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How Different Policy Instruments Affect the Creation of Green Energy Innovation: A Differentiated Perspective

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Abstract:

Based on representative firm-level survey data for the three countries Austria, Germany, and Switzerland, we investigate the effects of regulation, energy taxes, voluntary agreements, and subsidies, on the creation of green product innovations. Our data set allows us to distinguish between the supply-side effects (cost effects) and the demand-side effects of policy measures, which improves our understanding of the frequently observed positive net effect of policies. Controlling for the demand effect, taxes and regulations are negatively related with product innovations. Hence, if taxes and regulation do not trigger additional demand, they decrease the propensity to innovate. These effects are ameliorated for technologically very advanced firms and for firms with a high level of financial awareness. Subsidies and (partly) voluntary agreements are positively related with product innovations.

Keywords: Innovation; policy; demand

JEL classification: O30; O34; Q55.

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1 Introduction

Even though green innovations are essential in order to address climate change (IPCC 2014), private firms are often not willing to invest in the creation of such technologies. Probably the main reason for this is that the greatest benefits from green technologies are likely to be public rather than private. Therefore, potential customers' willingness to pay for these technologies is low, which normally results in lower or even negative returns compared to traditional innovation activities (Marin 2014, Soltmann et al. 2015). As a consequence, policy intervention is required to stimulate the creation of green technologies. In-depth knowledge about the meaning of different policy instruments for green product innovation is thus crucial.

Hence, it is not surprising that there are many studies analyzing how policies affect innovation. In general, they confirm the expected positive relationship between policy and innovation (for a review of this literature see Ambec et al. 2013 or Popp et al. 2010). With the study at hand, we add to the existing literature in several ways. First, we can contrast the effects of different policy measures in the three countries Austria, Germany, and Switzerland. Second, we capture a potential demand effect of the analyzed policy measures. As policy is likely to affect innovation not only directly, but also indirectly via demand expectations, it is important to identify the different channels in order to improve policy designs. Most of the existing studies identify the net (mixed) policy effect comprising demand- and supply-side factors. In this study, we argue that the direct (supply-side) policy effects are significantly smaller than the mixed policy effects. Third, most studies define innovation activities broadly. However, policies are likely to show different effects on different types of innovation, and it is rather unclear whether existing findings hold for both process and product innovation. In this study, we find evidence that policies show significantly smaller effects on product than on process innovation. Fourth, most existing studies use patent data in order to identify green innovation activities, limiting the investigation to a rather small group of mainly highly innovative firms (Griliches 1990). Since technologically more advanced firms are more likely to respond with innovation to cost

increasing policy measures, the observed effects tend to be larger for such leading innovators than for innovation laggards, referring to firms that normally are excluded from patent statistics. Against the background of these arguments many existing studies overestimate the direct effect of policies on product innovations, (a) as they do not capture potential demand effects, (b) mix product and process innovation, and (c) primarily consider innovations from leading innovators.

In this paper, we analyze the effect of different policy instruments on the creation of green technologies based on a unique survey about the innovation behavior of firms regarding green energy technologies. The survey was simultaneously conducted in 2015 in Austria, Germany and Switzerland, and includes information on the innovation decision of 1,987 (innovation-relevant) firms. The dataset includes comparable information on the relevance of taxes, subsidies, regulations and voluntary agreements, which allows us to contrast the effect of the different policy measures with each other. Moreover, unlike most previous studies our policy measures are firm-specific and should reflect the stringency of the different policy measures adequately. Hence, even though a certain instrument may be of low relevance for the average firm, we do observe variation between single firms, and should thus be able to identify potential policy effects. Another important advantage of the data is that it includes firm-level information on a broad set of other drivers of green innovation activities, which enables us to specify a widely accepted innovation model and thus to significantly reduce a potential omitted variable bias problem. Finally, the dataset also allows us to identify differences in the policy effects between the three countries, which is important as the characteristics of the environment (e.g., the firms' policy affinity) may moderate the effect of different policy types on innovation activities.

The empirical analysis confirms our expectations that existing studies are likely to overestimate the direct (supply-side) effects of policies on product innovation. While public subsides show the expected positive effect on product innovation, no significant effect is observed for voluntary agreements, and the (supply-side) effects of taxes and regulations on the creation of green energy technologies are even negative in our setting. However, the negative

direct effect is significantly ameliorated for firms operating at the technological frontier (leading innovators) and firms with a high financial awareness. These findings withstand several robustness tests, e.g., they are not driven by a selection of specific firms that have few opportunities for green innovation, and the results do not significantly differ between the three countries considered in our data. Moreover, we offer plausible explanations for the rather unexpected negative effects of taxes and regulations on product innovation and also test them empirically.

2 Conceptual background and hypotheses

The effect of policy on green product innovation

Our current understanding of how policy affects green innovation has strongly been influenced by the article of Porter and van der Linde (1995). They argued that firms face market imperfections, such as asymmetric information, organizational inertia or control problems (Rubashkina et al. 2015), that make it hardly possible for them to understand the full costs of incomplete utilization of resources and thus to identify all profitable opportunities for new products or processes. Policies help to overcome some of these market failure by signaling firms about likely resource inefficiencies and pursing otherwise neglected technological improvements. In what Jaffe and Palmer (1997) later defined as the "weak" version of the porter hypothesis, Porter and van der Linde thus concluded that "properly designed environmental standards can trigger innovation" (Porter and van der Linde 1995, p. 98). While Porter and van der Linde (1995) focus in their analysis on regulation, their hypothesis can be extended to other policy types as well (see Lanoie et al. 2011). Hence, we would expect that not only energy related regulations, but also subsidies, taxes and voluntary agreements push green innovation.

There are many studies that analyze the impact of regulation on green innovation, and most of them find the expected positive link, although the strength of the link varies (see Ambec et al. 2013 for a review of this literature). Studies that analyze the impact of other policy types on

green innovation are somewhat rarer, but most of them also identify a positive effect (e.g., Lanoie et al. 2011, Ley at al. 2016, Veugelers 2012).

In sum, the discussion above leads us to formulate the following hypothesis for green product innovation, i.e. the creation of new products or services for end-user:

Hypothesis 1: Taxes, regulations, voluntary agreements and subsidies positively affect a firm's green product innovation activities.

Identifying the direct (supply-side) effect of policy on green product innovation

The identification of the direct policy effect on green product innovation is not that simple. Following the policy-induced innovation view where innovation activities are directed to factors that become more expensive (e.g. energy), policy does not stimulate the creation of innovation only, but also leads to investments in ways to meet the policy-induced constraint at lower cost (Jaffe and Palmer 1997). Hence, energy related regulations, subsidies or taxes push end-users to buy new energy efficient technologies developed elsewhere[1], which will stimulate demand for such technologies. It is widely accepted that market demand is an important driver of innovation (Kleinknecht and Verspagen 1990, Schmookler 1966), and demand is also found to be important for the creation of environmental innovation (Horbach 2008). Hence, besides a direct effect of

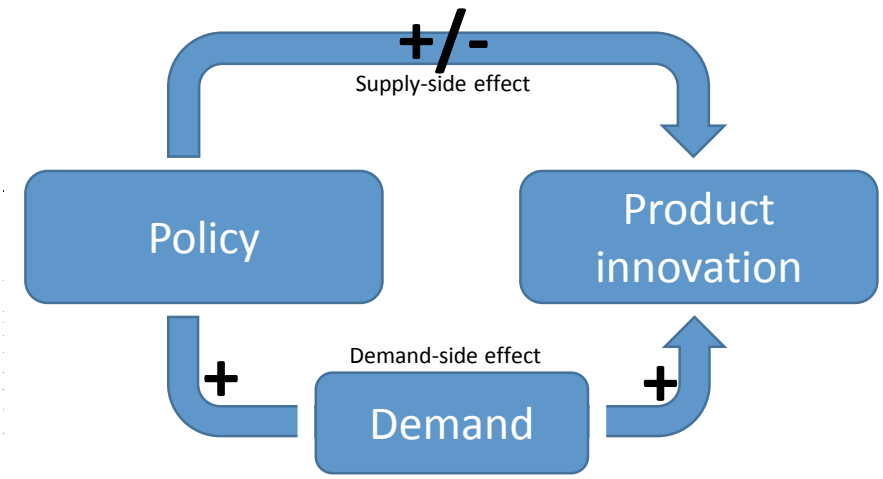

Figure 1: How policy is expected to affect green product innovation

policy on green product innovation, policy is also expected to have an indirect effect via policy-induced demand (see Figure 1). In order to identify the direct (supply-side) effect of policies on product innovation, we thus have to capture their indirect effect via demand.

In contrast to the policy-induced innovation view, the direct (supply-side) effect on green product innovation may even be negative for certain policy types as policies are not costless. Regulations tend to increase the costs of the production processes (Simpson and Bradford 1996, Mohr and Saha 2008), since formerly costless negative externalities have to be priced in. This will increase the lack of internally available funds and even might require a shift of internal funds away from more profitable projects (Gray and Shadbegian 1998) in order to comply with the rules. Since innovation activities are predominantly financed by firm-internal funds (Hall 2002, Hall and Lerner 2010) additional production costs will lower internally available funds, and, consequently, are likely to constrain the financial opportunities to invest in innovation activities. Following this view, policies are likely to lower the innovation output. However, if policies do not constrain the financial situation of a firm, like it is the case with public subsidies, innovation activities will be positively affected.

Based on Porter and van der Linde (1995), we expect that policy stimulates demand, which in turn leads to higher green product innovation activities. Most existing studies do not capture potential demand effects and thus identify a mixture of the positive demand-side and the positive or negative supply-side effect (e.g., Johnstone et al. 2012, Lanoie et al. 2011, Veugelers 2012). Even though the direction of the (supply-side) policy effects is not clear a priori, we expect that the policy effects significantly decrease when potential demand-side effects are captured.

Hypothesis 2: Controlling for policy-induced demand reduces the effect of taxes, regulations, voluntary agreements and subsidies on green product innovation, i.e., we expect that their effect become smaller in size or even negative.

3 Description of the data

The empirical testing of the hypotheses is based on firm-level data that were collected in the course of a survey on the "creation and adoption of energy related technologies" carried out in 2015. In order to test the robustness of our findings for different countries, the survey was simultaneously collected in the three countries Austria, Germany and Switzerland. To obtain representative results, the survey was based on representative firm samples i.e., the WIFO Enterprise Panel for Austria, the ZEW Enterprise Panel for Germany, and the KOF Enterprise Panel for Switzerland. Because most firms belonging to the service sector are rather unlikely to have generated green energy technologies for end-users (i.e., product innovation), the final samples used for this survey were restricted to the whole manufacturing sector (excluding the food industry, textile and cloth industry, printing, pharmaceuticals, and 'other manufacturing') and firms belonging to the two service industries 'information technology services' and 'technical services'.[2] Concretely the survey was sent to 2,129 Austrian firms, 2,780 German firms and 2,870 Swiss firms. Valid information was received for 210 Austrian firms (response rate: 10%), 1,056 German firms (37%), and 921 Swiss firms (32%). Given the very demanding questionnaire the response rates for Germany and Switzerland are satisfying, but disappointing for Austria. However, a comprehensive recall action in all three countries ensures that a sufficient large number of answers was received for all three counties, covering all industries and all firm size classes according to the underlying sampling schemes.[3]

Due to missing values for some model variables, our final estimation sample includes 1,987 observations; 48% of them are German firms, 44% Swiss firms and 8% Austrian firms. On average, the firms in our sample have 276 employees (median: 43 employees), whereupon 87% are SMEs with less than 250 employees. 72% of the firms belong to the manufacturing sector, 21% to the service sector and only 7% to the construction sector.

[2] In order to reduce confusion, all other industries received only questions referring to the adoption of green technologies (i.e., process innovation).
[3] See Arvanitis et al. (2016) for a detailed sample information.

Besides questions on some basic firm characteristics (sales, exports, employment, investment and employees' education), the survey included questions on energy related adoption and product innovation activities as well as on obstacles of such activities. Descriptive statistics for all model variables based on the estimation sample are presented in Table A.1 in the appendix; the correlation matrix is shown in Table A.2.

Related to the Communication Innovation Survey for innovation activities in general, the information on green energy innovation activities is based on questions that directly ask whether the firms created green energy technologies for end-user. In order to capture green energy innovation properly, a clear definition was used comprising *energy-saving* technology applications in (1) production, (2) information and communication technologies, (3) transport, (4) building and heating, and green *energy-generating* technologies from renewable sources. Moreover, as the focus is on innovations that have a clear environmental impact, the definition was restricted to innovations that are already introduced on the market.

14% of the firms in our sample created green energy technologies for end-user, i.e. had green energy product innovation, and the green technologies add up to 13% of the green innovators' total sales, on average.

The identification of the relative effect of different government policy types at firm level is hardly possible based on publicly available data. It requires survey data primarily for two reasons. First, to get a complete picture, all relevant policies would need to be identified, which is hardly possible as they can be firm/sector- and technology- specific. Second, besides the identification of relevant policies, also the stringency of single policies, i.e. how strong a firm is affected, has to be identified, which is a difficult task (Levinson 2008, Shadbegian and Wolverton 2010, Xing and Kolstad 2002). The difficulty arises from the fact that different policies typically cover different firms, policies may exist at multiple levels (e.g. federal and local), and monitoring and enforcement are imperfect (Millimet and Roy 2015).

To overcome these problems, a specific set of questions was included in the survey that directly asked the firm-specific relevance of different policy types (for a related procedure see, e.g., Johnstone et al. 2012, Lanoie et al. 2011, Stucki and Woerter 2016, Veugelers 2012). The relevance of the different policy types has been assessed by the firms on a three-point Likert scale. A first set of questions refers to four categories of policies, i.e. energy taxes, regulations, subsidies, and voluntary agreements. Additionally, information on the impact of demand for green products is available.

4 Empirical framework

The firms' share of green energy technologies in total sales is used to measure green production intensity in our baseline specification. In order to deal with the presence of many firms that did not have green product innovation at all, we estimate Tobit regressions. A general concern in the empirical economic literature is endogeneity. Policies are usually exogenous as they are designed by the respective governments and are beyond the influence of a single company. However, as our policy measures are based on self-assessments, the estimated policy effects may share systematic factors with the firms' green innovation activity (see Bertrand and Mullainathan 2001). We significantly reduce this potential problem in two ways:

First, by including, next to the policy variables, a broad set of observables affecting the firms' innovation activities in our estimations. Following the Schumpeterian tradition, we control for appropriability of research results, firm size, competition, demand, industry affiliation, and the technological potential (see Cohen 2010 for a review of the literature). Moreover, in order to be able to identify direct policy effects on green product innovation activities, we have to control for the firms' green innovation affinity. One could for example argue that energy related policies primarily affect energy intensive firms, which in turn are often in industries that typically have few opportunities to create themselves green products for end-user. To capture such indirect effects, we add specific controls for the firms' green process innovation activities, and a measure

for whether the firms' products are suited for green product innovation or not (in addition, we also control in detail for the firms' industry affiliation).

Second, the policy questions are asked in a separate section in the beginning of the survey with no link to the section referring to the firms' green energy innovation activities. In most existing studies using self-reported policy measures, the policy information comes from questions that ask firms directly to assess the importance of different policies as drivers for their green innovation activities (e.g., studies based on Community Innovation Survey). By avoiding such a direct link between the policy exposure and the firms' innovation behaviour, we can further reduce a potential assessment bias.

We thus expect that the policy variables affect the firms' green product innovation intensity directly and endogeneity is not a main concern.[4] Moreover, even if our results would be affected by an assessment bias, at least the effect of the different policy measures relative to each other should be unbiased as we simultaneously control for the relevance of different policy types. As all policy variables should be similarly affected by a potential assessment bias, the simultaneous inclusion of multiple policy measures captures a potential assessment bias of the policy variables making it unlikely that the effect of our policy measures is correlated with unobservables.

5 Estimation results

Policy effects on green energy product innovation

The effect of the different policy variables on green product innovation is presented in Table 2. Columns 1 to 8 present estimation results that test the effect of the different policy variables individually (columns with even numbers additionally include a control for demand). In line with hypothesis 1, we observe a significant positive effect of subsidies on product innovation (see columns 5 and 6). However, unlike expected significant negative effects are observed for taxes

[4] Alternatively, we could have pursued an instrumental variable approach. However, as the focus of this paper is on contrasting the effect of multiple policy measures rather than the identification of a single policy effect, we lack valid instruments for all different policy measures, which makes such an approach not feasible. Hence, we are left with the applied approach as the best available choice.

(columns 1, 2) and regulations (column 4). The effect of voluntary agreements seems to be moderate, but at least not significantly negative (columns 7 and 8).

In order to reduce a potential omitted variable bias, estimation results that include all policy variables simultaneously are presented in column 9. These results largely confirm previous findings. The only exception is the regulation effect that gets somewhat smaller and now is not significantly negative anymore.

A first explanation for the negative policy effects can be found in the models that control for demand. As predicted in hypothesis 2, demand shows the expected positive effect on product innovation. Because the policy variables also capture part of this positive demand effect, i.e. the effect from policy-induced demand, the policy effects significantly decrease and become negative or more negative when we add a control for demand. The effect of controlling for demand is quite substantial. While the effect of regulations and voluntary agreements switch their signs, the positive effect of subsidies is reduced by nearly two-thirds.

In Table A.3 the relevance of the policy stringency is analyzed for the different policy measures (based on the full model that also controls for demand). In general, the effects seem to accentuate with increasing relevance of the policy instruments. The effects, however, significantly differ only for taxes and demand.[5] While the negative effect of taxes is primarily driven by taxes that heavily affect firm activities, the effect of demand is significantly positive for both moderate and high demand.

The effects of the different policy types on product innovation are very robust and withstand several robustness tests. First, they hold for alternative estimation procedures and dependent variables (see Table A.4). Switching to an OLS model that does not control for the large number of firms without innovation activities does not affect the results (column 1). When focusing on innovation propensity rather than intensity (column 2), the effect of taxes gets

[5] P-values of tests on equality of coefficients for medium and high relevance: taxes 0.001; regulations 0.282; subsidies 0.791; voluntary agreements 0.501; demand 0.000

somewhat smaller compared to regulations, which shows a significantly negative effect in the propensity equation. However, the general pattern is the same as before: negative effects for taxes and regulations, positive effects for subsidies and demand, and no effect for voluntary agreements. Moreover, the effects look very similar when we analyze the effects on green R&D propensity (column 3). While the explanatory power of this model is somewhat smaller, the size and direction of the different policy effects is very similar to those observed in the model that analyzes green innovation propensity.

Second, the results hold for different sub-samples of firms. A possible explanation for the negative policy effects could be that taxes and regulations primarily affect firms that have few opportunities for green product innovation. However, such a problem should be significantly reduced by the inclusion of several controls for the firms green innovation affinity. To further test the robustness of our results, we present in Table A.5 regressions that do not control for the firms green innovation affinity only, but also restrict the estimation sample to firms that (a) at least were discussing about the creation of green products/services in their firms[6], or (b) believe that their products/services are suited for green product innovation[7]. Hence, firms that are affected by policy but have few green innovation opportunities drop out in both settings. The results in Table A.5 show that our previous findings also hold when we impose such sample restrictions.

Third, we test the robustness of our results for the different countries. Based on separate regressions for the three countries, we cannot identify large differences concerning the policy effects in Austria, Germany and Switzerland, respectively (see Table A.6). The only exception are taxes that show a more negative effect in Germany than in the other two countries (see column 2). This larger effect of taxes seem to be driven by the fact that taxes are more

[6] This information comes from a question that asked firms whether they never were discussing about the creation of green energy products within their firms. If firms answered this question with yes, they were excluded.
[7] This information is based on a question that asked firms to assess whether their products/services are *not* suited for green product innovation (four-level ordinary variable; level 1: 'fully disagree'; level 4: 'fully agree'). Firms with a value of 4 were excluded from the regression.

pronounced in Germany[8]; as we have seen in Table A.3, the negative effect of taxes on product innovation is primarily driven by taxes that heavily affect firm activities (as is shown in column 4 of Table A.6, this finding also holds for Germany).

With respect to the control variables we observe that primarily the firms' general innovation capabilities affect green product innovation activities; positive effects are observed for both the qualification level of the employees and the firms R&D propensity. Moreover, we identify a positive effect of competition. As expected, the firms' green innovation affinity seems to be relevant as well; the firms' green process innovation intensity and the suitability of their products for green product innovation both show statistically significant effects.

In what follows, we try to find explanations for the unexpected negative effects of taxes and regulations on product innovation.

What drives the negative effect of taxes on product innovation?

Taxes place constraints on the profit opportunities of firms, e.g., because they force the firms to pay CO_2 taxes. Firms maximizing profits subject to such constraints will be more likely to invest in ways to meet the constraint at lower cost (Jaffe and Palmer 1997). As product innovations are sold to end-users, they primarily affect the customers' production process. The production processes of the innovating firms, however, are primarily affected by process innovations. Hence, probably taxes primarily stimulate the firms' process innovation rather than their product innovation activities.

Differences in the policy effects on green product and process innovation, respectively, are tested in Table 3. While we observe a negative effect of taxes on green product innovation, we indeed observe a positive effect on green process innovation, which is in line with the general predictions of Porter and van der Linde (1995). Hence, taxes seem to affect the firms green

[8] Based on Chi-square test, we find that high taxes are observed significantly more often in Germany than in the other two countries (p-value: 0.000). No differences, however, are observed for moderate taxes (p-value: 0.945).

product and process innovation activities differently. The differences between product and process innovation are less pronounced for all other policy types. The effect of regulations also switches sign but is statistically insignificant for both types of innovation. The effects of public subsidies and voluntary agreements have positive signs for both product and process innovation. Interestingly, however, not only taxes, but also regulations, subsidies and voluntary agreements show larger effects on process innovation than on product innovation.[9]

The positive effect of taxes on process innovation may also be part of the explanation of its negative effect on product innovation. Process innovation is not cost-free. In our sample, about two-third of the firms with green energy product innovation also have green energy process innovation. Moreover, the median product innovator is relatively small: it has 70 employees, its annual total R&D spending is €150,000, whereof €50,000 are spent for green energy product innovation. Compared with these figures, the €28,000 annual spending for green process innovation looks quite substantial. Hence, if a policy stimulates a firm's green process innovation activities, costs are generated. These policy-induced investments may directly have consequences for product innovation. If a firm has to invest heavily in green process innovation, the firm's financial resources for product innovation may decrease, which would negatively affect the firm's product innovation activities. Hence, we expect a moderating effect of a firm's process innovation activities on the effect of taxes on green product innovation, i.e., due to more limited financial resources the effect of taxes on product innovation is expected to be significantly smaller for firms with high investments in process innovation than for firms with low investments in process innovation.

[9] The magnitude of the effect of subsidies on process innovation is twice as large compared with product innovation (p-value for test on equality of coefficients: 0.081). Moreover, we observe larger effects of taxes and regulations on green process innovation than on green product innovation (p-values for tests on equality of coefficients: 0.000 and 0.057, respectively). The difference in the effect of voluntary agreements is not statistically significant (p-value: 0.202). The effect of demand, however, is much smaller for process than for product innovation (p-value: 0.000). These tests are based on simultaneous regressions of the two models. In order to allow convergence, these tests are based on models that control for sector affiliation only, and not for industry affiliation as in the other models. Moreover, the product innovation model did not include a control for process innovation, as potential correlation between the two types of innovation is captured by the simultaneous regression of the two models.

In order to test this prediction, we add in Table 4 an interaction term between a firm's process innovation intensity and its policy affectedness to our baseline model, which simultaneously controls for all different policy effects. As predicted, we observe a moderating effect of process innovation for taxes identified by the significant negative sign of the interaction term between taxes and process innovation. Moreover, once we control for this moderating effect, the negative effect of taxes on product innovation is not statistically significant anymore (see column 1 and 6) and even becomes positive when we test the effect of taxes individually (see column 2). In sum, these results indicate that the main driver of the negative effect of taxes on product innovation are tax-induced process innovations that reduce a firm's innovation capital and thus negatively affect product innovation activities; if a firm does not have intensive process innovation activities, the effect of taxes is not statistically significant negative. No moderating effect of process innovation is detected for regulations (column 3), subsidies (column 4) and voluntary agreements (column 5), which is not surprising, as we do not observe opposite effects of these policies on process and product innovation.

Besides the negative interaction effect, we still observe a positive direct effect of green process innovation on green product innovation. This result indicates that green product and process innovations per se are complements. But, if process innovation is induced by policy, which is measured by the interaction term between process innovation and policy measures, the total effect of taxes on green product innovation decreases and becomes statistically significant negative. However, as the positive direct effect of green process innovation is much larger in magnitude than the negative indirect effect via policy, the total effect of green process innovation on green product innovation is still positive.

What drives the negative effect of regulations on product innovation?

The negative effect of regulations may be driven by compliance costs that often occur because regulations introduce high complexity into business operations. Firms are faced with rapidly evolving and increasingly severe and complex environmental regulations (Buysse and Verbeke

2003). “In 1970 there were about 2,000 federal, state, and local environmental rules and regulations in the United States; today there are more than 100,000. The code of Federal Regulations for protection of the environment currently exceeds the size of the U.S. Tax Code. Environmental regulations are listed in over 789 parts of the Code of Federal Regulations.” (Berry and Rondinelli 1998, p.39).

The complexity of regulation, however, is expected to decrease with a firm’s regulation experience. Dean and Brown (1995) for example predict that “the more a firm deals with environmental regulatory agencies and has to perform pollution control activities, the more the firm learns (1) which regulations and agencies apply to its activities and how to effectively handle them, (2) which pollution abatement technologies apply to its production processes and how to use them effectively, and (3) how to best modify its organizational and administrative processes to carry out these tasks” (Dean and Brown 1995, p.292). In sum, regulation experience is thus expected to reduce a firm’s compliance costs. This should not hold for regulation experience only, but also for innovation experience, or more generally, the firms’ innovation potential. The larger a firm’s green innovation potential, the easier it will be to adapt its products to new regulations or to detect completely new innovation opportunities. In line with this prediction, Amable et al. (2009) find for innovation in general that the impact of regulation on innovation, even when it is negative if a firm is far from the frontier, changes sign and is increasingly positive as one moves closer to the technological frontier.

Hence, in order to test whether complexity drives the negative effect of regulations on product innovations, we analyze potential differences in the effect of regulations on the green product innovation activities of leading innovators and laggards. While innovation laggards are expected to develop primarily products that are new to the firm, innovation leaders are expected to create primarily innovations that are new to the market. Accordingly, we would expect larger effects of regulations on the creation of new to the market innovations than on the creation of products that are new to the firm only.

Regressions where we split product innovations by its level of innovativeness into these two categories are presented in Table 5. The results largely confirm our predictions. As for innovation in general, we observe a statistically significant negative effect of regulations on new to the firm innovation (columns 3, 5 and 11). Regulations, however, positively affect new to the market innovation, even though the effect is statistically significant only when we do not control for demand (column 6).

Beside regulations, taxes also do not show a significant negative effect on new to the market innovation, which may be due to the fact that especially in the short run much innovation experience is required to react quickly to tax changes. The difference in the effects between new to the firm and new to the market innovation, however, is more accentuated for regulations than for taxes[10], which emphasizes the complexity of regulations. For subsidies, the effect even shows in the other direction, i.e. the positive effect of subsidies on new to the market innovation is somewhat larger than the effect on new to the firm innovation,[11] which indicates that primarily high-end research profits from public subsidies. The effect of voluntary agreements only slightly differs for the two types of innovation.[12]

The results look very similar, when we use the firms' green R&D activities as measure for their green innovation potential. As for innovations that are new to the market, the effect of regulations is positive and statistically significant when we restrict our sample to firms with green R&D activities (see Table A.5). Here, again we see that technologically advanced firms might positively respond to regulation with new technological developments that is likely to be no option for R&D inactive firms.

Additional test for the relevance of financial resources

[10] P-value for test on equality of coefficients for regulations: 0.011 for columns 3 and 4 and 0.021 for columns 11 and 12. The effect of taxes does not significantly differ for the two innovation types (p-values for tests on equality of coefficients: 0.187 for columns 1 and 2 and 0.814 for columns 11 and 12).

[11] However, the difference is not statistically significant (p-values for tests on equality of coefficients: 0.142 for columns 7 and 8 and 0.143 for columns 11 and 12).

[12] The effect of voluntary agreements does not significantly differ for the two innovation types (p-values for tests on equality of coefficients: 0.945 for columns 9 and 10 and 0.363 for columns 11 and 12).

In sum, the previous findings indicate that the negative effects of regulations and taxes on product innovation is driven by a reduction in financial resources–either due to high compliance costs or more indirectly via induced process innovation–that could alternatively be used for product innovation activities. In order to test the relevance of this financial channel more directly, we present in Table 6 regressions that include a specific measure for the firms' financial awareness.[13] If the reduced financial resources are really responsible for the negative effect of taxes and regulations on green product innovation, firms with high financial awareness should show more positive policy effects, because they can handle policy-induced financial restrictions easier. And in fact, we detect for taxes and regulations the expected positive interaction effects with financial awareness. In line with previous findings, no significant interaction effect is found for subsidies and voluntary agreements. We thus conclude that financial awareness indeed seem to moderate the negative effects of regulations and taxes on green product innovation.

6 Discussion

While the existing literature generally predicts a positive effect of policy on (product) innovation, we find such positive effects for subsidies and (at least partially) voluntary agreements only. Regulations and taxes, however, negatively affect product innovation. These results withstand several robustness tests and contrasts existing studies that observe a positive relationship between policy and product innovation (for a review of the literature see Ambec et al. 2013 or Popp et al. 2010)? What might drive the different results?

We have four different explanations. First, Porter and van der Linde (1995) use the term innovation very broadly, which includes innovation referring to a "product's or service's design, the segment it serves, how it is produced, how it is marketed and how it is supported" (Porter and

[13] The measure for financial awareness is based on a question that asks the firms to assess the relevance of lack of financial resources as an obstacle for their green product innovation activities (see Table 1 for exact definition). This variable can be interpreted as the firms' financial awareness, as particularly firms that are heavily dependent on financial resources should be aware of this restraint (see, e.g., D'Este et al. (2012) for a similar interpretation of related variables). In line with this interpretation, we observe a positive and not a negative correlation between product innovation and financial awareness (see Table A.7).

van der Linde 1995, p. 98). Similar to Porter and van der Linde most other studies that analyze the relationship between policy and innovation do not specify which type of innovation really is considered. In many studies the type of innovation that is investigated, is (partly) determined by the type of applied data. Many studies use patent data or R&D data to measure innovation (see, e.g., Aghion et al. 2016, Jaffe and Palmer 1997, Johnstone et al. 2010, Ley et al. 2016). While this allows collecting comparable data for different countries over a long time period, it makes it hardly possible to identify whether the innovation activities refer to process or product innovation. Even though one could argue that primarily product innovations will be patented, the identified innovation effects will be partially mixed. As we have shown in the study at hand, the effects are likely to differ for the two innovation types; in general, we expect to observe more positive effects for process innovation than for product innovation. Existing studies based on patent and R&D data are thus expected to overestimate the policy effects on product innovation.

Second, the use of patent data and to a lesser extend also R&D data to measure innovation activities induces another problem, as this data only captures very specific types of innovation, limiting the analysis to a rather small group of mainly highly innovative firms (Griliches 1990). In our data set, only 57% of the firms with green energy product innovation also have green R&D activities; for sure, the fraction is significantly lower for patenting firms.[14] In general, patenting firms are expected to operate at the technological front (leading innovators). As we have shown, the effect of taxes and regulations tend to be more negative for innovation laggards than for leading innovators, either identified based on the firms green R&D activities or the depth of their innovation output measured by commercialized products that are "new to the market". Hence, it is likely that existing studies based on patent data and R&D data overestimate the effect of taxes and regulations on product innovation in general.

[14] Unfortunately, our survey does not include information regarding the firms patenting activities. However, in the KOF Innovation Survey 2015 that captures traditional innovation activities in Switzerland, only 63% of the firms with product innovation had R&D activities, and only 30% had patenting activities.

Third, studies that are based on survey data mostly used policy measures that come from questions that asked firms directly to assess the importance of different policies as drivers for their *innovation activities* (see, e.g., Horbach et al. 2012, Stucki and Woerter 2016, Veugelers 2012). As firms with few or no innovation activities are unlikely to answer that their innovation activities are heavily affected by policies, a non-negative relationship between the assessment and the firms' innovation activities is prefigured in the data.

Fourth, in contrast to most of the existing studies (e.g., Aghion et al. 2016, Johnstone et al. 2012, Lanoie et al. 2011), we can control for demand which allows us to separate "supply-side" from "demand-side" driven policy effects. This is hardly possible in studies using data that is aggregated at the industry or country level. As the producers and the potential consumers at these aggregation levels often belong to the same observational unit–e.g. the country–and can thus hardly be separated, it is difficult to adequately control for demand in these studies. In the study at hand, we found that controlling for demand significantly reduces the policy effect on innovation. Hence, the often observed mixed policy effect is likely to be larger than the direct (supply-side) effect of policy on innovation.

7 Conclusions

In this study, the relationship between policy and product innovation is analyzed based on a unique data set that covers firm-level data for Austria, Germany and Switzerland. The cost perspective of policies is discussed in the neoclassical literature but it has been nearly ignored in the empirical literature in the tradition of the Porter-hypotheses. This paper tries to unify both views in an empirical model that controls for the demand effects of policies and consequently highlighting the cost-related effects of policy measures for the firm. The main results can be summarized as follows. First, different policy instruments differently affect green product innovation. While we observe positive effects of subsidies, no effects are found for voluntary agreements, and even negative effects are detected for taxes and regulations. Second, the effects of most tested policy instruments differ for product and process innovation. In general, we find

more positive effects of policies on process innovation than on product innovation. Third, the negative effect of regulations and taxes on green product innovation is mainly driven by a reduction in financial resources that can be used for product innovation, in the case of regulations due to high compliance costs or in the case of taxes more indirectly via induced process innovation. Fourth, the size of the policy effects largely depends on the firms' green innovation potential. Negative policy effects are observed for typical innovators only, but not for technological leaders. Fifth, capturing indirect demand effects significantly reduces the effect of policy on green product innovation.

The study shows that energy policies increase the costs for the economy, since financial means have to be shifted away from more profitable adventures to comply with regulations and/or taxes. This suggests a policy regime that considers supply-side as well as demand-side effects of new policies. Consequently, the cost related burden for the economy might turn into profitable business opportunities due to an advanced policy regime. This contrasting view reveals some important information for the effects of policies and it has some important implications for the design of new policies. First, in order to efficiently address climate change, the diffusion of green technologies is crucial. However, technologies can diffuse only, if someone is willing to create them. As our results indicate that policies differently affect product and process innovation, an effective policy design is challenging. Policies should stimulate both, process innovations and product innovations. This is the case for subsidies, since they allow a direct stimulation of product innovation and do not suffer from a negative effect via process innovation. Hence, supply-side promotion activities–like subsidies–are indicated by our results. Second, it becomes obvious that without demand increasing effects, taxes and regulations and even voluntary agreements do not show the often propagated positive effect on the innovation activities of firms. Hence, it is of eminent importance that policies stimulate demand if we want to face the climate change with new, more energy-efficient technologies. Third, more positive effects of taxes and regulation can be expected if firms operate at the technological front. Policies

that support firms to accumulate technological know-how or to develop innovative technological solutions, essentially contribute to the effectiveness to demand-side related policies. Such promotion schemes are not necessarily limited to energy technologies alone, the promotion of innovation excellence in general creates positive spillovers for energy technologies if the promotion schemes are bottom-up and if there is a societal consensus that new technologies are an essential part of facing climate change successfully. Moreover, the results indicate that a reduction in the complexity of regulations is crucial in order to broadly stimulate product innovation and not affect the innovation leaders only.

Finally, these findings have clear implications for research as well. First, nowadays the term innovation is used broadly in the empirical and theoretical literature that analyses policy effects. Our findings, however, indicate that research should be more precise in their definition of what is considered as innovation, because the effects are likely to differ for different types of innovation. Second, while most existing studies do not adequately control for demand, the results indicate that controlling for demand is crucial in order to be able to identify direct (supply-side) effects of policies.

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Table 1: Variable definition and measurement

Variable	Definition/measurement
Dependent variables	
Green product innovation propensity	Firm developed new green energy products or services for end-users yes/no
Green product innovation intensity	Share of new green energy products or services in total sales, ln
Green process innovation intensity	Share of investments for green energy products or services (for the use within the firm) in total investments, ln
New to the market propensity	Firm developed new green energy products or services that were new to the market yes/no
Green R&D propensity	Firm has domestic R&D activities in the field of green energy technologies yes/no
Independent variables	
Export intensity	Share of exports in total sales, ln
Share of high qualified employees	Share of employees with a tertiary-level degree, ln
Foreign owned	Firm is owned by a foreign company yes/no
Firm age	Firm age in years, ln
Competition intensity	Firm has more than five competitors on their domestic and foreign prime market yes/no
R&D propensity	Firm has domestic R&D activities yes/no
Green process innovation intensity	Share of investments for green energy products or services (for the use within the firm) in total investments, ln
Products not suited	Green energy innovation is hampered by the fact that existing products/services are not well suited for this type of innovation (four-level ordinary variable; level 1: 'low relevance'; level 4: 'high relevance')
Number of employees	Number of employees measured in full-time equivalents; ln
Swiss firm; German firm	Country of the firm's origin (reference country: Austria)
Taxes	Firm-specific relevance of energy related taxes (three-level ordinary variable; level 1: 'not relevant'; level 3: 'high relevance')
Regulations	Firm-specific relevance of energy related regulations and standards (three-level ordinary variable; level 1: 'not relevant'; level 3: 'high relevance')
Voluntary agreements	Firm-specific relevance of industry-specific energy related voluntary agreements or standards (three-level ordinary variable; level 1: 'not relevant'; level 3: 'high relevance')
Public subsidies	Firm-specific relevance of energy related public subsidies (three-level ordinary variable; level 1: 'not relevant'; level 3: 'high relevance')
Demand	Firm-specific relevance of demand for energy efficient products and services (three-level ordinary variable; level 1: 'not relevant'; level 3: 'high relevance')
Industry controls	Controls for industry affiliation on NACE two-digit codes
Financial awareness	Importance of lack of financial resources as obstacle for green product innovation (four-level ordinary variable; level 1: 'not relevant'; level 4: 'high relevance')

Table 2: Identification of direct (supply-side) policy effects (Tobit regressions)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Green product innovation intensity								
Export intensity	0.043	0.141	0.038	0.137	0.066	0.133	0.044	0.132	0.149
	(0.123)	(0.120)	(0.122)	(0.120)	(0.121)	(0.119)	(0.121)	(0.119)	(0.120)
Share of high qualified employees	0.447***	0.408**	0.478***	0.438***	0.457***	0.448***	0.490***	0.449***	0.388**
	(0.172)	(0.163)	(0.170)	(0.161)	(0.167)	(0.160)	(0.170)	(0.161)	(0.163)
Foreign owned	-0.340	-0.214	-0.340	-0.219	-0.196	-0.172	-0.331	-0.219	-0.138
	(0.480)	(0.461)	(0.481)	(0.460)	(0.476)	(0.459)	(0.479)	(0.460)	(0.459)
Firm age	0.011	0.008	0.009	-0.015	0.091	0.037	0.009	0.000	0.055
	(0.209)	(0.199)	(0.208)	(0.200)	(0.208)	(0.200)	(0.208)	(0.200)	(0.199)
Competition intensity	1.074***	0.782**	1.052***	0.759**	0.996***	0.769**	1.038***	0.764**	0.786**
	(0.366)	(0.349)	(0.366)	(0.349)	(0.358)	(0.348)	(0.363)	(0.349)	(0.345)
R&D propensity	1.811***	1.755***	1.818***	1.772***	1.788***	1.765***	1.784***	1.772***	1.755***
	(0.396)	(0.383)	(0.394)	(0.381)	(0.393)	(0.382)	(0.396)	(0.382)	(0.384)
Green process innovation intensity	0.247***	0.185***	0.230***	0.176***	0.172***	0.152***	0.217***	0.170***	0.167***
	(0.050)	(0.050)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
Products not suited	-0.580***	-0.497***	-0.590***	-0.508***	-0.587***	-0.519***	-0.594***	-0.512***	-0.503***
	(0.146)	(0.149)	(0.146)	(0.149)	(0.147)	(0.149)	(0.147)	(0.150)	(0.148)
Number of employees	0.229**	0.092	0.196*	0.087	0.146	0.058	0.180	0.066	0.099
	(0.115)	(0.112)	(0.115)	(0.113)	(0.113)	(0.112)	(0.115)	(0.113)	(0.111)
Swiss firm	-0.682	-0.730	-0.775	-0.685	-0.654	-0.762	-0.792	-0.791	-0.585
	(0.559)	(0.532)	(0.556)	(0.530)	(0.542)	(0.525)	(0.548)	(0.526)	(0.533)
German firm	-1.638***	-1.778***	-1.831***	-1.933***	-1.814***	-1.987***	-1.855***	-1.999***	-1.690***
	(0.561)	(0.528)	(0.551)	(0.519)	(0.536)	(0.515)	(0.540)	(0.518)	(0.524)
Taxes	-0.453*	-0.640***							-0.663***
	(0.237)	(0.232)							(0.250)
Regulations			0.110	-0.420*					-0.337
			(0.246)	(0.241)					(0.280)
Public subsidies					1.174***	0.423*			0.689***
					(0.206)	(0.220)			(0.245)
Voluntary agreements							0.487**	-0.087	0.027
							(0.243)	(0.234)	(0.263)
Demand		1.917***		1.952***		1.672***		1.879***	1.692***
		(0.192)		(0.196)		(0.214)		(0.196)	(0.212)
Industry controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	1987	1987	1987	1987	1987	1987	1987	1987	1987
Wald chi2	123.74***	271.22***	123.91***	270.58***	173.49***	266.87***	132.71***	263.01***	284.67***
Log Likelihood	-922.51	-880.23	-924.26	-882.67	-909.69	-882.57	-922.38	-884.17	-876.12

Notes: see Table 1 for the variable definitions; robust standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table 3: Compare policy effects on process and product innovation (Tobit regressions)

	(1) Green product innovation intensity	(2) Green process innovation intensity
Export intensity	0.149	0.166
	(0.120)	(0.118)
Share of high qualified employees	0.388**	0.164
	(0.163)	(0.160)
Foreign owned	-0.138	0.077
	(0.459)	(0.468)
Firm age	0.055	0.594***
	(0.199)	(0.209)
Competition intensity	0.786**	0.061
	(0.345)	(0.341)
R&D propensity	1.755***	1.739***
	(0.384)	(0.372)
Green process innovation intensity	0.167***	
	(0.049)	
Products not suited	-0.503***	0.124
	(0.148)	(0.137)
Number of employees	0.099	0.818***
	(0.111)	(0.116)
Swiss firm	-0.585	-1.376**
	(0.533)	(0.615)
German firm	-1.690***	0.303
	(0.524)	(0.598)
Taxes	-0.663***	0.649***
	(0.250)	(0.247)
Regulations	-0.337	0.122
	(0.280)	(0.268)
Public subsidies	0.689***	1.264***
	(0.245)	(0.248)
Voluntary agreements	0.027	0.455*
	(0.263)	(0.263)
Demand	1.692***	0.518**
	(0.212)	(0.258)
Industry controls	yes	yes
N	1987	1987
Wald chi2	284.67***	1428.39***
Log Likelihood	-876.12	-3282.57

Notes: see Table 1 for the variable definitions; robust standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table 4: Test the moderating effect of green process innovation (Tobit regressions)

	(1)	(2)	(3)	(4)	(5)	(6)
	Green product innovation intensity					
Export intensity	0.150	0.048	0.149	0.150	0.149	0.149
	(0.111)	(0.116)	(0.112)	(0.112)	(0.112)	(0.119)
Share of high qualified employees	0.399**	0.459***	0.390**	0.388**	0.388**	0.395**
	(0.163)	(0.172)	(0.164)	(0.163)	(0.164)	(0.164)
Foreign owned	-0.138	-0.336	-0.145	-0.138	-0.138	-0.128
	(0.453)	(0.481)	(0.454)	(0.453)	(0.453)	(0.459)
Firm age	0.052	0.008	0.054	0.055	0.055	0.053
	(0.207)	(0.214)	(0.208)	(0.208)	(0.208)	(0.198)
Competition intensity	0.802**	1.098***	0.787**	0.784**	0.786**	0.806**
	(0.340)	(0.361)	(0.340)	(0.340)	(0.340)	(0.342)
R&D propensity	1.756***	1.815***	1.755***	1.757***	1.755***	1.756***
	(0.379)	(0.394)	(0.380)	(0.380)	(0.380)	(0.382)
Green process innovation intensity	0.353***	0.000	0.198*	0.183+	0.164+	0.289**
	(0.119)	(.)	(0.113)	(0.113)	(0.111)	(0.143)
Products not suited	-0.528***	-0.609***	-0.505***	-0.503***	-0.503***	-0.530***
	(0.157)	(0.162)	(0.156)	(0.156)	(0.156)	(0.148)
Number of employees	0.112	0.241**	0.101	0.099	0.099	0.110
	(0.110)	(0.115)	(0.110)	(0.110)	(0.110)	(0.111)
Swiss firm	-0.589	-0.683	-0.581	-0.579	-0.586	-0.611
	(0.537)	(0.565)	(0.539)	(0.540)	(0.539)	(0.540)
German firm	-1.695***	-1.631***	-1.691***	-1.683***	-1.690***	-1.705***
	(0.551)	(0.581)	(0.552)	(0.553)	(0.552)	(0.528)
Taxes	-0.228	0.085	-0.662**	-0.663**	-0.663**	-0.110
	(0.354)	(0.345)	(0.261)	(0.261)	(0.261)	(0.370)
Regulations	-0.325		-0.251	-0.340	-0.337	-0.471
	(0.290)		(0.399)	(0.292)	(0.291)	(0.477)
Public subsidies	0.669***		0.686***	0.686***	0.681*	0.550
	(0.253)		(0.254)	(0.254)	(0.366)	(0.417)
Voluntary agreements	0.034		0.023	0.078	0.027	0.011
	(0.274)		(0.275)	(0.415)	(0.275)	(0.467)
Demand	1.680***		1.690***	1.691***	1.692***	1.692***
	(0.242)		(0.242)	(0.242)	(0.244)	(0.212)
Green process innovation intensity # Taxes	-0.113*	-0.140**				-0.144**
	(0.065)	(0.068)				(0.073)
Green process innovation intensity # Regulations			-0.021			0.038
			(0.067)			(0.091)
Green process innovation intensity # Voluntary agreements				-0.012		0.008
				(0.071)		(0.087)
Green process innovation intensity # Public subsidies					0.002	0.029
					(0.063)	(0.074)
Industry controls	yes	yes	yes	yes	yes	yes
N	1987	1987	1987	1987	1987	1987
Wald chi2	297.48***	205.94***	294.53***	294.46***	294.44***	309.37***
Log Likelihood	-874.60	-920.37	-876.08	-876.11	-876.12	-874.28

Notes: see Table 1 for the variable definitions; standard errors are in brackets under the coefficients (in order to allow convergence, only the regression presented in column 1 is based on robust standard errors); ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table 5: Policy effect by degree of innovativeness (multinomial logit regressions; reference category: no green product innovation)

	(1) New to the firm	(2) New to the market	(3) New to the firm	(4) New to the market	(5) New to the firm	(6) New to the market	(7) New to the firm	(8) New to the market	(9) New to the firm	(10) New to the market	(11) New to the firm	(12) New to the market
Export intensity	-0.034	0.008	-0.034	0.005	-0.084	-0.075	-0.038	0.008	-0.039	0.006	-0.025	0.010
	(0.067)	(0.085)	(0.067)	(0.085)	(0.065)	(0.081)	(0.067)	(0.085)	(0.066)	(0.086)	(0.067)	(0.086)
Share of high qualified employees	0.146+	0.269**	0.157*	0.277**	0.169*	0.267**	0.176*	0.272**	0.172*	0.273**	0.140+	0.250*
	(0.094)	(0.131)	(0.093)	(0.131)	(0.092)	(0.128)	(0.093)	(0.131)	(0.093)	(0.130)	(0.094)	(0.131)
Foreign owned	-0.032	-0.160	-0.024	-0.169	-0.053	-0.191	-0.021	-0.127	-0.034	-0.163	0.002	-0.129
	(0.275)	(0.323)	(0.276)	(0.324)	(0.271)	(0.313)	(0.275)	(0.324)	(0.275)	(0.323)	(0.277)	(0.326)
Firm age	0.080	-0.015	0.079	-0.011	0.066	0.012	0.082	0.010	0.080	-0.013	0.087	0.021
	(0.120)	(0.146)	(0.120)	(0.146)	(0.117)	(0.140)	(0.119)	(0.147)	(0.119)	(0.146)	(0.121)	(0.149)
Competition intensity	0.290+	0.268	0.292+	0.272	0.342*	0.401*	0.292+	0.289	0.289+	0.266	0.298+	0.294
	(0.197)	(0.236)	(0.197)	(0.236)	(0.194)	(0.228)	(0.196)	(0.237)	(0.196)	(0.236)	(0.198)	(0.238)
R&D propensity	0.595***	1.508***	0.605***	1.522***	0.588***	1.499***	0.590***	1.502***	0.598***	1.513***	0.600***	1.513***
	(0.216)	(0.317)	(0.216)	(0.317)	(0.211)	(0.308)	(0.215)	(0.317)	(0.215)	(0.316)	(0.218)	(0.318)
Green process innovation intensity	0.042	0.110***	0.041	0.106***	0.060**	0.120***	0.029	0.097***	0.034	0.108***	0.037	0.103***
	(0.029)	(0.036)	(0.029)	(0.036)	(0.028)	(0.034)	(0.029)	(0.036)	(0.029)	(0.036)	(0.030)	(0.036)
Products not suited	-0.044	-0.351***	-0.041	-0.353***	-0.066	-0.350***	-0.048	-0.350***	-0.046	-0.349***	-0.042	-0.341***
	(0.081)	(0.122)	(0.081)	(0.122)	(0.078)	(0.114)	(0.081)	(0.122)	(0.081)	(0.122)	(0.081)	(0.122)
Number of employees	0.123*	0.197**	0.129*	0.188**	0.161**	0.228***	0.106+	0.188**	0.111*	0.196**	0.129*	0.193**
	(0.065)	(0.078)	(0.066)	(0.078)	(0.064)	(0.075)	(0.065)	(0.078)	(0.065)	(0.078)	(0.066)	(0.078)
Swiss firm	-0.684**	-0.662*	-0.631**	-0.674*	-0.625**	-0.808**	-0.694**	-0.636*	-0.696**	-0.661*	-0.573*	-0.608*
	(0.317)	(0.354)	(0.318)	(0.354)	(0.313)	(0.341)	(0.317)	(0.354)	(0.316)	(0.354)	(0.321)	(0.358)
German firm	-0.293	-0.689**	-0.362	-0.737**	-0.331	-0.705**	-0.410	-0.717**	-0.406	-0.718**	-0.252	-0.652*
	(0.311)	(0.349)	(0.308)	(0.345)	(0.303)	(0.333)	(0.308)	(0.345)	(0.308)	(0.345)	(0.313)	(0.352)
Taxes	-0.347***	-0.115									-0.243+	-0.178
	(0.134)	(0.160)									(0.148)	(0.180)
Regulations			-0.488***	0.015	-0.238*	0.342**					-0.524***	0.076
			(0.151)	(0.162)	(0.143)	(0.151)					(0.181)	(0.196)
Public subsidies							0.088	0.263*			0.272*	0.357**
							(0.135)	(0.154)			(0.149)	(0.169)
Voluntary agreements									-0.106	-0.126	0.117	-0.228
									(0.145)	(0.166)	(0.170)	(0.189)
Demand	0.843***	1.163***	0.914***	1.146***			0.760***	1.035***	0.828***	1.179***	0.805***	1.061***
	(0.120)	(0.143)	(0.125)	(0.147)			(0.133)	(0.155)	(0.124)	(0.148)	(0.135)	(0.158)
Industry controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	1981		1981		1981		1981		1981		1981	
pseudo R2	0.18		0.19		0.14		0.18		0.18		0.19	
Wald chi2	371.71***		376.50***		280.35***		367.69***		365.64***		387.50***	
Log Likelihood	-823.47		-821.08		-869.15		-825.48		-826.51		-815.58	
Violation of IIA assumption	No		No		No		No		No		No	

Notes: see Table 1 for the variable definitions; standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term. In order to allow convergence, tests of independence of irrelevance alternatives (IIA) include sector controls only.

Table 6: Test the moderating effect of financial awareness (Tobit regressions)

	(1)	(2)	(3)	(4)	(5)	(6)
	Green product innovation intensity					
Export intensity	0.145	0.142	0.136	0.146	0.147	0.137
	(0.118)	(0.117)	(0.117)	(0.118)	(0.118)	(0.117)
Share of high qualified employees	0.342**	0.340**	0.350**	0.342**	0.344**	0.349**
	(0.164)	(0.163)	(0.164)	(0.164)	(0.163)	(0.164)
Foreign owned	-0.150	-0.155	-0.161	-0.149	-0.153	-0.157
	(0.452)	(0.453)	(0.451)	(0.452)	(0.452)	(0.452)
Firm age	0.057	0.048	0.088	0.056	0.062	0.081
	(0.197)	(0.197)	(0.198)	(0.198)	(0.197)	(0.201)
Competition intensity	0.668**	0.686**	0.692**	0.669**	0.685**	0.709**
	(0.339)	(0.338)	(0.336)	(0.339)	(0.338)	(0.337)
R&D propensity	1.604***	1.590***	1.582***	1.605***	1.611***	1.583***
	(0.378)	(0.377)	(0.376)	(0.378)	(0.377)	(0.376)
Green process innovation intensity	0.164***	0.166***	0.174***	0.164***	0.167***	0.173***
	(0.048)	(0.048)	(0.047)	(0.048)	(0.048)	(0.047)
Products not suited	-0.607***	-0.594***	-0.599***	-0.608***	-0.602***	-0.599***
	(0.158)	(0.157)	(0.157)	(0.159)	(0.158)	(0.157)
Number of employees	0.151	0.156	0.150	0.151	0.149	0.145
	(0.110)	(0.110)	(0.109)	(0.110)	(0.110)	(0.110)
Swiss firm	-0.330	-0.378	-0.392	-0.331	-0.333	-0.413
	(0.538)	(0.537)	(0.537)	(0.537)	(0.536)	(0.539)
German firm	-1.325**	-1.357***	-1.400***	-1.323**	-1.342**	-1.397***
	(0.525)	(0.525)	(0.526)	(0.526)	(0.524)	(0.529)
Taxes	-0.728***	-1.250***	-0.737***	-0.730***	-0.731***	-0.931*
	(0.247)	(0.434)	(0.246)	(0.247)	(0.247)	(0.477)
Regulations	-0.446+	-0.479*	-1.196**	-0.445+	-0.452+	-1.192**
	(0.277)	(0.282)	(0.470)	(0.278)	(0.278)	(0.541)
Public subsidies	0.678***	0.686***	0.689***	0.725*	0.678***	1.057**
	(0.244)	(0.244)	(0.243)	(0.395)	(0.244)	(0.442)
Voluntary agreements	0.033	0.026	0.044	0.033	-0.319	-0.058
	(0.258)	(0.260)	(0.260)	(0.259)	(0.430)	(0.501)
Demand	1.585***	1.600***	1.569***	1.587***	1.595***	1.590***
	(0.215)	(0.214)	(0.215)	(0.214)	(0.215)	(0.216)
Financial awareness	0.791***	0.155	0.012	0.844**	0.437	0.117
	(0.178)	(0.417)	(0.385)	(0.404)	(0.376)	(0.473)
Financial awareness # Taxes		0.352+				0.119
		(0.229)				(0.249)
Financial awareness # Regulations			0.463**			0.457*
			(0.216)			(0.271)
Financial awareness # Public subsidies				-0.031		-0.235
				(0.196)		(0.231)
Financial awareness # Voluntary agreements					0.229	0.064
					(0.214)	(0.268)
Industry controls	yes	yes	yes	yes	yes	yes
N	1987	1987	1987	1987	1987	1987
Wald chi2	304.69***	300.95***	305.18***	304.30***	305.24***	301.97***
Log Likelihood	-867.03	-865.93	-865.02	-867.02	-866.61	-864.47

Notes: see Table 1 for the variable definitions; robust standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table A.1: Descriptive statistics; based on basic model (column (9) of Table 2; N=1987)

	Mean	Std. Dev.	Min	Max
Green product innovation propensity	0,14	0,34	0	1
Green product innovation intensity	1,81	9,16	0	100
Taxes	1,69	0,73	1	3
Regulations	1,47	0,68	1	3
Public subsidies	1,38	0,62	1	3
Voluntary agreements	1,44	0,68	1	3
Demand	1,35	0,62	1	3
Export intensity	27,24	33,62	0	100
Share of high qualified employees	21,60	26,42	0	100
Foreign owned	0,12	0,33	0	1
Firm age	46,11	38,34	1	260
Competition intensity	0,69	0,46	0	1
R&D propensity	0,50	0,50	0	1
Green process innovation intensity	587,42	1922,07	0	41666,67
Products not suited	1,77	1,12	1	4
Number of employees	276,45	3105,67	1	112305
Swiss firm	0,44	0,50	0	1
German firm	0,49	0,50	0	1

Table A.2: Correlation matrix; based on basic model (column (9) of Table 2; N=1987)

	Green product innovation intensity	Taxes	Regulations	Public subsidies	Voluntary agreements	Demand
Taxes	-0,02					
Regulations	0,03	0,51				
Public subsidies	0,08	0,37	0,55			
Voluntary agreements	0,16	0,32	0,39	0,44		
Demand	0,25	0,12	0,24	0,29	0,46	
Export intensity	0,10	0,12	0,10	0,08	0,03	-0,05
Share of high qualified employees	0,06	-0,14	-0,13	-0,10	-0,04	0,04
Foreign owned	0,03	0,05	0,09	0,07	-0,01	-0,02
Firm age	0,03	0,08	0,12	0,09	0,02	0,02
Competition intensity	0,01	0,00	0,04	0,02	0,01	0,04
R&D propensity	0,16	0,02	0,04	0,07	0,06	0,02
Green process innovation intensity	0,13	0,23	0,22	0,23	0,26	0,14
Products not suited	-0,08	0,02	0,03	0,05	-0,02	-0,06
Number of employees	0,11	0,18	0,21	0,19	0,14	0,10
Swiss firm	0,01	-0,09	0,10	0,03	-0,07	-0,01
German firm	-0,06	0,10	-0,09	-0,03	0,04	0,02

	Export intensity	Share of high qualified employees	Foreign owned	Firm age	Competition intensity	R&D propensity
Share of high qualified employees	0,09					
Foreign owned	0,28	0,02				
Firm age	0,09	-0,25	0,07			
Competition intensity	-0,22	-0,13	-0,13	0,05		
R&D propensity	0,42	0,27	0,10	-0,04	-0,20	
Green process innovation intensity	0,20	-0,02	0,08	0,12	-0,05	0,20
Products not suited	0,04	-0,05	0,00	0,01	0,00	0,05
Number of employees	0,38	-0,06	0,25	0,34	-0,06	0,26
Swiss firm	-0,04	-0,29	0,11	0,39	0,15	-0,14
German firm	-0,06	0,33	-0,16	-0,40	-0,10	0,08

	Green process innovation intensity	Products not suited	Number of employees	Swiss firm
Products not suited	0,01			
Number of employees	0,29	0,01		
Swiss firm	-0,07	0,06	0,13	
German firm	0,03	-0,06	-0,20	-0,86

Table A.3: Testing the effect of policy stringency (Tobit regressions)

	(1)	(2)	(3)	(4)	(5)
	Green product innovation intensity				
Export intensity	0.163	0.151	0.148	0.148	0.149
	(0.118)	(0.119)	(0.120)	(0.120)	(0.120)
Share of high qualified employees	0.397**	0.387**	0.389**	0.387**	0.388**
	(0.163)	(0.163)	(0.163)	(0.163)	(0.163)
Foreign owned	-0.157	-0.135	-0.110	-0.128	-0.139
	(0.458)	(0.459)	(0.459)	(0.457)	(0.459)
Firm age	0.034	0.051	0.057	0.055	0.055
	(0.198)	(0.199)	(0.199)	(0.199)	(0.200)
Competition intensity	0.727**	0.777**	0.791**	0.784**	0.785**
	(0.343)	(0.345)	(0.346)	(0.346)	(0.347)
R&D propensity	1.723***	1.751***	1.756***	1.761***	1.755***
	(0.381)	(0.384)	(0.384)	(0.384)	(0.384)
Green process innovation intensity	0.171***	0.167***	0.166***	0.166***	0.167***
	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
Products not suited	-0.516***	-0.504***	-0.510***	-0.511***	-0.502***
	(0.147)	(0.149)	(0.148)	(0.150)	(0.148)
Number of employees	0.098	0.093	0.081	0.093	0.099
	(0.111)	(0.112)	(0.112)	(0.111)	(0.111)
Swiss firm	-0.624	-0.605	-0.591	-0.599	-0.585
	(0.535)	(0.537)	(0.536)	(0.533)	(0.533)
German firm	-1.695***	-1.700***	-1.654***	-1.694***	-1.690***
	(0.525)	(0.527)	(0.526)	(0.525)	(0.524)
Taxes		-0.659***	-0.661***	-0.661***	-0.663***
		(0.250)	(0.250)	(0.250)	(0.249)
Regulations	-0.301		-0.304	-0.344	-0.336
	(0.281)		(0.277)	(0.282)	(0.281)
Public subsidies	0.685***	0.688***		0.691***	0.688***
	(0.246)	(0.245)		(0.244)	(0.244)
Voluntary agreements	0.012	0.024	0.035		0.027
	(0.264)	(0.264)	(0.263)		(0.262)
Demand	1.688***	1.693***	1.687***	1.700***	
	(0.213)	(0.213)	(0.212)	(0.213)	
Taxes medium	-0.114				
	(0.339)				
Taxes high	-1.857***				
	(0.573)				
Regulations medium		-0.194			
		(0.385)			
Regulations high		-0.798			
		(0.609)			
Public subsidies medium			1.044***		
			(0.364)		
Public subsidies high			1.162**		
			(0.506)		
Voluntary agreements medium				0.222	
				(0.386)	
Voluntary agreements high				-0.137	
				(0.562)	
Demand medium					1.678***
					(0.352)
Demand high					3.389***
					(0.435)
N	1987	1987	1987	1987	1987
Wald chi2	300.30***	291.76***	288.34***	284.63***	284.85***
Log Likelihood	-873.19	-875.97	-875.23	-875.84	-876.12

Notes: see Table 1 for the variable definitions; robust standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table A.4: Test alternative dependent variables and estimation procedures

	(1) Green product innovation intensity OLS	(2) Green product innovation propensity Probit	(3) Green R&D propensity Probit
Export intensity	0.012	0.005	0.061+
	(0.013)	(0.032)	(0.040)
Share of high qualified	0.029*	0.073*	0.200***
	(0.016)	(0.043)	(0.054)
Foreign owned	-0.005	-0.034	-0.285*
	(0.063)	(0.127)	(0.150)
Firm age	-0.002	0.028	0.000
	(0.023)	(0.054)	(0.063)
Competition intensity	0.087**	0.201**	0.080
	(0.041)	(0.094)	(0.106)
R&D propensity	0.152***	0.530***	
	(0.040)	(0.102)	
Green process innovation	0.017***	0.044***	0.056***
	(0.006)	(0.014)	(0.015)
Products not suited	-0.055***	-0.092**	-0.192***
	(0.011)	(0.037)	(0.050)
Number of employees	0.007	0.090***	0.130***
	(0.016)	(0.031)	(0.034)
Swiss firm	-0.129	-0.114	-0.322*
	(0.097)	(0.157)	(0.179)
German firm	-0.230**	-0.014	-0.270+
	(0.096)	(0.154)	(0.176)
Taxes	-0.059**	-0.119*	-0.115+
	(0.027)	(0.068)	(0.078)
Regulations	-0.049	-0.145*	-0.114
	(0.035)	(0.078)	(0.098)
Public subsidies	0.070**	0.174**	0.118+
	(0.036)	(0.068)	(0.082)
Voluntary agreements	0.021	-0.018	-0.010
	(0.041)	(0.080)	(0.089)
Demand	0.267***	0.522***	0.428***
	(0.044)	(0.064)	(0.074)
N	1987	1987	1987
R2	0.14		
adj R2	0.12		
pseudo R2		0.21	0.24
Wald chi2		3061.51***	2702.44***
Log Likelihood	-2200.34	-633.60	-413.02

Notes: see Table 1 for the variable definitions; robust standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table A.5: Test robustness of results for specific sub-samples (Tobit regressions)

	(1)	(2)
	Green product innovation intensity	
Sample restriction:	Firms that had discussions about the creation of green products/services	Firms with products/services that are suited for green product innovation
Export intensity	0.093	0.137
	(0.115)	(0.121)
Share of high qualified employees	0.368**	0.371**
	(0.170)	(0.166)
Foreign owned	0.007	-0.095
	(0.432)	(0.475)
Firm age	-0.074	0.025
	(0.204)	(0.206)
Competition intensity	0.638*	0.752**
	(0.342)	(0.356)
R&D propensity	0.989***	1.734***
	(0.367)	(0.394)
Green process innovation intensity	0.088*	0.179***
	(0.049)	(0.050)
Products not suited	-1.018***	-0.188
	(0.161)	(0.208)
Number of employees	0.050	0.121
	(0.110)	(0.113)
Swiss firm	0.277	-0.525
	(0.474)	(0.556)
German firm	-1.486***	-1.766***
	(0.468)	(0.545)
Taxes	-0.551**	-0.729***
	(0.239)	(0.258)
Regulations	-0.247	-0.259
	(0.269)	(0.297)
Public subsidies	0.588***	0.622**
	(0.227)	(0.252)
Voluntary agreements	-0.197	0.141
	(0.250)	(0.274)
Demand	0.988***	1.689***
	(0.209)	(0.220)
N	847	1698
Wald chi2	154.03***	287.05***
Log Likelihood	-662.84	-823.11

Notes: see Table 1 for the variable definitions; robust standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table A.6: Test differences between countries (Tobit regressions)

	(1)	(2)	(3)	(4)	(5)	(6)
	Green product innovation intensity					
Country:	Switzerland		Germany		Austria	
Export intensity	0.045	0.054	0.201	0.216	0.173	0.183
	(0.169)	(0.167)	(0.191)	(0.192)	(0.386)	(0.362)
Share of high qualified employees	0.345	0.362*	0.441	0.454	0.464	0.458
	(0.220)	(0.219)	(0.285)	(0.287)	(0.433)	(0.435)
Foreign owned	-0.428	-0.460	0.049	0.049	0.395	0.257
	(0.554)	(0.556)	(1.049)	(1.047)	(0.879)	(0.897)
Firm age	-0.259	-0.262	0.352	0.325	0.159	0.073
	(0.286)	(0.279)	(0.334)	(0.336)	(0.464)	(0.500)
Competition intensity	0.534	0.557	0.860	0.828	1.907**	2.146**
	(0.523)	(0.526)	(0.536)	(0.536)	(0.924)	(0.892)
R&D propensity	2.123***	2.067***	1.661***	1.649**	1.344	1.609
	(0.507)	(0.515)	(0.639)	(0.641)	(1.124)	(1.183)
Green process innovation intensity	0.232***	0.238***	0.114	0.114	0.012	0.020
	(0.062)	(0.063)	(0.089)	(0.089)	(0.123)	(0.124)
Products not suited	-0.512***	-0.524***	-0.380	-0.398	-1.068**	-1.035**
	(0.178)	(0.182)	(0.259)	(0.260)	(0.431)	(0.429)
Number of employees	0.506***	0.499***	-0.186	-0.183	0.115	-0.000
	(0.184)	(0.181)	(0.171)	(0.171)	(0.404)	(0.402)
Taxes	-0.163	-0.318	-1.161***		-0.012	-0.181
	(0.369)	(0.328)	(0.411)		(0.853)	(0.616)
Taxes medium				-0.527		
				(0.563)		
Taxes high				-2.801***		
				(0.917)		
Regulations	-0.355		-0.758	-0.720	-0.823	
	(0.385)		(0.509)	(0.509)	(0.847)	
Public subsidies	0.595*		0.799*	0.842**	0.626	
	(0.350)		(0.412)	(0.413)	(0.669)	
Voluntary agreements	-0.282		0.522	0.521	-0.169	
	(0.353)		(0.479)	(0.479)	(0.732)	
Demand	1.586***	1.700***	2.018***	1.998***	1.252**	1.217**
	(0.278)	(0.254)	(0.408)	(0.407)	(0.607)	(0.565)
Industry controls	yes	yes	yes	yes	yes	yes
N	873	873	964	964	150	150
Wald chi2	353.30***	309.18***	124.93***	127.46***	100.72***	76.62***
Log Likelihood	-400.25	-401.94	-356.63	-355.36	-95.74	-96.51

Notes: see Table 1 for the variable definitions; standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.

Table A.7: Restrict sample to firms with green R&D activities (Tobit regressions)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Green product innovation intensity								
Export intensity	0.119	0.135	0.139	0.147+	0.131	0.137	0.115	0.131	0.153+
	(0.099)	(0.098)	(0.098)	(0.097)	(0.100)	(0.099)	(0.098)	(0.097)	(0.099)
Share of high qualified employees	0.258+	0.305*	0.224	0.273*	0.209	0.255+	0.254+	0.299*	0.231
	(0.160)	(0.156)	(0.160)	(0.157)	(0.168)	(0.162)	(0.160)	(0.156)	(0.162)
Foreign owned	-0.216	-0.062	-0.171	-0.043	-0.057	-0.003	-0.198	-0.063	-0.005
	(0.367)	(0.346)	(0.358)	(0.344)	(0.368)	(0.355)	(0.366)	(0.348)	(0.361)
Firm age	-0.070	-0.098	-0.011	-0.044	0.008	-0.030	-0.048	-0.079	-0.007
	(0.179)	(0.170)	(0.170)	(0.165)	(0.166)	(0.164)	(0.172)	(0.165)	(0.171)
Competition intensity	0.155	0.060	0.205	0.109	0.155	0.091	0.166	0.068	0.116
	(0.282)	(0.271)	(0.277)	(0.267)	(0.273)	(0.269)	(0.282)	(0.272)	(0.268)
R&D propensity	0.069	0.138	0.034	0.105	-0.010	0.062	0.030	0.124	0.093
	(0.375)	(0.349)	(0.366)	(0.345)	(0.370)	(0.359)	(0.373)	(0.353)	(0.356)
Green process innovation intensity	-0.027	-0.057	-0.037	-0.061	-0.054	-0.064+	-0.023	-0.051	-0.071+
	(0.044)	(0.045)	(0.044)	(0.045)	(0.043)	(0.043)	(0.043)	(0.044)	(0.045)
Products not suited	-0.320*	-0.304*	-0.329**	-0.311*	-0.351**	-0.327**	-0.318*	-0.296*	-0.329**
	(0.167)	(0.160)	(0.167)	(0.162)	(0.162)	(0.158)	(0.166)	(0.158)	(0.158)
Number of employees	-0.163*	-0.183*	-0.196**	-0.206**	-0.162*	-0.174**	-0.160*	-0.176*	-0.196**
	(0.097)	(0.095)	(0.095)	(0.095)	(0.088)	(0.089)	(0.093)	(0.092)	(0.094)
Swiss firm	-0.274	-0.395	-0.489	-0.554+	-0.338	-0.403	-0.287	-0.401	-0.543+
	(0.342)	(0.343)	(0.359)	(0.360)	(0.329)	(0.334)	(0.345)	(0.342)	(0.360)
German firm	-1.564***	-1.719***	-1.603***	-1.733***	-1.523***	-1.639***	-1.535***	-1.700***	-1.697***
	(0.366)	(0.363)	(0.375)	(0.372)	(0.350)	(0.353)	(0.368)	(0.365)	(0.364)
Taxes	0.132	0.129							0.004
	(0.236)	(0.228)							(0.247)
Regulations			0.435**	0.344+					0.317
			(0.209)	(0.210)					(0.248)
Public subsidies					0.470***	0.321*			0.317+
					(0.163)	(0.174)			(0.208)
Voluntary agreements							0.142	0.048	-0.204
							(0.180)	(0.173)	(0.201)
Demand		0.458***		0.414**		0.315*		0.452***	0.308*
		(0.171)		(0.176)		(0.188)		(0.175)	(0.186)
Industry controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	155	155	155	155	155	155	155	155	155
Wald chi2	157.10***	166.55***	159.44***	162.26***	184.79***	185.79***	160.27***	169.35***	183.75***
Log Likelihood	-250.61	-246.70	-248.70	-245.57	-246.93	-245.44	-250.51	-246.87	-244.35

Notes: see Table 1 for the variable definitions; robust standard errors are in brackets under the coefficients; ***, **, *, + denote statistical significance at the 1%, 5%, 10% and 15% test level, respectively; all models include a constant term.