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Competitiveness and ecological impacts of green energy technologies: firm-level evidence for the DACH region

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Abstract

For a large sample of enterprises in Germany, Austria and Switzerland (the "DACH"region) we study the impact of various policy instruments, such as energy related taxes, subsidies, regulations and standards or negotiated agreements on the firm's ecological and economic performance. To identify the causal linkages, we build a system of twelve equations, tracking first the impacts of policy on the adoption of green energy technologies for distinct areas. In a second set of equations, we estimate the perceived impacts of adoption on the firm's (i) energy efficiency, (ii) carbon emissions and (iii) competitiveness. The results confirm a differentiated pattern of channels for policy to affect the firm's energy efficiency and carbon emissions, while having a neutral impact on its competitiveness.

JEL Codes: Q48, Q55, O13, O25, O33

Key Words: Environmental policy, energy policy, technology adoption, innovation, Porter hypothesis

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1 Introduction

When the *Paris Agreement*[1] has entered into force on the 4th of november 2016, it represented so far the most ambitous plan for transnational coordination to mitigate the perils of climate change. At the same time, doubts about its scope, lack of enforcement mechanisms, or the bottom-up approach of "nationally determined contributions"(NDCs) point out its limitations and lack of global governance.

Broadly speaking, societies face three avenues to reduce harmful effects of their economy on the environment (Frankel, 2004). One is to address the *scale* of operations, that is pursuing less or no growth with all its consequences of foregone real income and distributional conflicts, especially between developed and developing regions. Consistent with recent experiences one must expect, that this will be suffered only as an involuntary effect of crises. Moreover, it runs counter the second avenue of changing the *composition* of activities. The environmental Kuznets curve postulates an inverted-U shaped relationship of harmful emissions and per capita income (Grossman and Krueger, 1995). Above a certain threshold of development environmental efficiency tends to improve, because of structural change in favour of services and higher preferences for a clean environment (e.g., Dinda, 2004; Halkos and Managi, forthcoming). While such changes contribute to the decoupling of the growth of emissions relative to that of output, they are unlikely to achieve an absolute decline in the volume of pollutants.

Innovation and technological change open a third avenue, which enjoys the most widespread political support. It enhances the former channel of structural change, but can also reduce the emissions of given activities. In a broad sense, innovation can mean, for instance, sophisticated urban and regional planning to reduce emissions from commuting. In a narrower sense, it refers to new technological artefacts that directly reduce emissions for a given level of output, or indirectly reduce emissions by substituting or increasing the efficiency of a polluting input such as energy from fossil fuels. While we consider the first a very powerful source of social transformation, the focus of our analysis will be on the latter, putting the emphasis on the environmental and economic impacts of the adoption of "green energy technologies"(GETs), that is technologies which reduce environmental impacts of energy production and consumption, increase energy efficiency, or use renewable energy sources.

More specifically, our interest is in how different policy instruments affect (i) energy efficiency, (ii) the reduction of carbon emissions, and (iii) competitiveness at the firm level. We thereby focus on the inducement of firms to adopt new GET, since ecological impacts of innovations will only become manifest by way of adoption. Consequently, we distinguish between two kinds of effects that relate three distinct levels of observations: First, the *adoption* equations explain how various determinants, including policy, affect the adoption of new GETs. Second, the *impact* equations test whether the adoption of GETs actually

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[1] Under the United Nations Framework Convention on Climate Change (UNFCCC).

have the desired ecological impacts and how they relate to the firm's competitiveness.

The remainder of this paper is organised as follows. Section 2 briefly discusses the rationale and instruments of policies available to induce new GETs. Section 3 presents the basic structure of the model and puts forward the main hypotheses. Section 4 presents the data and variables used for the analysis. Section 5 explains the econometric specification, while Section 6 discusses the empirical findings. Section 7 summarizes and concludes.

2 Policy rationale and instruments

Does the goal of energy efficiency really call for public intervention? At the micro-level, higher efficiency implies lower cost to the individual enterprise, thus providing private incentives to adopt new GETs as long as expected returns pay for it. Furthermore, for most non-renewable energy sources property rights are well established. If consumption is excludable, prices should reflect scarcity rents (that is, the properly discounted valuation of known reserves, opportunities for further extraction, technological advance or substitution, etc.) and the rate of exhaustion is expected to be welfare efficient in the sense of Hotelling's (1931) rule.

Instead of economic efficiency, one can invoke the principle of *sustainability*. Solow (1992) defines it as an ethical norm about inter-generational equity: to preserve the capacity of future generations to be as well off as we are. Since the far future is not well represented in the market, sustainability is not adequately covered by the argument of economic efficiency. It is however affected by the generation of new knowledge that one passes on to the next generation, e.g. about how to substitute for cleaner technologies or the use of renewable resources. So the balance and need for public intervention remains indeterminate, if based only on the rationale of resource exhaustion.

More robust concerns for sustainability arise with regard to the emission of green house gases and the consequent perils of climate change. The sheer scope of the problem dwarfs many of the economist's standard analytic tools. When assessing the benefits and costs of public intervention, the very long time-horizon, uncertainty, nonlinear impacts and the according risk of irreversible, catastrophic events, largely obliterate the use of expected values or market-based discount rates, and call instead for a conservationist bias (Arrow and Fisher, 1974; Weitzman, 1998; Pindyck, 2007).

Economists nevertheless have much to contribute in terms of analytic clarity and consistent arguments, that should support policy in choosing efficient instruments. More specifically, the economic rationale of public interventions to foster GETs originates in the so called *double externality* problem (Jaffe et al, 2005; Popp et al, 2010). One kind of externality refers to situations, where individual enterprises do not bear the cost for harmful consequences of their activity on the environment through pollution or the exhaustion of common resources. This generates negative spillovers from distorted price signals (Pigou, 1920), or can similarly be interpreted as a public goods problem emanating from incomplete property rights (Coase, 1960). Stavins (2011) discusses both as a problem of the commons, for which Ostrom (1990, 2010) had demonstrated the possibility of local communities to contain them by means of self-organized rules and institutional arrangements. But for climate change, the “ultimate commons problem“(Stavins, 2011), the affected community is global and potential barriers for coordination and governance are immensely more difficult. Though global coordination has proved to be effective, for instance, in containing the emission of FCKWs, the implied cost were on a much smaller scale and new technological solutions turned out to be more readily available than anticipated.

It is precisely for such technological advances, that the second kind of externality matters. Firms that invest in new knowledge about environmental technologies and practices cannot appropriate the full social returns, thus creating positive spillovers to society. As a consequence, pure market based allocation based on the individual calculus of marginal cost and return provides insufficient incentives to mitigate environmental harmful activities or to invest in environmental technologies and practices.

Policy can choose among a variety of instruments to address the double externality problem (Metcalf, 2009). Each has particular strengths and weaknesses, so that policy faces “a sobering conceptual reality: the absence of an objective procedure for deciding how much weight to give to the competing normative criteria“(Goulder and Parry, 2008, 153). Among these criteria one has to consider ecological objectives, economic efficiency, distributional concerns, or political feasibility.

One can organise the various policy tools under the heading of several broad categories: The first is *public funding*, e.g. in the form of grants, preferential credit, or tax allowances. It is a popular tool of technology policy in order to compensate for positive externalities. These are especially important for own innovations, but may also accrue to early adopters, who reduce uncertainty in the market by demonstrating the feasibility of a new technology. For the adoption of environmental technologies, public funding schemes additionally apply to mitigate the aforementioned negative externalities.[2]

Similarly, environmental *taxes and duties* aim to compensate for externalities by interfering with relative prices. In contrast to subsidies, they address negative spillovers. Their ecological impact depends on how closely they can target the true source of the externality. Ideally, it is emissions proper, such as carbon dioxide (CO2). In many instances, these are difficult to measure at the point of emissions, and taxes instead target critical inputs, such as certain fuels.[3]

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[2] A major drawback of public funding is the distortion of output prices, which can imply too much consumption of goods and services from environmental harmful production. Further distortions may arise in other markets from raising the public funds via taxes. Not surprisingly, a major advantage of public funding is their political feasibility. It hardly raises objections from business or consumers, and even taxpayers tend to sympathise, especially if they perceive the outcome as being beneficial also to their personal well-being.

[3] Cost efficiency is a major advantage of taxes and duties, since firms can choose the aspired level of abatement and the means to achieve it. This provides them with the flexibility to account for particular opportunity costs of their operations and thus optimize the overall outcome. Furthermore, under the notions

In contrast to the above price-based tools, rules and *regulations* more directly target specific ecological impacts, e.g. by banning certain inputs and processes, or defining the caps of allowed emissions. If permits are tradeable, the policy additionally aims for cost-efficiency by providing for more flexibility to the market participants.[4] As with environmental taxes and duties, the added flexibility of tradeable permits raises efficiency most, if firms and technologies are very heterogenous.

Finally, *standards* and negotiated (“voluntary“) agreements within the industry combine the advantages of lower administrative costs and certainty about the required ecological performance with the informational advantage of the industry’s stakeholders about technological opportunities and cost of implementation. There is however, also a disadvantage in terms of ecological effectiveness, since mandatory standards typically affect only a certain technology or prescribed level of performance, but create no inducement for further abatement activities beyond.

Different from economists, who focus on overall welfare, individual businesses tend to prefer standards over the incentive-based policies of taxes and tradeable permits. They perceive them to be less expensive, because they imply abatement costs only to reduce pollution to a specified level, whereas auctioned permits and taxes additionally require them to pay for polluting *up to* that level (Buchanan and Tullock, 1975; Keohane et al. 1998). Consequently, the major advantage of negotiated standards relates to the higher political feasibility of the agreed terms. Little can be said about their ecological effectiveness and economic efficiency, except that these depend on strategic interactions and the actual allocation of power and property rights between the stakeholders.

3 Heuristics and hypotheses

The guiding question of our research is, whether different policies such as energy related regulations, standards and negotiated agreements, taxes, or subsidies have improved the ecological impact of the individual firms’ operations in the DACH region. By inducing firms to adopt certain practices and technologies to achieve the desired ecological impacts, the

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of both fairness and overall efficiency, the incentives to invest in abatement continuously rise and fall with the targeted inputs or emissions. On the downside, there remains uncertainty about the actual scope of the ecological impacts. Also environmental taxes provoke much resistence from industry for fears of loosing competitiveness. This casts doubts about their political feasibility. Concerns about fairness, efficiency and ecological effectiveness arise, if the most energy intensive producers are exempted or enjoy preferential treatment in turn.

[4] *Tradable permits*, such as the European Union’s allowance system for carbon emissions, share many properties of the above taxes and duties. Their foremost strength lies in the flexibility that they offer to the firm in determining its scope and kind of abatement activities. It trades the uncertainty about the quantitative impact of environmental taxes for uncertainty about the actual price of permits, which result from market interactions and can fluctuate in substantial ways. Various design options, such as an initial free allocation versus auctioning of permits, price floors and ceilings, etc. will affect the criteria of political feasibility, fairness and ecological effectiveness.

nature of interventions is indirect. Consequently, we separate the general problem into two consecutive questions: First, whether policy can effectively influence the firm's action in the intended direction of raising their extensive and/or intensive margins of adoption. Second, whether the induced activities actually lead to the desired ecological effect of raising energy efficiency and reducing carbon emission.[5] Related to the second question, policy is also interested in the opportunity cost of interventions, that is whether the induced actions have negative, neutral or positive impacts on the firms' competitiveness.

The comprehensive nature of the survey allows us to test these relationships in two broad sets of equations. The first set is comprised of nine equations that explain the extensive margin of adoption for various areas of technology and the intensive margin overall by means of the vector of general determinants and specific policy instruments discussed above. The second set of three equations turns to the impacts of adoption on the firm's energy efficiency, carbon emissions and competitiveness.

We interpret the findings on both types of equations as *positive* statements, referring to the perceived importance of actual policies and impacts of the firms in our sample – that is as observed for the DACH region in the period from 2012 to 2014. Since we can only observe their relevance and perceived impact the way they are actually implemented, we do not aim for general *normative* statements about which policies are more effective in principle. The insignificant coefficient or inferior performance of any instrument may thus be due either to the insufficient scope of (an otherwise effective) intervention, its inefficient implementation, or a bad choice of instruments.

Figure 1 provides a simple representation of the heuristic model in order to keep better track of the different equations and variables. Despite its apparent complexity, the model aims for a straightforward chain of causation from policy to adoption and then from adoption to ecological and economic impacts. We consider this simplicity a necessary virtue. There are no plain reasons to suspect significant distortions from endogeneity, except if in the longer run past experiences shape current expectations about the respective effects. Given the limitation of purely cross-sectional data at hand, a credible structure of exogenous effects seems essential to advance towards a meaningful identification.

[Insert Figure 1 about here]

Another means to stay focused on the guiding questions, is to deliberately expatiate the particular hypotheses for the core relationships that we aim to test. Though some may appear obvious, if taken on their own, stating them explicitly intends to highlight their relevance to the overall argument.

To begin with, three hypotheses regard the expected *policy impacts* on adoption:

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[5] One generally finds little empirical work on the effectiveness of public policies at the firm level with regard to their ecological objectives. Notable exceptions are *Lanoie et al* (2011) and *Horbach et al* (2012).

- **Extensive margin** ($H1 - 0$): Policy raises the propensity to adopt new GETs. It must be rejected, if policy has no significant impact or decreases the probability to adopt new GETs.
- **Intensive margin** ($H2 - 0$): Policy raises the share of expenditures for new GETs in total investments. It must be rejected, if policy decreases or does not significantly affect the intensive margin of adoption.
- **Heterogenous impacts** of different policy instruments ($H3 - 0$): The impact of different policies varies according to particular aspects of adoption, such as the primary motivation, the introduction of energy related management systems (EMS), the extensive and intensive margins, or different areas of technology.

The latter hypothesis is explorative, since little is known from the literature about the heterogenous effects of different policy instruments. But from the discussion in the previous section one should expect that standards primarily affect the extensive margin of adoption, whereas subsidies and taxes may excert more influence on its intensive margin. Given the previous considerations, we also expect that standards are the most commonly relevant factor to the adoption of new GETs.

Further two hypotheses address the *ecological impacts* of adoption:

- **Impact on energy efficiency** ($H4 - 0$): The adoption of GETs increases the energy efficiency of firms. It must be rejected, if either kind of adoption significantly decreases or does not significantly affect energy efficiency.
- **Impact on carbon emissions** ($H5 - 0$): The adoption of GETs reduces the carbon emissions of firms. It must be rejected, if adoption significantly increases or does not significantly affect carbon emissions.

Turning to the *impacts on competitiveness*, contemporary concepts at the aggregate level emphasize the positive contribution of cleaner production to a society's overall standards of living (Peneder, 2017). But these social benefits are largely external to the individual firm, which bears the private cost of abatement (Pasurka, 2008).[6] The immediate impact of regulation thus is to add or tighten constraints on a firm's set of choices (Palmer et al 1995), which inflicts additional cost to the enterprise and depresses its competitiveness, if rival enterprises face less constraints. This argument leads us to the first of three competing hypotheses:

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[6] The adoption of energy saving technologies is a special case, since it also reduces the expenditures on current operations. This effect, however, has already been covered by the above hypothesis on energy efficiency. When we adress the impact of adoption on *competitiveness* proper, we ask differently for the specific impact of the new technology on the firms' relative position to its main competitors in the market.

- **Conventional trade-off hypothesis** ($H6a-0$): The adoption of new GETs decreases the competitiveness of firms. It must be rejected, if it increases or does not significantly affect its competitiveness.

In contrast, generalising the insights from a rich repository of case studies Porter (1990) and Porter and van der Linde (1995) argued to relax the conventional trade-off between competitiveness and environmental policy. They demonstrate how well designed, preferably incentive based regulations can alert individual companies – often captive to myopic optimisation within a given market environment – to better anticipate long-run trends in demand or international regulations. For a given location, a stricter regulatory environment can thus induce early innovations and first-mover advantages with regard to environmentally friendly products and processes.

While the most compelling part of the Porter hypothesis relates regulation to the incentives for own innovation, the meaning of innovation is not exactly specified in their analysis. When Porter and van der Linde refer, e.g., to the benefits of regulatory signals about likely resource inefficiencies, potential technological improvements, or the reduction of uncertainty for investments, the argument apparently encompasses the case of adopting new environmentally friendly technologies.

- **Porter hypothesis** ($H6b-0$): The introduction of new GETs increases the competitiveness of firms. It must be rejected, if it decreases or does not significantly affect its competitiveness.

The Porter hypothesis triggered much controversy and has been a fruitful platform for further research (Ambec et al., 2013). It has offered stronger theoretical explanations[7] and robust empirical support for a weaker restatement, which predicts a positive impact of environmental regulation on innovation (Jaffe and Palmer, 1997),[8] The evidence on its initial “strong“prediction of a positive impact on competitiveness is however mixed.[9]

One likely explanation is that environmental regulations apply uniformly to a given firm population, whereas the induced innovation races tend to produce skewed returns (Popp, 2005). Typically, the winner takes all or at least a large chunk of the innovation rent, sharing the remainder with firms that rapidly adopt the new technology. Consistent with its initial case study approach, the Porter hypothesis should therefore apply to the winners of an innovation race, and some fast followers, but not to an entire cross section of enterprises. Furthermore, in the case of technology adoption the need and incentives are likely to apply similarly to firms operating within the same market, which leaves little scope for differential impacts. Finally considering the special nature of GETs, where the increased

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[7] For example, Ambec and Barla (2002), André et al (2009), Constantatos and Herrmann (2011), or Greaker (2003).

[8] This weak version is also consistent with our above hypotheses on the ecological impacts.

[9] See, for example, Rexhäuser and Rammer (2014), Lanoie et al. (2011), Marin and Lotti (forthcoming), Van Leeuwen and Mohnen (2013).

energy efficiency compensates for (at least part of the policy induced) expenditures on adoption, our preferred hypothesis predicts a neutral impact on the current cross-section of firms:

- **Neutrality hypothesis** ($H6c - 0$): The adoption of new GETs does not affect the competitiveness of the average enterprise in a cross-section of firms. It must be rejected, if it significantly increases or decreases the competitiveness of the average firm.

4 Data and variables

The data used in the analysis originate from a comprehensive enterprise survey for the entire DACH region, which is comprised of Germany, Austria and Switzerland. The survey focused on the creation and adoption of new energy saving and related technologies. It was jointly developed and simultaneously launched in the summer of 2015 by the ETH Zürich, the Center of European Studies (ZEW) and the Austrian Institute of Economic Research (WIFO). In total, the gross sample amounted to 19,254 firms. The net sample of valid responses includes 4,634 firms, 49% of them in Germany, 39% in Switzerland and 12% in Austria. On average, the firms in the sample have 269 employees. The median is 38 employees. About half of the firms belong to industrial production broadly defined (manufacturing, energy and water supply, waste management) and half to services (including construction).[10]

The identification of the relevance of different energy policies at the firm level is hardly possible through data from public sources. We hence asked managers to rate their relevance to their business on a three-point Likert scale.[11] While the subjectivity of responses may limit comparability across firms (Bertrand and Mullainathan 2009), there are two advantages of our research design. First, we are able cover all types of policies on the same scale. Second, we can establish the relevance of energy policies also for firms that might not be directly targeted by a certain policy. This mitigates frequent problems of identification that arise, for instance, when policies target different firms, originate from multiple territorial levels (e.g. federal and local), or are subject to imperfect monitoring and enforcement.[12]

Consistent with the considerations in the previous section, the variables from the survey are organised along the three dimensions of (i) determinants, (ii) activities and (iii) impacts. Among the strictly independent *determinants*, we distinguish between general firm characteristics ($Firm$), specific energy related factors (Enr), inducement factors (Idc), barriers

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[10] Arvanitis et al (2016) provide detailed information on the sample, methodology, and comparisons of the three DACH countries.

[11] See Lanoie et al. (2011), Stucki and Woerter (2016), or Veugelers (2012) for similar approaches.

[12] See Rammer et al (2016) for a discussion and further references.

to adoption (Bar), fixed effects for the industry (Ind) and the country (Ctr) where the responding firm i is located.

Among the inducement factors, we distinguish five types: (a) energy-related taxes and duties; (b) regulations on the energy use, such as emission ceilings or emission certificates;[13] (c) standards and negotiated agreements; (d) subsidies for developing and adopting green energy technologies; and (e) the demand for energy-efficient products or products based on green energy. Tables 1 and 2 provide detailed descriptions for each variable used in the analysis.

[Insert Table 1 about here]

[Insert Table 2 about here]

For the firm *activities* the survey was designed to provide additional information on the adoption of certified management system or other measures for the regular audit of its energy use or environmental impacts (Adp_i^{ems}). With regard to the introduction of green energy technologies (GETs), we collected information about their adoption (*extensive margin*) in any and for each of six different areas of technology (production, buildings, transport, ICT, renewables and others). Respondents were also asked about the share of expenditures on the adoption of new GETs in total investments of the firm (*intensive margin*). In addition, we aimed to control for the genuine motivation of adoption, asking whether an increase in energy efficiency or reduction of carbon emissions was a primary objective or secondary effect of the investment.

Finally, the impact variables Imp report the subjective perception of the respondents about whether and to what degree the adoption of new GETs has improved performance with regard to its energy consumption per unit or process, its CO2 emissions per unit or process, and whether the competitive position on the market has worsened, not been affected, improved or much improved as a consequence of adoption GETs.

5 Econometric model

Turning to the econometric specification, we start again with the impact of policy on adoption. On the left hand side, we find the dependent variables for each of the n equations. On the right-hand side, the first vector gives the constant intercept α, the second vector the k common independent variables, depicted by the coefficients β_n^k, and finally the error terms υ_n.

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[13] In the period covered, the European carbon trading scheme had little impacts on energy costs of firms owing to the abundance of carbon certificates and the resulting low price for carbon emission rights (see, e.g., Joltreau and Sommerfeld (2016).

$$\begin{pmatrix} Adp_i^{ems} \\ Adp_i^{get} \\ Adp_i^{int} \\ Adp_i^{obj} \end{pmatrix} = \begin{pmatrix} \alpha_1 + & \beta_1^k X_i^k & + \upsilon_1 \\ \alpha_2 + & \beta_2^k X_i^k & + \upsilon_2 \\ \alpha_3 + & \beta_3^k X_i^k & + \upsilon_3 \\ \alpha_4 + & \beta_4^k X_i^k & + \upsilon_4 \end{pmatrix} \tag{1}$$

The metric of the dependent variables determines the choice of the appropriate method of estimation. For the dichotomous extensive margins of adoption Adp_i^{ems} and Adp_i^{get} we use *probit* regressions, which apply the maximum likelihood principle to cumulative normal distributions. The coefficients tell the impact of the independent variables on the respective response probabilities. Analogously, we apply an *ordered probit* regression to fit Adp_i^{obj}. The dependent variable is again discrete, but has three possible ordinal outcomes. Finally, the continuous nature of the intensive margin Adp_i^{int} allows for estimation by *ordinary least squares* (OLS). Alternative methods (e.g., *logit*, *multinomial logit*, or the *linear probability* model for discrete variables) were used to test the robustness of the empirical findings.

For the individual technology fields, we used a *multivariate probit* model, which applies the method of simulated maximum likelihood (SML) to jointly fit the five different binary choices of possible adoption covered by the survey:[14]

$$\begin{pmatrix} Adp_i^{prd} \\ Adp_i^{bld} \\ Adp_i^{trp} \\ Adp_i^{oth} \\ Adp_i^{ren} \end{pmatrix} = \begin{pmatrix} \alpha_5 + & \beta_5^k X_i^k & + \upsilon_5 \\ \alpha_6 + & \beta_6^k X_i^k & + \upsilon_6 \\ \alpha_7 + & \beta_7^k X_i^k & + \upsilon_7 \\ \alpha_8 + & \beta_8^k X_i^k & + \upsilon_8 \\ \alpha_9 + & \beta_9^k X_i^k & + \upsilon_9 \end{pmatrix} \tag{2}$$

Reflecting the different dimension of the explanatory variables in equation (1) and (2), the matrix X_i^k is comprised of the following vectors:

$$X_i^k = Firm_i^l + Enr_i^m + Idp_i^o + Bar_i^p + Ctr_i^q + Ind_i^r \tag{3}$$

The number of variables referred to in the superscripts on the right hand side sum up to k.

Turning to the impacts of adoption, we are interested in three dependent variables: Imp_i^{eff}, Imp_i^{co2}, and Imp_i^{cmp}. Reflecting the discrete ordinal nature of the dependent variables, we consistently conduct *ordered probit* regressions with the above adoption choices entering as explanatory variables:

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[14] See Capellari and Jenkins (2003).

$$\begin{pmatrix} Imp_i^{eff} \\ Imp_i^{co2} \\ Imp_i^{cmp} \end{pmatrix} = \begin{pmatrix} \alpha_{10} & +\gamma_1^t Adp_i^t & +\beta_1 0^u X_i^u & +\upsilon_{10} \\ \alpha_{11} & +\gamma_2^t Adp_i^t & +\beta_1 1^u X_i^u & +\upsilon_{11} \\ \alpha_{12} & +\gamma_3^t Adp_i^t & +\beta_1 2^u X_i^u & +\upsilon_{12} \end{pmatrix} \tag{4}$$

The superscript t denotes the adoption variables used in the impact equations. The superscript u denotes the general control variables. Their number must again be equal to the number of variables referred to in the superscripts on the right hand side of the following expression:

$$X_i^u = Firm_i^l + Enr_i^m + Idp_i^o + Ctr_i^q + Ind_i^r \tag{5}$$

6 Empirical findings

6.1 Descriptive data

Among the 4,634 valid observations of the enterprise survey, 27% have introduced a certified energy related management system (EMS) and 47% have introduced new energy saving or related technologies (GETs). Among them, a majority of 1,452 firms has adopted new GETs in the area of construction and buildings. 978 adopters did so in the field of information and communication technologies (ICTs), closely followed by 911 firms introducing them in the field of production. 645 and 456 firms reported new GETs with regard to transport and renewable energy. Only a small fraction referred to the adoption in other fields, such as the cogeneration of heat and power.

The pairwise correlation of policy factors with the introduction of EMS and GETs is strongest for standards, followed by public funding and taxes, whereas the association is weakest for regulation (Table 3). The adoption of new GETs in production displays the strongest association with the perceived import of taxes.

[Insert Table 3 about here]

Genuine energy related purposes of adoption were strongest in the field of renewable energy (Table 4). In the fields of production, buildings and transport no more than 27% claim that energy efficiency was the primary objective; for 35% to 38% it was a secondary effect. For the remainder both applies. New GETs in the field of ICT show the largest share of firms, where energy efficiency was secondary to other purposes.

Firms that introduced new GETs in the field of production are most positive about improvements in energy efficiency. About 76% say that it has improved; close to 35% affirm that it has even much improved. The strongest impacts on carbon emissions are perceived in the field of transport (30% much improved; another 29% improved). Finally, the impacts of new GETs on the competitiveness of the firm show little variation between different technological areas and spread rather evenly across the four categories offered for response.

[Insert Table 4 about here]

To summarize, the perceived import of policies such as energy related public funding, taxes, regulations, or standards shows a consistently significant and positive association with the adoption of EMS and new GETs. Even though a majority of firms concedes, that energy efficiency was not the sole or primary objective, most of them are positive about the ecological impacts of their adoption of new GETs. Finally, the ratio of firms, which perceive a positive impact on their competitiveness is about double that of the firms reporting a worsenening of their competitive position.

6.2 Drivers of GET adoption

Turning to the econometric analysis, the comprehensive approach reveals a strikingly differentiated picture. To begin with the adoption equations, *customer demand* for energy efficient products and processes appears to be the most powerful driver of the adoption of new GETs in all five technology fields (Tables 5 and 6). Consistent with Khanna et al (2009) the introduction of *energy related management systems* (EMS) significantly raises the firm's probability to adopt new GETs. This effect again applies to all five technological fields, but is strongest in production and weakest in the area of transport. Of related interest, firms that are large, part of an enterprise group, and exporters have a higher probability of introducing an EMS. Environmental taxes and standards are significant policy related factors that induce its introduction.

The findings reveal how the various policy instruments differ in their impacts on the introduction of both EMS and GETs: *Taxes and duties* related to energy use significantly raise the probability of adopting energy related management systems (EMS). Neither display a significant impact on the extensive nor the intensive margin of GET adoption. Energy related *standards* and voluntary agreements within the industry are the most persistent drivers of the extensive margin of adoption for both EMS and GETs in all five technology fields. Conversely, they do not affect its intensive margin. *Public funding* and *regulation* affect only the intensive margin of adoption. Public funding consistently raises the share of expenditures for new GETs in total investments. In contrast, regulation appears to decrease in one specification, but turns insignificant if we include own innovations in GET among the explanatory variables.

Among potential barriers to the introduction of new GETs, the *lack of finance* exerts a significant negative impact on the extensive margin of adoption. This applies to all technology fields, except ICT. [15]

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[15] Some suspected barriers of adoption show a significant but positive statistical association with the extensive margin. This is a well-known problem with survey data and reflects the greater awareness of

[Insert Table 5 about here]

[Insert Table 6 about here]

High and volatile *energy prices* are a significant determinant of the extensive margin of GET adoption in production and transport and generally affect the intensive margin. Fears of *energy shortages* only affect the extensive margin in the field of ICT. Rather than being substitutes, effective changes in the energy mix of the firm complement the adoption of EMS and new GETs. Adding own innovation in the field of energy related technologies to the set of regressors reduces the sample by more than half. We therefore display the outcome in two separate columns of Table 5. This serves also as a test of robustness of the main coefficients with respect to smaller sample sizes. While the other findings remain unaffected, own innovations with regard to GETs have a significant and positive impact on the extensive margin but not on the intensive margin. While the latter may be due to the small sample size, the finding on the extensive margin is consistent with the literature emphasising the importance of own innovations for a firm's *absorptive capacity* (Cohen and Levinthal, 1990).

Among other firm characteristics, *group* membership decreases the intensive margin of GETs. *Size* by number of employees generally raises the extensive margin of GET adoption (except for renewable energy). Similarly, *age* has a positive impact on the extensive margin of GETs (except if applied to ICTs). In comparison to German enterprises, Austrian firms more often report the adoption of EMS and GETs (except for ICT) and exhibit a higher intensive margin. Compared to German firms, Swiss enterprises show a higher probability of introducing EMS, a lower extensive margin and a higher intensive margin of adopting GETs.[16]

6.3 Impacts of GET adoption

The second set of equations is directed at the impacts of adopting EMS and GETs on energy efficiency, carbon emissions, and the firm's competitiveness. Thereby different activities condition the *genuine objective* of adoption. On the one hand, firms that have introduced an EMS show a significant higher propensity to adopt new GETs with the primary objective of raising energy efficiency or reducing carbon emissions (Table 7).

On the other hand, the propensity also rises with the import of customer demand for energy efficient products and services, the overall intensive margin of adoption, and for the extensive margin in the area buildings. For firms that expressed a concern about energy shortages, the ecological impacts more often are only a secondary effect (windfalls). These

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adopting firms abut the respective barriers. In the preferred specification we keep them as control variables, but also tested the sensitivity of results when removing them. None of the coefficients was affected in a relevant manner, except that the lack of finance then becomes insignificant.

[16] See Wörter et al (2016) for a discussion of the different energy related policies in the three countries of the DACH region.

findings are relevant for a comprehensive understanding, since the estimates further reveal that adoption with a genuine purpose of energy savings significantly improves its impact on energy efficiency and carbon emissions.

[Insert Table 7 about here]

The ecological impacts of adopting new GETs differ by technological fields. New GETs in production significantly improve the energy efficiency of operations and reduce carbon emissions. The adoption of new GETs in buildings significantly improves energy efficiency, but not the carbon imprint of the adopting firm. Conversely, new GETs in transport have significantly reduced the carbon emissions of the adopting firm, but not enhanced its energy efficiency.

With regard to the impact of new GETs on the firm's competitiveness, the estimates reject both the conventional expectation of a negative trade-off as well as the Porter hypothesis of a positive effect. Instead, the data support the hypothesis of a largely neutral effect of the adoption of new GETs on the competitiveness of the average firm. This points at the fact that in general the need and incentives for adoption apply similarly to firms in the same market, leaving little scope for differential impacts on their relative competitive position. Furthermore, the potential surplus of early adoption would apply only to a few firms, and not significantly affect the average enterprise in the sample.

Finally, among the auxiliary factors, group membership and more intense competition appear to reduce the economically feasible options when adopting new GETs and significantly decrease its impact on energy efficiency.

For all the equations, we have run manifold tests of robustness. The main relationships between our variables on policy, adoption and impacts are not sensitive to meaningful variations in the set of control variables. Similarly, using different methods of estimation, such as OLS or logit instead of probit and ordered probit models did not make any pronounced differences. Most informative are the tests of robustness of the impact equations using multinomial logit regressions (Tables 8 to 10 in the Annex).

7 Summary and conclusions

The analysis has tested the impact of different environmental policy instruments, such as energy related taxes, subsidies, regulations, and standards on the firm's ecological and economic performance. The empirical basis is a new dataset created from an enterprise survey that was simultaneously conducted in Germany, Austria and Switzerland (the DACH region). A quasi-system of twelve equations aims to to identify the main effects, tracking first the impacts of policy on the extensive and intensive margins of adoption for different fields of technology. A second set of equations estimates the perceived impacts of adoption on the firm's energy efficiency, carbon emissions and competitiveness.

In short, the results confirm the following hypotheses as presented in Section 3: Policy affects both the extensive ($H1-0$) and intensive margin of adoption of new GETs ($H2-0$), but not uniformly and only by means of differentiated impacts of the various policy tools ($H3-0$). In turn, the adoption of new GETs contributes significantly to improve energy efficiency ($H4-0$) and reduce carbon emissions ($H5-0$), confirming its positive ecological impacts. Finally, for the average firm adoption of new GETs does not significantly affect its competitive position ($H6c-0$), rejecting both the conventional hypothesis of a negative trade-off ($H6a-0$) as well as Porter's hypothesis of a double win situation ($H6b-0$).

The analysis demonstrates how different instruments and tools bring distinct strengths and weaknesses to the policy table. It leads to the conclusion, that a combination of instruments is the most effective means to improve energy efficiency and reduce carbon emissions. In other words, policy is likely to be most effective, if it applies incentive-based instruments like public funding, taxes or tradable permits together with government regulation and standards. In practice firms are most often affected by the latter. This reflects the practical relevance of detailed technical rules, but is also consistent with the political economy of environmental regulation. However, it also points at likely welfare losses from the insufficient use of incentive-based instruments.

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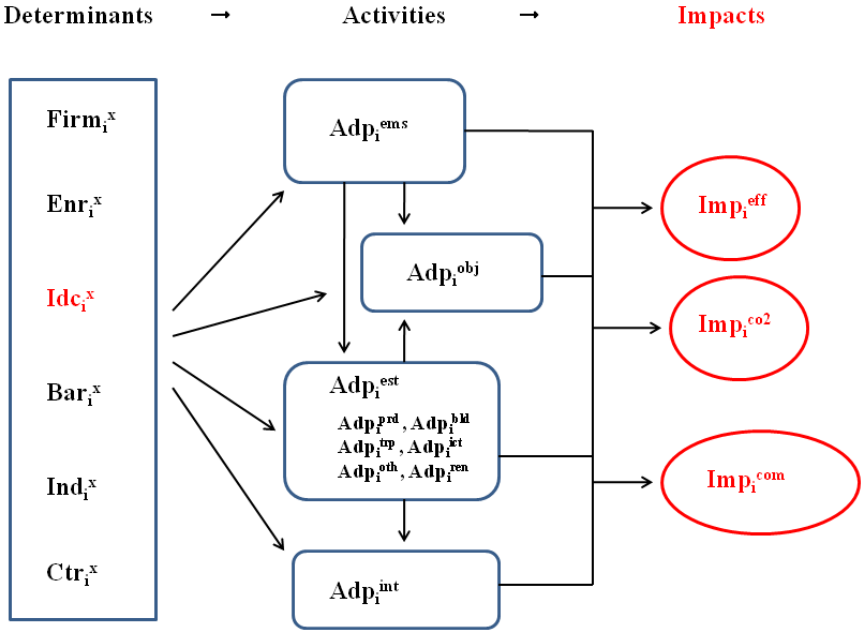
Main figures and tables



NB: See Tables 1 and 2 for a comprehensive description of the variables.

Figure 1: Basic structure of the model

Table 1: Description of the variables: potential drivers and barriers

Variable	**Label**	**Description**
DETERMINANTS		
$Firm_i^{grp}$	Group	Dummy whether the firm is part of a group of companies
$Firm_i^{age}$	Age	Survey year minus the firm's start of operations
$Firm_i^{sze}$	Size	Three classes by number of employees (< 50 / 51 - 250 / > 250)
$Firm_i^{com}$	Competition	Number of competitors for the firm's principal product
$Firm_i^{exp}$	Exports	Dummy whether the firm exports
$Firm_i^{uni}$	Human capital	Share of employees with university degree
$Firm_i^{ino}$	Innovation (GET)	Dummy whether the firm reported own innovations in GETs
Enr_i^{cos}	Energy cost	Share in total expenditures on intermediate inputs (2012)
Enr_i^{pri}	Energy prices	Import of high and volatile energy prices (2012 to 2014; not/somewhat/highly relevant)
Enr_i^{sht}	Energy shortages	Import of (fears of) energy shortages (2012 to 2014; see above)
Enr_i^{mix}	Energy mix	Change in energy mix (none/change with/without cost reduction)
Idc_i^{dem}	Demand	Import of customer demand for energy efficient goods and services (2012 to 2014; see above)
Idc_i^{pfu}	Public funding	Import of energy related public funding (see above)
Idc_i^{tax}	Taxes	Import of energy related taxes and duties (see above)
Idc_i^{reg}	Regulation	Import of energy related regulations (see above)
Idc_i^{std}	Standards	Import of energy related standards or negotiated environmental agreements (see above)
Bar_i^{frc}	Polit. framework	Impeded by political framework (2012 to 2014; four scales, “no “to “very relevant“)
Bar_i^{inc}	Techn. incompat.	Whether technological incompatibilities impeded adoption (see above)
Bar_i^{imm}	Immature techn.	Whether immature technology impeded adoption (see above)
Bar_i^{prm}	Permits	Whether costly procedures impeded adoption (see above)
Bar_i^{amr}	Amortisation	Whether long periods for amortisation impeded adoption (see above)
Bar_i^{fin}	Finance	Whether lack of finance impeded adoption (see above)
$Ctr_i^{at,ch}$	Country	Two dummies for firms located in Austria and Switzerland (Germany is comparison group)
Ind_i^{nace}	Industry	Sector dummies at the level of NACE 2-digits

Table 2: Description of the variables: activities and impacts

Variable	**Label**	**Description**
ACTIVITIES		
Adp_i^{ems}	Management system	Dummy for certified management system or audits related to energy
Adp_i^{obj}	Objectives	Whether adoption aimed for energy efficiency (secondary effect/both/primary objective)
Adp_i^{get}	Extensive margin	Adoption of new GETs in any of the following areas:
Adp_i^{prd}	... Production	Adoption related to production
Adp_i^{bld}	... Buildings	Adoption related to construction & buildings
Adp_i^{tra}	... Transport	Adoption related to transport
Adp_i^{ict}	... ICT	Adoption related to ICTs
Adp_i^{oth}	... Other	Adoption related to other areas
Adp_i^{ren}	... Renewable energy	Adoption related to the use of renewable sources
Adp_i^{int}	Intensive margin	Share of expenditures on new GETs in total investments
IMPACTS		
Imp_i^{eff}	Energy efficiency	Energy consumption per unit or process (not improved/can't say/improved/much improved)
Imp_i^{co2}	Carbon emissions	CO2 emissions per unit or process (see above)
Imp_i^{cmp}	Competitiveness	Competitive position on the market (worsened/didn't change/improved/much improved)

Table 3: Pairwise correlation of policy with EMS and GET by technology

	Public funding	**Taxes**	**Regulation**	**Standards**
	Coefficients of correlation			
EMS	0.273	0.245	0.269	0.280
GET total	0.205	0.204	0.194	0.217
Production	0.245	0.263	0.244	0.244
Buildings	0.197	0.188	0.193	0.223
Transport	0.128	0.100	0.131	0.152
ICT	0.114	0.079	0.107	0.126
Other	0.072	0.102	0.065	0.054
Renewables	0.095	0.081	0.090	0.108

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Table 4: Objectives and impacts by area of GET adoption

	Production	**Buildings**	**Transport**	**ICT**	**Other**	**Renewables**
	Share of adopting firms in %					
Primary or secondary objective						
Secondary	36.70	38.39	35.19	46.37	19.39	23.09
Both	38.13	34.73	39.35	34.29	40.82	37.69
Primary	25.16	26.88	25.46	19.34	39.80	39.22
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Impact on **energy efficiency**						
Not improved	7.24	8.26	9.46	9.10	8.25	9.87
Can't say	16.90	22.59	20.62	25.97	22.68	22.59
Improved	41.27	36.36	37.36	37.12	46.39	33.99
Much improved	34.58	32.78	32.56	27.81	22.68	33.55
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Impact on **carbon emission**						
Not improved	10.33	11.28	9.36	12.68	6.32	9.78
Can't say	31.65	37.09	31.51	38.88	36.84	35.33
Improved	31.43	27.57	29.02	25.78	33.68	27.11
Much improved	26.60	24.05	30.11	22.66	23.16	27.78
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Impact on **competitiveness**						
Worsened	24.86	23.61	20.87	23.58	26.80	21.15
No change	28.38	24.43	26.74	25.61	48.45	23.35
Improved	22.66	27.87	27.51	30.08	24.74	29.52
Much improved	24.09	24.09	24.88	20.73	0.00	25.99
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

NB: . . .

Table 5: Explaining EMS and GET adoption

VARIABLES	Extensive margin			Intensive margin	
	EMS	GET	GET	GET	GET
Management systems		0.512***	0.519***	-0.580	0.484
		(0.0695)	(0.0970)	(1.252)	(1.710)
Customer demand	0.0241	0.249***	0.204***	-0.470	-1.020
	(0.0529)	(0.0501)	(0.0678)	(0.852)	(1.154)
Public funding	0.102	0.0125	-0.0921	6.360***	5.311*
	(0.135)	(0.126)	(0.166)	(2.174)	(2.997)
Taxes	0.263***	0.0227	0.0646	0.297	-0.840
	(0.0528)	(0.0494)	(0.0713)	(0.889)	(1.250)
Regulations	-0.0314	0.00583	0.124	-5.536**	-1.792
	(0.137)	(0.130)	(0.172)	(2.228)	(3.094)
Standards	0.253***	0.147***	0.175**	-1.322	-1.932
	(0.0545)	(0.0550)	(0.0789)	(0.912)	(1.238)
Political framework	-0.00677	0.121***	0.119**	-0.330	-0.871
	(0.0434)	(0.0410)	(0.0592)	(0.680)	(0.916)
Immature tech.	-0.0305	0.136***	0.151***	-0.158	-0.224
	(0.0419)	(0.0396)	(0.0558)	(0.657)	(0.896)
Long amortisation	0.0762**	0.170***	0.178***	-1.034*	-1.084
	(0.0355)	(0.0342)	(0.0465)	(0.578)	(0.771)
Lack of finance	-0.00780	-0.140***	-0.198***	0.291	0.325
	(0.0379)	(0.0360)	(0.0510)	(0.657)	(0.901)
Energy prices	0.0436	0.0415	-0.0315	3.729***	2.993**
	(0.0520)	(0.0472)	(0.0697)	(0.870)	(1.195)
Energy mix	0.163***	0.418***	0.345***	2.304***	1.403
	(0.0415)	(0.0438)	(0.0641)	(0.649)	(0.922)
Group	0.288***	-0.0478	-0.0436	-2.414**	-1.512
	(0.0677)	(0.0636)	(0.0901)	(1.228)	(1.666)
Size class	0.593***	0.240***	0.140**	-2.931***	-1.934
	(0.0497)	(0.0484)	(0.0693)	(0.913)	(1.249)
Exports	0.397***	0.117*	0.190**	1.426	0.0239
	(0.0742)	(0.0639)	(0.0955)	(1.305)	(1.932)
Innovation (GET)			0.261**		1.102
			(0.111)		(1.862)
Austrian	0.222*	0.223*	0.100	7.803***	4.970*
	(0.117)	(0.116)	(0.163)	(1.865)	(2.628)
Swiss	0.354***	-0.529***	-0.579***	3.209**	4.036**
	(0.0742)	(0.0659)	(0.0964)	(1.344)	(1.858)
Observations	2,923	2,959	1,442	1,282	610

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Included but not displayed: Ind_i^{nace}, $Firm_i^{age}$, Enr_i^{cos}, Enr_i^{sht}, Bar_i^{inc}, Bar_i^{prm}.

Table 6: Explaining GET adoption by technology fields

VARIABLES	Production	Buildings	Transport	ICT	Renewables
Management systems	0.440***	0.380***	0.197***	0.350***	0.227***
	(0.0675)	(0.0616)	(0.0722)	(0.0636)	(0.0790)
Customer demand	0.192***	0.149***	0.271***	0.209***	0.262***
	(0.0499)	(0.0450)	(0.0504)	(0.0444)	(0.0534)
Public funding	0.0275	0.103	-0.105	0.0424	0.120
	(0.129)	(0.114)	(0.132)	(0.115)	(0.133)
Taxes	0.108**	0.00196	-0.0401	-0.0594	0.0371
	(0.0517)	(0.0465)	(0.0538)	(0.0475)	(0.0592)
Regulations	-0.00885	-0.0569	0.0242	-0.0451	-0.133
	(0.131)	(0.116)	(0.134)	(0.118)	(0.137)
Standards	0.142***	0.190***	0.120**	0.111**	0.0987*
	(0.0518)	(0.0486)	(0.0548)	(0.0489)	(0.0596)
Political framework	0.0667*	0.0831**	0.137***	0.0459	0.0999**
	(0.0394)	(0.0364)	(0.0407)	(0.0369)	(0.0458)
Incompatible tech.	0.129***	-0.0784**	-0.0689*	0.0227	-0.110**
	(0.0377)	(0.0356)	(0.0401)	(0.0353)	(0.0458)
Immature tech.	0.0976**	0.108***	0.184***	0.0848**	0.0982**
	(0.0387)	(0.0354)	(0.0391)	(0.0355)	(0.0441)
Long amortisation	0.102***	0.183***	0.0973***	0.0882***	0.0242
	(0.0326)	(0.0298)	(0.0342)	(0.0304)	(0.0385)
Lack of finance	-0.101***	-0.105***	-0.106***	0.0420	-0.102**
	(0.0355)	(0.0325)	(0.0377)	(0.0327)	(0.0433)
Energy prices	0.0972*	0.0196	0.100*	0.0112	-0.0121
	(0.0509)	(0.0444)	(0.0517)	(0.0456)	(0.0584)
Energy shortage	0.0250	-0.0297	-0.0248	0.114**	-0.0339
	(0.0528)	(0.0480)	(0.0550)	(0.0478)	(0.0623)
Energy mix	0.156***	0.331***	0.133***	0.153***	0.513***
	(0.0395)	(0.0358)	(0.0402)	(0.0360)	(0.0392)
Age	0.00124*	0.00177***	0.00177**	-0.000886	0.00133*
	(0.000729)	(0.000636)	(0.000729)	(0.000692)	(0.000799)
Size class	0.294***	0.276***	0.208***	0.169***	0.0154
	(0.0475)	(0.0417)	(0.0482)	(0.0427)	(0.0542)
Austrian	0.169	0.266***	0.270***	-0.175*	0.421***
	(0.105)	(0.0929)	(0.104)	(0.0945)	(0.110)
Swiss	-0.310***	-0.419***	-0.109	-0.402***	-0.102
	(0.0747)	(0.0632)	(0.0750)	(0.0644)	(0.0847)
Observations	3,369	3,369	3,369	3,369	3,369

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Included but not displayed: Ind_i^{nace}, Enr_i^{cost}.

Table 7: Objectives and impacts of GET adoption

VARIABLES	Objective	Energy efficiency	Carbon emissions	Competitiveness
Management systems	0.352***	0.0707	0.154*	0.00863
	(0.0833)	(0.0796)	(0.0789)	(0.0805)
Objective		0.175***	0.123***	0.0298
		(0.0433)	(0.0428)	(0.0434)
Adoption: Production	-0.0536	0.343***	0.128*	-0.0863
	(0.0818)	(0.0777)	(0.0768)	(0.0784)
Adoption: Buildings	0.261***	0.199***	0.0298	-0.0558
	(0.0791)	(0.0737)	(0.0737)	(0.0750)
Adoption: Transport	0.0453	0.0847	0.276***	-0.0568
	(0.0817)	(0.0781)	(0.0772)	(0.0784)
Adoption intensity	0.0100***	0.00438**	0.00434**	-0.000951
	(0.00194)	(0.00188)	(0.00185)	(0.00187)
Energy cost 2012	0.00766	-0.00719**	-0.00393	0.000856
	(0.00558)	(0.00336)	(0.00343)	(0.00338)
Energy prices	0.00575	0.130***	0.0460	-0.0928*
	(0.0584)	(0.0500)	(0.0495)	(0.0505)
Energy shortage	-0.135**	-0.0315	0.0572	0.0340
	(0.0611)	(0.0561)	(0.0558)	(0.0565)
Group	-0.0837	-0.186**	-0.127	0.0849
	(0.0832)	(0.0782)	(0.0778)	(0.0792)
Competition	-0.0247	-0.0680***	-0.0187	-0.0142
	(0.0253)	(0.0237)	(0.0236)	(0.0240)
Customer demand	0.189***			
	(0.0568)			
Austrian	0.270**	0.271**	0.204*	0.990***
	(0.122)	(0.114)	(0.114)	(0.116)
Swiss	-0.116	0.790***	0.237***	1.592***
	(0.0873)	(0.0846)	(0.0815)	(0.0875)
Observations	1,245	1,234	1,217	1,232

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Included but not displayed: Ind_i^{nace}, $Firm_i^{sze}$, $Firm_i^{exp}$; only column 1: Idc_i^{pfu}, Idc_i^{tax}, Idc_i^{reg}, Idc_i^{std}.

Table 8: Impact of GETs on energy efficiency - MLogit

VARIABLES	Not improved	Can't say (c.g.)	Improved	Much improved
Adoption: Production	0.201		0.780***	0.932***
	(0.299)		(0.202)	(0.227)
Adoption: Buildings	-0.437		0.131	0.331
	(0.269)		(0.186)	(0.220)
Adoption: Transport	-0.344		0.155	-0.00995
	(0.310)		(0.204)	(0.231)
Adoption intensity	-0.00577		-0.000325	0.00893*
	(0.00858)		(0.00503)	(0.00537)
Objective	-0.0598		-0.0533	0.543***
	(0.175)		(0.112)	(0.127)
Management systems	-0.175		-0.00286	0.123
	(0.310)		(0.208)	(0.227)
Energy prices	-0.137		0.206	0.270*
	(0.194)		(0.130)	(0.146)
Energy supply	0.211		-0.0906	0.0792
	(0.213)		(0.149)	(0.167)
Energy cost 2012	-0.0120		-0.0209	-0.0206*
	(0.0166)		(0.0155)	(0.0120)
Group	0.159		-0.571***	-0.403*
	(0.290)		(0.202)	(0.228)
Size class	-0.0216		0.154	-0.0252
	(0.221)		(0.147)	(0.168)
Competition	0.157*		-0.0201	-0.117*
	(0.0913)		(0.0599)	(0.0705)
Exports	-0.350		-0.174	-0.270
	(0.312)		(0.216)	(0.242)
Austrian	-1.141		0.633**	0.694*
	(0.784)		(0.287)	(0.354)
Swiss	1.287***		-0.967***	2.662***
	(0.309)		(0.274)	(0.252)
Observations	1,234	1,234	1,234	1,234

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9: Impact of GETs on carbon emissions - MLogit

VARIABLES	Not improved	Can't say (c.g.)	Improved	Much improved
Adoption: Production	0.0355		0.481**	0.184
	(0.257)		(0.191)	(0.216)
Adoption: Buildings	-0.448*		-0.0956	-0.290
	(0.245)		(0.185)	(0.212)
Adoption: Transport	-0.556*		0.461**	0.292
	(0.287)		(0.192)	(0.215)
Adoption intensity	-0.00385		-0.00524	0.0112**
	(0.00693)		(0.00486)	(0.00481)
Objective	-0.0832		0.0677	0.300**
	(0.153)		(0.106)	(0.123)
Management systems	-0.129		-0.200	0.424*
	(0.266)		(0.200)	(0.219)
Energy prices	0.0647		0.295**	0.0689
	(0.168)		(0.125)	(0.140)
Energy supply	0.112		0.0432	0.271*
	(0.194)		(0.141)	(0.156)
Energy cost 2012	-0.00363		-0.00669	-0.0122
	(0.0115)		(0.0110)	(0.00984)
Group	0.496*		-0.143	-0.0128
	(0.257)		(0.197)	(0.222)
Size class	0.0276		0.0924	-0.0395
	(0.193)		(0.138)	(0.160)
Competition	0.0646		0.0135	-0.0138
	(0.0809)		(0.0583)	(0.0689)
Exports	-0.307		0.245	-0.0206
	(0.268)		(0.214)	(0.235)
Austrian	-0.252		0.663**	0.832**
	(0.580)		(0.262)	(0.338)
Swiss	2.241***		-0.736***	2.455***
	(0.264)		(0.264)	(0.231)
Observations	1,217	1,217	1,217	1,217

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 10: Motive for adopting GETs - MLogit

VARIABLES	Secondary	Both effects	Primary
Adoption: Production		0.249	-0.193
		(0.173)	(0.197)
Adoption: Buildings		0.170	0.643***
		(0.163)	(0.198)
Adoption: Transport		0.264	0.0462
		(0.173)	(0.200)
Adoption intensity		0.0136***	0.0236***
		(0.00452)	(0.00475)
Management systems		0.627***	0.780***
		(0.177)	(0.202)
Customer demand		0.216*	0.479***
		(0.124)	(0.138)
Public funding		0.260	0.353
		(0.326)	(0.357)
Taxes		-0.119	0.176
		(0.127)	(0.143)
Regulations		0.00709	-0.108
		(0.333)	(0.366)
Standards		0.0743	0.132
		(0.130)	(0.145)
Energy cost 2012		0.00240	0.0170
		(0.0150)	(0.0147)
Energy prices		0.218*	-0.0331
		(0.124)	(0.141)
Energy supply		0.0989	-0.397**
		(0.127)	(0.160)
Group		-0.195	-0.177
		(0.175)	(0.202)
Size class		0.102	0.108
		(0.126)	(0.143)
Austrian		0.245	0.624**
		(0.275)	(0.286)
Swiss		-0.136	-0.292
		(0.184)	(0.216)
Observations	1,245	1,245	1,245

NB: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Included but not displayed: fixed industry effects; competition and exports