innovation also perform organizational innovation; this observation must also be addressed. From Table 1B, it is evident that 401 of the 527 firms (76 percent) that conduct product innovation also engage in organizational innovation. Nearly 83 percent of the firms that engage in both product and marketing innovation also conduct organizational innovation.

Before turning our attention to the regression analysis, we consider the average labor productivity growth for various types of firms. In Figure 1, the average growth rates of skill-intensive firms are compared with the average growth rate of all firms. In particular, as discussed in the following paragraph, firms are organized in terms of their innovation activities, and the growth rates in this figure are presented as deviations in the average growth rates of skill-intensive firms from the overall average growth rates for each firm type. Firms are considered to be skill-intensive if their education share exceeds the median education share within their firm type.

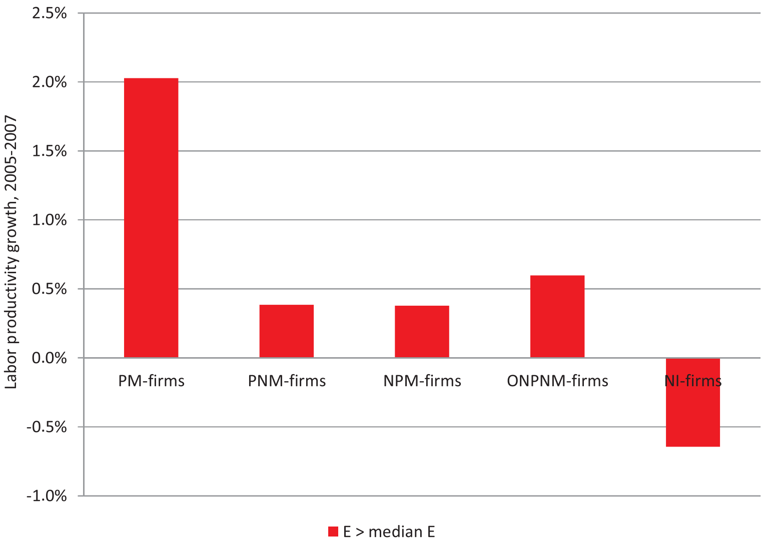

Figure 1. Labor Productivity Growth, 2005–07 (deviation from average growth rate in skill-intensive firms from mean); Groups of Firms Divided after Types of Innovation Activities

Note: Firms are considered to be skill-intensive if their education share in 2001 exceeds the median share within their firm type.

We split the data into four types of innovative firms based on the innovation activities in which each firm participates. Specifically, the sampled firms are grouped according to whether they conduct (1) both product and marketing innovation (*PM*), (2) product innovation but no marketing innovation (*PNM*), (3) marketing innovation but no product innovation (*NPM*), or (4) organizational innovation but no product or marketing innovation (*ONPNM*). Finally, we also include firms without innovation activities (*NI*).[4]

One interesting observation may be gleaned from Figure 1. It is clear that for each type of firm that conducts innovation activities, the average growth rate of skill-intensive firms is greater than the average growth rate of all firms of the same type. This effect is found for all firm types that feature innovation and suggests that innovation is indeed a skill-intensive activity. Moreover, this effect is especially pronounced in firms that engage in both product and marketing innovation. With this observation in mind, we turn to the regression analysis.

3.2. *Econometric Problems*

A number of econometric problems arise during estimations of the relationship between a firm's productivity and knowledge stock. Specifically, these problems are unobserved heterogeneity and endogeneity. We address unobserved

[4]In the main text, we only apply four firm types with innovation activities to reduce the number of parameters to estimate. This approach is utilized despite the fact that the combinations of three innovation types can be used to define seven firm types with innovation activities. Please see the appendix for a discussion of this topic.

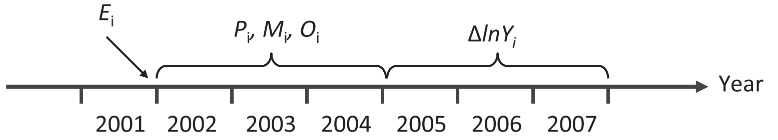

Figure 2. Timing of Variables in Regressions

heterogeneity by estimating the first differences model. Consequently, we use annualized changes during the 2005–07 time period, which considers time invariant fixed effects.

We are concerned with two aspects of endogeneity: first, that the applied innovation measures are endogenous if, for example, productivity shocks are increasing the tendency of firms to innovate. To mitigate this aspect of endogeneity, we use lagged innovation variables in the regressions, as discussed by Griffith *et al*. (2004). More precisely, we use data for innovation activities during the 2002–04 time period. Furthermore, we utilize the initial education share measured in the first week of November 2001; thus, this share is measured before the period that the innovation measures address. The timing of the dependent and explanatory variables is illustrated in Figure 2.

Although we apply lagged innovation variables to mitigate endogeneity, we remain concerned about this issue. An issue that can make the survey-based innovation variables endogenous involves measurement errors. Measurement errors may plausibly produce downward biases in the estimates. Another issue is that some unobserved productivity shocks—changing management practices, etc.—provide incentives to invest in innovation and also improve productivity. These shocks will cause biases in the innovation coefficients. To overcome these endogeneity issues, we employ an instrumental variable approach. Furthermore, to address a potential selection problem, we include lagged growth rates in one of the regressions in the robustness analysis. This approach may address the concern that high-growth firms potentially select themselves into innovation activities in a manner that is not replicated by low-growth firms.

Another aspect of endogeneity relates to simultaneity and selection bias for point estimates of primary production factors. The former bias should be considered if productivity shocks simultaneously affect value added and capital, whereas the latter bias should be considered if surviving relates to productivity shocks. To consider these types of endogeneity, we apply a two-stage estimation procedure. First, we use the estimation methods developed in Olley and Pakes (1996), Levinsohn and Petrin (2003), and Ackerberg *et al*. (2006) to estimate production functions and predict total factor productivity growth. Second, we apply the estimated total factor productivity growth measure as the dependent variable and innovation measures as explanatory variables.

3.3. *Regression Results*

In the following discussions, two sets of regression results are presented. First, we attempt to disentangle the growth effects that are produced by each different *innovation type*. From an empirical perspective, disentangling the effects of different innovation types is challenging because most of these types coexist in the production function and thus create possible collinearity issues (Anderson and Schmittlein, 1984; Milgrom and Roberts, 1990; Athey and Stern, 1998). In this study, we are able to obtain precise estimates of the combined growth effects of product and marketing innovation; however, due to multicollinearity problems, it is not possible to determine the separate effects of product innovation or marketing innovation. Therefore, in lieu of explicitly examining different innovation types, we subsequently focus on *firm types* that engage in innovation. We use the firm types that were defined above in relation to Figure 1. These two approaches are derived from the same general model. Moreover, the same qualitative empirical results are obtained from both of these approaches. These aspects of the two approaches are discussed in greater detail in Appendix C.

3.3.1. Innovation Types

First, we consider the results for the growth effects of different combinations of product and marketing innovation.[5] In Column 1 of Table 2, product innovation is introduced, and the relationship between growth in real value added and this innovation type is estimated. The interaction term between product innovation and the education share, that is, the $P{\cdot}E$ coefficient, is positive and significantly different from zero at the 5 percent level. This result implies that skill-intensive firms that engage in product innovation grow faster than skill-intensive firms that do not engage in product innovation.

It is also evident in Column 1 that the direct coefficient of product innovation, that is, the coefficient of P, is approximately zero and insignificantly different from zero, implying that the average firm does not experience any growth effect from product innovation. This result implies that the skill intensity may be too low to generate positive growth effects, given that the demeaned effect of $P{\cdot}E$ is negative for firms with a below-average skill share. In particular, firms with skill intensities below 0.1663 will experience a negative growth effect from conducting product innovation. This difference suggests that innovation only fosters growth in skill-intensive firms; a result that is also found for organizational innovation in Caroli and Van Reenen (2001).

In Column 2 of Table 2, marketing innovation is included as the only innovation type in the growth regression. Similar to product innovation, the interaction term between marketing innovation and skill intensity is positive; however, in this instance, the point estimate is not significantly different from zero. Column 3 presents the results of including both product and marketing innovation as separate and non-complementary activities. The findings in Column 3 reflect the results of Columns 1 and 2.

Column 4 includes the interaction between product and marketing innovation. It is clear that the estimates are influenced by multicollinearity. All three innovation type estimates are imprecise. The combined growth effect

[5]In the regression analysis, the interaction terms are determined as the interaction between innovation dummies and the demeaned skill intensity. Subtracting the skill share mean ensures that the observed average treatment effect (ATE) is the coefficient of the innovation dummy itself.

TABLE 2
Firm Level Production Functions; Product and Marketing; Change in ln(value added 2004–07) (annualized mean = 0.024)

	1	2	3	4	5	6
dlnL	0.833***	0.831***	0.833***	0.835***	0.834***	0.833***
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
dlnK	0.084***	0.082***	0.085***	0.084***	0.084***	0.083***
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
P*M				–0.013	0.000	–0.003
				(0.022)	(0.012)	(0.010)
P	–0.003		–0.005	–0.002	–0.003	
	(0.008)		(0.009)	(0.010)	(0.010)	
M		0.008	0.009	0.013		
		(0.009)	(0.010)	(0.019)		
P*M*E				0.196	0.080	0.125***
				(0.168)	(0.058)	(0.045)
P*E	0.091**		0.093*	0.052	0.066	
	(0.044)		(0.052)	(0.051)	(0.053)	
M*E		0.019	–0.008	–0.116		
		(0.069)	(0.076)	(0.158)		
E	–0.003	0.029	–0.001	0.013	–0.002	0.018
	(0.035)	(0.029)	(0.033)	(0.031)	(0.035)	(0.031)
F-test				(P + M + P*M)*E = 0	(P + P*M)*E = 0	
				7.87***	9.14***	
R2	0.493	0.491	0.493	0.495	0.494	0.493
N	1321	1321	1321	1321	1321	1321

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Value added, capital, and labor are annualized changes 2004–07. Marketing innovation (M) and product innovation (P) are binary indicators equal to one if innovation during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

of conducting product and market innovation simultaneously is equal to 0.132 (0.196 + 0.052 – 0.116); in an F-test, this value is significant at the 1 percent level, as shown in the bottom part of the column. This result establishes the main result of the paper, namely that product and marketing innovation in skill-intensive firms results in significantly faster productivity growth.

Because the direct effect of marketing innovation was found to be insignificant in Column 2, it is excluded in Column 5. In this case, the combined effect of engaging in product and marketing innovation is equal to 0.146 (0.080 + 0.066), which is significant at the 1 percent level. Finally, the direct effect of product innovation is also excluded in Column 6. In this case, we find that the coefficient for the interaction term is equal to 0.125, which is significant at the 1 percent level.

As shown in Table 1B, most firms with product and marketing innovation also engage in organizational innovation. Therefore, the interpretation of the results in Table 2 can be questioned. In particular, this phenomenon raises the question of whether, on the one hand, this result implies the true growth effect of product–marketing innovation or, on the other hand, the applied measures of product–marketing innovation simply reflect the growth effect produced by organizational innovation. Caroli and Van Reenen (2001), who argue that organizational change has an independent role in productivity growth in skill-intensive firms, amplify the concern about spurious regression results.

TABLE 3

Firm Level Production Functions; Product, Marketing, and Organizational Innovation; Change in ln(value added 2004–07) (annualized mean = 0.024)

	1	2	3	4
dlnL	0.829***	0.834***	0.832***	0.831***
	(0.034)	(0.034)	(0.034)	(0.034)
dlnK	0.089***	0.089***	0.089***	0.089***
	(0.029)	(0.029)	(0.029)	(0.029)
P*M		–0.013	0.000	–0.003
		(0.022)	(0.012)	(0.010)
P		–0.002	–0.004	
		(0.010)	(0.010)	
M		0.014		
		(0.019)		
O	0.002	0.001	0.002	0.002
	(0.008)	(0.009)	(0.008)	(0.008)
P*M*E		0.185	0.070	0.096**
		(0.163)	(0.060)	(0.049)
P*E		0.027	0.041	
		(0.058)	(0.058)	
M*E		–0.115		
		(0.153)		
O*E	0.106**	0.085*	0.085	0.093*
	(0.048)	(0.051)	(0.052)	(0.049)
E	–0.030	–0.026	–0.040	–0.033
	(0.047)	(0.039)	(0.046)	(0.047)
F-test		(P + M + P*M)*E = 0	(P + P*M)*E = 0	
		3.24*	4.39**	
R2	0.494	0.497	0.496	0.495
N	1321	1321	1321	1321

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Value added, capital, and labor are annualized changes 2004–07. Product innovation (P), marketing innovation (M), and organizational innovation (O) are binary indicators equal to one if innovation during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

For these reasons, in addition to product and marketing innovation, we include organizational innovation in the growth regressions. The results for these regressions are presented in Table 3. In Column 1, organizational innovation is included as the only considered innovation type. The results indicate that organizational innovation activities have a positive growth effect in skill-intensive firms, a finding that is consistent with the results of Caroli and Van Reenen (2001).

In Column 2, in addition to organizational innovation, we include product and marketing innovation. Once again, the estimation for product and marketing innovation suffers from multicollinearity. The combined effect for product and marketing innovation is positive and equal to 0.097 (0.185 + 0.027 – 0.115), which is significant at the 10 percent level using an F-test. In other words, we find lower significance for product–marketing innovation if organizational innovation is included in the model, but the effect of the former type of combined innovation remains positive and significant.

As final remarks regarding this topic, it should be noted that skill intensity itself does not contribute to growth, that is, skills only exert a growth effect through innovation. This result holds for all regressions reported in Table 2 and Table 3 because the point estimates for lagged skill intensity are insignificantly different from zero. In addition, the conventional factors of labor and capital possess their expected signs. The point estimate for the effects of labor growth equals 0.83, which is close to the share of labor costs in value added and consistent with estimates that are found elsewhere in the literature.

The point estimate for the effects of capital growth equals 0.09. Although this point estimate is a relatively low value, estimates of this magnitude are found elsewhere (Balsvik, 2011). One potential explanation for the low point estimate is that physical capital most likely suffers from measurement errors, as discussed by Levinsohn and Petrin (2003). Despite this inappropriate result, we assess the main result to be unaffected by the inclusion of poorly measured physical capital. We reach this conclusion because the qualitative results for the growth effects of innovation are unaffected if restrictions with respect to constant returns to scale are enforced for the regressions.

3.3.2. Firm Types

An alternative estimation approach that addresses the multicollinearity problem of different innovation types is the estimation of different firm types' growth effects. Under this alternative approach, we split the firms into the innovative firm categories that were organized in Figure 1. For a more general discussion of this model, see Appendix C.

The results from this approach are presented in Table 4. In Column 1, it is revealed that skill-intensive firms that conduct product and marketing innovation have higher growth effects from innovation than firms that conduct either product innovation or marketing innovation. Firms that engage in product innovation but no marketing innovation experience a positive growth effect; however, this effect is not significantly different from zero. Furthermore, the growth effect for firms that engage in marketing innovation but no product innovation is negative but insignificant. This finding implies that neither product innovation nor marketing innovation alone contribute significantly to productivity growth.

Firms that belong to one of these three firm types may also conduct organizational innovation. Therefore, it is difficult to determine whether the observed growth effects reflect product and/or marketing innovation or result from organizational innovation. Therefore, the applied strategy in the following analysis tests whether skill-intensive firms with product and/or marketing innovation have a significantly higher growth effect than firms that only have organizational innovation.

In Column 2, in addition to the three firm types included in Column 1, we include firms that engage in organizational innovation but no marketing innovation or product innovation. Firms with product–marketing innovation have higher growth effects than do firms with only organizational innovation. To investigate whether the effect of product and marketing innovation exceeds the effect of organizational innovation in a significant manner, we perform a one-sided Wald test. The difference is found to be significant, as demonstrated by the F-test in the bottom part of Column 2. This finding implies that the null hypothesis (that the

TABLE 4

Firm Level Production Functions; Product, Marketing, and Organizational Innovation; Change in ln(value added 2004–07) (annualized mean = 0.024)

	1	2	3	4
dlnL	0.835***	0.834***	0.832***	0.827***
	(0.035)	(0.034)	(0.033)	(0.039)
dlnK	0.084***	0.089***	0.124***	0.095**
	(0.028)	(0.028)	(0.028)	(0.040)
PM	–0.001	0.002	0.008	–0.001
	(0.010)	(0.011)	(0.011)	(0.012)
PNM	–0.002	0.002	–0.003	–0.010
	(0.010)	(0.011)	(0.012)	(0.013)
NPM	0.013	0.016	0.015	0.006
	(0.019)	(0.019)	(0.015)	(0.016)
ONPNM		0.007	0.008	
		(0.011)	(0.011)	
PM*E	0.131***	0.171***	0.157***	0.092**
	(0.046)	(0.050)	(0.047)	(0.037)
PNM*E	0.052	0.091*	0.114**	0.049
	(0.051)	(0.055)	(0.055)	(0.051)
NPM*E	–0.116	–0.077	0.142*	0.107
	(0.158)	(0.159)	(0.077)	(0.074)
ONPNM*E		0.087*	0.091*	
		(0.049)	(0.049)	
E	0.013	–0.026	–0.035	0.035
	(0.031)	(0.037)	(0.036)	(0.046)
F-test		PM*E > O*E	PM*E > O*E	
		2.43*	1.70*	
R2	0.495	0.497	0.512	0.461
N	1321	1321	1158	776

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Value added, capital, and labor are annualized changes 2004–07. Firms performing: product–marketing innovation (PM), product innovation but no marketing innovation (PNM), marketing innovation but no product innovation (NPM), organizational innovation but no product or marketing innovation (ONPNM) are binary indicators equal to one if firm belongs to firm type during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

point estimate for organizational innovation is equal to or greater than the point estimate for product–marketing innovation) is rejected at the 10 percent significance level.

In Column 3, to more carefully assess the additional effect that product–marketing innovation contributes beyond the effect of organizational innovation, we exclude innovative firms that do not engage in organizational innovation. In particular, firms that conduct product–marketing innovation but no organizational innovation are excluded from the subsample; however, firms with no innovation activities whatsoever are included. This restriction results in a subsample of 1,158 firms. The results for this subsample imply that at the 10 percent significance level, skill-intensive firms that engage in product, marketing, and organizational innovation demonstrate higher growth than do skill-intensive firms that conduct only organizational innovation.

Finally, in Column 4, we only include firms that conduct organizational innovation. This exclusion results in a subsample of 776 innovative firms, which is presented in the upper panel of Table 1B. We find that in skill-intensive firms, the product–marketing innovation combination generates higher growth effects than does any combination that lacks either product or marketing innovation.

3.3.3. Simultaneity, Selection, and Measurement Errors

In this section, we handle a number of issues related to endogeneity. First, we employ an instrumental variable approach in an attempt to address the endogeneity (simultaneity and measurement errors) of product–marketing innovation. Second, we handle simultaneity-related endogeneity and selection bias for primary production factors.

We present the results from an instrumental variable approach where we first employ product–marketing innovation. This instrumental variable approach uses a form of exogenous variation in innovation costs, which will give us independent variation with respect to the choice of investments in product–marketing innovation. The applied instrument is industry-region variation in the employment share of educated workers within the social sciences. This instrument relies on the notion that coordination is required between the creation of new and improved products and their commercialization; in addition, workers educated within the social sciences are presumed to possess the requisite competences and qualifications to accomplish this type of coordination. As a consequence, a high presence of this type of labor is expected to lower innovation costs and thus increase the probability that firms will perform product–marketing innovation.

The regional clustering of the relative employment shares is natural. In Denmark, there are distinct local labor markets due to the costs of geographical mobility. We identify five different regions. Moreover, the clustering by industry is founded on the idea that certain industry-specific knowledge is required to be able to coordinate product–marketing innovation activities in particular industries. The industry classification follows the 2-digit NACE classification system, with 40 industries represented in the applied sample. This classification results in 126 industry–region clusters, as contained in the sampled firms. The instrument is calculated using the firm employment and education mix for the entire population of Danish firms in 2001, not just that of sample firms.

To obtain consistent estimates for the parameters of the interaction term between product–marketing innovation and skill intensity, we employ a two-step IV procedure that Wooldridge (2010) suggests. The first step of this procedure involves estimating a probit model for the choice of product–marketing innovation. The second step involves the estimating equation (1), using a 2SLS approach with the interactions between skill intensity and the predicted probabilities of product–marketing innovation as an instrument.[6]

The regression results for the probit model are presented in Table 5. In Column 1, we include the share of workers with at least 16 years of education

[6]It should be stressed that we instrumentalize for firms' choices of product–marketing innovation rather than for the skill intensity, which is treated as exogenous and is measured in 2001. The skill intensity may not produce any particular endogeneity problems because it is largely predetermined. With respect to technological adoption, a key determinant appears to be the plant's skill intensity. However, the adoption of new technology does not typically produce a significant increase in a firm's skill intensity (Doms *et al.*, 1997; Caselli and Coleman, 2001).

TABLE 5

Probability of Product and Marketing Innovation; Dependent Variable Prob (product and marketing) 2002–04

	1	2	3
E_industry_region_lag	1.241**		
	(0.613)		
TECH_industry_region_lag		0.122	
		(0.625)	
SOC_industry_region_lag		5.131**	5.674***
		(2.091)	(1.685)
HUM_industry_region_lag		1.292	
		(1.838)	
dlnK	–0.304	–0.319	–0.318
	(0.239)	(0.243)	(0.242)
dlnL	0.560***	0.561***	0.558***
	(0.192)	(0.193)	(0.193)
χ^2-test	4.10	14.09	11.34
Pseudo R2	0.029	0.035	0.034
N	1321	1321	1321

Notes: Robust standard errors are in parentheses. Capital and labor are annualized changes 2004–07. E_industry_region_lag is the industry-region education share as measured by the share of full-time employees who possess at least 16 years of education in 2001. TECH_industry_region_lag, SOC_industry_region_lag, and HUM_industry_region_lag are the industry-region education shares as measured by the share of full-time employees who possess at least 16 years of education in 2001 within technical education, social science and humanities, respectively. All regressions include industry dummies, regional dummies, and ownership dummies. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

within each industry–region cluster; this measure is not the preferred instrument because it does not separate workers into education types but only evaluates employees by the duration of their education. It is evident that the instrument is significant, with a χ^2-test value of only 4.1, which suggests that this variable represents a weak instrument (Staiger and Stock, 1997).

Next, in Column 2, we split the share of educated workers in industry–region clusters with respect to educational types: technical education (tech), social sciences (soc), and humanities (hum). It is evident that the shares of workers who were trained in technical fields or the humanities do not significantly contribute to explaining firm choice. In contrast, the preferred instrument, that is, the share of employed workers in each industry–region cluster who were educated in social sciences in 2001, is positive and significant in explaining this choice. Column 3 only includes this preferred instrument in the analysis; it is significant with a χ^2-test of approximately 11, suggesting that it possesses reasonable strength as an instrument.[7]

In Column 1 of Table 6, we present the OLS of the growth regression. In this case, the point estimate for the interaction term between product–marketing inno-

[7]One concern with respect to this approach is whether the industry–region cluster's share of workers educated in social sciences captures the effect of the firm's share of workers that are educated in social sciences. As it happens, this concern is unfounded. If we include both the instrument and the firms' share in the analysis, the results are similar to the findings that are presented in Column 3 of Table 5.

TABLE 6

Firm Level Production Functions; Product and Marketing; Change in ln(value added 2004–07) (annualized mean = 0.024), 2 Stage Least Square; Instrument: Share of workers with at Least 16 Years of Education within Social Sciences in Industry-Region Cluster in 2001

	1 OLS	2 2SLS
dlnL	0.835***	0.835***
	(0.035)	(0.034)
dlnK	0.083***	0.088***
	(0.028)	(0.028)
P*M*E	0.135***	0.494**
	(0.040)	(0.207)
F-test of including instrument first stage		26.50
R2	0.493	0.474
N	1321	1321

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Value added, capital, and labor are annualized changes 2004–07. Marketing innovation (M) and product innovation (P) are binary indicators equal to one if innovation during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

vation and skill intensity equals 0.136. In Column 2, we present the 2SLS results. It is evident that the interaction term is both positive and significant.[8]

These results suggest that the OLS coefficients are downwardly biased; however, the parameter estimates for the interaction term are not significantly different from the OLS and the 2SLS estimates. The increase in the point estimate for the interaction term that occurs between the OLS and 2SLS estimates is relatively large but does not exceed the effects that are observed in other studies, such as Abramovsky and Griffith (2006). Although we are careful not to claim causality because the instruments used are not applicable at the firm level and, thus, do not explain the full random variation in the variable of interest, the results strongly support the idea that product–marketing innovation leads to faster productivity growth in skill-intensive firms.

Second, we present the estimation results for three alternative estimation methods, which predict total factor productivity growth in a first-stage regression that is then used as a dependent variable in a second-stage regression that includes innovation measures as explanatory variables. The results obtained from all methods are presented in Table 7. In Column 1, we present our baseline

[8]We present the results from a specification in which the dummy variables for product–marketing innovation (*PM*) and skill intensity (*E*) have been excluded from the regressions. These variables are excluded because they factor insignificantly into the OLS regressions of Table 2.

TABLE 7

Firm Level Production Functions; Product, Marketing, and Organizational Innovation; Change in ln(value added 2004–07) (annualized mean = 0.024)

	1 OLS	2 LP	3 OP	4 ACF	5 Selection—growth
dlnL	0.834***				0.822***
	(0.034)				(0.039)
dlnK	0.089***				0.085***
	(0.028)				(0.028)
PM	0.002	0.000	0.003	–0.001	0.001
	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)
PNM	0.002	0.001	–0.003	–0.001	0.001
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
NPM	0.016	0.019	0.013	0.017	0.015
	(0.019)	(0.020)	(0.023)	(0.020)	(0.019)
ONPNM	0.007	0.007	0.007	0.004	0.007
	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)
PM*E	0.171***	0.169***	0.150***	0.171**	0.180***
	(0.050)	(0.050)	(0.049)	(0.051)	(0.053)
PNM*E	0.091*	0.094*	0.050**	0.094*	0.095*
	(0.055)	(0.055)	(0.049)	(0.056)	(0.055)
NPM*E	–0.077	–0.092	–0.146*	–0.089	–0.068
	(0.159)	(0.163)	(0.182)	(0.164)	(0.155)
ONPNM*E	0.087*	0.078*	0.054*	0.078	0.089*
	(0.049)	(0.049)	(0.050)	(0.051)	(0.052)
E	–0.026	–0.027	–0.021	–0.036	–0.031
	(0.037)	(0.036)	(0.036)	(0.038)	(0.037)
F-test	PM*E > O*E	PM*E > O*E	PM*E > O*E	PM*E > O*E	PM*E > O*E
	2.43*	2.84*	2.90*	2.83*	2.49*
R2	0.497	0.028	0.023	0.027	0.481
N	1321	1319	1194	1277	1321

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Value added, capital, and labor are annualized changes 2004–07. Firms performing: product–marketing innovation (PM), product innovation but no marketing innovation (PNM), marketing innovation but no product innovation (NPM), organizational innovation but no product or marketing innovation (ONPNM) are binary indicators equal to one if firm belongs to firm type during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. LP follows Levinsohn and Petrin (2003), OP follows Olley and Pakes (1996) and ACF follows Ackerberg *et al*. (2006). *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

specification, which is included in Column 2 of Table 4; the next three columns contain estimates for the three alternative methods.

The main insight that firms with product–marketing innovation have higher growth effects than do firms with only organizational innovation is robust for the applied estimation method. The point estimates for PME are marginally lower when the methods from Levinsohn and Petrin (2003) and Olley and Pakes (1996) are applied in Column 2 and Column 3, whereas the point estimate for the method suggested by Ackerberg *et al.* (2006) is similar to that of the baseline regression. The three methods are discussed in Appendix B.

Another concern about the results established in the previous section is that they may simply reflect high-growth firms' choices to engage in innovation. In other words, product–marketing innovations may simply be frequently introduced in firms with high productivity growth rates (e.g., Ichniowski *et al.*, 1997; Caroli and Van Reenen, 2001). To address this potential selection problem, we include the lagged growth rates of real value added in the regressions. In particular, we include the annualized log changes for the 2002–04 time period. This approach should permit us to examine whether high-growth firms potentially select innovation activities in a manner that is not replicated in low-growth firms. The lagged growth rates are found with the initial real value-added level that was measured in 2001; this tactic is consistent with the approach of Caroli and Van Reenen (2001). The main result of this paper is unaffected by this specification, as indicated in Column 5.

Our results may still suffer from survival selection bias, although we are trying to handle this issue for capital using the methodology of Olley and Pakes (1996). This bias occurs if survival relates to productivity shocks, which also relate to the innovation decision. The estimated effect of innovations' impact on productivity growth could then be biased. We do not expect this potential problem to be considerable because firms that did not survive during the investigated 4-year period did not have significantly different innovation activities than those of the firms that did survive. The share of firms with product innovation was equal to 0.32 for the firms that did not survive compared with 0.40 for surviving firms, whereas the shares were 0.54 and 0.59, respectively, for organizational innovation for the two groups. However, in probability models that use industry and region dummies or control for employment and capital, the differences between the two groups are not significantly different from zero. This finding means that we cannot establish any evidence that the innovation activities measured from 2002 to 2004 are affected by productivity shocks that may lead to lower or higher innovation activities for firms that do not survive during the 2004–07 period.[9]

4. Additional Robustness

Finally, we investigate the robustness of the results that have been established for product–marketing innovation in the previous section. We present a number of alternative specifications in Table 8. In Column 1, we present our baseline specification, which is provided in Column 2 of Table 4. We compare this specification with the examined alternative regressions.

Firm Size

The first issue addressed in Table 8 is firm size. The applied binary measure of product innovation may be problematic; large firms have a tendency to answer yes to the question of whether they engage in product innovation because they are involved in a wider range of activities and thus are more likely to be involved in product innovation (Hall, 2011).

We expect the size problem to be particularly pronounced for product innovation. We do not expect firm size to be an important problem for marketing and

[9]The results are available upon request.

TABLE 8

Firm Level Production Functions; Product, Marketing, and Organizational Innovation; Change in ln(value added 2004–07) (annualized mean = 0.024)

	1 Baseline	2 <median	3 >median	4 Cooperation and In House	5 In House	6 Firm Age
dlnL	0.834***	0.879***	0.807***	0.833***	0.838***	0.837***
	(0.034)	(0.048)	(0.051)	(0.034)	(0.035)	(0.036)
dlnK	0.089***	0.086***	0.074	0.089***	0.084***	0.097***
	(0.028)	(0.028)	(0.063)	(0.028)	(0.030)	(0.031)
PM	0.002	–0.005	0.008	0.001	–0.004	..
	(0.011)	(0.019)	(0.014)	(0.012)	(0.013)	
PNM	0.002	0.009	–0.002	0.002	0.001	..
	(0.011)	(0.016)	(0.015)	(0.011)	(0.012)	
NPM	0.016	–0.015	0.062	0.017	0.016	..
	(0.019)	(0.023)	(0.024)**	(0.019)	(0.019)	
ONPNM	0.007	0.004	0.015	0.007	0.007	..
	(0.011)	(0.015)	(0.014)	(0.011)	(0.011)	
PM*E	0.171***	0.242***	0.087*	0.179***	0.234***	0.153***
	(0.050)	(0.074)	(0.050)	(0.051)	(0.054)	(0.059)
PNM*E	0.091*	0.090	0.071	0.095*	0.132*	0.080
	(0.055)	(0.073)	(0.063)	(0.057)	(0.069)	(0.060)
NPM*E	–0.077	–0.135	0.207*	–0.078	–0.081	0.107
	(0.159)	(0.194)	(0.108)	(0.159)	(0.159)	(0.080)
ONPNM*E	0.087*	0.05	0.162**	0.087*	0.086*	0.076
	(0.049)	(0.060)	(0.075)	(0.049)	(0.049)	(0.057)
E	–0.026	–0.019	–0.029	–0.026	–0.025	–0.021
	(0.037)	(0.047)	(0.044)	(0.037)	(0.037)	(0.040)
F-test						
PM*E > O*E	2.43*	6.23***	N.A	2.91**	6.79***	1.39
R2	0.497	0.480	0.535	0.497	0.513	0.579
N	1321	664	657	1298	1187	1320

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Value added, capital, and labor are annualized changes 2004–07. Firms performing: product–marketing innovation (PM), product innovation but no marketing innovation (PNM), marketing innovation but no product innovation (NPM), organizational innovation but no product–marketing innovation (ONPNM) are binary indicators equal to one if firm belongs to firm type during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

organizational innovation. To a large extent, marketing innovation will focus on overall firm demand, whereas organizational innovations are expected to be implemented for the firm as a whole.

The results obtained after splitting the sample by firm size are presented in Column 2 and Column 3. Column 2 presents firms with employment below the median level of 60 full-time equivalent workers. It is evident that product–marketing innovation has a high growth effect in skill-intensive firms of this size. Organizational innovation also produces a positive growth effect; however, this effect is not significantly different from zero. In contrast, Column 3 reveals that the opposite conclusions are reached for larger firms. In particular, it is clear that organizational innovation constitutes an important growth driver for these firms, while firms conducting product–marketing innovation do not gain as much from this activity.

The latter finding indicates that the size-based critique of the measure of product innovation may be valid. The result of the differential impacts of size can be interpreted in relation to firm life cycle theories (Klepper, 1996). According to these theories, when it is young and small, a firm may focus on the exploitation of product innovation niches; when it is older and larger, a firm may focus more on improving the quality of a particular product. If these theories are true, there are advantages for product innovation when the firm is small, and advantages for process innovation when the firm is large. We only establish one side of the story, namely the part related to product innovation, as we lack well-measured indicators for process innovation, as discussed in the Introduction.

Product Innovation Outside the Firm

In the CIS, responding firms provide additional information with respect to the development of product innovation. More precisely, the survey asks whether the product innovation is developed in-house, in cooperation with other firms, or by other firms. Because our main hypothesis relates to in-house innovation activities, we investigate the sensitivity of the results if firms that conducted product innovation outside the firm and in cooperation with other firms are excluded from the analysis.

In Column 4, we exclude firms with product innovation that takes place outside the firm; in Column 5, we exclude these firms and firms that conduct product innovation in cooperation with other firms. The main result is robust for these changes. In fact, the inclusion of firms with in-house and cooperative/in-house product innovation only strengthens the main result.

Firm Age

Another concern that we address is firm age or "cohort" effects. A positive point estimate for interaction terms may be generated by "cohort" effects, that is, variations in the growth effects from innovation across firm cohorts. This concern is relevant because other studies have found cohort effects to be important in various areas of the economics literature (e.g., Heckman *et al.*, 2003).

In Column 6, we have included dummies for firm type × firm establishment year in the regression. These dummies will capture cohort variation in the return to product–marketing innovation. The results from these analyses demonstrate that the main result is robust for the inclusion of firm age.

In summary, in this section, we have performed a large number of robustness checks that vary from the baseline model specification in Table 4. None of these specifications alters the main conclusion.

5. Sector-Specific Analysis

An important question is whether the main result is driven by firms belonging to specific sectors or reflects a more general phenomenon. Although we have controlled for industry dummies in all regressions, the effect of innovation may nonetheless differ from sector to sector. To investigate this issue, we perform a separate analysis for manufacturing firms and service sector firms.

In addition to investigating the productivity effects of product–marketing innovation and organizational innovation for groups of firms that belong to these two broadly defined sectors, we also study a wider set of firm variables than simply productivity growth. This analysis is performed to better understand different transmission mechanisms for the productivity effects across sectors.

For manufacturing firms, product–marketing innovation is expected to increase product demand. The higher demand in turn is expected to increase the measured productivity growth. Thus, we expect sales and/or value added to increase as a consequence of product–marketing innovation. This reasoning forms the main idea behind equation (1).

For service sector firms, these considerations are less straightforward. A "service innovation" will not necessarily primarily influence service demand. Instead, such an innovation may, for example, reduce the need for labor input and thereby improve productivity. Examples of service innovations include internet banking and internet sales; these innovations may only impact demand through a second-order effect in which fewer production factors are required for a given level of output after the "service innovation" has been implemented.

Motivated by the discussion above, we examine the following variables: firm sales, intermediate inputs, value added, and productivity. In addition, we assess firms' market shares to better understand whether firms become larger and more productive or merely more productive as a result of innovation activities. This topic is an important issue for understanding industry or aggregate productivity growth. The applied measure of market share is firm sales relative to total industry sales. Notably, we use the entire population of firms to determine industry sales.

From the full sample of 1,321 firms, 576 firms are manufacturing firms and 614 firms are service sector firms. The service sector includes firms that belong to the Finance, Insurance, and Real Estate (FIRE) sectors (290 firms) and the retail and wholesale sector (324 firms). We have excluded 131 firms belonging to other sectors.

In Table 9 and Table 10, the results of the analysis for manufacturing firms and service sector firms, respectively, are presented. From Column 5 of Table 9, it is clear that skill-intensive manufacturing firms that perform product–marketing innovation demonstrate faster productivity growth than do non-skill-intensive manufacturing firms. This result is statistically significant, as demonstrated by the F-test in the bottom of this column. This test assesses whether skill intensity influences the productivity growth rate in a significant manner in firms that perform product–market innovation. This null hypothesis is rejected at the 10 percent significance level. Thus, the main result also holds true for the manufacturing sector.

In addition to product–marketing innovation as a driver for productivity growth in manufacturing, we also find that the growth rates of the market share and value added are significantly higher in skill-intensive firms with product–marketing innovation than in other firms. However, it is surprising that the growth rate of sales is not significantly higher for these innovative firms. It is worth noting

TABLE 9

Firm Level Functions; Product, Marketing, and Organizational Innovation; Change in ln(variable), Manufacturing

Variable	1 Market Share	2 Sales	3 Intermediate	4 Value Added	5 Value Added
dlnL					0.756***
					(0.068)
dlnK					0.118***
					(0.049)
PM	0.000	–0.001	–0.011	0.010	–0.018
	(0.000)	(0.033)	(0.023)	(0.042)	(0.032)
PNM	0.001	0.004	0.003	0.001	–0.019
	(0.000)	(0.031)	(0.019)	(0.039)	(0.030)
NPM	0.000	–0.066	–0.073	0.007	–0.015
	(0.000)	(0.044)	(0.029)	(0.045)	(0.033)
ONPNM	–0.000	–0.002	–0.021	0.019	0.012
	(0.000)	(0.033)	(0.054)	(0.064)	(0.055)
PM*E	0.005*	0.135	–0.102	0.237	0.122
	(0.003)	(0.263)	(0.166)	(0.322)	(0.237)
PNM*E	–0.002	0.119	–0.001	0.120	0.084
	(0.002)	(0.241)	(0.153)	(0.305)	(0.227)
NPM*E	0.000	–0.309	–0.174	–0.135	–0.046
	(0.001)	(0.437)	(0.250)	(0.404)	(0.304)
ONPNM*E	0.000	0.021	–0.282	0.303	0.294
	(0.001)	(0.264)	(0.443)	(0.423)	(0.446)
E	0.000	0.007	–0.057	0.063	0.060
	(0.002)	(0.229)	(0.136)	(0.285)	(0.207)
F-test					
PM*E + E = 0	4.45**	1.26	2.62	4.13**	2.99*
ONPNM*E + E = 0	0.13	0.05	0.65	0.71	0.80
R2	0.024	0.032	0.0368	0.042	0.373
N	576	576	576	576	576

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Market share, sales, intermediate input value added, capital, and labor are annualized changes 2004–07. Firms performing: product–marketing innovation (PM), product innovation but no marketing innovation (PNM), marketing innovation but no product innovation (NPM), organizational innovation but no product–marketing innovation (ONPNM) are binary indicators equal to one if firm belongs to firm type during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

that the empirical analysis is based on a framework of different firm types, in which we assume that firms with product and marketing innovation and firms with product, marketing, and organizational innovation have similar growth effects (see Appendix C). If this assumption is not imposed on the estimation, we find that manufacturing firms with product, marketing and organizational innovation have significantly higher growth rates of market share, sales, value added, and productivity compared with other firms.

In Table 10, we present sector-specific results for service sector firms. Skill-intensive service firms that engage in product–marketing innovation demonstrate rapid productivity growth. In contrast, these firms do not experience increased growth rates for market share, sales, and value added growth relative to other firms. These results suggest that the productivity

TABLE 10

Firm Level Functions; Product, Marketing, and Organizational Innovation; Change in ln(variable), Service

Variable	1 Market Share	2 Sales	3 Intermediate	4 Value Added	5 Value Added
dlnL					0.847***
					(0.042)
dlnK					0.082**
					(0.035)
PM	0.000	0.040	0.013	0.027	0.010
	(0.000)	(0.026)	(0.018)	(0.027)	(0.018)
PNM	0.000	–0.003	–0.018	0.015	0.021
	(0.000)	(0.025)	(0.022)	(0.028)	(0.021)
NPM	0.000	0.024	0.021	0.002	0.030
	(0.000)	(0.036)	(0.028)	(0.037)	(0.025)
ONPNM	0.000	0.048**	0.016	0.032	0.023
	(0.000)	(0.024)	(0.018)	(0.024)	(0.017)
PM*E	0.000	–0.014	0.000	–0.013	0.129**
	(0.000)	(0.095)	(0.079)	(0.083)	(0.059)
PNM*E	0.000	0.077	0.152*	–0.074	0.007
	(0.000)	(0.073)	(0.089)	(0.111)	(0.077)
NPM*E	0.000	0.152	0.233	–0.080	–0.143
	(0.000)	(0.097)	(0.171)	(0.199)	(0.176)
ONPNM*E	0.000	0.047	0.067	–0.019	0.013
	(0.000)	(0.079)	(0.079)	(0.097)	(0.053)
E	0.000	0.072	–0.067	0.137	–0.006
	(0.000)	(0.062)	(0.082)	(0.106)	(0.041)
F-test					
PM*E + E = 0	0.63	0.46	2.04	2.85*	6.10***
ONPNM*E + E = 0	0.64	3.57*	0.00	4.47**	0.03
R2	0.017	0.045	0.042	0.023	0.554
N	614	613	613	614	614

Notes: Robust standard errors are in parentheses. These are long-differenced specifications. Market share, sales, intermediate input value added, capital, and labor are annualized changes 2004–07. Firms performing: product–marketing innovation (PM), product innovation but no marketing innovation (PNM), marketing innovation but no product innovation (NPM), organizational innovation but no product–marketing innovation (ONPNM) are binary indicators equal to one if firm belongs to firm type during 2002–04. E is the skill intensity as measured by the share of full-time employees who possess at least 16 years of education in 2001. All regressions include industry dummies, regional dummies, ownership dummies, and export intensity. *, **, *** denote significance at the 10%, 5%, or 1% level, respectively.

effects for service firms are obtained through innovations that conserve factors of production.

6. Discussion and Conclusion

The main result of this paper is that skill-intensive firms that engage in product and marketing innovation grow faster than other firms. Moreover, firms that conduct either product innovation or marketing innovation alone do not reap higher productivity growth.

An independent issue is separating the effects of product and marketing innovation from those of organizational innovation. In the examined data set, most firms that conduct product and marketing innovation also conduct organizational innovation. Therefore, we examine whether firms that conduct product and/or marketing innovation gain positive growth effects that extend beyond the influence of organizational innovation. We are able to rule out the concern that the estimated effect of product and marketing innovation simply reflects the growth effects of organizational innovation. Instead, we find that product–marketing innovation and organizational innovation both play independent roles in productivity growth.

To address the endogeneity of product and marketing innovation, we use an instrumental variable approach. Although we are careful not to claim causality, as the instruments used are not applicable at the firm level and, thus, do not explain the full random variation in the variable of interest, the results strongly support the idea that product–marketing innovation leads to faster productivity growth in skill-intensive firms. In addition, we also address issues related to simultaneity and selection biases. We find that the established results are robust for the implementation of numerous methodologies that handle these issues. Finally, the main result is not only highly robust in a number of additional robustness analyses but also reflects a general phenomenon, given that the result is also established through separate sector-specific assessments of manufacturing and service sector firms.

One important result of this analysis is that innovation activities generate higher productivity growth rates in skill-intensive firms; in contrast, this effect is not observed in non-skill-intensive firms. Indeed, innovation activities may result in no growth effects in non-skill-intensive firms. Taking the estimated coefficients at face value, firms that engage in product and marketing innovation should feature a skill intensity that exceeds the threshold level.

The broader implications of the positive growth effect in skill-intensive firms are twofold. The analysis reveals that it may not always be appropriate to engage in innovation activities in non-skill-intensive firms because these activities may not prove to be beneficial. In this respect, an important question is whether the commencement of innovation causes firms to become more skill-intensive or whether the skill intensity of a firm is largely fixed. If the latter situation holds true, it may be important to target skill-intensive firms for innovation-promoting policy programs. Instead of targeting all firms with innovation-fostering programs, governments may instead choose to direct these programs toward skill-intensive firms.

Alternatively, governments should simultaneously target human capital accumulation and implement innovation-promoting programs. Danish innovation policies have not implemented these aspects. Another important issue relates to the ways in which we obtain a deeper understanding of product–marketing innovation. Marketing innovation is defined as the introduction of new or significantly changed sales or distribution methods and/or significant changes in a product or service design or packaging. Because most firms with product–marketing innovation answer that they introduce both types of marketing innovation, we cannot distinguish between these innovation types in the current empirical analysis. Thus, it is unclear whether product–marketing innovation reflects the development of products and services with respect to functionality and design/packaging, the introduction of sales and distribution methods, or a combination of these innovation types. To obtain greater clarity about the interpretation of the main results presented in this paper, additional research on the importance of design/packaging and sales/distribution methods is required. We leave this topic for future studies.

Finally, it should be noted that the result that product–marketing innovation is an important growth-driver is consistent with Danish innovation policies that target firms' marketing efforts to some extent, at least after 2010. For example, the Danish Market Development Fund helps firms bring their new products to market faster. From 2013 to 2015, about 18.2 million EUR is allocated for the Market Development Fund each year. In this sense, the results presented in this study substantiate the idea that product–marketing innovation is an important activity. Whether there are any externalities that result in too few marketing activities is another question.

Appendix A: Model

A.1. *Production and Demand*

The model that we consider is based on a framework that is presented in various other studies (e.g., Hall, 2011). This model consists of the following components: a demand function, a production function, and two knowledge production functions.

Firms undertake innovation activities to gain monopolistic advantages or more effective production processes. For simplicity's sake, we assume that firms face a constant elasticity demand function in the following form:

$$\ln Q = \eta_0 \ln \pi + \eta_1 \ln A^D,$$

with $\eta_0 < 0$ and $\eta_1 > 0$. In the equation above, Q denotes the demanded quantity; π denotes the (relative) output price of the firm; and A^D denotes the knowledge capital stock that is relevant for demand. A^D constitutes a measure of the monopolistic advantage. η_0 is a constant price elasticity. Moreover, firms produce according to the following production function:

$$\ln Q = \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L + \alpha_3 \ln A^S,$$

where K denotes the physical capital stock, L denotes employment, and A^S denotes knowledge capital that is relevant for production, which is a measure of production effectiveness.

The combination of the demand and production function results in the following function for real value added:

$$\begin{aligned} (2) \qquad \ln Y &= \ln \pi + \ln Q \\ &= \frac{\eta_0 + 1}{\eta_0}(\alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L) + \frac{\alpha_3(\eta_0 + 1)}{\eta_0} \ln A^S - \frac{\eta_1}{\eta_0} \ln A^D, \end{aligned}$$

where Y denotes real value added. In the next sub-section, we examine the model's knowledge production functions.

A.2. *Knowledge Production*

Firms can conduct product innovation and/or marketing innovation. In addition to these innovation types, firms can also engage in organizational innovation. We include the latter innovation type because it is an important growth driver, as discussed in the Introduction, and because the majority of firms that conduct product and/or marketing innovation also conduct organizational innovation, as described in Tables 1a and 1b in the main text. The three innovation types are denoted by P (product innovation), M (marketing innovation), and O (organizational innovation). Innovation activities potentially affect real value added growth through the growth rate of knowledge capital, that is, $\Delta\ln A^S$ and $\Delta\ln A^D$. We assume that the knowledge production relevant for demand, A^D, is affected by product innovation and marketing innovation, whereas organizational innovation is important for knowledge production that is relevant for production, A^S.

An important element that we study is the complementarity between product and marketing innovation in the knowledge creation of A^D. We hypothesize that marketing innovation strengthens the growth effect of product innovation (and vice versa). In other words, firms that not only innovate new and improved products but also expend the required effort to bring their products to market by developing sales and distribution methods or by changing the design or packaging of their products, are expected to perform better than firms that simply innovate their products. Another important aspect of this investigation is that innovation is assumed to be a skill-intensive activity. The introduction of innovation activities in skill-intensive firms is expected to lead to significantly faster productivity growth than the introduction of innovation activities in firms that are not skill-intensive.

The innovation process generates new knowledge, and its development is assumed to obey the following equation:

$$\begin{aligned} \Delta \ln A^D &= f\left(I^P, I^M\right)E \\ \Delta \ln A^S &= I^O E \end{aligned} \tag{3}$$

where I^P, I^M, and I^O denote intensities of product, marketing and organizational innovation, respectively. In the equation above, E denotes the education mix; high values of this variable indicate skill-intensive firms, and low values indicate firms that are not skill-intensive. Therefore, a key explanatory variable in the knowledge production function is the education mix of the examined firms. We do not target specific firm departments in our focus on the relationship between education mix and knowledge production (i.e., we do not restrict the analysis to employees in R&D or in other specific firm departments). Instead, we assume that the more intensive overall use of educated workers increases the intensity of the different innovation types and that these activities can be performed in any part of the firm.[10]

Furthermore, it is assumed that product and marketing innovations are complementary, which implies that the following condition must be satisfied:

[10]Variations in marketing capabilities across firms may also be important for the growth effect of production innovation because a high marketing capability may produce a larger growth effect than a low marketing capability will. We do not study this aspect of production innovation because we do not have data that address marketing capabilities.

$$\left(\frac{\partial f(I^P, I^M)}{\partial I^M}\right)\Big/\partial I^P = \left(\frac{\partial f(I^P, I^M)}{\partial I^P}\right)\Big/\partial I^M = \frac{\partial^2 f(I^P, I^M)}{\partial I^P \partial I^M} > 0.$$

As presented by this condition, the effect of more intensive product innovation activities increases the effect of marketing innovation on knowledge creation (and vice versa).

Moreover, the assumption of innovation as a skill-intensive activity implies the following condition:

$$\frac{\partial^2 \Delta \ln A^D}{\partial I^P \partial E} > 0, \frac{\partial^2 \Delta \ln A^D}{\partial I^M \partial E} > 0, \frac{\partial^2 \Delta \ln A^S}{\partial I^O \partial E} = 1 > 0.$$

A.3. *Real Value Added Growth*

Using (2) and (3), we derive the growth rate of real value added as a function of innovation activities:

$$\Delta \ln Y = \frac{\eta_0 + 1}{\eta_0}(\Delta a_t + \alpha_1 \Delta \ln K + \alpha_2 \Delta \ln L)$$
$$+ \frac{\alpha_3(\eta_0 + 1)}{\eta_0} I^O E - \frac{\eta_1}{\eta_0}(\phi_1 I^P + \phi_2 I^M + \phi_3 I^P I^M)E + \varepsilon$$

where we treat $\alpha_0 = a_i + a_t + u_{i,t}$, with $\Delta u_{i,t} = \varepsilon_{i,t}$. Moreover, we model function $f(\cdot)$ as $f(I^P, I^M) = \phi_1 I^P + \phi_2 I^M + \phi_3 I^P I^M$. In total, the model to be estimated in the empirical section of this paper may be expressed as follows:

$$\Delta \ln Y = \beta_0 + \beta_1 \Delta \ln K + \beta_2 \Delta \ln L + \lambda_1 I^P E + \lambda_2 I^M E + \lambda_3 I^P I^M E + \lambda_4 I^O E + \varepsilon$$

where the coefficients are determined by $\beta_0 = (\eta_0 + 1)\Delta a_t/\eta_0$, $\beta_1 = (\eta_0 + 1)\alpha_1/\eta_0$, and so forth. Our main interest is in the interaction term between product and marketing innovation, that is, $\lambda_3 = -\eta_1\phi_3/\eta_0$. The advantage of estimating the regression in first differences is that this estimation includes firm-specific fixed effects to control for unobserved firm heterogeneity.

Appendix B: Data and Definitions

The applied data set is derived from two sources. First, data on innovation activities originate from the Danish version of the CIS-4, which examines a representative sample of the Danish economy. This data set includes information on firm-level innovation activities. The questions about innovation activities relate to the innovation activities that were performed in firms during the 2002–04 time period. Second, other firm variables that originate from the Danish register data sets of IDA and FIDA are included. Specifically, the backbone of the analysis is an employer–employee matched data set that enables us to track each employee's educational attainment in every sampled firm. Consequently, it is possible to obtain very precise measures of each firm's education mix. Moreover, firm information in the data set provides, for example, data about each firm's value added, labor inputs, and physical capital inputs. In addition, we not only utilize industry, regional, and ownership dummies but also consider export intensities. Finally, the register data allow the aforementioned variables to be measured for different years. We implement these measurements and describe the results in the following sections.

B.1. *Innovation*

In the empirical analysis three types of innovations are applied. These three types of innovations are product innovation (*P*), marketing innovation (*M*), and organizational innovation (*O*).

A firm is regarded as having performed:

- *product innovation* if it has answered yes to the following question: "Did the firm introduce new or significantly improved products or services?"
- *marketing innovation* if it has answered yes to one or both of the following questions: "Did the firm introduce (i) new or significantly changed sales or distribution methods or (ii) significant changes in a product or service design or packaging?"
- *organizational innovation* if it answers yes to one or both of the following questions: "Did the firm introduce (i) new or significantly improved business processes for the better use or exchange of information, knowledge and skills in the firm or (ii) a major organizational change within the company?"

We are not able to observe innovation intensities. Based on the innovation questions, we therefore construct binary indicators from the survey data that indicate whether firms had these three types of innovation activities during the 2002–04 time period. In the empirical analysis, these binary variables are used as measures for innovation activities.

B.2. *Capital Stock*

The firm's capital stock, denoted by K, is composed of the capital stock of machinery and equipment, denoted by K^M, and the capital stock of structures and buildings, denoted by K^S. K^M is developed using the Perpetual Inventory Method (PIM) method for investment data. The investments are measured in fixed prices using national account industry deflators for value added. K^S is obtained from accounting data using the book value of the structures and buildings, as we do not have access to long investment series of structures and buildings that are required to construct reliable capital stock measures due to low depreciation rates. Below, we describe the applied method in detail.

Assuming a constant depreciation rate, the PIM states that:

$$K_{i,t}^{M} = I_{i,t}^{M} + \left(1 - \delta^{M}\right) K_{i,t-1}^{M}$$

where I^M denotes machinery and equipment investments or gross fixed capital, and δ^M is a constant depreciation rate of machinery and equipment. In addtion, i and t denote firm and time period, respectively.

A key challenge in applying the PIM is the estimation of initial capital stock. We use the following method proposed by Hall and Mairesse (1995) and applied by Hempell (2005). Under the assumption that investment expenditures on capital goods have grown at a similar and constant average rate g_K^M in the past in all firms, the PIM equation can be rewritten as follows:

$$K_{i,0}^M = I_{i,0}^M \big/ \left(\delta^M + g_K^M\right).$$

To construct the capital stock of machinery and equipment, we apply investment data for the period 1999–2007. We measure $I_{i,0}$ as the 3-year investment average because investments may fluctuate quite a bit from year to year. Moreover, we assume that $\delta = 20$ percent whereas g_K is measured as the 5-year mean of the growth rate in investments in machinery and equipment from 1999 to 2004.

In the analysis, we present results where K^S is measured as the book value of structures and buildings for the years 2004–07. Alternatively, we could have used the 2004 book value as the initial capital stock and then used PIM to determine capital values for 2007, which would produce similar results to those presented in this analysis.

B.3. *Alternative Estimation Methods*

Section 3 indicated that we estimate productivity growth rates using three alternative estimation methods. We briefly describe these three estimation methods. Olley and Pakes (1996) use investments to control for unobservable productivity shocks assuming that positive shocks increase forward looking investments. An advantage of the method is that it also takes survival selection bias into account by controlling for firm exits due to low productivity levels. A disadvantage is that firms have to have positive invest levels; firms with zero-investments are excluded in the regression. Motivated by this disadvantage, Levinsohn and Petrin (2003) suggest using energy input to control for productivity shocks instead of investments, as energy inputs are positively related to utilization of capital and because firms always have positive energy use. Downsides of this method are the absence of forward looking behavior and that the method does not account for firm exits. Finally, Ackerberg *et al.* (2006) is based on Olley and Pakes (1996) and focuses on solving for multicollinearity.

To implement these methods we apply additional data for Danish firms. First, we apply investment data on machinery and equipment as well as investment data on structures for the implementation of Olley and Pakes (1996). Moreover, we take advantage of full population Danish firm register data to identify firms that answered the CIS survey in 2004 but exited the data before the CIS survey 2007 was collected. Second, we merge firm data on energy use and intermediate inputs to the applied data set to apply the Levinsohn and Petrin (2003) method. Third, we use data on value added, labor, capital and energy inputs for the implementation of the method in Ackerberg *et al.* (2006).

B.4. *Other Firm-Specific Variables*

Real value added, Y, is measured as value added in current prices that have been deflated by narrow industry specific price series. Physical capital, K, is measured in terms of fixed assets and is obtained from accounting data, whereas labor input, L, is measured by full-time equivalent units. The log differences in these variables between 2004 and 2007 are determined. These log differences are measured as annualized changes. As a measure of the education mix in each single firm, E, we use the share of full-time employees who possess at least 16 years of education. By this measure, higher levels of E indicate more skill-intensive firms. The descriptive statistics of the sampled firms are provided in Table A1.

TABLE A1

Descriptive Statistics of Sample

Variable	Obs	Mean	Std. Dev	Min	Max
dln(value added)	1,321	0.024074	0.189312	−1.21353	1.187493
dln(employment)	1,321	0.012832	0.152181	−1.25579	1.116635
dln(capital)	1,321	−0.01217	0.1689699	−1.14174	1.626777
Value added (million kroner)	1,321	104.1648	335.1636	0.3511704	9,057.948
Employment	1,321	195.7033	513.3778	0	10,047
Capital (million kroner)	1,321	109.2023	453.5757	0.0315857	13,147.75
E_{2001}	1,321	0.166255	0.209093	0	1
Product innovation	1,321	0.39894		0	1
Product–marketing innovation	1,321	0.124148		0	1
Product innovation, no marketing innovation	1,321	0.274792		0	1
Organizational innovation only	1,321	0.2324		0	1
Export intensity	1,321	0.260733	0.336472	0	1
Firms in primary sector	1,321	0.003028		0	1
Firms in manufacturing	1,321	0.436033		0	1
Firms in construction	1,321	0.050719		0	1
Firms in retail and wholesale trade	1,321	0.245269		0	1
Firms in transportation	1,321	0.031794		0	1
Firms in communication	1,321	0.009841		0	1
Firms in FIRE	1,321	0.219531		0	1
region1	1,321	0.024981		0	1
region2	1,321	0.097653		0	1
region3	1,321	0.120363		0	1
region4	1,321	0.043906		0	1
Ownership 1	1,321	0.870553		0	1
Ownership 2	1,321	0.11355		0	1
Ownership 3	1,321	0.015897		0	1

Appendix C: The General Model

In Section 4.3, two empirical approaches are applied; one approach is based on innovation types and another approach utilizes firm types. In this appendix, we demonstrate that both of these approaches are consistent with the general version of the model that was presented in equation (1). In the following discussion, we concentrate on the portion of the model that is related to innovation; we designate this portion of the model as *INNO*:

$$INNO = \lambda_1 I^P E + \lambda_2 I^M E + \lambda_3 I^P I^M E + \lambda_4 I^O E + \lambda_5 I^P I^O E + \lambda_6 I^M I^O E + \lambda_7 I^P I^M I^O E.$$

Compared to (1), we have included additional interaction terms that produce the three extra parameters of λ_5, λ_6, and λ_7.

C.1. *Innovation Types*

The model that is applied through the innovation types approach, that is, equation (1), is obtained under the restriction that $\lambda_5 = \lambda_6 = \lambda_7 = 0$. This results in the following estimates for $\hat{\lambda}_1$, $\hat{\lambda}_2$, $\hat{\lambda}_3$, and $\hat{\lambda}_4$:

$$\widehat{INNO}_1 = \hat{\lambda}_1 I^P E + \hat{\lambda}_2 I^M E + \hat{\lambda}_3 I^P I^M E + \hat{\lambda}_4 I^O E.$$

C.2. *Firm Types*

Given the three innovation types, we can group innovative firms into seven different groups in accordance with the innovative activities that they perform:

$$T_1 = 1 \text{ if } I^P = 1, I^M = 1, I^O = 1; T_1 = 0 \text{ otherwise}$$

$$T_2 = 1 \text{ if } I^P = 1, I^M = 0, I^O = 1; T_2 = 0 \text{ otherwise}$$

$$T_3 = 1 \text{ if } I^P = 0, I^M = 1, I^O = 1; T_3 = 0 \text{ otherwise}$$

$$T_4 = 1 \text{ if } I^P = 0, I^M = 0, I^O = 1; T_4 = 0 \text{ otherwise}$$

$$T_5 = 1 \text{ if } I^P = 1, I^M = 1, I^O = 0; T_5 = 0 \text{ otherwise}$$

$$T_6 = 1 \text{ if } I^P = 1, I^M = 0, I^O = 0; T_6 = 0 \text{ otherwise}$$

$$T_7 = 1 \text{ if } I^P = 0, I^M = 1, I^O = 0; T_7 = 0 \text{ otherwise}$$

Given these seven types of innovative firms, the general version of *INNO* may be rewritten as follows:

$$INNO = \psi_1 T_1 E + \psi_2 T_2 E + \psi_3 T_3 E + \psi_4 T_4 E + \psi_5 T_5 E + \psi_6 T_6 E + \psi_7 T_7 E$$

with

$$\psi_1 = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7$$

$$\psi_2 = \lambda_1 + \lambda_4 + \lambda_5$$

$$\psi_3 = \lambda_2 + \lambda_4 + \lambda_6$$

$$\psi_4 = \lambda_4$$

$$\psi_5 = \lambda_1 + \lambda_2 + \lambda_3$$

$$\psi_6 = \lambda_1$$

$$\psi_7 = \lambda_2$$

The firm type approach is consistent with the innovation type approach if the restrictions $\lambda_5 = 0$, $\lambda_6 = 0$, and $\lambda_7 = 0$ are implemented. Given these restrictions, $\psi_1 = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4$, $\psi_2 = \lambda_1 + \lambda_4$, $\psi_3 = \lambda_2 + \lambda_4$, and $\psi_4 = \lambda_4$, $\psi_5 = \lambda_1 + \lambda_2 + \lambda_3$, $\psi_6 = \lambda_1$, and $\psi_7 = \lambda_2$.

To avoid using seven different firm types in the main text, the baseline regression in Section 3.3 is not based on these restrictions. Instead, we base the analysis reported in the main text on four firm types with innovation activities. The model applied under the firm types approach is obtained under the following restrictions.

- Firm type 1 in the main text is defined as firms with product–marketing innovation. Thus, these firms must satisfy $T_1 = 1$ or $T_5 = 1$. These firm types are assumed to demonstrate similar growth effects, implying that: $\psi_{1,5} = \psi_1 = \psi_5$ or that $\lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 = 0$.
- Firm type 2 in the main text is defined as firms with product innovation but no marketing innovation. These firms must satisfy $T_2 = 1$ or $T_6 = 1$. These firm types are assumed to demonstrate similar growth effects, implying that: $\psi_{2,6} = \psi_2 = \psi_6$ or that $\lambda_4 + \lambda_5 = 0$.
- Firm type 3 in the main text is defined as firms with marketing innovation but no product innovation. These firms must satisfy $T_3 = 1$ or $T_7 = 1$. These firm types are assumed to demonstrate similar growth effects, implying that: $\psi_{3,7} = \psi_3 = \psi_7$ or that $\lambda_4 + \lambda_6 = 0$.
- Firm type 4 in the main text is defined as firms with organizational innovation but no product innovation or marketing innovation. This specification produces no restrictions for the relevant parameter ψ_4.

Thereby, we specify that firms from the first firm group and firms from the fifth firm group of firms demonstrate productivity growth, despite the fact that firms in the former group engage in both organizational innovation and product–marketing innovation, whereas firms in the latter group only conduct product–marketing innovation. Similar considerations also apply for the firm types that include firms with product innovation but no marketing innovation and the firm types that include firms with marketing innovation but no product innovation. This specification is inherently inconsistent with the applied theoretical model, given that we ignore that firms that belong to the first three firm groups conduct organizational innovation in addition to product and/or marketing innovation.

Implementing the restrictions that are described in the above bullet points imply that *INNO* can be rewritten as follows:

$$\widehat{INNO}_2 = \hat{\phi}_{1,5}(T_1+T_5)E + \hat{\phi}_{2,6}(T_2+T_6)E + \hat{\phi}_{3,7}(T_3+T_7)E + \hat{\phi}_4 T_4 E.$$

It is clear that the two approaches lead to different estimates, given that $\hat{\phi}_{1,5} \neq \hat{\lambda}_1$ and that similar statements apply to the other equation coefficients. In other words, the two approaches originate from the same general model but are not nested. Under the firm type approach, the constraints imply that $\lambda_4 = -\lambda_5 = -\lambda_6 = \lambda_7$. Thus, complementarities other than the complementarity between product and marketing are enforced. The two approaches, however, lead to identical estimates under the restriction that $\psi_4 = \lambda_4 = 0$; this conclusion is evident from Column 4 of Table 2 and Column 1 of Table 4, which present identical results. Moreover, the two approaches generate identical results if all innovative firms with innovation activities perform organizational innovation. The results for this situation are reported in Column 4 of Table 4.

As mentioned, we do not present estimation results for the seven groups of firms. However, the qualitative results for this case are similar to the findings that are presented in Table 4, implying that the facts that $\lambda_5 \neq 0$, $\lambda_6 \neq 0$, and $\lambda_7 \neq 0$ do not greatly influence the results. The simultaneous assessment of these constraints for the firm type approach through an F-test produces a critical p-value of 0.55, implying that the restrictions cannot be rejected. These results are available upon request.

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