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Arvanitis S., Peneder M., Rammer C., Stucki T. and Woerter M.

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KOF

ETH Zurich
KOF Swiss Economic Institute
LEE G 116
Leonhardstrasse 21
8092 Zurich, Switzerland

Phone +41 44 632 42 39
Fax +41 44 632 12 18
www.kof.ethz.ch
kof@kof.ethz.ch

Development and Utilization of Energy-related Technologies, Economic Performance and the Role of Policy Instruments*

Spyros Arvanitis[1], Michael Peneder[2] Christian Rammer[3], Tobias Stucki[1] and Martin Woerter[1]

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[1] ETH Zurich, KOF Swiss Economic Institute, Zurich, Switzerland
[2] Austrian Institut of Economic Research (WIF), Vienna, Austria
[3] Centre for European Economic Research (ZEW), Mannheim, Germany

Abstract

The present study investigates the effects of energy-related technologies on economic performance at firm level. We distinguish clearly between *adoption* and *use* of energy-related technologies (process innovation in the broad sense) and *product innovation* in energy-related fields. We take into consideration four energy-related policy instruments (and expected demand for energy-related new products and services). We investigate the possibility of indirect effects of policy on performance via adoption or innovation by interacting adoption and innovation variables with policy instrument dummies. We test our hypotheses not only for the pooled data but also separately for the three countries (Austria, Germany, Switzerland) that are taken into consideration in this study

We find a positive *direct* effect of investment expenditures for energy-related technologies on labour productivity and a positive *indirect* effect of *energy taxes* via investment in energy-related technologies. We find neither direct nor indirect effects of product innovation in energy-related products on labour productivity. No differences among the three countries could be detected.

JEL classification: O31

Key words: use of energy-related technologies; energy-related innovation; policy instruments; productivity

1. Introduction

Aim of this study is the empirical investigation of the "strong" version of the Porter Hypothesis (Porter and van Linde 1994; Jaffe and Palmer 1997), which states that policy-induced innovation (in a broad sense including adoption of new technologies) exerts a positive influence on business performance. This strong version has been the subject of several older empirical studies, which mostly analyzed the relationship between environmental policy and economic performance "without looking at the cause of any variation in business performance (i.e. whether it is linked to innovation or another cause" (Ambec et al. 2013, p. 10).[4] More recent studies avoid this neglect of the explicit examination of the mediating role of environmental policy via process or product innovation (see section 3).

The present study adds some new insights to empirical literature by trying to close existing gaps and complement existing insights. To this end, (a) we concentrate to energy-related technologies, (b) distinguish clearly between adoption of existing energy-related technologies and product innovation, i.e. development of new products and services in energy-related fields, (c) take into consideration four energy-related policy instruments and expected demand for new energy-related products and services, (d) investigate the possibility of indirect effects of policy on performance via adoption or innovation by interacting adoption and innovation variables with policy instrument dummies, and (e) test our hypotheses not only for the available pooled firm data but also separately for the three countries (Austria, Germany, Switzerland) that are taken into consideration in this study

We specify two econometric models, one for the economic performance of the adoption of energy-related technologies and a second one for the economic performance of the development of new energy-related products. We find a positive direct effect of investment expenditures for energy-related technologies on labour productivity and a positive indirect effect of energy taxes via investment in energy-related technologies. We find neither direct nor indirect effects of product innovation in energy-related products on labour productivity.

The structure of the paper is as follows: in section 2 the conceptual background is presented. In section 3 we discuss related empirical literature. In section 4 we present the data, in section the model specifications and in section 6 the results of the econometric estimations. Section 7 gives a summary and some conclusions.

2. Conceptual background

The debate about the Porter Hypothesis

The public promotion of the development and use of energy-efficient technologies is considered to be an important part of a set of environment-friendly policy instruments that have received

[4] See Jaffe et al. (1995) for a review of this earlier literature.

much attention by state authorities as well as the public mostly in western countries in the last twenty years. Contrary to other environment-relevant technologies, energy-efficiency technologies are characterized by a specific feature, namely by the fact that they offer themselves incentives to profit-oriented enterprises to use such technologies through direct cost reduction. Nevertheless, it is well-justified to embed them conceptually in the broader framework of the Porter Hypothesis (Porter and van Linde 1995). The very slow diffusion of apparently cost-reducing energy-efficient technologies demonstrates that also in this case serious impeding factors are involved ("energy paradox"; Jaffe and Stavins 1994).

Ambec et al. (2013) offer an excellent overview of the Porter Hypothesis, we present here a summary of it. The main idea has been that environmental protection technologies (e.g., for reduction in air or water pollution) may lead to an improvement of productivity with which resources are used – contrary to the "traditional" view that such technologies would not be introduced voluntarily by profit-oriented firms because they caused only costs and no benefits for the firms. As a consequence, environmental regulations, particularly market-based instruments such as taxes, would effectively induce broadly defined innovation – primarily, adoption of new process technologies – that may fully compensate the costs of acquisition and installation. An important precondition for this would be that inducing policies are properly designed and stringently applied.

The main causal links between environmental regulations, (broad defined, primarily process) innovation and business performance – that primarily interests us in this paper – as formulated in the Porter Hypothesis are as follows:

- Environmental regulation exerts a positive influence on innovation ("weak" hypothesis)
- Induced innovation exerts a positive influence on business performance ("strong" hypothesis).[5]

A main theoretical argument against the Porter Hypothesis by "mainstream" economists has been that it is not compatible with firms' profit-maximizing, a central assumption of "mainstream" microeconomics (Palmer et al. 1995). The critical question is: if environmental improvement at firm level implies profitable opportunities, why would be regulation needed to induce the adoption of technologies improving? Ambec et al. (2013, p. 5) summarize the Porter argument against this criticism as follows: "Porter argues that environmental regulation may help firms identify inefficient uses of costly resources. They may also produce and disseminate new information (e.g., best-practice technologies) and help overcome organizational inertia".

Meanwhile, there exists a large economic literature on theoretical arguments that could support the Porter Hypothesis: behavioral arguments (e.g., bounded rationality); market failure caused, e.g., by market power, asymmetric information, externalities; organizational failure in form of

[5] Jaffe and Palmer (1997) first distinguished between 'weak' and 'strong' versions of Porter Hypothesis. There is a further part of the Porter Hypothesis referring to the positive effect of innovation on environmental performance (e.g., reduction of air or water pollution), which we do not pursue further in this paper.

strong organizational inertia (see Ambec e al. 2013). Particularly, as to energy-efficiency Jaffe and Stavins (1994) mention a series of factors that explain why energy-saving technologies that are cost-effective according to engineering calculations are not widely used without policy inducement:

- Information problems: Lack of information about available technologies, particularly when there are no demand-pull incentives;
- Principal/agent problems: Energy-efficiency decisions are made by parties that other than those that pay the investment for energy-efficient technologies, e.g., firms that rent a building may pay for fuel but cannot decide for energy-saving technologies without the agreement of the building's owner;
- Energy prices may artificially be kept low;
- High implicit discount rates because energy investments are uncertain, both because future energy prices are highly uncertain and because energy-savings for any particular application can only be estimated.

Thus, even for the widespread adoption of energy-saving technologies it is probably necessary to have policy-induced impulses that help firms to overcome adoption obstacles.[6]

Research questions and hypotheses

Aim of this study is (a) the investigation, first, of the "strong" part of the Porter Hypothesis applied on the *adoption of energy-saving technologies* (i.e. process innovations in the broad sense used in the Porter Hypothesis), particularly possible direct effects on productivity as well as indirect effects via inducement by several policy instruments. A second goal is the analysis of the effects of the *development of new energy-efficient products* (i.e. product innovations), a topic that is rather neglected in existing empirical literature.

Based on the above discussion we postulate the following hypotheses:

Hypothesis 1: The *adoption* of energy-related technologies is positively correlated with economic performance as measured by labour productivity (direct effect).

Hypothesis 2: The positive effect of the adoption of energy-related technologies on labour productivity is increased by policy measures, particularly by market-based ones (indirect effect).

[6] See also DeCanio (1998) for a study based on USA data and investigating bureaucratic and organizational barriers to profitable energy-saving investments. The study of Newell et al. (1999) investigated for a long period (from 1958 through 1993) the influence of government regulations on the product characteristics of consumer durables in the USA and found evidence that both the rate of overall innovation and the direction of innovation were independent of regulations, the latter being responsive to energy price changes. However, the density of policy measures has been considerable lower in that long period than it has been in the last twenty years.

Hypothesis 3: The *development* of new energy-related products and services is positively correlated with economic performance as measured by labour productivity (direct effect).

Hypothesis 4: The positive effect of the *development* of new energy-related products and services on labour productivity is increased by policy measures, particularly by market-based ones (indirect effect).

3. Related empirical literature

Table 1 shows a summary of most recent related empirical literature. Ten studies are taken into consideration, nine of them refer to firm data, one to industry-level data. Firm data come from Germany, Italy, the Netherlands and Canada, one study is a multi-country investigation at firm level, a further one is a multi-country longitudinal analysis at industry level. Only one study uses more than one measure of economic performance, five of them refer to labour or total factor productivity, four of them to profitability. It is not in all studies clear whether the investigation subject is the adoption of environment-friendly technologies or the generation of environment-friendly products and services for customers, due to the fact that particularly the German studies use the broad CIS definition of innovation, which includes incremental or "innovations-new-to-firm" that could be seen also as adoption of existing technologies, particularly with respect to process innovation that cannot be clearly distinguished from adoption of process-related environment-friendly technologies. For the assessment of the outcomes of the studies according to the distinction of adoption and innovation as it is undertaken in this paper, we consider the studies that explicitly use standard innovation measures such as the number of patents, propensity to patent, and R&D as studies that correspond to our innovation-performance (model 2 see section 5); four studies belong to this category. Most of the other studies correspond better to our adoption-performance model (model 1; see section 5); four studies refer to this category. Two studies (Van Leeuwen and Mohnen 2013 and Rennings and Rammer 2011) cover both aspects.

A further aspect refers to the explicit or implicit consideration of policy instruments as drivers of adoption or generation of environment-friendly technologies. Six studies take environmental regulation into account. Two of them do this explicitly, i.e. by inserting a regulation variable in the model (Van Leeuwen and Mohnen 2013 and Lanvoie et al. 2011). Four studies consider regulation only implicitly, i.e. by asking firms to report whether the use of environment-friendly technologies or environment-friendly innovations was induced by environmental regulation. One study investigates the direct effects of several policy instruments, namely regulation, taxes and standards (Lanoie et al. 2011).

Finally, only three studies deal with energy-saving technologies or the use of renewable energy sources, which is the specific topic of the present study. These studies can be taken into consideration for comparing with our results. Renning and Rammer (2011) found a negative effect for regulation-induced process innovations (corresponding to technology adoption according to our definition) and no effect for total regulation-induced product innovations (corresponding to our definition of innovation) with respect to profitability. The overall negative effect of process innovation can be primarily traced back to mobility-related technologies. For the categories energy efficiency-related novelties and power generation-related novelties no effects were found. Also no effects could be found for the same categories as product innovations. Rexhäuser and Rammer (2014) investigated efficiency-improving technology adoption[7] and found an overall positive effect on profitability. Further, more detailed analysis showed that the positive effect was significantly stronger for regulation-induced adoption than for autonomous, voluntary adoption of the same technologies. Marin (2014) found a positive effect of innovation in renewable energy technologies on labour productivity.

Further, it is noticeable that Lanvoie et al. (2011) is the only study known to us that analyzes more than one policy instrument. These authors found – besides a positive effect of green R&D on profits – positive direct effects of low stringency regulation and low-stringency technical standards. High-stringency regulation resulted to a negative effect. No effect could be found for taxes.

The present study adds some new insights to empirical literature by trying to close existing gaps and complement existing insights. To this end, (a) we concentrate to energy-related technologies, (b) distinguish clearly between adoption and use of energy-related technologies and product innovation in energy-related fields, (c) take into consideration four energy-related policy instruments and expected demand for energy-related new products and services, and (d) investigate the possibility of indirect effects of policy on performance via adoption or innovation by interacting adoption and innovation variables with policy instrument dummies.

4. Data

The data used in this study has been collected through firm surveys conducted in all three countries at the same time. The surveys used a harmonized questionnaire and collected information both on the *development* and on the *adoption* of energy-related innovations during the years 2012 to 2014. The questionnaire was sent to 5758 Swiss firms (KOF-Enterprise Panel), 6374 German firms (ZEW-Enterprise Panel) and 7091 Austrian firms (WIFO-Enterprise Panel). The original samples, which are representative for the respective firm populations of the three countries, were stratified random samples for firms with more than 5 employees. The sample stratification refers to the 2-digit industry level and three industry-

[7] Technologies reducing CO_2, energy or material use per unit of output.

specific firm size classes. The response rates amounted to 31.4% for Switzerland, 36.4% for Germany and 7.6% for Austria.

While data on the *adoption* of energy-related technologies has been obtained for all major economic sectors (manufacturing, construction and services, excluding state-related services such as public administration, education and health and excluding the energy sector), data on the *development* of energy-related innovations has only been collected for a group of manufacturing sectors (excluding food, textiles and clothing, printing, pharmaceuticals, and "other manufacturing") as well as two service sectors, "information technology services" and "technical services".[8]

The pooled dataset that was used for estimating our adoption-performance model (model 1; see section 5) included 3745 observations (1527 Swiss firms, 1768 German firms and 450 Austrian firms). The respective dataset for our innovation-performance model (model 2; see section 5) contained 1917 observations (744 Swiss firms, 953 German firms and 220 Austrian firms).

5. Model specification

We specify two models, a first one for the productivity impact of energy-related investment (as a measure of intensity of adoption of energy-related technologies) and a second one for the productivity impact of sales of energy-related innovative products (as a measure of energy-related product innovation). In both models the dependent variable is labour productivity (value added per employee) (see Table 4).

In the questionnaire, energy-related investment, which is the central variable in model 1, is defined as investment expenditures for the introduction energy-saving technologies and/or renewable energy sources. In this sense, this variable measures the intensity of the adoption of energy-related technologies. Model 2 refers to energy-related innovation, which in questionnaire is defined as the development and market introduction of products and services for customers in the field of energy technologies.[9]

Both models contain proxies for human capital (HQUAL), physical capital (LINVL) and innovation (LINNL) as standard productivity determinants as well as controls for firm size (LEMP), foreign ownership (FOREIGN), country and industry affiliation (see Table 4).

The first model includes a variable for energy-related investment per employee (LINVL_E). The variable LINVL_E contains many zero values, for this reason a dummy variable for firms investing in energy-saving technologies or renewable energy technologies (ADOPT_E) is

[8] For more details about the data collection and the composition of the country samples see Arvanitis et al. (2016).
[9] Table 2 presents some information at country level about the share of energy-related investment and sales share of innovative products. The share of energy-related investment is at highest in Austria and at lowest in Switzerland. The sales shares for Switzerland and Germany are of the same magnitude, that for Austria is much larger. The figures for Austria might be less representative than in the other two countries due to the smallness of the available firm sample.

added to the model. Energy investment is subtracted from total investment to avoid double-counting (LINVL_NE).[10]

The second model contains a variable for sales of energy-related innovative products per employee (LINNL_E). Also this variable contains many zero values, so that a dummy variable for firms innovating in the field of energy technologies (INNOV_E) is added to the model. Sales of energy-related innovative products is subtracted from total sales of innovative products to avoid double-counting (LINNL_NE).[11]

Both models include dummy variables for measures of firm-specific relevance of energy-related policy instruments (POLICY) such as taxes, regulation, voluntary standards and agreements, subsidies, and a variable for expected demand for energy-related products and technologies. Table 3 shows the percentage of firms that reported that the respective policy instruments (and the expected demand for energy-related products and services) are relevant for their economic activities. Energy taxes seems to be for all three countries the most important policy instrument. It is interesting to see that the relevance of these instruments is similarly distributed among the three countries. Nevertheless, it is noticeable that regulation is more important for German firms and subsidies for Austrian firms. Expected demand is relevant for only 26% of all firms.

The energy-related investment model (model 1) is formally expressed as follows:

$$LVAL_i = \alpha_0 + \alpha_1\, LINVL\_NE_i + \alpha_2\, HQUAL_i + \alpha_3\, LINNL_i + \alpha_4\, LINVL\_E_i + \alpha_5\, ADOPT\_E_i + \alpha_6\, LEMP_i + \alpha_7\, FOREIGN_i + \alpha_8\, POLICY_i + \textit{industry and country dummies} + e_i \quad \textit{(for firm i)} \qquad (1)$$

Where POLICY: Taxes; Regulation; Standards/agreements; Subsidies; Expected demand

The model for sales of energy-related innovative products (model 2) is in formal terms as follows:

$$LVAL_i = \beta_0 + \beta_1\, LINVL_i + \beta_2\, HQUAL_i + \beta_3\, LINNL\_NE_i + \beta_4\, LINNL\_E_i + \beta_5\, INNOV\_E_i + \beta_6\, LEMP_i + \beta_7\, FOREIGN_i + \beta_8\, POLICY_i + \textit{industry and country dummies} + e_i \quad \textit{(for firm i)} \qquad (2)$$

Where POLICY: Taxes; Regulation; Standards/agreements; Subsidies; Expected demand

6. Results

Econometric issues

[10] See Table A.1 in the Appendix for descriptive statistics and Table A.3 for the correlation matrix of model 1.
[11] See Table A.2 in the Appendix for descriptive statistics and Table A.4 for the correlation matrix of model 2.

There is a twofold possible endogeneity problem (a) with respect to the energy-related variables for investment and innovation and (b) with respect to the policy variables. Both the investment and the innovation variable are (partly) pre-determined with respect to labour productivity. Labour productivity is measured for 2014. Our questionnaire asks for energy-related investment as share of total investment on average of the years 2012 to 2014. Under the reasonable assumption of equally-distributed energy investment along the three years, two thirds of this investment could have been done before 2014. The same argument of a (partly) pre-determined right-hand variable can be used – but only to a smaller extent – also for the sales of energy-related innovative products, which were introduced according to our questionnaire in the three years 2012 to 2014. In this way, the problem of reverse causality might be somewhat mitigated. The problem of unobserved heterogeneity still remains, even if we control extensively for 65 2-digit industries.

The endogeneity issue for the policy variables might result from the "subjective" evaluation of the relevance of the respective policy instruments. Firm assessments might be correlated with some unobserved firm factors that can bias our coefficients. An amendment for both problems is not easy because it is not possible to find valid instruments for these policy variables in our dataset.

For these reasons no claims are made for causality effects but only for conditional correlation effects that might yield useful insights for possible causality effects in the sense of the hypotheses of section 2.

Productivity model for energy-related investment expenditures

The estimates in Table 5 refer to the pooled dataset for firms from all sectors and from all three countries. Column 1 shows the results for model 1 without policy variables. The variable for energy-related investment expenditure per employee (LINVL_E) has a positive and statistically significant coefficient of 0.018. This means that an increase of 1% of energy investment is correlated with an increase of 1.8% of labour productivity as compared with an increase of 8.5% for non-energy investment. Thus, *hypothesis 1* is confirmed by our findings.[12] The control variable for firms with zero energy investment expenditures ADOPT_E has a statistically significant coefficient which indicates that this control is justified.

[12] This finding is (partly) similar to the findings of Ghisetti and Rennings (2013) and Rexhäuser and Rammer (2014) for the adoption of resource efficiency-improving technologies in German firms. However, there is also a significant difference with respect to our result because in Ghisetti and Rennings (2013) technology adoption is according to firms' assessment not voluntary (as in our case) but regulation-induced (see also section 3). Rexhäuser and Rammer (2014) find a stronger effect for firms reporting regulation inducement than those reporting voluntary adoption. In both papers the performance variable is profitability. Rennings and Rammer (2011) – based also on data for German firms – report no effect of adoption of energy-efficiency and power generation technologies on profitability, presumably because their data come from an earlier period (2000-2002) than in the other two studies (2008-2011), in which energy policy measures were still not very effective in Germany.

Column 2 contains also an interaction term of the variables for energy-related (LINVL_E) and not energy-related investment (LINVL_NE), which is statistically insignificant. This finding can be interpreted as a hint that the relationship between these two categories of investment is neither complementary (in case of a positive coefficient of the interaction term) nor substitutive (in case of a negative coefficient of the interaction term) to each other with respect to productivity.

Columns 3 to 7 present the findings with respect to possible effects of several policy instruments (plus expected demand) on the *effectiveness* of energy-related investment. The insignificant coefficients of the interaction terms between the variable for energy investment of three of the four policy variables, which were inserted separately in the model, demonstrate that regulation, voluntary standards/agreements, and subsides do not appear to have any additional effect on the impact of energy-related investment on productivity (columns 4 to 6). The same can be observed for the variable for expected demand for innovative energy-related products (column 7). The only indirect effect of policy on productivity via energy investment could be found for *energy taxes*. Thus, *hypothesis 2* is only partly confirmed; it is valid for energy taxes, which are an important and widely used market-based policy instrument. This finding is also evidence for the "strong" version of the Porter hypothesis, according to which policy should affect positively economic performance via process innovation, in this case investment in energy-related technologies that are new to the firm.

Table A.5 shows estimates of model 1, in which the model variables were multiplied with country dummies, in columns 1 and 2 for Switzerland and Austria (with Germany as reference country), in columns 3 and 4 for Germany and Austria (with Switzerland as reference country). Columns 1 and 4, respectively present model 1 without policy effects, columns 2 and 4, respectively the interaction effect for energy taxes. An inspection of the estimates shows that there are no statistically significant difference among the countries with respect to the variables that are relevant for this study, namely LINV_L_E and LINVL_E*taxes.

Productivity model for energy-related innovation

The estimates in Table 6 refer to the pooled dataset for firms from selected industries (most of manufacturing industries and two service industries; see section 4) and from all three countries. Column 1 shows the results for model 2 without policy variables. The variable for sales of energy-related innovative products has a statistically insignificant coefficient. This means that there is no significant correlation between the energy-innovation variable and productivity. *Hypothesis 3* is not confirmed.[13] The control variable for firms with zero energy investment

[13] We are not aware of any study investigating the effect of energy-related innovation on productivity. Marin and Lotti (2014) analyze the effect of eco-patents on productivity and find no effect. Marin (2014) also based on patents as innovation variable finds a positive effect for renewable energy technologies. Lanvoie et al (2011) and Van

expenditures INNOV_E is also insignificant. All other variables show the expected positive and statistically significant coefficients.

Column 2 contains also an interaction term of the variables for energy-related (LINNL_E) innovation variable and the variable for not energy-related innovation (LINNL_NE), which is statistically insignificant. This finding can be interpreted as a hint that the relationship between these two categories of innovation is neither complementary (in case of a positive coefficient of the interaction term) nor substitutive (in case of a negative coefficient of the interaction term) to each other with respect to productivity.

Columns 3 to 7 present the findings with respect to possible effects of several policy instruments (plus expected demand) on the effectiveness of energy-related innovation. Even if no direct effects of energy-related innovation on productivity could be found, it could be that indirect effects via policy instruments could amplify the effectiveness of energy innovation on productivity. The insignificant coefficients of the interaction terms between the variable for energy innovation of all four policy variables, which were inserted separately in the model, demonstrate that taxes, regulation, voluntary standards/agreements, and subsides as perceived by firms do not appear to have any effect on the impact of energy-related innovation on productivity (columns 3 to 6). *Hypothesis 4* is not confirmed by our estimates.[14] The same can be observed for the variable for expected demand for innovative energy-related products (column 7). Thus, *demand-induced* innovation appears to be still too weak to affect economic performance.

For the policy effects, we also tested an extension of hypothesis 4, according to which it is not the policy effects that an innovating firms perceives for itself that impact its economic performance, but rather its perception of the *aggregated effects* of policy instruments at industry level that can be considered as proxies for emerging policy-induced demand for new energy-related products. Also in this case, in estimates not shown here we could not find any significant indirect effects on productivity via the variable for energy-related product innovation.

Table A.6 shows estimates of model 2 without policy effects, in which the model variables were multiplied with country dummies, in column 1 for Switzerland and Austria (with Germany as reference country), in columns 2 for Germany and Austria (with Switzerland as reference country). An inspection of the estimates shows that there are no statistically significant difference among the countries with respect to the variable that is relevant for this part of the present study, namely LINNL_E.

Productivity and policy measures

Leeuwen and Mohnen (2013) report a positive effect of green R&D in general. However, in the latter study the authors could not find any effect for a measure of output innovation, which is in accordance to our finding.

[14] No other study is known to us that explores this indirect effect.

Table 7 shows estimates of the basic model used above, i.e. without energy-related variables as in Tables 5 and 6, augmented by policy variables (and the variable for expected demand). The policy variables were first inserted separately in the estimates in columns 1 to 5. In column 6 all five of them are included.[15] Only the variable for *voluntary standards/agreements* is positive and statistically significant in the separate estimates and remain so also when all other policy variables are inserted in the estimation equation (column 6).[16] It is understandable that voluntary agreements/standards, which are quite popular particularly in Switzerland, would yield positive direct effects on productivity because firms that accept such agreements would expect net benefits from the adoption of energy-saving technologies, otherwise they would not engage in such agreements or apply such standards.

7. Summary and conclusions

It is the aim of this study to investigate first, the "strong" version of the Porter Hypothesis applied on the *adoption of energy-saving technologies* (i.e. process innovations in the broad sense used in the Porter Hypothesis), particularly possible direct effects on productivity as well as indirect effects via inducement by several policy instruments. A second goal is the analysis of the effects of the *development of new energy-efficient products* (i.e. product innovations), a topic that is rather neglected in existing empirical literature.

The present study adds some new insights to empirical literature by trying to close existing gaps and complement existing insights. To this end, (a) we concentrate to energy-related technologies, (b) distinguish clearly between adoption and use of energy-related technologies and product innovation in energy-related fields, (c) take into consideration four energy-related policy instruments (and expected demand for energy-related new products and services), and (d) investigate the possibility of indirect effects of policy on performance via adoption or innovation by interacting adoption and innovation variables with policy instrument dummies, and (e) test our hypotheses not only for the pooled data but also separately for the three countries that are taken into consideration in this study.

We find a positive *direct* effect of the *adoption of energy-related technologies* (as measured by energy-related investment per employee) labour productivity, thus empirical support for *hypothesis 1*. Further, we find a positive *indirect* effect of *energy taxes*, a market-based policy

[15] At a more general level, see Kozluk and Zipperer (2015) for a survey of empirical findings with respect to direct effects of environmental policies on productivity growth. See also Albrizio et al. (2014) for a comprehensive study on the effects of environmental policy stringency on productivity grow at country, industry and firm level.

[16] Lanvoie et al. (2013) investigated – based on data from 7 countries with different policy regimes – the direct impact of several policy instruments on profits and find positive effects for regulation and technical standards provided that policy is implemented with low stringency, but no effect for taxes. Van Leeuwen and Mohnen (2013) find in accordance to our results no direct effect for regulation. Howarth et al. (2000) discuss the positive effects of two voluntary participation environmental programmes in the USA. Rassier and Earnhart (2015) find for the USA that clean water regulation affects positively actual profitability outcomes but not expected profitability.

instrument, on labour productivity via the adoption of energy-related technologies (partial confirmation of *hypothesis 2*).

Hypotheses 3 and *4* receive no empirical support (neither direct nor indirect (policy-induced) effect of the sales of energy-related products per employee on labour productivity). Further, *demand-induced* innovation appears to be still too weak to affect economic performance.

Finally, we find evidence that the relationship between the two investment categories (energy-related vs. other) as well as between the two innovation categories (energy-related vs. other) is neither complementary nor substitutive to each other with respect to productivity. A further interpretation could be that energy-related investment as well as energy-related innovation are not crowding out other types of investment/innovation.

There are some implications for policy: *market-based* policy instruments like energy taxes seem to lead to a stronger inducement effect with respect to the adoption of energy-related technologies on productivity than other instruments such as regulation, voluntary standards/agreements, and subsidies. This is not the case for energy-related innovation, which appears to be (still) unprofitable and not responsive to policy instruments with respect to productivity.

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Table 1: Related empirical literature

Study	*Data / country*	*Adoption / innovation Measure*	*Policy measure*	*Economic performance measure*	*Impact on economic performance*
Marin/Lotti (2016)	47990 obs. of 11938 Italian firms; 1995-2006	Propensity to eco-patenting; number of eco-patents	None	Labour productivity	No effect
Hottenrott et al. (2016)	1669 German manufacturing firms	Adoption of CO_2-reducing and material-reducing technologies (dummy variables)	None	Total Factor Productivity	CO_2-reducing: positive; material-reducing: positive; both positive only in combination with organizational innovation
Soltmann et al. (2015)	12 countries, 22 manufacturing industries; 7920 observations at industry level; 1980-2009	Number of green patents	None	Labour productivity	U-shaped relationship to productivity
Rexhäuser/Rammer (2014)	3614 German firms; 2008	Adoption of several environment-friendly technologies (dummy variables)	Regulation (indirectly)[1]	Profitability	Resource efficiency-improving (reduction of CO_2, energy or material use per unit of output): positive effect; = regulation-driven: strongly positive effect; = voluntary adoption: positive effect; Other technologies: negative effect
Marin (2014)	11049 Italian firms; 1995-2006	Number of patents	None	Labour productivity	All environmental patents: no effect; renewable energy technol.: positive effect; pollution/waste technol.: no effect
Van Leeuwen/Mohnen (2013)	2062 observations of Dutch manufacturing firms; 2000-2008	Investment expenditures in: = eco end-of-pipe innovation;	Environmental regulation (dummy variable)	Total Factor Productivity	Eco RD: positive effect; eco end-of pipe innovation: negative effect; eco process integrated innovation: no effect; Regulation: no effect

		= eco process integrated innovation = eco R&D			
Ghisetti/Rennings (2013)	1063 observations of German firms; 2009/2011	Adoption several environment-friendly technologies (dummy variables)	Regulation (indirectly)[1]	Profitability	Improving energy and resource efficiency: positive effect; Reducing externalities(pollution: harmful materials): negative effect
Rennings/Rammer (2011)	4538 German firms; 20002-2002	Introduction of environmental innovations (dummy variables)	Regulation (indirectly)[1]	Profitability (price-cost margin)	Regulation-induced *process* innovations total: negative effect; = energy-efficiency-related process innovations: no effect; = power generation-related process innovations: no effect; = mobility-related process innovations: negative effect Regulation-induced *product* innovations total: no effect; = energy-efficiency-related product innovations: no effect; = power generation-related process innovations: no effect; = resource-efficiency product innovations: positive effect;
Lanvoie et al. (2011)	4144 observations of manufacturing firms from 7 countries; 2003	Green R&D (dummy variable	Regulation; standards; taxes	Profits yes/no	Green R&D variable: positive effect; = regulation (low stringency): positive effect; = regulation (high stringency): negative effect; = tech-standards (low stringency): positive effect;

					= taxes: no effect
Hanel (2003)	6143 Canadian firms; 1999	Introduction of environmental innovations (dummy variables)	Regulation (indirectly)[1]	Labour productivity; profitability; market share	Environmental damage-reducing innovations: no effect; regulation-induced innovations: negative effect; combination of the two types of innovation: positive effect

[1]Firms report that innovations were induced by environmental regulation measures.

Table 2: Energy-related investment expenditures and sales of energy-related innovative products

	Pooled	Switzer-land	Germany	Austria
Energy-related investment expenditures as share of total investment expenditures (in %)	5.9	4.6	6.1	10.2
Sales share of energy-related innovative products (in %)	0.8	0.7	0.7	1.8

Table 3: Relevance of *energy-related* policy instruments

	Pooled	Switzerland	Germany	Austria
Taxes	53.2	49.9	57.2	48.9
Regulation	36.6	43.2	32.2	31.8
Standards/voluntary agreements	30.7	33.5	28.2	31.1
Subsidies	34.1	31.7	34.1	42.4
Expected demand	25.7	25.5	24.9	29.3
N	*3745*	*1527*	*1768*	*450*

Note: Percentage of firms reporting (some or high) relevance of a certain *energy-related* policy instrument for the firm in the period 2012-2014.

Table 4: Definition of variables

Variable	Definition
LVAL	Value added (sales minus material costs and costs for purchasing services) per employee
LINVL	Gross investment expenditures per employee; natural logarithm
LINVL_NE	Gross investment expenditures (minus energy-related expenditures) per employee; natural logarithm
LINVL_E	*Energy-related* investment expenditures per employee; natural logarithm
ADOPT_E	Adoption of at least one *energy-saving technology* and/or use of a *renewable energy* technology[1]
HQUAL	Share of employees with tertiary-level education
LEMP	Number of employees (in full-time equivalents); natural logarithm
LINNL	Sales of *overall* new and/or significantly modified products/services per employee; natural logarithm
LINNL_NE	Sales of *overall* new and/or significantly modified products/services (minus sales of *energy-related* innovative products) per employee; natural logarithm
LINNL_E	Sales of *energy-related* innovative products per employee; natural logarithm
INNOV_E	Development of new products in the field of *energy-saving* technologies and/or *renewable* energy technologies[2]
Policy instruments (POLICY):	
Taxes	Some or high relevance of energy taxes and duties; binary variable
Regulation	Some or high relevance of energy-related regulation and laws; binary variable
Voluntary standard/agreements	Some or high relevance of energy-related standards and negotiated agreements; binary variable
Subsides	Some or high relevance of public promotion (subsides); binary variable
Expected demand	Some or high relevance of expected demand for energy efficient products and services; binary variable
FOREIGN	Foreign-owned; binary variable
Germany	German firm; binary variable
Austria	Austrian firm; binary variable

Note: [1]Energy-saving technology in production process, computer equipment, transport vehicles and buildings; [2]see note 1. The quantitative variables refer to the year 2014; the qualitative variables refer to the period 2012-2014.

Table 5: Labour productivity, *energy-related* investment expenditures and *energy-related* policy instruments (model 1): OLS estimates; dependent variable: LVAL

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LINVL_NE	0.085***	0.086***	0.085***	0.085***	0.084***	0.085***	0.085***
	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
HQUAL	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LINNL	0.004**	0.004**	0.004**	0.004**	0.004**	0.004**	0.004**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
LINVL_E	0.018***	0.022	0.009	0.015**	0.019***	0.021***1	0.019***
	(0.007)	(0.018)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
ADOPT_E	-0.081*	-0.083*	-0.074*	-0.077*	-0.085**	-0.084**	-0.082*
	(0.042)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)
LINV_NE*LINV_E		-0.001					
		(0.002)					
LEMP	0.033***	0.033***	0.033***	0.032***	0.032***	0.034***	0.033***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
FOREIGN	0.160***	0.160***	0.158***	0.160***	0.160***	0.158***	0.160***
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
LINVL_E* taxes			0.013***				
			(0.005)				
LINVL_E*regulation				0.004			
				(0.005)			
LINVL_E*standard/agreements					-0.005		
					(0.006)		
LINVL_E*subsides						-0.006	
						(0.006)	
LINVL_E*expected demand							-0.005
							(0.006)

Taxes			-0.057***				
			(0.023)				
Regulation				-0.002			
				(0.025)			
Standards/agreements					0.035		
					(0.027)		
Subsides						-0.009	
						(0.027)	
Expected demand							0.004
							(0.029)
Germany	-0.457***	-0.457***	-0.454***	-0.456***	-0.457***	-0.456***	-0.457***
	(0.021)	(0.021)	(0.021)	((0.021)	(0.021)	(0.021)	(0.021)
Austria	-0.432***	-0.432***	-0.429***	-0.429***	-0.432***	-0.430***	-0.432***
	(0.029)	(0.029)	(0.029)	(0.030)	(0.029)	(0.029)	(0.029)
Industry dummies (64)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Const.	10.749***	10.738***	10.777***	10.749***	10.744***	10.746***	10.745***
	(0.077)	(0.086)	(0.077)	(0.077)	(0.077)	(0.077)	(0.077)
N	3745	3745	3745	3745	3745	3745	3745
F-test	24.2***	23.8***	23.6***	23.5***	23.5***	23.6***	23.5***
Adj. R^2	0.311	0.311	0.312	0.311	0.311	0.311	0.311
Root MSE	0.516	0.516	0.516	0.516	0.516	0.516	0.516

Note: Standard errors in brackets; ***, ** and * denote statistical significance at the 1%-, 5%- and 10%-test level, respectively; reference country: Switzerland.

Table 6: Labour productivity, *energy-related* innovation and *energy-related* policy instruments (model 2): OLS estimates; dependent variable: LVAL

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LINVL	0.032***	0.032***	0.032***	0.032***	0.032***	0.032***	0.032***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
HQUAL	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LINNL_NE	0.005**	0.006**	0.005**	0.005**	0.005**	0.005**	0.005**
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
LINNL_E	-0.000	0.012	-0.002	-0.001	0.002	0.004	0.004
	(0.008)	(0.012)	(0.009)	(0.008)	(0.008)	(0.009)	(0.009)
INNOV_E	-0.028	-0.028	-0.029	-0.028	-0.029	-0.031	-0.036
	(0.064)	(0.064)	(0.064)	(0.064)	(0.064)	(0.063)	(0.064)
LINNL*LINNL_E		-0.001					
		(0.001)					
LINNL_E* taxes			-0.004				
			(0.008)				
LINNL_E*regulation				0.004			
				(0.008)			
LINNL_E*standard/agreements					-0.005		
					(0.008)		
LINNL_E*subsides						-0.007	
						(0.008)	
LINNL_E*expected demand							-0.009
							(0.008)
Taxes			0.008				
			(0.024)				
Regulation				-0.008			
				(0.025)			

Standards/agreements					0.016		
					(0.026)		
Subsides						0.020	
						(0.026)	
Expected demand							0.041
							(0.028)
LEMP	0.065***	0.065***	0.065***	0.065***	0.064***	0.064***	0.064***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
FOREIGN	0.105***	0.105***	0.104***	0.105***	0.103***	0.105***	0.104***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Germany	-0.474***	-0.475***	-0.475***	-0.474***	-0.474***	-0.475***	-0.475***
	(0.027)	(0.027)	(0.027)	((0.027)	(0.027)	(0.027)	(0.027)
Austria	-0.388***	-0.390***	-0.387***	-0.387***	-0.386***	-0.389***	-0.389***
	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)
Industry dummies (24)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Const.	11.264***	11.265***	11.261***	11.263***	11.265***	11.267***	11.272***
	(0.088)	(0.087)	(0.087)	(0.088)	(0.089)	(0.089)	(0.077)
N	1917	1917	1917	1917	1917	1917	1917
F-test	33.3***	32.3***	32.2***	31.5***	32.2***	31.0***	31.7***
Adj. R^2	0.321	0.322	0.321	0.321	0.321	0.321	0.322
Root MSE	0.471	0.470	0.471	0.471	0.471	0.471	0.471

Note: Standard errors in brackets; ***, ** and * denote statistical significance at the 1%-, 5%- and 10%-test level, respectively; Reference country: Switzerland.

Table 7: Labour productivity and *energy-related* policy instruments: OLS estimates; dependent variable: LVAL

	(1)	(2)	(3)	(4)	(5)	(6)
LINVL_NE	0.031***	0.031***	0.031***	0.031***	0.031***	0.031***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
HQUAL	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LINNL	0.006***	0.006***	0.006***	0.006**	0.006***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
LEMP	0.034***	0.033***	0.032***	0.034***	0.034***	0.032***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
FOREIGN	0.183***	0.183***	0.182***	0.183***	0.183***	0.181***
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Taxes	-0.001					-0.024
	(0.018)					(0.020)
Regulation		0.021				0.014
		(0.018)				(0.022)
Standards/agreements			0.036**			0.040*
			(0.018)			(0.022)
Subsides				0.004		-0.007
				(0.018)		(0.021)
Expected demand					0.007	-0.003
					(0.020)	(0.022)
Germany	-0.492***	-0.492***	-0.493***	-0.493***	-0.493***	-0.488***
	(0.020)	(0.020)	(0.020)	((0.020)	(0.020)	(0.021)
Austria	-0.4359***	-0.456***	-0.457***	-0.459***	-0.459***	-0.455***
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Industry dummies (64)	Yes	Yes	Yes	Yes	Yes	Yes
Const.	11.251***	11.240***	11.241***	10.749***	11.247***	11.249***

	(0.062)	(0.062)	(0.061)	(0.077)	(0.061)	(0.062)
N	4176	4176	4176	4176	4176	4176
F-test	28.9***	28.0***	27.7***	28.7***	28.9***	26.1***
Adj. R^2	0.304	0.304	0.305	0.304	0.304	0.305
Root MSE	0.537	0.537	0.537	0.537	0.537	0.537

Note: Standard errors in brackets; ***, ** and * denote statistical significance at the 1%-, 5%- and 10%-test level, respectively; reference country: Switzerland.

APPENDIX

Table A.1: Descriptive statistics; energy-related investment (model 1; N=3745)

Variable	Mean	Standard Deviation	Minimum	Maximum
LVAL	11.488	0.621	9.253	13.802
HQUAL	17.866	23.430	0	100
LINVL_NE	8.260	1.465	2.095	13.357
LINVL_E	2.764	3.239	0	10.872
LINNL	5.034	5.237	0	13.592
ADOPT_E	0.471	0.499	0	1
LEMP	3.935	1.566	0	11.629
FOREIGN	0.108	0.310	0	1
Taxes	0.532	0.499	0	1
Regulation	0.366	0.482	0	1
Standards/agreements	0.307	0.461	0	1
Subsidies	0.341	0.474	0	1
Expected demand	0.257	0.437	0	1

Table A.2: Descriptive statistics; energy-related innovation (model 2; N=1917)

Variable	Mean	Standard Deviation	Minimum	Maximum
LVAL	11.475	0.566	9.393	13.789
HQUAL	22.002	26.752	0	100
LINVL	8.260	1.465	2.095	13.357
LINNL_NE	5.733	5.221	0	13.538
LINNL_E	0.713	5.521	0	12.036
LEMP	3.873	1.487	0	11.629
INNOV_E	o.145	0.352	0	1
FOREIGN	0.123	0.328	0	1
Taxes	0.531	0.499	0	1
Regulation	0.361	0.480	0	1
Standards/agreements	0.294	0.456	0	1
Subsidies	0.327	0.469	0	1
Expected demand	0.261	0.439	0	1

Table A.3: Correlation matrix (N=3745); energy-related investment (model 1)

	LINVL_NE	HQUAL	LINNL	LINVL_E	ADOPT_E	LEMP	FOREIGN	Taxes	Regulation	Standards/ agreements	Subsidies
LINVL_NE	1.000										
HQUAL	-0.128	1.000									
LINNL	0.125	0.085	1.000								
LINVL_E	0.199	-0.095	0.171	1.000							
ADOPT_E	0.062	-0.063	0.163	0.905	1.000						
LEMP	0.178	-0.152	0.222	0.275	0.273	1.000					
FOREIGN	0.092	-0.004	0.133	0.027	0.007	0.212	1.000				
Taxes	0.100	-0.167	0.023	0.203	0.178	0.122	0.006	1.000			
Regulation	0.134	-0.149	0.053	0.195	0.157	0.207	0.055	0.458	1.000		
Standards/agreements	0.127	-0.126	0.061	0.224	0.198	0.195	0.062	0.353	0.546	1.000	
Subsides	0.109	-0.105	0.064	0.272	0.250	0.152	-0.026	0.291	0.369	0.383	1.000
Expected demand	0.036	-0.014	0.092	0.174	0.185	0.131	0.017	0.165	0.274	0.315	0.388

Table A.4: Correlation matrix (N=1917); energy-related innovation (model 2)

	LINVL	HQUAL	LINNL_NE	LINNL_E	INNOV_E	LEMP	FOREIGN	Taxes	Regulation	Standards/ agreements	Subsidies
LINVL	1.000										
HQUAL	-0.199	1.000									
LINNL_NE	0.161	0.086	1.000								
LINNL_E	0.059	0.044	0.178	1.000							
INNOV_E	0.024	0.091	0.178	0.798	1.000						
LEMP	0.321	-0.229	0.238	0.127	0.147	1.000					
FOREIGN	0.135	-0.056	0.132	0.018	-0.003	0.248	1.000				
Taxes	0.142	-0.199	0.006	-0.008	0.022	0.161	0.052	1.000			
Regulation	0.092	-0.164	0.017	0.033	0.033	0.223	0.093	0.422	1.000		
Standards/agreements	0.100	-0.146	0.030	0.045	0.047	0.224	0.091	0.311	0.538	1.000	
Subsides	0.111	-0.094	0.025	0.134	0.150	0.168	-0.010	0.266	0.351	0.385	1.000
Expected demand	0.061	0.001	0.031	0.170	0.198	0.119	-0.009	0.110	0.230	0.263	0.415

Table A.5: Labour productivity, *energy-related* investment expenditures and *energy-related* policies (model 1): OLS estimates; dependent variable: LVAL

	(1)	(2)	(3)	(4)
Pooled				
LINVL_NE	0.083***	0.083***	0.083***	0.084***
	(0.009)	(0.009)	(0.011)	(0.011)
HQUAL	0.002***	0.002***	0.005***	0.005***
	(0.000)	(0.000)	(0.001)	(0.000)
LINNL	0.004	0.004	0.004	0.004
	(0.003)	(0.003)	(0.003)	(0.003)
LINVL_E	0.026***	0.016	0.012	0.004
	(0.010)	(0.011)	(0.010)	(0.012)
ADOPT_E	-0.125**	-0.116**	-0.052	-0.046
	(0.059)	(0.059)	(0.069)	(0.069)
LEMP	0.041***	0.041***	0.001	0.001
	(0.009)	(0.009)	(0.010)	(0.010)
FOREIGN	0.292***	0.294***	0.128***	0.126***
	(0.057)	(0.057)	(0.038)	(0.038)
LINVL_E*taxes		0.015*		0.013
		(0.008)		(0.008)
Taxes		-0.073**		-0.031
		(0.035)		(0.033)
Country	*Switzerland*	*Switzerland*	*Germany*	*Germany*
LINVL_NE	0.001	0.001	-0.001	-0.001
	(0.014)	(0.014)	(0.014)	(0.014)
HQUAL	0.003***	0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
LINNL	0.000	0.000	-0.000	-0.000
	(0.004)	(0.004)	(0.004)	(0.004)
LINVL_E	-0.014	-0.013	0.014	0.013
	(0.014)	(0.016)	(0.014)	(0.016)
ADOPT_E	0.073	0.069	-0.073	-0.069
	(0.091)	(0.091)	(0.091)	(0.091)
LEMP	-0.040***	-0.040***	0.040***	0.040***
	(0.013)	(0.013)	(0.013)	(0.013)
FOREIGN	-0.165**	-0.169**	0.165***	0.169**
	(0.068)	(0.068)	(0.068)	(0.068)
LINVL_E*taxes		-0.002		0.002
		(0.012)		(0.012)
Taxes		0.042		-0.042
		(0.048)		(0.048)
Country	*Austria*	*Austria*	*Austria*	*Austria*
LINVL_NE	-0.001	0.002	-0.001	0.001
	(0.019)	(0.020)	(0.020)	(0.020)
HQUAL	0.001	0.001	-0.002	-0.002

	(0.001)	(0.001)	(0.002)	(0.002)
LINNL	0.008	0.008	0.007	0.008
	(0.007)	(0.007)	(0.007)	(0.007)
LINVL_E	-0.018	-0.015	-0.004	-0.002
	(0.022)	(0.024)	(0.022)	(0.025)
ADOPT_E	0.132	0.130	0.058	0.061
	(0.146)	(0.148)	(0.151)	(0.152)
LEMP	0.028	0.028	0.068***	0.068***
	(0.018)	(0.018)	(0.019)	(0.019)
FOREIGN	-0.234***	-0.237***	-0.070	-0.069
	(0.089)	(0.090)	(0.078)	(0.078)
LINVL_E*taxes		-0.004		-0.001
		(0.017)		(0.017)
Taxes		-0.009		-0.051
		(0.082)		(0.082)
Switzerland /Germany	0.580***	-0.554***	-0.580***	-0.554***
	(0.126)	(0.127)	(0.126)	((0.127)
Austria	-0.175	-0.196	-0.755***	-0.750***
	(0.172)	(0.173)	(0.181)	(0.182)
Industry dummies (64)	Yes	Yes	Yes	Yes
Const.	10.293***	10.336***	10.873***	10.890***
	(0.092)	(0.094)	(0.110)	(0.110)
N	3745	3745	3745	3745
F-test	21.0***	19.7***	21.0***	19.7***
Adj. R^2	0.317	0.317	0.317	0.317
Root MSE	0.514	0.513	0.514	0.513

Note: Standard errors in brackets; ***, ** and * denote statistical significance at the 1%-, 5%- and 10%-test level, respectively; column (1) and (2): reference country: Germany; column (3) and (4): reference country: Switzerland.

Table A.6: Labour productivity, *energy-related* innovation (model 2): OLS estimates; dependent variable: LVAL

	(1)	(2)
Pooled		
LINVL	0.031***	0.034***
	(0.006)	(0.008)
HQUAL	0.001**	0.005***
	(0.000)	(0.001)
LINNL_NE	0.007**	0.004
	(0.003)	(0.004)
LINNL_E	0.000	0.036
	(0.009)	(0.030)
INNOV_E	-0.019	-0.336
	(0.061)	(0.286)
LEMP	0.079***	0.017
	(0.011)	(0.014)
FOREIGN	0.167***	0.117***
	(0.065)	(0.046)
Country	*Switzerland*	*Germany*
LINVL	0.004	-0.004
	(0.010)	(0.010)
HQUAL	0.003***	-0.003***
	(0.001)	(0.001)
LINNL_NE	-0.003	-0.003
	(0.005)	(0.005)
LINNL_E	0.036	-0.036
	(0.031)	(0.031)
INNOV_E	-0.317	0.317
	(0.292)	(0.292)
LEMP	-0.062***	0.062***
	(0.018)	(0.018)
FOREIGN	-0.050	0.050
	(0.079)	(0.079)
Country	*Austria*	*Austria*
LINVL	-0.008	-0.012
	(0.022)	(0.022)
HQUAL	0.001	-0.002
	(0.002)	(0.002)
LINNL_NE	0.005	0.008
	(0.010)	(0.010)
LINNL_E	0.036	0.001
	(0.035)	(0.045)
INNOV_E	-0.492	-0.175
	(0.318)	(0.424)
LEMP	0.049	0.111***
	(0.031)	(0.032)

FOREIGN	-0.250**	-0.200*
	(0.114)	(0.105)
Switzerland /Germany	0.656***	-0.656***
	(0.097)	(0.097)
Austria	-0.085	-0.741***
	(0.208)	(0.216)
Industry dummies (24)	Yes	Yes
Const.	10.793***	11.449***
	(0.335)	(0.343)
N	1917	1917
F-test	19.6***	16.6***
Adj. R^2	0.317	0.317
Root MSE	0.468	0.468

Note: Standard errors in brackets; ***, ** and * denote statistical significance at the 1%-, 5%- and 10%-test level, respectively; column (1): reference country: Germany; column (2): reference country: Switzerland.